Attachment A to Resolution No. 03-011

Amendment to the Water Quality Control Plan – Los Angeles Region
to Incorporate the
Santa Clara River Nitrogen Compounds TMDL

Proposed for adoption by the California Regional Water Quality Control Board, Los Angeles Region on August 7, 2003.

Amendments

Table of Contents
Add:

Chapter 7. Total Maximum Daily Loads (TMDLs)

List of Figures, Tables, and Inserts
Add:

Chapter 7. Total Maximum Daily Loads (TMDLs)
Tables

Chapter 7. Total Maximum Daily Loads (TMDLs)
Santa Clara River Nitrogen Compounds TMDL

This TMDL was adopted by:

The Regional Water Quality Control Board on [August 7, 2003].

This TMDL was approved by:

The State Water Resources Control Board on [Insert Date].
The Office of Administrative Law on [Insert Date].
The U.S. Environmental Protection Agency on [Insert Date].

The following table describes the key elements of this TMDL.

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Table 7-9.1. Santa Clara River Nitrogen Compounds TMDL: Elements

<table>
<tr><th>Element</th><th>Santa Clara River Nitrogen Compounds TMDL</th></tr>
<tr><td>Problem Statement</td><td>Discharge of wastes containing nitrite, nitrate and ammonia to the Santa Clara River causes exceedances of water quality objectives for ammonia, nitrate and nitrite established in the Basin Plan. The Santa Clara River is listed as impaired by ammonia in Reach 3 and by nitrate plus nitrite in Reach 7 on the 2002 303(d) list of impaired water bodies. Reach 8 of the Santa Clara River is included on the State Monitoring List for organic enrichment/dissolved oxygen, which may be caused by excessive nitrogen. Nitrate and nitrate are biostimulatory substances that can cause eutrophic effects such as low dissolved oxygen and algae growth. Excessive ammonia can cause aquatic life toxicity.</td></tr>
<tr><td>Numeric Target (Interpretation of the numeric water quality objective, used to calculate the load allocations)</td><td>
• Total ammonia as nitrogen (NH_3-N)
<table>
<tr><th>Reach</th><th>One-hour (mg-N/L)</th><th>Thirty-day (mg-N/L)</th></tr>
<tr><td>Reach 8</td><td>14.8</td><td>3.2</td></tr>
<tr><td>Reach 7 above Valencia</td><td>4.8</td><td>2.0</td></tr>
<tr><td>Reach 7 below Valencia</td><td>5.5</td><td>2.0</td></tr>
<tr><td>Reach 7 at County Line</td><td>3.4</td><td>1.2</td></tr>
<tr><td>Reach 3 above Santa Paula</td><td>2.4</td><td>1.9</td></tr>
<tr><td>Reach 3 at Santa Paula</td><td>2.4</td><td>1.9</td></tr>
<tr><td>Reach 3 below Santa Paula</td><td>2.2</td><td>1.7</td></tr>
</table>
• Nitrate plus Nitrite as Nitrogen (NO_3-N + NO_2-N)
Thirty-day average
9.0 mg-N/L in Reach 8
4.5 mg-N/L in Reaches 3 and 7
Narrative objectives for biostimulatory substances and toxicity are based on the Basin Plan. The TMDL analysis indicates that the numeric targets will implement the narrative objectives. The Implementation Plan includes monitoring and special studies to verify that the TMDL will implement the narrative objectives.</td></tr>
<tr><td>Source Analysis</td><td>The principal source of ammonia, nitrite, and nitrate to the Santa Clara River is discharges from the Saugus and Valencia Water Reclamation Plants (WRPs) and the Fillmore and Santa Paula Publicly Owned Treatment Works (POTWs). Agricultural runoff, stormwater discharge and groundwater discharge may also contribute nitrate loads. Further evaluation of these sources is set forth in the Implementation Plan.</td></tr>
<tr><td>Linkage Analysis</td><td>Linkage between nitrogen sources and the in-stream water quality was established through hydrodynamic and water quality models. The Watershed Analysis Risk Management Framework was used to model the hydrodynamic characteristics and water quality of the Santa Clara River. The analysis demonstrated that major point sources (WRPs and POTWs)</td></tr>
</table>

Element	Santa Clara River Nitrogen Compounds TMDL
	were the primary contributors to in-stream ammonia and nitrate plus nitrite loads. Nonpoint sources and minor point sources contributed a much smaller fraction of these loads.

Wasteload Allocations (for point sources)

Major point sources:

Concentration-based wasteloads are allocated to major point sources of ammonia in Reach 3, which include the Fillmore and Santa Paula POTWs; concentration-based wasteloads are allocated to major point sources of nitrite + nitrate in Reaches 7 and 8 , which include the Valencia and Saugus WRPs. The Implementation Plan provides reconsideration of the WLAs by the Regional Board based on water effect ratio (WER) studies and updated data 5 years after the effective date of the TMDL.

- Total ammonia as nitrogen (NH_3-N):

POTW	One-hour average	Thirty-day average
Saugus WRP	5.6 mg/L	2.0 mg/L
Valencia WRP	5.2 mg/L	1.75 mg/L
Fillmore POTW	4.2 mg/L	2.0 mg/L
Santa Paula POTW	4.2 mg/L	2.0 mg/L

- Nitrate-nitrogen (NO_3-N), Nitrite-nitrogen (NO_2-N), and Nitrate plus Nitrite as nitrogen (NO2-N+NO3-N):

	Thirty-day average WLA*		
POTW	NO_2-N	NO_3-N	NO2-N+NO3-N
Saugus WRP	0.9 mg/L	7.1 mg/L	7.1 mg/L
Valencia WRP	0.9 mg/L	6.8 mg/L	6.8 mg/L
Fillmore POTW	0.9 mg/L	8.0 mg/L	8.0 mg/L
Santa Paula POTW	0.9 mg/L	8.0 mg/L	8.0 mg/L

*Receiving water monitoring is required on a weekly basis to ensure compliance with the water quality objectives for nitrite, nitrate, nitrite + nitrate, and dissolved oxygen.

Minor Point Sources:

Concentration-based wasteloads are allocated to minor discharges enrolled under NPDES or WDR permits. The allocations for minor point sources are based on the water quality objectives for ammonia, nitrite, nitrate and nitrite plus nitrate. For minor dischargers discharging into Reach 7, the thirty-day average WLA for ammonia as nitrogen is 1.75, the one-hour WLA for ammonia as nitrogen is 5.2, and the thirty-day average WLA for nitrate plus nitrite as nitrogen is 6.8 mg/L. For minor dischargers discharging into Reach 3, the thirty-day WLA for ammonia as nitrogen is

<table>
<tr><th>Element</th><th>Santa Clara River Nitrogen Compounds TMDL</th></tr>
<tr><td></td><td>2.0 mg/L and the one hour WLA for ammonia as nitrogen is 4.2 mg/L, and the thirty-day average WLA for nitrate plus nitrite as nitrogen is 8.1 mg/L.

<u>MS4 and Stormwater Sources:</u>

Concentration-based wasteloads are allocated to municipal, industrial and construction stormwater sources regulated under NPDES permits. For stormwater permittees discharging into Reach 7, the thirty-day WLA for ammonia as nitrogen is 1.75 mg/L and the one-hour WLA for ammonia as nitrogen is 5.2 mg/L; the thirty-day average WLA for nitrate plus nitrite as nitrogen is 6.8 mg/L. For stormwater permittees discharging into Reach 3, the thirty-day WLA for ammonia as nitrogen is 2.0 mg/L and the one-hour WLA for ammonia as nitrogen is 4.2 mg/L; the thirty-day average WLA for nitrate plus nitrite nitrogen is 8.1 mg/L.</td></tr>
<tr><td>Load Allocation (for nonpoint sources)</td><td>Concentration-based loads for nitrogen compounds are allocated for nonpoint sources. For nonpoint sources discharging to Reach 7, the combined ammonia, nitrate, nitrite (NH_3-N + NO_2-N + NO_3-N) load as nitrogen is 8.5 mg-N/L. For non-point sources discharging into other reaches of the Santa Clara River, Mint Canyon Reach 1, Wheeler Canyon/Todd Barranca, and Brown Barranca/Long Canyon, the combined ammonia, nitrate, nitrite (NH_3-N + NO_2-N + NO_3-N) loads as nitrogen is 10 mg-N/L. Monitoring is established in the TMDL Implementation Plan to verify the nitrogen nonpoint source contributions from agricultural and urban runoff and groundwater discharge.</td></tr>
<tr><td>Implementation</td><td>

Ammonia, nitrite, and nitrate reductions will be regulated through effluent limits prescribed in POTW and minor point source NPDES Permits, Best Management Practices required in NPDES MS4 Permits, and SWRCB Management Measures for non point source discharges.
At the Regional Board's discretion, the following interim effluent limits will be allowed for a period not to exceed five years from the effective date of the TMDL:

<u>Interim Limits for Nitrite, Nitrate, and Nitrite plus Nitrate as nitrogen</u>
<table>
<tr><th></th><th colspan="3">Thirty-day Average Interim Limits</th></tr>
<tr><th>POTW</th><th>NO_2-N</th><th>NO_3-N</th><th>NO_2-N + NO_3-N</th></tr>
<tr><td>Saugus WRP</td><td>1mg/L</td><td>10 mg/L</td><td>10 mg/L</td></tr>
<tr><td>Valencia WRP</td><td>1mg/L</td><td>10 mg/L</td><td>10 mg/L</td></tr>
</table>
<u>Interim Limits for combined Ammonia, Nitrate, and Nitrite as nitrogen</u>
<table>
<tr><th>POTW</th><th>Thirty-day Average</th><th>Daily Maximum</th></tr>
<tr><td>Fillmore WRP</td><td>32.8 mg-N/L</td><td>38.9 mg-N/L</td></tr>
<tr><td>Santa Paula WRP</td><td>41.8 mg-N/L</td><td>49.0 mg-N/L</td></tr>
</table>
The Implementation Plan also includes special studies and monitoring for
</td></tr>
</table>

Exhibit [illegible]	Santa Clara River Nitrogen Compounds TMDL [illegible]
	ammonia, nitrite, and nitrate to evaluate the effectiveness of nitrogen reductions. The Implementation Plan also includes special studies to address issues regarding water quality standards and site-specific objectives and a reconsideration of waste load allocations based on monitoring data and special studies.
Margin of Safety	An explicit margin of safety of 10 percent of the nitrogen loads is allocated to address uncertainty in the source and linkage analyses. In addition, an implicit margin of safety is incorporated through conservative model assumptions and statistical analysis.
Future Growth	Urban growth in the upper watershed is predicted to require the expansion of the Valencia Water Reclamation Plan, construction of an additional water reclamation plant, and increased use of reclaimed water. Wasteload and load allocations will be developed for these new sources as required to implement appropriate water quality objectives for ammonia, nitrite, and nitrate
Seasonal Variations and Critical Conditions	The critical condition identified for this TMDL is based on the low flow condition defined as the 7Q10. In addition, the driest six months of the year are identified as a more critical condition for nitrogen compounds because less surface flow is available to dilute effluent discharge. The model result also indicates a critical condition during the first major storm event after a dry period. The implementation plan includes monitoring to verify this potential critical condition.

Table 7-9.2. Implementation Schedule

Implementation Tasks, Milestones and Provisions	Responsible Party	Completion Date
1. Apply interim limits for ammonia, nitrite, and nitrate to Fillmore and Santa Paula POTWs. 2. Apply interim limits for Nitrate to Saugus and Valencia WRPs. 3. Apply WLAs to minor point source dischargers and MS4 permittees. 4. Include monitoring for nitrogen compounds in NPDES and WDR permits for minor dischargers as permits are renewed.	Fillmore and Santa Paula POTWs; NPDES and WDR permittees	Effective Date of TMDL
5. Submittal of a Work Plan by Los Angeles County and Ventura County MS4 permittees to estimate ammonia and nitrogen loadings associated with runoff loads from the storm drain system for approval by the Executive Officer of the Regional Board. The Work Plan will include monitoring for ammonia, nitrate, and nitrite. The Work Plan may include a phased approach wherein the first phase is based on monitoring from the existing mass emission station in the Santa Clara River. If the monitoring studies reflect a higher average concentration in stormwater than originally considered, then the linkage analysis would be refined to consider the increased loading. The Work Plan will also contain protocol and a schedule for implementing additional monitoring if necessary. The Work Plan will also propose triggers for conducting source identification and implementing BMPs, if necessary. Source identification and BMPs will be in accordance with the requirements of MS4 permits.	Los Angeles and Ventura Counties MS4 Permittees	1 year after the Effective Date of TMDL
6. Submittal of Work Plan by major NPDES permittees to asses and monitor the surface water quality, including, without limitation, monthly measurement of dissolved oxygen on an hourly basis, pH and instream denitrification processes, and groundwater	Cities of Fillmore and Santa Paula, and County Sanitation Districts of Los Angeles County	1 year after Effective Date of TMDL

Implementation Tasks, Milestones and Provisions	Responsible Party	Completion Date
where appropriate, for aquatic life impacts, macroinvertebrate diversity, algal mass, and nutrient species in the Santa Clara River for approval by the Regional Board's Executive Officer. The Work Plan will include evaluation of the effectiveness of the POTW in meeting WLAs. Submittal of a work plan that demonstrates compliance with final wasteload allocations or demonstrates a schedule for compliance with final wasteload allocations is as short as possible.		
7. Submittal of special studies Work Plan by County Sanitation Districts of Los Angeles County to evaluate site-specific objectives (SSOs) for nitrate for approval by the Regional Board's Executive Officer.	County Sanitation Districts of Los Angeles County	1 year after Effective Date of TMDL
8. Submittal of results from water effects ratio study for ammonia by County Sanitation Districts of Los Angeles County.	County Sanitation Districts of Los Angeles County	Effective Date of TMDL
9. Evaluation of feasibility of including stakeholders in the Upper Santa Clara River watershed in the Regional Board Septic Tank task force.	Regional Board	3.5 year after Effective Date of TMDL
10. Regional Board considers a Basin Plan Amendment for site-specific objectives for ammonia and nitrite plus nitrate based on results of Tasks 7 and 8.	Regional Board	1 year after Effective Date of TMDL for ammonia; 4 years after the Effective Date of the TMDL for nitrite plus nitrate
11. Based on the results Task 5-10 and NPDES Monitoring, complete implementation of advanced treatment or additional treatment modifications to achieve WLAs for POTWs, if necessaryin as short a period of time as possible, as determined during NPDES permit issuance or modification, but not later than eight years after the effective date of the TMDL; if advanced treatment is not required, interim limits will expire in as short a period of time as possible, as determined during NPDES permit reissuance or modification, no later than five years after the effective date of the TMDL. The	POTW Permittees	8 years after Effective Date of TMDL

Implementation Tasks, Milestones and Provisions	Responsible Party	Completion Date
wasteload allocation compliance date will be synchronized with the expiration date of interim limits specified in Task 13.		
12. Interim limits for ammonia and nitrate expire and WLAs apply to WRPs and POTWs. The Regional Board will consider extending the duration of the remaining schedule and re-evaluating interim limits if WLAs for WRPs and POTWs are reduced after SSO considerations.	POTW Permittees Regional Board	Based on results of Tasks 6 and 10: if additional modifications or advanced nitrification/denitrification facilities are required, interim limits will expire in as short a period of time as possible, as determined during NPDES permit issuance or modification interim limits, but not later than eight years after the effective date of the TMDL; if advanced treatment is not required, interim limits will expire in as short a period of time as possible, as determined during NPDES permit issuance or modification, but not later than 5 years after the Effective Date of the TMDL.
13. Annual progress reports on the Implementation Plan shall be provided to the Regional Board by the responsible parties or their representatives.	➢ NPDES permitees, ➢ Board staff ➢ MS-4 permittees. ➢ Newhall Land and Farming ➢ United Water Conservation District ➢ Friends of the Santa Clara River ➢ Ventura Coast Keeper and Heal the Bay.	Annually after Effective Date of TMDL.

STATE WATER RESOURCES CONTROL BOARD

RESOLUTION NO. 2003 - 0073

APPROVING AN AMENDMENT TO THE WATER QUALITY CONTROL PLAN FOR THE LOS ANGELES REGION INCORPORATING A TOTAL MAXIMUM DAILY LOAD FOR NITROGEN COMPOUNDS IN THE SANTA CLARA RIVER

WHEREAS:

1. The Los Angeles Regional Water Quality Control Board (Regional Board) adopted the revised Water Quality Control Plan for the Los Angeles Region (Basin Plan) under Resolution No. 94-07 on June 13, 1994. The revised Basin Plan was approved by the State Water Resources Control Board (SWRCB) on November 17, 1994 and by the Office of Administrative Law (OAL) on February 23, 1995.

2. On August 7, 2003, the Regional Board adopted Resolution No. 2003-011 (Attachment 1) amending Chapters 5 and 7 of the Basin Plan by establishing a Total Maximum Daily Load (TMDL) for nitrogen compounds in the Santa Clara River (Nitrogen TMDL).

3. SWRCB staff found that provisions of the amendments, as adopted, warrant minor non-substantive clarification of the language and, therefore, requested such clarifications. Regional Board Resolution No. 2003-011 delegated to the Regional Board Executive Officer authority to make minor, non-substantive corrections to the adopted amendments for clarity or consistency. The Regional Board Executive Officer has made the necessary clarifications to the amendment in the attached memorandum (Attachment 2).

4. SWRCB finds that the Nitrogen TMDL is in conformance with the requirements for TMDL development specified in section 303(d) of the federal Clean Water Act and SWRCB Resolution No. 68-16.

5. The Regional Board staff prepared documents and followed procedures satisfying environmental documentation requirements in accordance with the California Environmental Quality Act and other State laws and regulations.

6. SWRCB finds that these Basin Plan amendments are in conformance with Water Code section 13240, which specifies that Regional Water Quality Control Boards may revise Basin Plans.

7. Basin Plan amendments do not become effective until approved by SWRCB and until the regulatory provisions are approved by OAL. In addition, TMDLs must be approved by USEPA and a Notice of Decision must be filed with the Secretary of the California Resources Agency.

THEREFORE BE IT RESOLVED THAT:

SWRCB:

1. Approves the amendment to the Basin Plan adopted under Regional Board Resolution No. 2003-011, as clarified by the Regional Board Executive Officer.
2. Authorizes the Executive Director or designee to submit the amendment and administrative record for this action to OAL and the TMDL to USEPA for approval.

CERTIFICATION

The undersigned, Clerk to the Board, does hereby certify that the foregoing is a full, true, and correct copy of a resolution duly and regularly adopted at a meeting of the SWRCB held on November 19, 2003.

Debbie Irvin

Debbie Irvin
Clerk to the Board

STATE OF CALIFORNIA
OFFICE OF ADMINISTRATIVE LAW

In re:

STATE WATER RESOURCES CONTROL BOARD

REGULATORY ACTION:

Title 23, California Code of Regulations
Adopt sections 3939.6

NOTICE OF APPROVAL OF REGULATORY ACTION

Government Code Section 11349.3

OAL File No. 04-0123-03 S

Los Angeles Regional Water Quality Control Board (Regional Board) Resolution No. 2003-011, adopted on August 7, 2003, with minor modifications by the executive officer via memo dated October 3, 2003, establishes a Total Maximum Daily Load (TMDL) for nitrogen compounds in the Santa Clara River.

Numeric targets will primarily be achieved by limiting the amount of nitrogen compounds discharged from four major permitted wastewater treatment plants (Saugus Water Reclamation Plant (WRP), Valencia WRP, Fillmore Publicly Owned Treatment Work (POTW), and Santa Paula POTW). These major point sources are assigned wasteload allocations for ammonia, nitrite, nitrate, and combined nitrite and nitrate. At the Regional Board's discretion, the Saugus and Valencia WRPs may be allowed higher interim loads for nitrate, nitrite, and combined nitrate and nitrite for a period as short as possible, but not to exceed eight years from the effective date of the TMDL. The Fillmore and Santa Paula POTWs may be allowed higher interim loads for combined ammonia, nitrate and nitrate for a period also not to exceed eight years after the effective date of the TMDL. Receiving water monitoring is required weekly of these major point sources.

Minor point sources (including stormwater sources) in Reaches 3 and 7 are assigned concentration-based wasteload allocations for ammonia and combined nitrite and nitrate. Wasteload allocations for minor point sources will be implemented through effluent limits or Best Management Practices (BMPs) for stormwater. Load allocations for nonpoint sources for combined ammonia, nitrite, and nitrate are implemented through State Water Resources Control Board BMPs.

The County Sanitation District of Los Angeles County (CSDLAC) must submit the results from a water effects ratio study for ammonia when the TMDL takes effect. Within one year after the effective date of the TMDL, the following workplans must be submitted to the Regional Board for approval: (1) a workplan for estimating nitrogen loading from stormwater sources which includes triggers for conducting source identification and implementing BMPs must be submitted by affected major National Pollutant Discharge Elimination System permittees; (2) a workplan for monitoring nitrogen-related effects and evaluate progress in meeting targets must be submitted by affected major National Pollutant Discharge Elimination System permittees; and (3) a special studies workplan to evaluate site-specific objectives for nitrate must be submitted by CSDLAC. If monitoring and study results indicate it is appropriate, the Regional Board will consider adopting site-specific objectives for ammonia within one year after the effective date of the TMDL, and site-specific objectives for nitrate, and combined nitrite and nitrate within four years after the effective date of the TMDL. If site-specific objectives are adopted, the TMDL will be revised through a Basin Plan Amendment. Five years after the effective date of the TMDL, the Regional Board will consider whether the numeric targets and wasteload allocations specified in the TMDL are sufficient to protect the Santa Clara River from nutrient effects of discharged nitrogen compounds or whether the TMDL must be revised

OAL approves this regulatory action pursuant to section 11349.3 of the Government Code

DATE: 02/27/04

Michael McNamer

MICHAEL McNAMER
Senior Counsel

DEBRA M. CORNEZ
Senior Counsel

Original : Celeste Cantu, Executive Director
cc : Joanna Jensen

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, CA 94105-3901

MAR 18 2004

Ms. Celeste Cantú
Executive Director
State Water Resources Control Board
P.O. Box 100
Sacramento, CA 95812-0100

Dear Ms. Cantú:

Thank you for submitting the Basin Plan Amendments containing total maximum daily loads (TMDLs) for the following pollutants and water bodies:

- Bacteria in Marina Del Rey Harbor Mother's Beach and Back Basins (MDR)
- Nitrogen Compounds and Related Effects in Los Angeles River and its Tributaries (LAR)
- Nitrogen Compounds in Santa Clara River (SCR)

The State submitted letters describing the TMDLs and implementation plans, and supporting documentation from the State Board and Regional Board administrative records, on February 10, 2004 for MDR, and March 5, 2004 for LAR and SCR. The State adopted TMDLs for the following water bodies:

Marina Del Rey

- Marina Del Rey Harbor Mother's Beach
- Back basins D, E and F

Los Angeles River

- Los Angeles River at Sepulveda Basin
- Los Angeles River from Sepulveda Dam to Sepulveda Blvd.
- Los Angeles River from Riverside Dr. to Figueroa St.
- Tunjunga Wash from Hansen Dam to Los Angeles River
- Burbank Western Channel
- Verdugo Wash from Verdugo Wash Rd to Los Angeles River
- Arroyo Secco from West Holly Ave. to Los Angeles River
- Los Angeles River from Figueroa St. to Carson St.
- Rio Hondo at the Spreading Grounds
- Rio Hondo from the Santa Ana Fwy. To Los Angeles River
- Compton Creek
- Los Angeles River from Carson St. to estuary

Santa Clara River

- Santa Clara Estuary to Highway 101 Bridge (EPA Reach 1)
- Highway 101 Bridge to Freeman Diversion (EPA Reach 2)
- Freeman Diversion to Timber Canyon (EPA Reach 3)
- Timber Canyon to Grimes Canyon (EPA Reach 4)

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QUALITY CONTROL BOARD
LOS ANGELES REGION

- Grimes Canyon to Propane Road (EPA Reach 5)
- Propane Road to Blue Cut Gauging Station (EPA Reach 6)
- Blue Cut Gauging Station to West Pier Highway 99 (EPA Reach 7)
- West Pier Highway 99 to Bouquet Canyon Road Bridge (EPA Reach 8)
- Bouquet Canyon Road Bridge to above Lang Gauging Station (EPA Reach 9)

Based on EPA's review of the TMDL submittals under Section 303(d), I have concluded that the TMDLs adequately address the pollutants of concern and, upon implementation, will result in attainment of the applicable water quality standards. These TMDLs include wasteload and load allocations as needed, take into consideration seasonal variations and critical conditions, and provide adequate margins of safety.

The State has provided adequate opportunities for public review and comment on the TMDLs and demonstrated how public comments were considered in the final TMDLs. All required elements are adequately addressed; therefore, the TMDLs are hereby approved pursuant to Clean Water Act Section 303(d)(2).

The TMDL submittals contain detailed plans for implementing the bacterial density reductions for MDR, and nitrogen species load reductions for LAR and SCR. Furthermore, the implementation plans identify critical monitoring efforts to continually assess the status of the water quality for MDR, LAR and SCR. Current federal regulations do not define TMDLs as containing implementation plans; therefore, EPA is not taking action on the implementation plans provided with the TMDLs. EPA commends the Regional Board's commitment to review the TMDLs and associated data and information upon (1) the completion of the technical reports and studies evaluating and proposing measures to implement necessary pollutant load reductions, and (2) implementation of phased pollutant reductions by major sources.

We would like to continue working with you and the Regional Boards to ensure that future TMDLs are adopted and submitted to EPA on schedule and, in particular, ensure that TMDLs required under the consent decrees are adopted by the State in time to meet the decree deadlines.

The enclosed reviews discuss the basis for these decisions in greater detail. I appreciate the State and Regional Boards' work to complete and adopt these TMDLs and look forward to our continuing partnership in TMDL development. If you have questions concerning this approval, please call me at (415) 972-3435 or David Smith at (415) 972-3416.

Sincerely,

18 March 2004

Alexis Strauss
Director
Water Division

enclosures

cc: Dennis Dickerson, Los Angeles RWQCB

TMDL Checklist

State: California

Waterbodies: Santa Clara River

Pollutant(s): Nitrogen Compounds

Date of State Submission: March 5, 2004

Date Received By EPA: March 9, 2004

EPA Reviewer: Cindy Lin & David Smith

Review Criteria	Comments
1. Submittal Letter: State submittal letter indicates final TMDL(s) for specific water(s)/pollutant(s) were adopted by state and submitted to EPA for approval under 303(d).	Letter dated March 5, 2004. The Los Angeles Regional Water Quality Control Board (Regional Board) completed the TMDL on June 16, 2003. The TMDL was adopted by the Los Angeles Regional Water Quality Control Board through Resolution No. 03-011 on August 7, 2003, and by the State Water Resources Control Board (State Board) through Resolution No. 2003-0073 on November 19, 2003. The State Office of Administrative Law approved the TMDL on February 27, 2004. The Regional Board developed a TMDL and determined the primary pollutants impacting the 2002 303(d) listed Santa Clara River are ammonia, nitrate and nitrite. In order of impact, the sources of impairment are point source discharges, groundwater and non-point source loading and other non-point sources.
2. Water Quality Standards Attainment: TMDL and associated allocations are set at levels adequate to result in attainment of applicable water quality standards.	The Staff TMDL Report, dated June 16, 2003. The TMDL is designed to implement the existing numeric and narrative objectives for nitrogen compounds and their related effects (Staff TMDL Report, pp20-34). The Regional Board's Basin Plan provides numeric water quality objectives for ammonia (acute and chronic criteria), nitrate, nitrite, and nitrate + nitrite. Narrative objectives are provided for biostimulatory substances and toxicity. The existing water quality objectives are also protective of the ground water beneficial use (Staff TMDL Report, pp29). The State reasonably concluded that attainment of the specified numeric and narrative targets and associated TMDLs; load allocations, and wasteload allocations which call for the reduction of targeted pollutant loads, will result in elimination of the adverse effects associated with nitrogen loads in the water and bring about attainment of the applicable standards.
3. Numeric Target(s): Submission describes applicable water quality standards, including beneficial uses, applicable numeric and/or narrative criteria. Numeric water quality target(s) for TMDL identified, and adequate basis for target(s) as interpretation of water quality standards is provided.	The Staff TMDL Report dated June 16, 2003, pp34-40 and Basin Plan Amendment Summary, pp6. TMDL implements numeric WQS for ammonia, nitrate, nitrite and nitrate + nitrite. The Staff TMDL Report analysis concludes that exceedences of the these nitrogen compounds can adversely affect the beneficial uses including municipal and domestic supply, groundwater recharge, agricultural supply, industrial and surface water quality, recreational water contact (REC-1 and REC-2) and sensitive habitat uses (pp21). Numeric targets in this TMDL are based on the water quality objectives in the Basin Plan and an explicit margin of safety (10%) (Staff TMDL Report, pp34).

The numeric targets for ammonia are based on the "USEPA 1999 Update of Ambient Water Quality Criteria for Ammonia (USEPA 1999)", and have already been adopted by the Regional Board (Resolution No. 2002-11). For ammonia, numeric targets are pH and temperature dependent, and concentration based to protect water quality criteria for aquatic life.

The ammonia numeric targets are based on median concentrations of pH and temperature and do not assume application of an ammonia water effects ratio.

Numeric targets for this TMDL are listed as follows:

Total Ammonia (NH_3-N) (mg/L)

	1Hr Avg	30 day Avg
Reach 8	14.8	3.2
Reach 7 above Valencia	4.8	2.0
Reach 7 below Valencia	5.5	2.0
Reach 7 County Line	3.4	1.2
Reach 3 above Sta Paula	2.4	1.9
Reach 3 at Sta Paula	2.4	1.9
Reach 3 below Sta Paula	2.2	1.7

In accordance with the Basin Plan, the numeric targets for nitrate, nitrite and nitrate+nitrite are daily maximum values.

Nitrate-nitrogen & Nitrite-nitrogen (mg/L)

	NO3-N	NO2-N	NO3-N+NO2-N
Reach 8	4.5	0.9	4.5
Reach 7	4.5	0.9	4.5
Reach 6	9.0	0.9	9.0
Reach 5	4.5	0.9	4.5
Reach 4	4.5	0.9	4.5
Reach 3	4.5	0.9	4.5
Reach 2	9.0	0.9	9.0
Reach 1	9.0	0.9	9.0

In addition, the Basin Plan designates ground water recharge (GWR) as a beneficial use of the Los Angeles River. For all ground waters of the Region, "ground waters shall not exceed 10 mg/L nitrogen as nitrate-nitrogen plus nitrite-nitrogen (NO_3-N + NO_2-N), 45 mg/L as nitrate (NO_3), 10 mg/L as nitrate-nitrogen (NO_3-N), or 1 mg/L as nitrite-nitrogen (NO_2-N).

Narrative objectives for biostimulatory substances and toxicity are based on the Basin Plan. The TMDL analysis shows that the numeric targets will implement the narrative objectives. As a precautionary practice, the Implementation Plan will provide monitoring and special studies to verify that the TMDL will implement the narrative objectives.

The State's approach is a reasonable and environmentally protective approach for accounting for uncertainty in the relationship between pollutant loading levels and attainment of water quality standards, as required by the CWA Section 303(d)(1)(C).

4. Source Analysis: Point,	Staff TMDL Report, pp40-44 and Basin Plan Amendment Summary, pp6. The

nonpoint, and background sources of pollutants of concern are described, including the magnitude and location of sources. Submittal demonstrates all significant sources have been considered.	TMDL analysis provided a detailed summary of all nutrient sources in the Santa Clara River watershed and found the direct sources include discharge sources and sources transported via surface runoff or groundwater flow. Discharge sources include reservoir releases and direct point source discharges from the Saugus and Valencia WRPs and the Fillmore and Santa Paula POTWs. Groundwater sources include septic system discharges. Surface runoff sources are a result of land application activities and include diversions for groundwater recharge and/or irrigation, agricultural pumping, atmospheric deposition, and fertilizer application. Utilizing information from discharge monitoring reports, NPDES permits, groundwater quality data, rainfall data from nearby meteorological stations, fertilization loading rates, etc., loadings were computed for dry and wet periods for ammonia and nitrate by reach (Table 12, Staff TMDL Report, pp43). Source analysis identified all potential sources and determined that point source loads contribute almost all of ammonia, nitrite, and phosphorus in the water quality impaired segments of the Santa Clara River Watershed. The source of nitrate is due to a combination of point, non-point and groundwater sources. Non-point source loads are greater during the wet year than dry year and contribute nitrate to the impaired river segments through groundwater accretion Staff TMDL Report, pp43). Further evaluation of non-point sources is established in the Implementation Plan. The source analysis provided an effective basis for evaluating the source loads in the watershed and determined the primary water quality parameters of concern are nutrients, specifically ammonia, nitrite and nitrate. The Staff TMDL report adequately considered all significant sources by examining data from primary sources. The TMDL sufficiently described all sources of impairments.
5. Allocations: Submittal identifies appropriate wasteload allocations for point sources and load allocations for nonpoint sources. If no point sources are present, wasteload allocations are zero. If no nonpoint sources are present, load allocations are zero.	Staff TMDL Report, pp55-66 and Basin Plan Amendment Summary, pp7-8. The TMDL includes both waste load allocations for point sources and load allocations for non point sources. EPA concludes that the State's approach of setting the TMDLs and allocations on a concentration basis is appropriate for the waters and pollutants of concern and consistent with the provisions of 40 CFR 130.2(i), which authorizes expression of TMDLs in terms of "mass per time, toxicity, or other appropriate measure." **Waste load Allocations** Waste load allocations are established for the Water Reclamation Plants and Publicly Owned Treatment Works, and the municipal separate storm sewer system permittees in the upper reaches of the watershed. Waste load allocations for four different alternatives (1. setting effluent concentrations at the numeric target, 2. reducing the ammonia loading, 3. & 4. evaluate loads based on expected upgrades of WRP with a nitrate effluent concentration of 8.0 mg/L or 6.7 mg/L) were considered and were calculated using the WARMF model. The tightest condition (Alternative 4) was selected because it provided full compliance in all reaches and both the ammonia and nitrate+nitrite targets will be met. Concentration-based waste loads are allocated to the Fillmore and Santa Paula POTWs, major point sources of ammonia and nitrate+nitrite in Reach 3; concentration-based waste loads are allocated to Valencia and Saugus WRPs,

major point sources of ammonia and nitrate+nitrite in Reaches 7 and 8.

Total Ammonia (NH3-N) mg/L:

POTW	1 Hr Avg	30 Day Avg
Saugus WRP	5.6	2.0
Valencia WRP	5.2	1.75
Fillmore POTW	4.2	2.0
Santa Paula POTW	4.2	2.0

Nitrate (NO3-N), Nitrite (NO2-N) and Nitrate+Nitrite (NO2-N + NO3-N)

	30 Day Avg WLA*		
POTW	NO2-N	NO3-N	NO2-N + NO3-N
Saugus WRP	0.9	7.1	7.1
Valencia WRP	0.9	6.8	6.8
Fillmore POTW	0.9	8.0	8.0
Santa Paula POTW	0.9	8.0	8.0

*Receiving water monitoring is required on a weekly basis to ensure compliance with the water quality objectives for nitrite, nitrate, nitrite + nitrate, and dissolved oxygen.

Minor Point Sources

Minor waste load allocations are set equivalent to the water quality objectives for ammonia, nitrite, nitrate and nitrate + nitrite. WLAs for minor dischargers discharging into the following reaches are:

		mg/L	
	30-Day Avg NH3-N	1 Hr Avg NH3-N	30-Day Avg NO3-N+NO2-N
Reach 7	1.75	5.2	6.8
Reach 3	2.0	4.2	8.1

MS4 and Stormwater Sources

Concentration-based waste loads are allocated to municipal, industrial and construction stormwater sources regulated under the NPDES permits. WLAs for stormwater permittees discharging into the following reaches are:

		mg/L	
	30-Day Avg NH3-N	1 Hr Avg NH3-N	30-Day Avg NO3-N+NO2-N
Reach 7	1.75	5.2	6.8
Reach 3	2.0	4.2	8.1

In general, minor point sources (including MS4 and Stormwater sources) are not considered a significant source of ammonia, nitrite or nitrate loads to the Santa Clara River. However, due to potential localized effects on water quality, these waste loads will be implemented through the individual NPDES permits

	and the Monitoring and Reporting Programs associated with those permits (Staff TMDL Report, pp61). **Load Allocations** Concentration-based loads for nitrogen compounds are allocated for non-point sources. LAs for non point sources discharging into the following reaches are: mg/L NH_3-N + NO_2-N + NO_3-N Reach 7 8.5 Santa Clara River 10 Mint Cyn Reach 1 10 Wheeler Canyon/Todd Barranca 10 Brown/Long Canyon 10 Additional monitoring will be established in the Implementation Plan to verify the nitrogen non point source loadings from agricultural and urban runoff and groundwater discharge. Based on the information in the Staff TMDL Report, Basin Plan Amendment, and the letter of March 5, 2004, EPA concludes that the TMDLs include as appropriate waste load and load allocations which are consistent with the TMDLs and with the provisions of the Clean Water Act and federal regulations. The Regional Board's TMDL acknowledges the presence of significantly high nutrient loadings from both point and non-point sources. TMDL is defined in the federal regulation as the sum of all waste load allocations from point sources and load allocations for non-point sources and natural background (40 CFR 130.2(i)). The State's TMDL focuses permissibly, and in EPA's view properly, on point source loadings of ammonia, nitrate and nitrite from major WRPs and POTWs and minor dischargers and MS4 and stormwater sources, and non point source loadings of ammonia, nitrate and nitrite from surface runoff and groundwater discharge.
6. Link Between Numeric Target(s) and Pollutant(s) of Concern: Submittal describes relationship between numeric target(s) and identified pollutant sources. For each pollutant, describes analytical basis for conclusion that sum of wasteload allocations, load allocations, and margin of safety does not exceed the loading capacity of the receiving water(s).	Staff TMDL Report, pp44-55 and Appendix A, and Basin Plan Amendment Summary, pp6. The Regional Board provided adequate linkage analysis between nitrogen sources and the in-stream water quality. An appropriate linkage was established by using hydrodynamic and water quality models. The Watershed Analysis Risk Management (WARMF) was used to model the hydrodynamic characteristics and water quality of the Santa Clara River. WARMF can simulate the physical and chemical processes that affect river hydrology and water quality. Model analysis showed major point sources (WRPS and POTWs) were the primary contributors to in-stream ammonia and nitrate plus nitrite loads. Non-point sources and minor point sources composed a much smaller fraction of the loads. The model defines the storm flow conditions and adequately accounts for critical conditions (i.e., wet and dry weather months) and allows estimation of an implicit margin of safety associated with conservative assumptions in the model. The model includes a sensitivity analysis to account for parameter inputs with high uncertainty. The model was calibrated against critical conditions and monitoring data to verify its range of accuracy (pp48-55). EPA concludes the analysis sufficiently describes the link between numeric targets and the pollutant sources in Santa Clara River.

7. **Margin of Safety:** Submission describes explicit and/or implicit margin of safety for each pollutant.	Staff TMDL Report, pp66-69 and Basin Plan Amendment Summary, pp9. The TMDL includes an implicit and explicit margin of safety. The implicit margin of safety is included in the model through conservative model assumptions and statistical analysis. An explicit margin of safety is incorporated by reserving 10% of the load for uncertainty circumstances and limited data set availability. In addition, a number of special studies (e.g., rapid nitrogen compound disappearance, nitrate loading via groundwater) are planned to address the many assumptions built in the model. EPA considers this a permissible and appropriate way of dealing with uncertainty concerning the relationships between WLAs and water quality.
8. **Seasonal Variations and Critical Conditions:** Submission describes method for accounting for seasonal variations and critical conditions in the TMDL(s)	Staff TMDL Report, pp71-73 and Basin Plan Amendment Summary, pp9. The critical condition identified for this TMDL is based on the low flow condition defined as the 7Q10. Furthermore, the driest six months of the year are identified as a more critical condition for nitrogen compounds because less surface flow is available to dilute effluent discharge. The critical conditions for water quality in the Santa Clara River for nitrogen compounds are during low flow conditions, in particular at the end of the dry season. Model results also suggest the first strong storm events after a dry period can lead to significant short-term increases of nitrate compounds in the river. The implementation plan includes monitoring to verify this latter potential critical condition. The TMDL adequately accounts for the seasonal variations and critical conditions by examining the existing flow record and water quality data. The impairment assessment sufficiently included these situations in the analysis and margin of safety.
9. **Public Participation:** Submission documents provision of public notice and public comment opportunity; and explains how public comments were considered in the final TMDL(s).	<u>Regional Board Documents (Regional Board Administrative Record):</u> Pubic Stakeholder Steering Committee Meetings composed of vested stakeholders were held on a monthly basis from January 2002 to June 2003. The following public meetings were held for the Santa Clara River Nitrogen Compounds TMDL: Stakeholder meetings, October 15, 2002 and July 23, 2003; CEQA Scoping Meeting, June 12, 2003; Public Hearing, August 7, 2003. Summary of responses to public comments by Regional Board, July 2003. The Regional Board provided public notice and opportunities to comment on the TMDL through mailings to the Basin Plan mailing lists, by holding public meetings, and by hearing the public comments at these meetings on the TMDL. Several public comments were received in writing and in oral testimony. The State demonstrated how it considered these comments in its final decision by providing reasonably detailed responsiveness summaries, which include responses to each comment.
10. **Technical Analysis:** Submission provides appropriate level of technical analysis supporting TMDL elements.	The TMDL analysis provides a thorough review and summary of available information concerning nitrogen compounds impairing the specific areas of concern. We conclude the Regional Board was reasonably diligent in its technical analysis of nitrogen compounds in the Santa Clara River and its tributaries. Neither the Regional Board nor public commenters identified research nor study results which provided an analytical basis for setting the TMDL at a level higher than identified at this time.

SANTA CLARA RIVER

TOTAL MAXIMUM DAILY LOADS FOR NITROGEN COMPOUNDS

STAFF REPORT

California Regional Water Quality Control Board
Los Angeles Region

June 16, 2003

Santa Clara River Total Maximum Daily Loads for Nitrogen Compounds

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1 INTRODUCTION

Segments of Santa Clara River and its tributaries are impaired by ammonia, nitrate and nitrite and are included on the California 2002 303(d) list of water quality limited segments, which was approved by the State Water Resources Control Board on February 4, 2003. Additionally, one segment of the Santa Clara River is included on the State Monitoring List for organic enrichment/low dissolved oxygen. Two segments of the Santa Clara River are included on the State Enforceable Programs list for ammonia with one of those segments also listed for nitrite as nitrogen. Figure 1 depicts the Santa Clara River with the EPA reach designations. The Clean Water Act requires Total Maximum Daily Loads (TMDLs) be developed to restore impaired waterbodies, and the Porter-Cologne Water Quality Act requires that an Implementation Plan be developed to achieve water quality objectives. This document fulfills these statutory requirements and serves as the basis for amending the Water Quality Control Plan for the Los Angeles Region (Basin Plan) to achieve water quality standards in Santa Clara River for nutrients. This document contains:

- A description of the Santa Clara watershed including the segments of Santa Clara River and its tributaries that are impaired by nitrogen compounds,
- The data and methods to quantify the nitrogen compounds TMDL for Santa Clara River,
- Waste load and load allocations of nitrogen compounds sources in the Santa Clara River, and.
- An Implementation Plan to achieve water quality objectives for nitrogen compounds in the Santa Clara River.

This TMDL addresses the requirements prescribed by Section 303(d) of the Clean Water Act, 40 CFR 130.2 and 130.7, and U.S. Environmental Protection Agency guidance (U.S. EPA, 1991).

Santa Clara River Total Maximum Daily Loads for Nitrogen Compounds

This TMDL is based on analysis provided by Systech Engineering Inc. and Dr. Arturo Keller of UC Santa Barbara under contract to the Santa Clara River Stakeholder Group Steering Committee (Steering Committee) with financial support from the California Regional Water Quality Control Board-Los Angeles (Regional Board). Key analyses and data are referenced throughout this report as the "Technical Support Document" (Appendix A) and contain: The Santa Clara River TMDL Nutrient Analysis, Source Analysis and Linkage Analysis: Hydrology and Water Quality by Systech Engineering Inc. and Determination of the Critical Water Quality Conditions for the Impaired Reaches of the Santa Clara River Watershed, Analysis of Potential Nutrient Load Allocation of the Reaches of the Santa Clara River Considered in the 1998 303(d) List, and Analysis of pH variation in the Impaired Reaches of the Santa Clara River.

The nitrogen compound impairments in the River threaten warm water fish and wildlife habitats and groundwater recharge beneficial uses. Modeling was completed to link the documented nutrient sources to the in-stream water quality. The sources were characterized, in order of relative impact, as point discharges, groundwater with nonpoint source loading, and other nonpoint sources. Critical conditions were identified as occurring during low flow. Numeric targets and allocations for ammonia, nitrate and nitrite were set according to a model scenario which attains water quality objectives with a 10 percent margin of safety everywhere in the watershed except EPA Reach 7, where additional monitoring is required.

The Implementation Plan of this TMDL is designed to attain water quality objectives for nitrate, nitrite, and ammonia and to ensure protection of beneficial uses in the Santa Clara River. Attaining the nitrogen compound objectives will likely address ancillary nutrient effects, including dissolved oxygen and organic enrichment and ecological health indicators. The implementation plan requires continued studies to verify this assumption. There are insufficient data to characterize nitrogen sources from groundwater, septic systems, and agricultural drainage and runoff. There are also limited data regarding aquatic life and eutrophic impacts of the Santa Clara River. Consequently, the Implementation Plan includes monitoring to assess these parameters. Should these studies demonstrate that aquatic life habitat needs lower nitrogen targets than proposed in this TMDL, the Regional Board may revise targets and reallocate wasteloads through a reevaluation process included in the Implementation Plan.

1.1 Regulatory Background

Section 303(d) of the Clean Water Act (CWA) requires that "Each State shall identify those waters within its boundaries for which the effluent limitations are not stringent enough to implement any water quality standard applicable to such waters." The CWA also requires states to establish a priority ranking for waters on the 303(d) list of impaired waters and establish TMDLs for such waters.

The elements of a TMDL are described in 40 CFR 130.2 and 130.7 and Section 303(d) of the CWA, as well as in the U.S. Environmental Protection Agency guidance (U.S. EPA, 1991). A TMDL is defined as the "sum of the individual waste load allocations for point sources and load allocations for nonpoint sources and natural background" (40 CFR 130.2) such that the capacity of the waterbody to assimilate pollutant loadings (the Loading Capacity) is not exceeded. TMDLs are also required to account for seasonal variations, and include a margin of safety to address uncertainty in the analysis.

States must develop water quality management plans to implement the TMDL (40 CFR 130.6). The U.S. EPA has oversight authority for the 303(d) program and is required to review and either approve or disapprove the TMDLs submitted by states. If the U.S. EPA disapproves a TMDL submitted by a state, U.S. EPA is required to establish a TMDL for that waterbody.

The Regional Board identified over 700 waterbody-pollutant combinations in the Los Angeles Region where TMDLs are required (LARWCQB, 1996, 1998). A schedule for development of TMDLs in the Los Angeles Region was established in a consent decree (Heal the Bay Inc., et al. v. Browner C 98-4825 SBA) approved on March 22, 1999. The consent decree combined waterbody pollutant combinations in the Los Angeles Region into 92 TMDL analytical units. According to the consent decree, the Santa Clara River Nitrogen TMDL must be approved or established by US EPA by March 22, 2004. In accordance with the consent decree, this document summarizes the analyses performed and presents the TMDL for nitrogen compounds and related effects for the Santa Clara River.

Ammonia is one of the key nitrogen compounds addressed by this TMDL. The Basin Plan includes an objective-specific compliance schedule for the inland surface water ammonia objectives. Specifically, the Basin Plan provided dischargers until June 13, 2002, 8 years from adoption of the Basin Plan, to make the necessary adjustments and improvements to meet the objectives or to conduct studies leading to an approved site-specific objective for ammonia. At public hearings on January 11, 2001 and May 31, 2001, the Regional Board heard status reports on Publicly Own Treatment Works (POTWs) progress toward compliance with inland surface water ammonia objectives from Regional Board staff. The status report indicated that Saugus and Valencia Treatment Plants expected to be in compliance with the ammonia objective by June 2003. Due to recent delays, the Regional Board will consider a Time Schedule Order for to extend the compliance date for the Saugus WRP until September 2003. Santa Paula Wastewater Treatment Facility, and Fillmore Wastewater Treatment Plant have done some research, modified the treatment plants and conducted some experimentation with process operation. Without nitrifying and denitrifying, the Santa Paula and Fillmore POTWs will not be able to meet the water quality objective for ammonia, nitrite and nitrate.

1.2 Environmental Setting

The Santa Clara River is the largest river system in the Los Angeles Region that remains in a relatively natural state. Like most areas in southern California, the watershed of the Santa Clara River has been subjected to significant land use and flow modifications due to urban development and agricultural practices. However, compared to other watersheds in southern California, the Santa Clara River still retains many forested areas and relatively undisturbed tributaries, and has important biological resources, including the endangered steelhead trout and stickleback. The mountains are composed of marine and terrestrial sedimentary and volcanic rocks. The basins are filled with a mixture of deposits of sands, silts and clays interspersed throughout the region, representing the exposure of several of the underlying formations.

1.2.1 Historic and Current Flow

Much of the lower watershed was originally Spanish land grants used for grazing cattle and dry-land farming. Urbanization since the late 1940's has continuously modified the land use, resulting in discharge of imported water and municipal wastewater. Since the 1950's, agriculture has shifted from seasonal dry-land farming to predominantly year-round irrigated farming of citrus, avocado and row crops.

The basin drains from the east beginning in the Transverse Ranges below Soledad Pass through the Santa Clara River and its major tributaries, Castaic, Piru, Hopper, Sespe and Santa Paula Creeks. Natural flow in all the major streams and tributaries in the basin is intermittent and ephemeral, with most of the streamflow related to flood flows. At certain times of the year, the river is continuous from the headwaters to the discharge at the estuary. The controlled release of water from Lake Piru since 1955 and from Pyramid Lake since 1975 has resulted in fewer days of no flow in the lower portion of the Santa Clara River, in Ventura County above the Freeman Diversion. In addition, the release of treated wastewater treatment plant effluent and imported water has resulted in an additional flow in the Santa Clara River across the Los Angeles-Ventura County line. This surface flow, however, may not persist as it percolates to the underlying groundwater within a relatively short distance downstream of the Los Angeles-Ventura County line. Part of the year a dry or low flow gap exists from the point the surface water disappears to the confluence of the river with Piru Creek. Water from Northern California is imported by United Water Conservation District through Pyramid Lake and Lake Piru, and periodically released down Piru Creek and the lower portion of the Santa Clara River, in Ventura County. Water is also imported by Castaic Lake Water Agency for municipal use in the Santa Clarita Valley and releases in Castaic Creek. In addition, some of this imported water enters the watershed either as treated effluent, irrigation return flow or via groundwater (USGS, 1998).

Thus, the flow of the Santa Clara River (SCR) has been modified due to the climatic conditions, partial drawdown of some regional aquifers from decades of pumping, release of treated effluent and imported water (USGS, 1998). Discharges from waste water treatment plants, and nonpoint source emissions in the watershed have changed the flow and concentration of nutrients and other contaminants in receiving waters.

1.2.2 Climate

The climate of the Santa Clara River watershed is mild and characterized as Mediterranean, typical of much of southern California. Average annual temperature ranges from about 70°F near the coast to 60°F inland. On the coastal plain the maximum temperature is about 100°F and the minimum only slightly below freezing. Frosts on the coastal plain are uncommon. Inland, maximum temperatures are higher, minimum temperatures are lower, and frosts are much more frequent. Like the rest of coastal Southern California, the climate is of the Mediterranean type with a long dry summer and a short, comparatively wet winter. Almost all of the precipitation occurs in the November-to-April period. Even during the wet season, skies are clear and humidity low during a very large percentage of the time.

1.2.3 Discharges in the Watershed

The Regional Board has granted National Pollutant Discharge Elimination System (NPDES) permits to five major dischargers (average effluent flow rate exceeds 0.5 million gallons per day (MGD)) and numerous minor dischargers in the Santa Clara River watershed.. The major dischargers include four Water Reclamation Plants (WRP) that discharge into the Santa Clara River, the Saugus, Valencia, Santa Paula and Fillmore WRPs. The Fillmore WRP discharges to percolation ponds during dry weather and to the River during wet weather. In addition, the City of San Buenaventura WRP discharges to the Santa Clara River estuary. Minor discharges in the Santa Clara River watershed include dewatering and construction projects that are covered by general NPDES permits. In addition, other minor dischargers include MS4 permittees and industrial facilities that are covered by individual permits. The number of minor discharge permits varies in number and duration each year. The major and minor discharges are discussed in Section 2.3, Source Assessment.

Among the minor NPDES discharge permits are those for storm runoff from construction sites. In 2000, there were 310 sites enrolled under the construction storm water permit with a similar number of sites located in the upper and lower watershed. The majority of these are residential sites 10 acres or larger in size.

1.2.4 Surface Water/Groundwater Interactions

The underlying groundwater basins are, from east to west, Upper Santa Clara, Piru, Fillmore, Santa Paula, Oxnard Forebay and Oxnard Plain. Under natural conditions, groundwater flow is predominately seaward. In the Oxnard Plain, overpumping has resulted in seawater intrusion toward the centers of pumping.

The watershed has been studied extensively beginning in 1957 and as recently as 2002(United Water Conservation District 1957, 1968, USGS 1995, 1996, 1999, 2002). These studies find that a large amount of groundwater recharge occurs at the upstream end of the Piru Basin, at about the L.A./Ventura county line. Controlled surface recharge also occurs by conservation releases from Piru reservoir via Piru Creek, Castaic Lake via Castaic Creek and waste discharges. A large amount of surface recharge is introduced by Sespe Creek and is associated with groundwater discharge from the Fillmore Basin. Groundwater discharge also occurs at the downstream end of the Santa Paula basin and includes water high in sulfates. The surface flow is usually diverted at the Freeman Diversion in the Santa Paula Basin for agricultural supply water.

1.2.5 Habitat

Extensive patches of high quality riparian habitat are present along the length of the river and its tributaries. Two endangered fish, the unarmored stickleback and the steelhead trout reside in the river. One of the largest of the Santa Clara River's tributaries, Sespe Creek, is designated a wild trout stream by the State of California and supports significant spawning and rearing habitat for the steelhead trout. Sespe Creek is also designated a Wild and Scenic River. According to a presentation by Ian Smith, Los Angeles County Parks and Recreation and Kate Simons, Fish and Wildlife, in Santa Clarita, on March 12, 2003 to the Wetland Recovery Project Managers Meeting, the Santa Clara River serves as an important wildlife corridor and habitat for several endangered, listed or indicator species including: Arroyo Toad, Slender Horned Spineflower, Southwest Willow Flycatcher, Red-Legged Frog, California Gnat Catcher, Plummers Mariposa Lily, Ocelated Humboldt Lily, Prostrand Navarretia, Forest Camp Sandwort, Summer Taninger, Riverside Fairy Shrimp, Nevins Barberry and Loggerhead Shrike. The estuary at the mouth of the river supports a large variety of wildlife as well.

1.2.6 Reach Designations

The Santa Clara River is characterized by a number of reaches according to two reach designations as shown in Table 1, Regional Board Basin Plan and USEPA (2002 303(d) list). Unless otherwise noted, the USEPA reach designations are used to develop numeric targets and wasteload allocations. The Source and Linkage Analyses are also based on US EPA designations.

Table 1. Santa Clara River Reach designations - US EPA

EPA Reach	Regional Board Reach	Designation
EPA Reach 1	RB Reach 1	Santa Clara Estuary to Highway 101 Bridge
EPA Reach 2	RB Reach 2	Highway 101 Bridge to Freeman Diversion
EPA Reach 3	RB Reaches 3 & 4 (partial)	Freeman Diversion to Timber Canyon (above Santa Paula Creek)
EPA Reach 4	RB Reach 4	Timber Canyon to Grimes Canyon
EPA Reach 5	RB Reach 4	Grimes Canyon to Propane Road
EPA Reach 6	RB Reach 4	Propane Road to Blue Cut Gauging Station
EPA Reach 7	RB Reach 5	Blue Cut Gauging Station to West Pier Highway 99
EPA Reach 8	RB Reach 6	West Pier Highway 99 to Bouquet Canyon Road Bridge
EPA Reach 9	RB Reach 7	Bouquet Canyon Road Bridge to above Lang Gauging Station

EPA Reach	Regional Board Reach	Designation
EPA Reach 10	RB Reach 8	Above Lang Gauging Station

1.2.7 Aquatic Life Habitat

The beneficial uses of the Santa Clara River include aquatic life habitat. Two recent studies by UCLA and Department of Fish and Game (Appendix B) contain observations and evaluations of aquatic life habitat in the Santa Clara River. The UCLA (2003) study of algae, macroinvertebrates, chemistry and physical characteristics found that segments of the Santa Clara River showed a decreased diversity of sensitive macroinvertebrates below the Valencia WRP relative to another site just upstream of the outflow and that other indicators of biological health did not change consistently (UCLA, 2003). The Implementation Plan of this TMDL includes development of a monitoring program to document the aquatic life conditions in the Santa Clara River.

1.3 Santa Clara River Nutrient TMDL Stakeholder Participation Process

The stakeholder involvement process for the Santa Clara River Nutrient TMDL began in November 2001 with a kick-off meeting led by the Regional Board. Stakeholders include representatives of wastewater treatment plants, cities, counties, private property owners, agricultural organizations, and environmental groups with interests in the watershed; a complete stakeholder list is attached. These groups were informed by the Regional Water Quality Control Board of the ensuing TMDL and were invited to participate in its development. At the kickoff meeting the Regional Board presented the preferred conceptual process for the TMDL, involving a coordinated effort among the Regional Board, stakeholders and outside consultants. This approach is different from the approach used in other TMDLs, where the process has typically been either a Regional Board-led or a stakeholder-led process. This is a new coordinated approach among stakeholders and the Regional Board developed to improve participation of all interested parties.

1.3.1 Technical Steering Committee Involvement

A Steering Committee was formed to allow those stakeholders interested in taking a more active role in the TMDL technical work to guide and participate in the analysis. Steering committee meetings were held monthly, with quarterly stakeholder meetings for summary and update purposes. A complete list of Steering Committee members and a meeting schedule summary is presented below.

Steering Committee:

- Los Angeles Regional Water Quality Control Board (Regional Board)*: Jon Bishop, Samuel Unger, Elizabeth Erickson, Dr. C.P. Lai
- Los Angeles County Sanitation District (LACSD)*: Victoria Conway, Beth Bax, Christian Alarcon, Sharon Green, Heather Lamberson, Sharon Landau
- The Newhall Land and Farming Company (Newhall Land)*: Mark Subbotin, Norm Brown (Integrated Water Resources), Brandon Steets (Integrated Water Resources)
- City of Santa Clarita*: Heather Merenda, Travis Lang
- City of Fillmore*: Bert Rapp
- City of Santa Paula*: Norm Wilkinson, Bob Guerra
- United Water Conservation District (UWCD): Steve Bachman, Dan Detmer, Murray McEachron
- Ventura County Department of Public Works (VCDPW): Jayme Laber, Lorraine Timmons, Gail Robinson, Paul Tantet
- Los Angeles County Department of Public Works (LADPW): Ofori Amoah, Suk Chong, TJ Kim, Joy Krejci
- Ventura County Supervisor Kathy Long: Martin Hernandez
- Ventura County Farm Bureau: Rex Laird
- Friends of the Santa Clara River: Ron Bottorff, Richard Sweet
- California Department of Water Resources: Diane Sanchez
- University of California Santa Barbara (facilitator): Dr. Arturo Keller, Timothy Robinson
- California Center for Public Dispute Resolution (facilitator/conflict resolution expert): Judith Talbot
- Systech Engineering (modeler): Joel Herr

* These groups shared the costs for facilitation and modeling consultants.

The following provides a summary of the Steering Committee meetings:

Date	Meeting Highlights	Meeting Type
2/11/02	Define problem, discuss data needs.	Steering Committee.
3/4/02	Discuss: draft problem statement, modeling RFP, funding for modeling, facilitators' and stakeholders' roles.	Steering Committee.
3/29/02	Presentations by four contractors for modeling proposals.	Steering Committee.
4/3/02	Discuss timeframe and focus of modeling analysis; compare BASINS v. WARMF; select modeling consultant; discuss costs.	Steering Committee.
4/22/02	Review and discuss revised problem statement, overview on the nature of – and approaches to setting–numeric targets.	Steering Committee.
6/11/02	Review and discuss source assessment results: subregions; loading mechanisms and data sources, loading by subregions. Identify data gaps.	Steering Committee.
6/22/02	Presentation on progress to date and source assessment.	Public - Stakeholders
7/22/02	Discuss: available water quality data; current and future WQ sampling plans. Overview of procedure for hydrologic modeling; water effects ratios and source assessment update.	Steering Committee.
8/19/02	Present and discuss hydrologic modeling results.	Steering Committee.
9/9/02	Present and discuss linkage analysis results. Updates on WWTP upgrades. Brief discussion on numeric targets.	Steering Committee.
9/23/02	Detailed response to comments on linkage analysis.	Steering Committee.
10/15/02	Presentation on progress to date and linkage analysis.	Public - Stakeholders
10/31/02	Discuss: basis for numeric targets, revisions to linkage analysis.	Steering Committee.
11/18/02	Present and discuss modeling scenarios. (base case and permit) to meet numeric targets;	

	implications of changes to 303 (d) list.	Steering Committee.
12/9/02	Present and discuss modeling scenarios (representing four different strategies) to meet numeric targets; next steps for writing technical TMDL document.	Steering Committee.
2/3/03	Present and discuss: key points in problem statement and linkage analysis sections of TMDL; possible studies which could be part of the implementation phase.	Steering Committee.
4/16/03	Present and discuss key elements of draft staff report on technical options; WWTP cost options.	Steering Committee.
5/15/03	Review and discuss revisions to draft staff report on technical options.	Steering Committee
6/5/03	Review and discuss revisions to draft staff report on technical option	Steering Committee
6/12/03	CEQA Scoping	Public

The Steering Committee members contracted outside experts to provide technical facilitation and modeling services in support of the TMDL analysis. The Steering Committee selected Dr. Arturo Keller from the UC Santa Barbara Bren School of Environmental Science and Management as technical facilitator. Dr. Keller was asked to conduct project management, summarize and coordinate technical analysis and facilitate Stakeholder meetings. This process was intended to assist the Regional Board in developing stakeholder consensus on the nutrient TMDL plan for the Santa Clara River watershed. Facilitation was funded by the RWQCB.

1.3.2 Meeting Facilitation

The facilitator coordinated and assisted the TMDL development process, including organization and facilitation of quarterly meetings open to all stakeholders. Principal work items for meeting facilitation included:

- Facilitation of Santa Clara River nutrient TMDL meetings (including production and distribution of agendas and meeting minutes summaries);
- Integration of stakeholder and Regional Board interests and concerns;
- Oversight and assistance in modeling work;

- Organization and execution of modeling laboratory sessions for stakeholders interested in learning how to use the watershed model;
- Use of the calibrated model to simulate implementation scenarios requested by stakeholders and the Regional Board; and,
- Presentation of a report summarizing modeling results for various load allocation scenarios.

Dr. Keller drafted a request for proposals (RFP) for the modeling consultant selection process and led the interviews for modeling consultant applicants. The Steering Committee selected Systech Engineering, Inc. (San Ramon, California) for the modeling work. The cost of the modeling effort was shared by LACSD, LADPW, Newhall Land, and the cities of Santa Clarita, Fillmore and Santa Paula.

1.3.3 Model Development and Calibration.

After consideration of watershed modeling proposals from several consultants, the Steering Committee selected Systech, Engineering, Inc. who proposed to model the watershed using the WARMF (Watershed Analysis Risk Management Framework) watershed modeling software. Systech's scope of work included two primary tasks: (1) to provide a nutrient source load identification and characterization analysis, and (2) to provide a linkage analysis, linking nutrient source loads with in-stream concentrations using the WARMF watershed model.

The level of involvement of stakeholders was very high throughout the modeling process. Stakeholders provided water quality and flow input data sets as well as detailed comments on each of the task reports provided by Systech. Stakeholders also participated in model setup, calibration, sensitivity analysis, verification and scenario selection. Consensus from the Steering Committee was achieved subsequent to each stage of model development.

With support from the stakeholder group, Systech used the WARMF model to integrate all water quality, air quality, hydrologic, meteorological, topographic, land use and soil type data in a single, consistent spatial-database. A Source Identification and Characterization report was presented that described assumptions and results of the source analysis, together with an assessment of the relative magnitude of point and non-point sources in the various subcatchments of the Santa Clara River watershed.

Following identification and quantification of all point and nonpoint nutrient sources in the Santa Clara River watershed, the WARMF modeling sought to characterize the magnitude and timing of nutrient loading to surface water bodies. This step, known as the linkage analysis, involves the linkage of nutrient source loads to in-stream concentrations. Systech provided a linkage analysis report to the Steering Committee, and further analysis was conducted by, and on behalf of, the stakeholder group to test new and different assumptions and scenarios using the model. Systech also provided a calibrated executable version of the model that allows the facilitator and Steering Committee members to perform simulations of different scenarios independently.

1.3.4 Summary

A high level of stakeholder involvement has occurred throughout the TMDL development process. There have been no interventions from outside groups, and much of the work has been performed, or paid for, by members of the Steering Committee. All parties involved consider the process to be a significant improvement over other methods used for TMDL development. This TMDL process should receive statewide attention as an excellent model for a successful stakeholder-Regional Board cooperative effort.

2 PROBLEM IDENTIFICATION

The 2002 water quality assessment identifies reaches of the Santa Clara River that are impaired for ammonia (Reach 3) and nitrate and nitrite (Reach 7). Nitrite and nitrate are biostimulatory substances that can cause or contribute to eutrophic effects such as low dissolved oxygen and algae growth in inland surface waters such as the Santa Clara River. Excessive ammonia can cause aquatic life toxicity in inland surface waters such as the Santa Clara River. Although the Santa Clara River is not listed as impaired for the effects of nitrogen impairment, Regional Board staff finds evidence that the following effects may be of concern in the Santa Clara River, including:

- The 1998 303 (d) list contains an impairment for organic enrichment and dissolved oxygen in Reach 8. Although this impairment was removed from the 2002 303(d) list, it was placed on the State of California "Monitoring List" indicating that the State considers monitoring to be appropriate and a high priority.
- Studies by UCLA and California Department of Fish and Game (Appendix B) indicate low diversity of benthic macroinvertebrate samples in the area below the Valencia WRP outfall. More data are required to assess the status of aquatic life habitat.
- Observations of algae by Regional Board staff and other researchers and stakeholders.

This TMDL addresses impairments on the 2002 303(d) list and it is appropriate to consider water quality effects that these impairments can cause. Consequently, this section provides an overview of water quality standards for the Santa Clara River, reviews water quality data used in the 1998 water quality assessment and additional data used to analyze sources in this TMDL.

2.1 Water Quality Standards

California state water quality standards consist of the following elements: 1) beneficial uses; 2) narrative and/or numeric water quality objectives; and 3) an antidegradation policy. For inland surface waters in the Los Angeles Region, beneficial uses are identified in the Basin Plan. Numeric and narrative objectives are specified in the Basin Plan, designed to be protective of the beneficial uses in each waterbody in the region or State Water Quality Control Plans. The Basin Plan for the Los Angeles Regional (1994) defines 14 beneficial uses for the Santa Clara River.

2.1.1 Beneficial Uses

The Basin Plan has identified the following beneficial uses for the Santa Clara River:

Table 2. Beneficial Uses of the Santa Clara River and Tributaries

STREAM REACH	Hydro Unit No.	MUN	IND	PROC	AGR	GWR	FRSH	REC1	REC2	WARM	COLD	WILD	RARE	MIGR	WET
Santa Clara River	403.11	P*	E	E	E	E	E	E	E	E	E	E	E	E	E
Santa Clara River	403.21	P*	E	E	E	E	E	Ed	E	E		E	E	E	E
Santa Clara River	403.31	P*	E	E	E	E	E	Ed	E	E		E	E	E	E
Santa Clara River	403.41	P*	E	E	E	E	E	E	E	E		E	E	E	E
Lake Piru	403.42	P	E	E	E	E	P	E	E	E	E	E	E		
Pyramid Lake	403.42	E	E	E	E	E	P	E	E	E	E	E	E		
Castaic Lagoon	403.51	E*	E	E	E	E	E	E	E	E		E			
Elizabeth Lake	403.51	P	I	I	I	I	I	I	E	I		E			
Lake Hughes	403.51	P	P	P	P	P	P	E	E	E		E			
Mint Canyon Creek	403.51	I	I	I	I	I	I	Im	I	I		E			
Munz Lake	403.51	P*	P	P	P	E	P	E	E	E		E			
Santa Clara River	403.51	P*	E	E	E	E	E	E	E	E		E	E		E
Santa Clara River (Soledad Cyn)	403.55	E*	E	E	E	E	E	E	E	E		E	Ei		E
Brown Barranca/ Long Canyon		P*	E	E	E	E	E	E	E	E		E	E,	E	E
Wheeler Canyon/ Todd Barranca		P*	E	E	E	E	E	E	E	E		E	E	E	E

E Existing beneficial use
P Potential beneficial use
I Intermittent beneficial use
* Conditional designation that may be considered for exemption at a later date

d Limited public access precludes full utilization
i Soledad Canyon is the habitat of the Unarmored Three-Spine Stickleback
m Access prohibited by Los Angeles County DPW in the concrete-channelized area
s Access prohibited by Los Angeles County DPW

Unless otherwise noted, these designated beneficial uses are either existing or potential. The designated beneficial uses are briefly described below.

2.111 MUN; Municipal and Domestic Supply

Municipal and Domestic Supply (MUN) is defined as uses of water for community, military, or individual water supply systems including, but not limited to, drinking water supply. The MUN designations for the Santa Clara River are designated as potential uses, except for SCR Hydro Unit 403.55 and Mint Canyon Creek that are designated as existing and intermittent, respectively. The MUN designations that are noted with an asterisk are conditional designations that were designated under SB 88-63 and RB 89-03. Conditional designations are currently not recognized under federal law and are not water quality standards subject to enforcement at this time. (See Letter from Alexis Strauss [USEPA] to Celeste Cantú [State Board], Feb. 15, 2002.)

2.112 GWR; Groundwater Recharge

The Basin Plan defines groundwater recharge as: "Uses of water for natural or artificial recharge of ground water for purposes of future extraction, maintenance of water quality, or halting seawater intrusion into freshwater aquifers."

Water use in the Santa Clara River watershed supports the GWR designation of the Santa Clara River as an existing beneficial use. Surface water infiltrates into aquifers underlying the Santa Clara River from pervious land surfaces, the river and tributaries, and from engineered recharge basins. Groundwater from the alluvial and Saugus aquifers is extracted for municipal supply and agricultural supply and discharges to the surface water as a TMDL source.

Because the State has designated GWR as a beneficial use for the Santa Clara River, the use becomes a federally recognized (and hence enforceable) "state water quality standard." Consequently, GWR is a beneficial use that the TMDL must protect.

2.113 AGR; Agricultural Supply

Agricultural Supply is defined as uses of water for "farming, horticulture, or ranching including, but not limited to, irrigation, stock watering, or support of vegetation through range grazing." AGR is an existing beneficial use of the Santa Clara River, with surface water directly diverted for irrigation and groundwater extracted for irrigation.

2.114 IND, PROC, and FRSH; Industrial and Surface Water Quality

Industrial Service Supply, Industrial Process Supply, and Freshwater Replenishment are designated as existing beneficial uses of the Santa Clara River. Industrial Service Supply and Industrial Process Supply are both defined as uses of water for industrial activities, with PROC denoting uses that depend on water quality and IND denoting uses that do not depend on water quality. FRSH is defined as uses of water for natural or artificial maintenance of surface water quality.

2.115 REC-1 and REC-2: Recreational Uses

Water Contact Recreation (REC-1) and Non-Contact Water Recreation (REC-2) are defined as uses of water for recreational activities involving body contact and proximity to water. Some of these activities include fishing, sightseeing and aesthetic enjoyment in conjunction with recreational activities. These beneficial uses are directly affected by ammonia and nitrogen because ammonia causes fish and aquatic life toxicity and nitrogen in surface water can lead to excessive aquatic growth.

2.116 WARM,WILD,RARE,WET,COLD; Habitat Related Uses

Several habitats related beneficial uses are designated for the Santa Clara River. These uses include warm freshwater habitat, cold freshwater habitat, wildlife habitat, rare, threatened or endangered species habitat, migration of aquatic organisms, and wetland habitat. These habitat-related beneficial uses are affected by ammonia and nitrogen because ammonia causes fish and aquatic life toxicity and nitrogen in surface water can lead to excessive aquatic growth.

2.1.2 Water Quality Objectives

The Basin Plan provides water quality objectives (WQOs) for nitrogen compounds and their related effects, including numeric and narrative objectives discussed below. Both types of objectives are used in developing numeric targets and wasteload allocations.

2.12.1 Ammonia

The Basin Plan provides the following objectives for ammonia:

> The neutral, un-ionized ammonia species (NH_3) is highly toxic to fish and other aquatic life. The ratio of toxic NH_3 to total ammonia ($NH_4^+ + NH_3$) is primarily a function of pH, but is also affected by temperature and other factors. Additional impacts can occur as the oxidation of ammonia lowers the dissolved oxygen content of the water, further stressing aquatic organisms. Ammonia also combines with chlorine (often both are present) to form chloramines – persistent toxic compounds that extend the effects of ammonia and chlorine downstream.
>
> *In order to protect aquatic life, ammonia concentrations in receiving waters shall not exceed the values listed for the corresponding in-stream conditions in Tables 3-1 to 3-4 [of the Basin Plan.]*

The Basin Plan objectives for ammonia currently are based on "Ambient Water Quality Criteria for Ammonia – 1984," developed by EPA, which contains criteria for protection of freshwater aquatic life. In 1999, EPA revised its recommended values for the Criteria Continuous Concentration (CCC) through a memorandum entitled "Revised Tables for Freshwater Ammonia Concentrations."

The EPA's updated 1999 criteria reflect research and data analyzed since 1985, and represent a revision of several elements in the 1984 guidance, including the relationship between ammonia toxicity, pH and temperature, and the recognition of increased sensitivity of early life stage forms of fish to ammonia toxicity. The 1984 criteria were based on un-ionized ammonia (NH_3), while the 1999 criteria are expressed only as total (un-ionized plus ionized or $NH_3 + NH_4^+$) ammonia. The criteria apply to freshwater and do not impact the Ammonia Water Quality Objectives contained in the California Ocean Plan.

Chronic values presented in the updated criteria were derived based on regression analysis. In the past, hypothesis testing was used whereby the chronic value was derived by calculating the geometric mean of the "no observed effects concentration" (NOEC) and the "lowest observed effects concentration" (LOEC). Regression analysis is the preferred method because it is more reflective of the magnitude of the toxic response. The results of hypothesis testing vary depending on the values tested and the variability of the database. The updated chronic criteria are raised slightly because one of the chronic toxicity tests involving white sucker used to develop the 1984 criteria was no longer considered valid.

The toxicity of ammonia is a function of pH and temperature, as indicated in these documents. Low pH and low temperature result in lower toxicity. The target for ammonia also depends on the averaging time, as follows:

1) The one-hour average concentration of total ammonia as nitrogen (in mg N/L) shall not exceed (more than once every three years on average) the criteria maximum concentration (CMC) calculated as follows:

Where salmonid fish are present:

$$CMC = \frac{0.275}{1+10^{7.204-pH}} + \frac{39.0}{1+10^{pH-7.204}}$$

Where salmonid fish are not present:

$$CMC = \frac{0.411}{1+10^{7.204-pH}} + \frac{58.4}{1+10^{pH-7.204}}$$

2) The thirty-day average concentration of total ammonia as nitrogen (in mg N/L) shall not exceed (more than once every three years on average) the criteria continuous concentration (CCC) calculated as follows:

Where early life stage fish are present:

$$CCC = \left(\frac{0.0577}{1+10^{7.688-pH}} + \frac{2.487}{1+10^{pH-7.688}}\right) * MIN(2.85, 1.45x10^{0.028*(25-T)})$$

Where early life stage fish are not present:

$$CCC = \left(\frac{0.0577}{1+10^{7.688-pH}} + \frac{2.487}{1+10^{pH-7.688}}\right) * 1.45x10^{0.028*(25-MAX(T,7))}$$

where T = temperature in °C.

3) The highest four-day average within the 30-day period shall not exceed 2.5 times the CCC.

The most significant differences in the 1999 U.S. EPA guidance for ammonia are:

- Acute criteria are no longer temperature-dependent but remain dependent on pH and fish species present,
- There is a greater recognition of the temperature dependence of the chronic criteria, especially at low temperatures,
- An Early Life Stage (ELS) chronic criterion was introduced,

- Chronic criteria are no longer dependent on the presence or absence of specified fish species, but remain dependent on pH and temperature, and
- A 30-day averaging period for the ammonia chronic criteria replaced the 4-day averaging period.

The 1984 chronic criteria were dependent mainly on pH and there was no temperature dependency below 20 degrees. The updated chronic criteria are dependent on pH and temperature. At lower temperatures, the chronic criteria are also dependent on the presence or absence of early life stages of fish (ELS), regardless of species. Another significant revision to the 1999 Update is EPA's recommendation of 30 days as the averaging period for the chronic criteria instead of 4 days. The averaging period has been extended because the most sensitive test species used; fathead minnow (Pimephales promelas) and fingernail clam (Muscullum transversum) show their sensitivity after long periods of exposure.

The Regional Board approved revised Basin Plan objectives for ammonia based on EPA's updated criteria on April 25, 2002. The revised objectives were approved by State Board on April 30, 2003 and were approved by the Office of Administrative Law (OAL) on June 5, 2003. This TMDL has been developed to be consistent with the updated objectives. Further, the Regional Board's resolution adopting the TMDL will specify that the ammonia allocations will take effect following the approval of the revised criteria by USEPA.

2.12.2 Oxidized Nitrogen

In terms of use protection levels for nitrate as nitrogen, the primary drinking water standard is 10 mg-nitrogen/L. The drinking water standard for nitrite as nitrogen is 1 mg-nitrogen/L. Since nitrite oxidizes to nitrate under ambient conditions, when both nitrate plus nitrite are present, their sum should not exceed 10 mg nitrogen/L when considering the protection of a drinking water beneficial use. Many segments of the Santa Clara River have been designated with a conditional potential MUN beneficial use as noted in Section 1.4.1. These waters do not have this beneficial use until the State undertakes additional study and modifies its Basin Plan.

The Basin Plan establishes numeric water quality objectives for nitrogen in surface waters in the Los Angeles Region, including Santa Clara River and its tributaries, expressed as nitrate-nitrogen plus nitrite-nitrogen (NO_3-N +NO_2-N). Table 3-8 of the Basin Plan prescribes water quality objectives for nitrate-nitrogen plus nitrite-nitrogen (NO_3-N +NO_2-N) for reaches above Freeman Diversion equal to 5 or 10 mg/L nitrogen. Below Highway 101, numeric objectives are not defined in the Basin Plan, but narrative objectives apply.

2.12.3 Biostimulatory Substances

The Basin Plan specifies, "Waters shall not contain biostimulatory substances in concentrations that promote aquatic growth to the extent that such growth causes nuisance or adversely affects beneficial uses." The Basin Plan also recognizes that such excessive growth can cause water quality problems (e.g., high pH) and aesthetic problems (e.g., odor, scum). Excess nitrogen, as ammonia, nitrite or nitrate, promotes the growth of algae and is considered a biostimulatory substance subject to the narrative objective.

2.12.4 Toxicity

The Basin Plan states that "All waters shall be maintained free of toxic substances in concentrations that are toxic to, or that produce detrimental physiological responses in, human, plant, or aquatic life. The survival of aquatic life in surface waters, subjected to waste discharge or other controllable water quality factors, shall not be less than that for the same waterbody in areas unaffected by the waste discharge or, when necessary, other control water." Ammonia causes aquatic life toxicity and is considered a toxic substance.

2.12.5 Groundwater Objectives

Because the numeric objective for nitrogen in Regional Ground Waters is either greater than or equal to the numeric objective for nitrogen in Inland Surface Waters for the Santa Clara River Watershed, Regional Board staff conclude that the existing water quality objective for nitrogen established in the Basin Plan for selected constituents in Inland Surface Waters is protective of the GWR beneficial use.

The implementation plan includes groundwater monitoring to verify that nitrogen loads from rising groundwater are not causing exceedances of the numeric targets for ammonia and nitrite+nitrate. If monitoring shows that rising groundwater is causing exceedances of numeric targets, load allocations or revision of the groundwater objective for nitrogen by the Regional Board may be appropriate.

2.12.6 Alternatives Considered by Regional Board

Two alternatives were considered for developing an appropriate water quality objective for ammonia in the Santa Clara River: 1) Use existing Basin Plan objectives; and 2) apply the "1999 Update of Ambient Water Quality Criteria for Ammonia" developed by U.S. EPA. The criteria used for selecting the recommended alternative included:

- Consistency with State and federal water quality laws and policies;
- level of beneficial use protection; and
- consistency with the current science regarding water quality necessary to reasonably protect the beneficial uses of the Santa Clara River.

Under Alternative 1, Using existing Basin Plan objectives, the existing Basin Plan water quality objective for ammonia would remain unchanged and would continue to apply to Santa Clara River without consideration of the updated criteria for ammonia. Under Alternative 2, the 1999 Update of Ambient Water Quality Criteria for Ammonia would be applied to Santa Clara

River as a water quality objective. Alternative 2 is the recommended alternative since the action would:

- be consistent with recent modifications to State and federal water quality regulations;
- facilitate development of an objective that would be protective of Santa Clara River's beneficial uses; and
- improve the scientific basis upon which the water quality objective is based.

Adoption of Alternative 1 (using existing Basin Plan objectives for ammonia) would be inconsistent with the updated objectives.

2.1.3 Antidegradation

State Board Resolution 68-16, Statement of Policy with Respect to Maintaining High Quality Water in California, known as the "Antidegradation Policy," protects surface and ground waters from degradation. According to the Antidegradation Policy, any actions that can adversely affect water quality in all surface and ground waters must be consistent with the maximum benefit to the people of the state, must not unreasonably affect present and anticipated beneficial use of such water, and must not result in water quality less than that prescribed in water quality plans and policies. Furthermore, any actions that can adversely affect surface waters are also subject to the federal Antidegradation Policy (40 CFR 131.12). The proposed TMDL will not lower water quality, and will in fact improve water quality as it is designed to achieve compliance with existing water quality standards.

2.2 Basis of Listing

In 1996, Regional Board staff conducted a Water Quality Assessment that identified exceedances of water quality objectives (WQOs) for nitrogen compounds in the Santa Clara River. The water quality assessment data are summarized in Table 3. Table 3 shows the number of samples, the range of values, the average value and the standard deviation, with exceedances of the water quality objectives noted in bold.

Table 3. Summary of water quality data – 1996 water quality assessment. Exceedances indicated in bold.

EPA Reach	Statistical Information	NH_3 (mg/L)	NO_3+NO_2 (mg/L)	DO (mg/L)	pH (-)	Temp (°C)
1 and 2	# of Samples	No data	2 samples	No data	6 meas.	19 meas.
	Range		0.8-0.9		7.7-8.3	9-28
	Average±Std Dev		0.85±0.05		8.0±0.2	16±6
3	# of Samples	5 samples	5 samples	No data	3 meas.	20 meas.
	Range	**0.02-0.45**	1.6-3.2		8.2-8.3	13-28
	Average±Std Dev	**0.25±0.19**	2.5±0.7		8.2±0.05	19±3
4	# of Samples	No data	17 samples	17 meas.	17 meas.	21 meas.
	Range		0.6-3.5	7.0-10.7	7.8-8.4	7-29
	Average±Std Dev		2.2±1.0	9.1±1.1	8.0±0.2	17±6
5 and 6	# of Samples	3 samples	9 samples	No data	11 meas.	15 meas.
	Range	**0.11-0.8**	**0.6-22.6**		7.5-8.6	17-29
	Average±Std Dev	**0.5±0.3**	**5.5**		8.1±0.3	22±3
7	# of Samples	4 samples	8 samples	8 meas.	13 meas.	14 meas.
	Range	**0.07-0.44**	**1.3-7.5**	8.1-8.9	7.3-8.5	21-27
	Average±Std Dev	**0.26±0.13**	**4.5±1.9**	8.2±0.4	8.2±0.4	23±2
8	# of Samples	69 samples	89 samples	20 meas.	91 meas.	88 meas.
	Range	**ND-4.9**	**0.3-15.4**	4.2-10.8	6.8-8.4	10-27
	Average±Std Dev	**1.4±1.3**	**5.7±2.4**	7.4±2.0	7.8±0.3	18±4
9 and 10	# of Samples	No data	15 samples	6 meas.	15 meas.	3 meas.

EPA Reach	Statistical Information	NH_3 (mg/L)	NO_3+NO_2 (mg/L)	DO (mg/L)	pH (-)	Temp (°C)
	Range		ND-4.5	5.7-9.8	7.9-8.6	18-30
	Average±Std Dev		0.5	7.6±1.2	8.1±0.2	25±5
Brown Barranca /Long Canyon	# of Samples	No data	6 samples	No data	6 meas.	3 meas.
	Range		2.5-9.9		7.4-8.4	15-17
	Average±Std Dev		4.8±2.7		7.8±0.3	16±1
Wheeler Canyon/ Todd Barranca	# of Samples	No data	**12 samples**	No data	12 meas.	7 meas.
	Range		**0.8-25.8**		7.3-8.1	3-31
	Average±Std Dev		**5.6**		7.7±0.2	19±9
Sespe Creek*	# of Samples	No data	4 samples	1 meas.	6 meas.	4 meas.
	Range		ND-1.3	10.8	8.0-8.6	18-25
	Average±Std Dev		0.4		8.2±0.2	23±3
Torrey Canyon	# of Samples	No data	**3 samples**	No data	4 meas.	2 meas.
	Range		**1.2-17.7**		7.1-8.2	12-14
	Average±Std Dev		**7.0**		7.6±0.5	

*Algae was noted in Sespe creek.

Based on the water quality assessment, U.S. EPA listed the Santa Clara River (SCR) segments, tributaries and waterbodies in Table 4 as impaired in the 1998 303(d) list of impaired waterbodies in California.

Table 4. Santa Clara River (SCR) Impairments, 1998 (303)d List

Nutrient/Effect	Impaired Waterbody/Segment
Ammonia	SCR Reach 3, Freeman Diversion to Fillmore Street A
Ammonia, nitrate+nitrite	SCR Reach 5 (EPA Reach 7), Blue Cut to West Pier Hwy 99
Ammonia, nitrate+nitrite, organic enrichment/DO	SCR Reach 6 (EPA Reach 8), Hwy 99 to Bouquet Canyon Rd

Nutrient/Effect	Impaired Waterbody/Segment
Nitrate+nitrite	Brown Barranca/Long Canyon
Nitrate+nitrite	Wheeler Canyon/Todd Barranca
Nitrate+nitrite	Mint Canyon Creek

1. The Regional Board assessed the water quality impairment again in 2002. Based on the results of that analysis, the State Water Resources Control Board approved a 2002 Federal Clean Water Act Section 303(d) List of Water Quality Limited Segments on February 4, 2003 (Resolution No. 2003-0009). California's 2002 section 303(d) list is presently awaiting final approval by the U.S. Environmental Protection Agency (USEPA), but the State and USEPA have proposed listing the Santa Clara River for nitrogen compound impairments. The listings are summarized in Tables 5 and 6.

Table 5. Santa Clara River (SCR) Impairments 2002 303(d) List

Nutrient/Effect	Impaired Waterbody/Segment	Extent
Ammonia	SCR Reach 3, Freeman Diversion to A. Street	31 Miles
Nitrate and nitrite	SCR Reach 7, Blue Cut to West Pier Hwy 99	9.4 Miles
Nitrate and nitrite	Brown Barranca/Long Canyon	2.6 Miles
Nitrate and nitrite	Wheeler Canyon/Todd Barranca	10 Miles
Nitrate and nitrite	Mint Canyon Creek Reach 1	8.1 Miles

Table 6 summarizes the Santa Clara River segments that were included on the US EPA 1998 303(d) List for nitrogen compounds and related effect impairments that have been revised to be included on the State Enforceable Programs or Monitoring lists.

Table 6. Santa Clara River segments included on State Enforceable Programs or Monitoring Lists

List Status	Nutrient/Effect	Impaired Waterbody/Segment	Extent
Enforceable Program	Ammonia	Reach 7 (Blue Cut to West Pier Hwy 99)	9.4 Miles

List Status	Nutrient/Effect	Impaired Waterbody/Segment	Extent
Monitoring Program	Organic Enrichment/Dissolved Oxygen	Reach 8 (West Pier Hwy 99 to Bouquet Cyn Bridge)	5.6 Miles
Enforceable Program	Ammonia	Reach 8 (West Pier Hwy 99 to Bouquet Cyn Bridge)	5.6 Miles

The eutrophic effects observed in lakes within the Santa Clara watershed are addressed in this TMDL as water sources. Impairments of these lakes will be addressed in a future Regional Board action.

3 NUMERIC TARGETS

Numeric targets for this TMDL are the target conditions in the waterbody necessary to support the beneficial uses. Numeric targets for this TMDL were based on the water quality objectives in the Basin Plan and the explicit Margin of Safety (10%) described in Section 6.3.

The water quality objectives for ammonia, and nitrate plus nitrite are intended to support aquatic life, recreation, water supply and other beneficial uses. Given that the 1994 Basin Plan contains numeric objectives for nitrate/nitrite, nitrite and nitrate, and Regional Board Orders provide guidance on using the 1999 EPA ammonia criteria, these objectives are appropriate numeric targets for the TMDL.

3.1 Ammonia

The numeric targets for ammonia are consistent with the recently revised Basin Plan objectives based on US EPA's 1999 update of Ambient Water Quality Criteria for Ammonia. The ammonia targets will take effect following approval by US EPA. For this TMDL, the ammonia targets are based on the criteria developed by U.S. EPA, in the "1999 Update of Ambient Water Quality Criteria for Ammonia," December 1999 and adopted by the Regional Board in 2002. The 1999 Update contains U.S. EPA's most recent freshwater aquatic life criteria for ammonia and supersedes all previous freshwater aquatic life criteria for ammonia. In this revision the acute criteria is dependent on pH and the chronic criteria is based on pH and temperature of the receiving water. A review of pH data does not show evidence of a seasonal signal. However, dischargers have noted that there may be a seasonal variation in temperature. This will be subject of a special study by the dischargers to determine possible effects on ammonia targets. The 1999 U.S. EPA Ambient Water Quality for Ammonia acknowledges that ammonia toxicity may be dependent on the ionic composition of the waterbody. This issue can be addressed by performing a water effects ratio (WER) study or other site-specific approaches, if approved by the Regional Board through the Basin Plan amendment process. The Basin Plan outlines the requirements for development of a Site-Specific Objective (SSO). At this time, stakeholders have initiated a WER study for ammonia in the Santa Clara River in conformance with a Work Plan that has been approved by Regional Board staff. It is anticipated that the WER study will serve as the basis for development of a proposed SSO and revised effluent limits, as appropriate, for Regional Board approval. A SSO based on a WER for ammonia would be implemented as a Basin Plan Amendment that, if approved, would amend both the Basin Plan and this TMDL. The SSO would be required to demonstrate that both the ammonia objectives would be in conformance with the Antidegradation Policy (State Board Resolution 68-16). A separate analysis would be required to support a SSO to determine if any increases in ammonia effluent limits would cause exceedances of the water quality objectives for nitrate or nitrate + nitrite.

For ammonia, numeric targets that are pH and temperature dependent will be applied to protect water quality criteria for aquatic life. Numeric targets for this TMDL are concentration based. The implementation provisions for the Application of Ammonia Objectives to Inland Surface Waters in the Los Angeles Region indicate that the selection of acute ammonia objectives is based on the equations for "salmonids present" in Reach 3 because this segment is designated in the Basin Plan as "MIGR." The acute ammonia objectives in Reach 7 is based on the equations for "salmonids not present" because Reach 7 is not designated in the Basin Plan as either "COLD" or "MIGR." The implementation provisions for the Application of Ammonia Objectives to Inland Surface Waters in the Los Angeles Region indicate that the selection of chronic ammonia objectives is based on the equations for "early life stages for fish are absent" because the Santa Clara River watershed listed segments are not designated in the Basin Plan as

"SPWN." The acute numeric targets and chronic numeric targets for ammonia will be calculated using the equations set forth in Resolution No. 2002-11.

For illustrative purposes, based on the pH and temperature data in EPA Reaches 3, 7 and 8 for the past five years, thirty day ammonia targets range from 1.7- mg/L to 1.9 mg/L in Reach 3, 1.2 mg/L to 2.0 mg/L in Reach 7, and 3.2 mg/L in Reach 8. These numeric targets are based on the median concentrations of pH and temperature and do not assume application of an ammonia water effects ratio.

A statistical summary of in-stream pH and temperature in the Santa Clara River is presented in Tables 7 and 8, collected from 1989 to 2000 by several agencies, as noted in the Source Analysis report. For calculation of the Criteria Continuous Concentration, the 50-percentile of pH and temperature was used. The criteria maximum concentration (CMC) is based on the 95th percentile of pH data. Tables 7 and 8 show the pH generally increases while the temperature generally decreases from upstream to downstream locations.

Table 7. Statistical Summary of pH data from 1989-2000

Statistical Parameter	Reach 8	Reach 7 above Valencia	Reach 7 below Valencia	Reach 7 at County Line	Reach 3 above Santa Paula	Reach 3 at Santa Paula	Reach 3 below Santa Paula
50th percentile	7.33	7.89	7.78	8.20	8.00	8.00	8.08
90th percentile	7.53	8.16	8.04	8.30	8.30	8.30	8.35
95th percentile	7.62	8.24	8.17	8.41	8.37	8.37	8.43
Mean	7.31	7.85	7.73	8.15	8.00	8.00	8.03
Standard Deviation	0.22	0.29	0.31	0.21	0.26	0.26	0.31
CV*	0.03	0.04	0.04	0.03	0.03	0.03	0.04

*CV = coefficient of variation

Table 8. Statistical Summary of temperature (in °C) data from 1989-2000

Statistical Parameter	Reach 8	Reach 7 above Valencia	Reach 7 below Valencia	Reach 7 at County Line	Reach 3 above Santa Paula	Reach 3 at Santa Paula	Reach 3 below Santa Paula
50 percentile	19.89	18.23	20.22	19.03	16.68	16.81	16.81
90 percentile	24.34	23.68	25.32	24.59	19.00	19.73	19.87
95 percentile	25.02	24.58	25.90	25.41	19.48	20.44	20.57
Mean	19.55	18.43	20.21	19.22	16.39	16.52	16.52
Standard Deviation	3.92	4.05	3.97	4.15	2.32	2.78	2.85
CV	0.20	0.22	0.20	0.22	0.14	0.17	0.17

Using this information, the CCC for each segment is calculated using the corresponding equations and are presented in Table 9. A 10% margin of safety (to be discussed further in Section 6.3) is considered for the Ammonia Numeric Target, using the same rationale as for the Nitrate plus Nitrate numeric target, to be discussed in Section 3.2. Based on the temperature in these segments of the Santa Clara River, there is no need to differentiate between the CCC for "early life stages of fish present" and "early life stages of fish not present".

Table 9. Ammonia Water Quality Objectives and Numeric Targets (mg/L as Nitrogen)

Reach	Water Quality Objective		Numeric Target	
	One-hour average	**Thirty-day average**	**One-hour average**	**Thirty-day average**
Reach 8	16.5	3.5	14.8	3.2
Reach 7 above Valencia	5.5	2.2	4.82	2.0
Reach 7 below Valencia	6.1	2.3	5.5	2.0
Reach 7 at County Line	3.8	1.3	3.4.3	1.2
Reach 3 above Santa Paula	2.7	2.1	2.4	1.9
Reach 3 at Santa Paula	2.7	2.1	2.4	1.9
Reach3 below Santa Paula	2.4	1.9	2.2	1.7

3.2 Nitrate and Nitrite

For this TMDL, initial numeric targets for oxidized nitrogen are based on the existing objectives in the Basin Plan for each reach and the explicit Margin of Safety(10%). Tables 10 and 11 give these targets. In accordance with the Basin Plan, which does not provide guidance for interpreting the water quality objectives as averages, the numeric targets for nitrite, nitrate, and nitrite+nitrate are daily maximum values.

Table 10. Water Quality Objectives and Numeric Targets for Nitrate plus Nitrite (mg/L as Nitrogen)

Reach	Nitrate + Nitrite WQO	Numeric Target
8 (above Lang)	5	4.5
7 (above Bouquet)	5	4.5
6 (above Hwy99)	10	9.0
5 (above Blue Cut)	5	4.5
4 (above Fillmore)	5	4.5
3 (above Freeman diversion)	5	4.5
2 (above Hwy101)	10	9.0
1 (above estuary)	10	9.0

Table 11. Water Quality Objectives and Numeric Targets for Nitrate and Nitrite (mg/L as Nitrogen)

Reach	Nitrate WQO mg/L	Nitrate Numeric Target	Nitrite WQO mg/L	Nitrite Numeric Target
8 (above Lang)	5	4.5	1	.9
7 (above Bouquet)	5	4.5	1	.9
6 (above Hwy99)	10	9.0	1	.9
5 (above Blue Cut)	5	4.5	1	.9
4 (above Fillmore)	5	4.5	1	.9
3 (above Freeman diversion)	5	4.5	1	.9
2 (above Hwy101)	10	9	1	.9
1 (above estuary)	10	9	1	.9

3.3 Nitrogen Effects

The 2002 303(d) list that triggered the development of this TMDL documents impairments of the Santa Clara River by ammonia and nitrate+nitrite. Ammonia, nitrate and nitrite are known to impact aquatic life through toxicity, organic enrichment and eutrophication processes, which result in decreased, dissolved oxygen. The 1998 section 303(d) listing included narrative measures of impairment, specifically organic enrichment/dissolved oxygen in Reach 8. Based on information since 1998, this section 303(d) listing was transferred to the 2002 'Monitoring List' by State Board, indicating a high priority for monitoring before the next section 303(d) list is completed.

3.4 Alternatives Considered by Regional Board

Two alternatives were considered for developing an appropriate numeric target for algae: 1) develop the numeric target for algae based on a narrative objective; and 2) not include a numeric target for algae and require special studies for algae impairment. The criteria used for selecting the recommended alternative included:

- consistency with State and federal water quality initiatives policies;
- level of beneficial use protection;
- consistency with the current science regarding water quality necessary to reasonably protect the beneficial uses; and
- applicability to existing condition of Santa Clara River.

Alternative 1 is not recommended because the 2002 proposed 303(d) list for the Santa Clara River does not include an impairment listing for algae. The available data on algal biomass in the Santa Clara River are not well documented as showing the connection between nitrogen and related effects. Therefore, application of Alternative 1 for Santa Clara River is inappropriate. Moreover, Alternative 1 does not offer an applicable technical approach for developing a measurable and enforceable compliance target for algae.

Alternative 2 is the recommended alternative since the action would be consistent with State and federal water quality initiatives under the Regional Technical Advisory Group (RTAG), which has been established to address federal requirements for States to adopt numeric criteria for nutrients. This TMDL requires evaluation of the algae condition of the Santa Clara River and set triggers that would develop appropriate numeric targets to attain the water quality objective for biostimulatory substances should algae or other nutrient related impairments be measured during TMDL monitoring. In addition, Alternative 2 facilitates the development of an appropriate numeric target if needed that would be protective of Santa Clara River's beneficial uses and improves the scientific basis upon which the numeric target is based.

4 SOURCE ASSESSMENT

The Source Analysis is a detailed summary of nutrient sources in the Santa Clara River watershed and is based on data from the Regional Board permit programs, agencies responsible for reservoir releases and groundwater basin management, agricultural experts, municipalities, and water treatment agencies. The data used to develop the TMDL is summarized in the Technical Support Document (Appendix A). During development of the Source Analysis, Systech met with members of the Steering Committee regularly to review the accuracy and completeness of the Source Analysis. The Steering Committee concluded that the data are sufficient to conduct a thorough loading analysis. The Source Analysis is provided in the Technical Support Document (Appendix A) and is briefly summarized below.

Systech characterized the sources as follows: direct sources, subsurface discharges and land application sources. Direct sources are those that discharge pollutants directly to the Santa Clara River. The subsurface discharges and land application sources are those in which pollutants are discharged to land surface or subsurface and are transported to the Santa Clara River via surface runoff or groundwater flow.

Direct point sources are those which discharge directly to the Santa Clara River and its tributaries and include reservoir releases and direct point source discharges. These surface water discharges are permitted through the NPDES program administered by the Regional Board. Direct point sources were assessed by evaluating discharge monitoring reports and from other data supplied by major dischargers. Reservoir discharges were evaluated based on flow data from USGS gauging stations downstream of the dams and water quality data for Piru Creek, which was also used to assess Castaic Creek due to the lack of data for Castaic Creek.

Subsurface discharges include groundwater discharges to the Santa Clara River and septic system discharges. Groundwater sources were identified through Regional Board permits. However, because there are little data associated with these discharges, a State of California waste discharge database was used to define flow and combined with nominal pollutant concentration data from package sewage treatment plants to estimate loads. Septic system loading was estimated by multiplying the number of septic systems, an assumed number of people per septic system and nominal loadings for nitrogen and phosphorus based on literature values. This load was then modeled by distributing its location in the upper portion of the watershed in relation to the location of the Santa Clara River. The number of septic systems was based on estimates from Los Angeles County Department of Health Services (DHS) personnel.

Land application sources include diversions for groundwater recharge and/or irrigation, agricultural pumping, atmospheric deposition, and fertilizer application. The source analysis analyzed eight diversions with two reaching groundwater and six used for irrigation. The loading was calculated from the flow and average monthly concentrations from water quality monitoring near each diversion. Agricultural pumping flow and well water quality was obtained from data supplied by United Water Conservation District for Ventura County. For Los Angeles County, pumping was assumed to provide irrigation water for crops, based on crop irrigation requirements from local agricultural experts. Nominal concentrations based on groundwater quality data were assumed for ammonia, nitrate, and phosphorus. Atmospheric deposition loads were estimated for both wet and dry conditions. Wet atmospheric deposition was estimated based on rainfall data from various meteorological stations, and rain chemistry from Tanbark

Flat in the mountains east of the watershed in Los Angeles County. Dry deposition was based on particulate deposition rates from Joshua Tree National Monument, the nearest of a national network of monitoring stations. Fertilization loading rates were derived from agricultural production records from Ventura County records and discussions with local agricultural experts.

The time period used for the Source Analysis is water years 1990-2000 (10/1/1989 – 9/30/2000). The loading is described seasonally by averaging the loading for each month in the 11-year time frame.

The Source Analysis also included a Loading Balance, which compared the direct and surface loadings to the in-stream loading, i.e. the loading estimated based on measured flow rates and nutrient concentrations. The loading balance provides a check that the loading in the river is accounted for by the sources. The in-stream loading was estimated for each catchment. For all catchments, the total of the direct and indirect loadings exceeded the in-stream loadings. However, for EPA Reach 7 and the catchment upstream of Sespe Creek, the direct sources exceed the in-stream loadings for ammonia, suggesting that nitrification is an important process in this reach.

Systech subdivided the watershed into nine major subbasins; Mint Canyon Creek, Santa Clara EPA Reach 9, Santa Clara EPA Reach 8, Santa Clara EPA Reach 7, Santa Clara River above Sespe Creek, Sespe Creek, Santa Clara River Reach 3, Wheeler Canyon/Todd Barranca, and Brown Barranca/Long Canyon. Regional pollution loads and source contributions of pollutants to the water quality impaired segments were calculated by Watershed Analysis Risk Management Framework (WARMF), which will be described in detail in the Linkage Analysis section. Source loadings include assimilation, transformation and dilution of all loads to yield the mass loading to the reach. The following summary of source loadings by reach is in lbs/day for select wet and dry years (Table 12).

Table 12. Total Point and Nonpoint Source (NPS) Loadings by Reach

EPA Reach	NPS lb/day	Point Source lb/day	NPS lb/day	Point Source lb/day
Ammonia (1991-dry year)			*Ammonia (1998 wet year)*	
8	0.0005	43.2	0.06	41.
7	0.008	23.7	0.132	67.47
3	0.007	72.3	0.088	55.35
Nitrate(1991-dry year)			*Nitrate(1998 wet year)*	
8	6.74	197.6	78.1	130.3
7	29.99	829.1	339	1128.06
3	31.53	180.8	374.9	218.96

The results show that point source loads contribute almost all of ammonia, nitrite, and phosphorus in the water quality impaired segments of the Santa Clara River watershed. The source of nitrate in impaired segments is combination of point, nonpoint, and groundwater sources. The nonpoint source load contribution is greater in the wet year than the dry year.

The primary purpose of the model is to calculate TMDLs for the water quality impaired river segments in the watershed. There are no data to calibrate the three smaller impaired tributaries (Mint Canyon Creek, Wheeler Canyon / Todd Barranca, and Brown Barranca/Long Canyon). The flow and pollutants are routed downstream to the main stem of the Santa Clara River where data is more plentiful. The linkage analysis indicates the importance of point sources, managed flows, and groundwater interactions between Blue Cut and Santa Paula Creek, for which there are adequate data available.

The water quality parameters of concern are nutrients, principally ammonia, nitrite, and nitrate. Point source loads contribute ammonia, nitrite, and nitrate to the impaired river segments. Nonpoint source loads also contribute nitrate to the impaired river segments through groundwater accretion. To a degree, nitrification of ammonia, nutrient assimilation, and denitrification, which removes nitrate from the water, appears to occur in the riverbed of the impaired river segments, located in most cases downstream of the WRP discharges. Because of the assimilation processes that may be occurring within river segments of the watershed, it is important to distinguish between loading to the rivers, and loading in the rivers, the latter of which is directly reflective of water quality.

5 LINKAGE ANALYSIS

Systech Engineering, Inc. (Systech) was contracted by the Steering Committee of the Santa Clara River Nutrient TMDL stakeholder group to conduct an analysis linking the nitrogen (ammonia, nitrite, and nitrate) and phosphorus sources in the Santa Clara River watershed to the in-stream water quality. The Linkage Analysis is the second task completed by Systech to develop and calibrate a model linking the pollutant sources and in-stream water quality. During development of the Linkage Analysis, Systech met with members of the Steering Committee regularly to review the assumptions and accuracy of the Linkage Analysis. The detailed report is presented in the Technical Support Document (Appendix A).

5.1 Model Description

The linkage analysis of the Santa Clara River watershed is based on a dynamic water quality model to determine the linkage between inputs to the Santa Clara River and the water quality of the river. The watershed model selected for this Linkage Analysis is the Watershed Analysis Risk Management Framework (WARMF). WARMF is capable of simulating the physical and chemical processes that affect river hydrology and water quality.

WARMF is a comprehensive modeling framework which links land catchments, river segments, and reservoir segments into a seamless watershed network. WARMF provides such linkage by simulating the hydrology, the nonpoint source loads from land catchments, and then the resulting receiving water quality from the point and nonpoint source loads of pollutants. The model was run on a daily time step from October 1, 1989 to September 30, 2000.

5.1.1 Model Setup

The Santa Clara River watershed is divided into land catchments, river segments, and reservoir segments. Each is linked together in a network so that output from catchments is automatically input to the adjacent river segment, and each river segment is connected to the segment downstream, to reservoir segments, and back to river segments to form a complete network. Figure 2 in Appendix F shows the land catchments, river segments and reservoir segments in the Santa Clara River Watershed.

Each catchment is divided into the canopy, land surface, and several soil layers. Below the surface, it is assumed that each soil layer has uniform hydrology and water quality. The nonpoint source loads from land catchments include pollutants associated with surface runoff and those associated with ground water accretion to the adjacent river segment. Each river segment is assumed to be completely mixed. Reservoir segments are divided into horizontal layers, each of which is assumed to be well mixed.

The time period selected for modeling was water years 1990-2000 (10/1/1989-9/30/2000). This time period has sufficient data to calibrate the model and includes a variety of hydrologic conditions. In particular, water years 1991 (10/1/1990-9/30/1991) and 1998 (10/1/1997-9/30/1998) represent a very dry year and a very wet year, respectively. These two years will be used to represent critical hydrologic conditions when using the model for watershed management and TMDL calculation. WARMF is typically run with a daily time step because meteorological and point source input data is most available at that temporal resolution. The WARMF model for the Santa Clara River watershed has been set up to run on a daily time step.

5.1.2 Hydrology Model

The WARMF hydrology model is based on the mass balance of water, driven by precipitation. Water is routed from catchments to river segments, and reservoir segments. The model also includes prescribed flows, such as point sources, reservoir releases, diversions, and groundwater pumping. The accuracy of hydrologic model therefore depends on the accuracy of data for precipitation and prescribed flows.

Each catchment is assigned to a meteorology station. To translate the precipitation recorded at a meteorology station to the precipitation occurring at a catchment, a precipitation multiplier is used to account for orographic effects. A temperature lapse rate is used to transpose the temperature at the meteorology station to the temperature at the catchment due to elevation differences between the catchment and the meteorology station. Falling precipitation is divided into rainfall and snowfall based on temperature. The canopy intercepts some rainfall. The remaining throughfall reaching the soil surface percolates into the soil. Snowfall accumulates and melts on the soil surface with the water volume tracked each day.

WARMF represents the soil by layers. Each layer has a specific thickness, field capacity, porosity, hydraulic conductivity, and slope. The moisture content of each soil layer is tracked every day. Water percolating into the soil first raises the moisture content to field capacity. At moisture levels above field capacity, lateral flow occurs according to Darcy's Law. When all soil layers reach saturation, overland flow occurs.

Septic system discharges occur in the Santa Clara River watershed. The number of people served by septics per catchment is specified and the per capita flow and loading is the same for all septic systems.

Catchments can have pumping according to a flow schedule. The pumped water can be used for municipal/industrial purposes, in which case the model removes the water. The pumped water can also be applied to the land surface as irrigation, in which case the model removes the volume of water from the lowest soil layer of the catchment, and then applies it at its known location.

5.1.3 Water Quality Model

The water quality model is based on a mass balance of each chemical constituent. As part of the water quality simulation, temperature simulation is based on heat transfer with ambient air. As the model routes water through catchments, rivers, and reservoir segments, the associated chemical constituents are routed with the water. At each step of the simulation, chemical interactions are simulated to transform nitrogen compounds. WARMF tracks each chemical compound with its sources, such as point sources, septic systems, and land uses. When two quantities of water are mixed, the chemical constituents are also mixed and the source of the new mixture is a mass weighted average of the sources for each chemical.

Water quality simulation begins with atmospheric deposition to the land surface. Wet deposition is applied to the canopy and land surface based on the chemical concentrations in rain. Dry deposition is loaded to the canopy and land surface based on a monthly deposition rate and air quality concentrations determined by meteorological studies.

To perform the calculations, WARMF requires monitoring stations with precipitation chemistry and air quality data. Rainfall chemistry data came from several air stations, including a station at Tanbark Flat in the mountains east of the watershed in Los Angeles County (NADP 2002).

Atmospheric deposition is joined by land application from fertilizers, urban debris, and wildlife. The canopy absorbs some of the total deposition to incorporate into its biomass, and the remainder is then carried by throughfall to the soil surface. As rainfall and snow melt percolate into the soil, they carry the chemical constituents washed down from the canopy. Once inside the soil, chemicals undergo many processes, including competitive cation exchange, anion adsorption, chemical reactions, and uptake by vegetation. The pH is calculated from alkalinity and inorganic carbon by tracking the mass of each of the cations and anions. As lateral flow occurs, dissolved constituents are carried with it to river segments. When the soil is saturated, chemicals accumulated on the soil surface flow with overland flow to river segments. It is noted that in some of the more urbanized areas of the Santa Clara River watershed, storm drains convey runoff to the Santa Clara River, both during wet and dry weather. These sources are modeled as runoff from land surfaces rather than direct sources. However, as discussed in the Section 6, Allocations, this source is considered a point source because these discharges are regulated under NPDES permits that address the runoff through the storm drain systems in Los Angeles and Ventura counties. This regulatory consideration does not affect the accuracy of the Linkage Analysis.

Chemical constituents associated with septic systems and subsurface discharges are mixed with the constituents already present in the soil layers. Water pumped out of the catchment carries with it the dissolved constituents in the soil solution.

5.1.4 Model Calibration and Sensitivity Analysis

Hydrology and water quality calibration have been conducted for the Santa Clara River watershed. The calibration results are discussed in three sections: the perennial western tributaries, the intermittent flow eastern tributaries, and the main stem of the Santa Clara River. Since nutrients are the primary interest, the Santa Clara River Nutrient TMDL Steering Committee has recommended that calibration priority should be given to those nutrients of immediate concern (all forms of nitrogen). Phosphorus and dissolved oxygen are also included because they affect algal growth, which removes nitrogen. Chemical constituents such as pH, the major cations and anions, and total dissolved solids, were not calibrated.

Some calibration priority has also been given to simulation of low flow conditions, since those are believed to be the most critical for calculation of TMDLs. However, it is also important to achieve a good overall water balance and representation of peak flows to simulate timing of flows and distribution between high flow and low flow periods. Calibration is also focused on the impaired streams of the watershed. WARMF calculates simulation results for flow and all chemical constituents for all river segments in the watershed. The results presented here are for those locations relevant to the impaired streams and for which there is observed data to compare against simulation results.

In the Santa Clara River, water quality modeling requires proper hydrologic accounting. This includes the accounting of uncontrolled flows (natural unimpaired flow and water losses or gains across the riverbed), managed flows with good records (reservoir releases, large diversions, and point source discharges), and managed flows with poor records (dewatering operations, small diversions, and small point source discharges). In a heavily managed river like the Santa Clara River, the accuracy of simulation depends on the accuracy of managed flow data. The estimates of groundwater gains and losses between Blue Cut and Santa Paula Creek are also key to predicting flow and water quality. At this point, the model has been calibrated to match the seasonal pattern and range of observed values. Further improvement can be made with more data and time in the future. The procedure and parameters used for hydrology are believed to be scientifically appropriate .

The WARMF model for the Santa Clara River contains many different parameter inputs. For parameters for which there is more uncertainty, sensitivity analysis can be performed to evaluate how their parameter values affect the match between model predictions and observed data variability (see Table 6 and Table 8 in Appendix A, Technical Support Document-Linkage Analysis). Appropriate parameter values can be selected quickly during the model calibration. Figure 3 in Appendix F shows the simulated and observed data of ammonia, nitrite, and nitrate for Santa Clara River at Castaic Creek. For Santa Clara River, many parameters are considered known and are not adjusted. The values of these parameters are within the range of available scientific literatures. The parameters that need to be adjusted for Santa Clara River mainly are nitrification and denitrification rates. After several iteration to minimize relative and absolute errors, a set of best-fit rates was developed. The values of those two parameters are within reasonable range of available literatures.

The sensitivity analysis was used to determine the effect of pollution sources on the predicted water quality responses. For the Santa Clara River nutrient TMDL study, the analysis provided information about the relative importance of controlling point source discharges, atmospheric deposition (air quality), septic system discharges, and fertilizer applications, dewatering operations in order to meet the water quality standards for nutrients (ammonia, nitrite and nitrate).

At the direction of the Steering Committee, WARMF model calibration refinement for nitrogen compounds was conducted. The original calibration of the WARMF model application for the Santa Clara River was presented in the Task 2 report prepared by Systech Engineering, Inc. The original calibration was generally based on standard rates of nitrification and denitrification in the various segments of the river. However, in some regions the apparent rate of disappearance of ammonia, nitrite and/or nitrate is faster or slower, based on an evaluation of the observed data. This could be due to additional assimilation of these nitrogen compounds by in-stream and riparian vegetation, increased volatilization of ammonia due to the relatively high surface area and mixing energy of the rocky river bottom, or slightly anoxic conditions which would reduce the rate of nitrification and increase denitrification in some regions. Given the length of the river segments, from a few hundred meters to several kilometers, it is conceivable that all of these processes take place within a river segment. Thus, it seems appropriate to adjust the first-order rate constants for the rate of ammonia, nitrite and nitrate disappearance. The segments indicated in Table 13 were evaluated with respect to their nitrification and denitrification rates.

After several iterations to minimize relative and absolute errors, a set of best-fit rate constants was developed (Table 14). Some of the guiding concepts in the calibration refinement were:

- Slightly overpredict concentrations relative to observed data, to provide a small additional margin of safety;
- Calibrate nitrate and nitrite together, given that any nitrite is likely to rapidly convert to nitrate, and that adjustment of nitrite concentrations alone is difficult given the dependence on both the rate of nitrification and denitrification;

- Consistently adjust rate constants throughout a region;
- For those segments where no observed data is available, adjust the rate constants by interpolating the values from segments where data is available.

Table 13. Identification of river segments in Santa Clara River

ID	Segment Designation	Approximate boundaries of SCR segment
7	EPA Reach 3 below Santa Paula	Between Adams Canyon and Todd Barranca
9	EPA Reach 3 at Santa Paula	Between Todd Barranca and Santa Paula Creek
69	EPA Reach 3 above Santa Paula	Above Santa Paula Creek and below Reach 4
111	EPA Reach 7 at County Line	Between Salt Canyon and Potrero Canyon Creeks
56	EPA Reach 7 below Valencia	Between Castaic Creek and Valencia WRP
129	EPA Reach 7 above Valencia	Between Valencia WWTP and Highway 5
159	EPA Reach 8	Between Bouquet Canyon Creek and the South Fork

Table 14. Nitrification and denitrification rate constants (in day^{-1}) for the refined calibration. Segment IDs are presented from lower to upper watershed.

Reach	3	3	3	7	7	7	7	7	7	8	8	8	9
Segment ID	7	9	69	111	113	115	56	137	129	47	149	159	167
Nitrification rate	1.0	0.8	0.7	0.8	0.6	0.4	0.35	0.035	1.0	0.65	0.35	0.0	0.2
Denitrification rate	0.4	0.4	0.3	0.05	0.1	0.2	0.3	0.0	0.3	0.3	0.3	0.15	0.0

Note that common values for nitrification rate constants range from 0 to 1.0 day^{-1} and for denitrification from 0 to 0.5 day^{-1}, depending on redox conditions (aerobic or anaerobic).

The results of the calibration refinement are presented in the following figures for those river segments where there is adequate observed data. Tables 15 to 17 present the statistics of the calibration, in terms of concentrations at 50, 90, 95, 99 and 99.9 percentiles, as well as relative error (RE), absolute error (AE) and root mean square error (RMSE), as defined here:

$$RE = \frac{1}{n}\sum_{i=1}^{n}(x_i - c_i)$$

$$AE = \frac{1}{n}\sum_{i=1}^{n}\left|(x_i - c_i)\right|$$

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_i - c_i)^2}$$

where x_i is the simulated value, c_i is the observed value and n is the number of observations. RE is the average of all errors over all time steps (11-year at a daily time step or 4018 time steps). It is a measure of model accuracy and any consistent bias. However, over-predictions can cancel out under-predictions. AE is the absolute value of the average of all errors over all time steps, and provides another measure of model accuracy, indicating whether the simulated values are generally close to the observed values. RMSE is a measure of model precision, and magnifies the effect of larger than average errors.

Table 15. Statistics of Ammonia calibration refinement

Reach ID	7	9	69	111	56	137	129	159
Number of Observations	22	9	0	10	136	138	50	138
Observed								
50 percentile	0.08	0.43	N.D.	0.65	3.62	6.39	0.35	9.52
90 percentile	0.39	3.14	N.D.	1.31	7.46	13.56	2.70	15.40
95 percentile	0.50	4.81	N.D.	1.36	8.43	15.36	3.36	16.76
99 percentile	1.61	6.15	N.D.	1.39	11.84	20.44	10.05	20.86
99.9 percentile	1.88	6.46	N.D.	1.40	12.83	25.29	11.62	22.45
Simulated								
50 percentile	0.22	0.52	0.00	0.46	4.00	7.42	0.75	9.56
90 percentile	0.76	1.85	0.01	0.96	5.88	11.17	1.68	12.72
95 percentile	1.11	2.67	0.04	1.14	6.75	12.36	2.04	14.13
99 percentile	2.31	5.05	0.17	1.48	9.27	16.23	2.69	16.98
99.9 percentile	4.39	7.44	0.36	2.08	12.59	18.93	4.12	19.22
Relative error	-0.020	-0.968	N.D.	-0.034	0.677	2.011	-0.338	-1.972
Absolute error	0.214	1.158	N.D.	0.281	1.938	3.367	1.071	3.618
Root mean square	0.404	2.068	N.D.	0.326	2.486	4.192	2.172	5.022

N.D. = No data

Table 16. Statistics of Nitrate calibration refinement

Reach ID	7	9	69	111	56	137	129	159
Number of Observations	276	11	48	58	41	41	39	38
Observed								
50 percentile	1.51	1.40	1.73	5.26	4.61	5.59	4.15	2.32
90 percentile	2.39	2.30	2.70	6.67	6.90	8.33	5.90	5.05
95 percentile	2.64	2.55	3.07	7.25	7.54	9.62	6.78	5.58
99 percentile	4.13	2.75	3.41	8.06	8.88	11.38	7.56	8.02
99.9 percentile	4.52	2.80	3.49	8.12	9.62	11.49	7.82	8.48
Simulated								
50 percentile	1.45	1.75	1.99	5.10	4.73	5.88	4.37	3.73
90 percentile	2.71	2.85	2.36	7.98	7.25	8.53	6.33	5.38
95 percentile	3.89	4.15	3.06	8.77	7.82	9.09	6.74	5.83
99 percentile	5.74	5.54	4.60	11.24	9.77	11.79	8.55	7.63
99.9 percentile	6.73	6.17	5.21	12.98	10.93	12.50	9.93	8.03
Relative error	-0.189	-0.025	0.104	0.29	0.128	0.0247	0.0393	1.331
Absolute error	0.491	0.488	0.566	1.65	1.503	1.722	1.262	2.105
Root mean square	0.621	0.589	0.728	2.162	1.987	2.429	1.509	2.543

Table 17. Statistics of Nitrite calibration refinement

Reach ID	7	9	69	111	56	137	129	159
Number Observations	19	12	14	16	40	41	39	38
Observed								
50 percentile	0.00	0.00	0.00	0.00	0.88	0.62	0.21	1.02
90 percentile	0.40	0.00	0.00	0.49	1.31	0.92	0.80	2.74
95 percentile	1.20	0.14	0.00	0.49	1.69	1.32	0.95	3.14
99 percentile	1.20	0.27	0.00	0.49	2.07	1.41	1.04	4.16
99.9 percentile	1.20	0.30	0.00	0.49	2.25	1.45	1.06	4.50
Simulated								
50 percentile	0.07	0.10	0.00	0.09	0.21	0.09	0.21	0.16
90 percentile	0.25	0.35	0.00	0.24	0.35	0.21	0.56	0.43
95 percentile	0.38	0.50	0.01	0.29	0.39	0.24	0.67	0.51
99 percentile	0.81	0.97	0.06	0.39	0.48	0.29	0.91	0.72
99.9 percentile	1.55	1.46	0.14	0.53	0.80	0.34	1.44	0.99
Relative error	-0.063	0.0624	0.0007	-0.069	-0.649	-0.497	-0.1	-1.251
Absolute error	0.195	0.0932	0.0007	0.183	0.655	0.497	0.228	1.27
Root mean square	0.393	0.105	0.0011	0.226	0.786	0.583	0.3	1.55

The calibration processes performed and parameters used for Santa Clara River are believed to be appropriate and within the range of available scientific data.

6 ALLOCATIONS

This study evaluates a number of nitrogen allocations from point and nonpoint Sources (PS and NPS) present in the reaches of the Santa Clara River (SCR) considered in the 1998 303(d) listing, namely Reaches 3, 7 and 8 (US EPA designation -Figures 4 and 5 in Appendix F). For modeling purposes, these reaches have been segmented further, providing an opportunity to consider water quality monitoring data for a number of segments, and to evaluate the PS and

NPS loads for each segment. The segments are presented in Figures 4 and 5, using the identification number used in the WARMF model. The approximate locations and descriptions of segment boundaries are presented in Table 13 for reference. For this analysis, the WARMF model was used as described in the Linkage Analysis, with a refined calibration of the nitrogen processes as described in the Technical Support Document (Appendix A).

The load allocations require a consideration of the numeric targets, which are based on the Water Quality Objectives (WQO), defined in the Basin Plan. Numeric targets have been defined based on the WQO and Margin of safety with the intent of preventing the exceedance of the WQO. For example, in most reaches the combined nitrate plus nitrite WQO is 5.0 mg/L as $N\text{-}NO_3 + N\text{-}NO_2$, except in Reach 8 where the WQO is 10.0 mg/L as $N\text{-}NO_3 + N\text{-}NO_2$. The numeric target has been set with a 10% explicit Margin of Safety (MOS), such that it is 4.5 mg/L as $N\text{-}NO_3 + N\text{-}NO_2$ in most reaches except Reach 8 where it is 9.0 mg/L as $N\text{-}NO_3 + N\text{-}NO_2$.

The Total Maximum Daily Load (TMDL) for each segment must be divided into a Waste Load Allocation (WLA) from point sources and a Load Allocation (LA) from nonpoint sources. In addition, the TMDL must consider a margin of safety (MOS) and Future Growth (FG), such that:

$$TMDL = WLA + LA + MOS + FG$$

6.1 Wasteload Allocations: Point Source Loading Analysis

Wasteload allocations were set through analysis of different alternatives constructed using observed meteorological conditions from 10/01/1989 to 9/30/2000, based on the calibrated WARMF model. These alternatives modified the ammonia, nitrate and nitrite concentrations in the treated WRP effluent at the flowrates indicated in Table 32. Four key alternatives were considered: 1) concentrations of ammonia, nitrate, and nitrite in WRP effluent are set equal to the numeric targets; 2) point source loads remain equal to Alternative 1 except that the ammonia concentration in the Saugus WRP effluent is lowered to 2 mg/L; 3) point source loads are based on performance of WRP upgrades for ammonia treatment where a nitrate effluent concentration of 8.0 mg/L is anticipated; and 4) point source loads are based on performance of WRP upgrades where a nitrate effluent concentration of 6.7 mg/L is anticipated. In addition to the wasteload allocations for the Water Reclamation Plants and Publicly Owned Treatment Works, wasteload allocations are developed for the municipal separate storm sewer system permittees in the upper reaches of the watershed.

One important consideration in developing wasteload allocations is the interaction between various nitrogen species, since ammonia oxidizes to nitrite, which then oxidizes to nitrate. Ammonia, nitrite and nitrate can also be assimilated by the in-stream and riparian vegetation, and ammonia may be lost to the atmosphere due to volatilization. Nitrate might be reduced to nitrogen gas under low oxygen conditions, such as those that might exist in some sediment and in slow-flowing pools along the river. Thus, loading alternatives have to consider all these interactions.

Simulations for the SCR segments identified in Table 18 were run for the four alternatives considered. Table 18 presents the results for the four alternatives considered. Results for selected segments are illustrated in Figures 6 to 28 of Appendix F.

Table 18. Model Results for the Four Alternatives Considered

	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Description	Effluent Limits = Numeric Targets	Effluent Limits = Numeric Targets except $[NH_3] = 2$ mg-N/L at Saugus WRP	Based on performance of WRP ammonia treatment upgrades with $[NO_3^-] + [NO_2^-] = 8.1$ mg-N/L	Based on performance of WRP ammonia treatment upgrades with $[NO_3^-] + [NO_2^-] = 6.8$ mg-N/L at Valencia and [NO3-] + $[NO_2^-] = 7.1$mg-N/L at Saugus
% Time Ammonia Numeric Targets exceeded*				
River Segment ID 7	0%	0%	0%	0%
River Segment ID 9	0%	0%	0%	0%

	Alternative 1	Alternative 2	Alternative 3	Alternative 4
River Segment ID 69	0%	0%	0%	0%
River Segment ID 111	0%	0%	0%	0%
River Segment ID 56	0%	0%	0%	0%
River Segment ID 129	< 0.1%	one exceedance	< 0.1%	<5% ****
River Segment ID 159	10%**	one exceedance	10% ****	<5% ****
% Time Nitrate+Nitrite Numeric Targets exceeded				
River Segment ID 7	0%	0%	0%	0%
River Segment ID 9	0%	0%	0%	0%
River Segment ID 69	0%	0%	0%	0%
River Segment ID 111	0%	0%	<1%	0%
River Segment ID 56	0%	0%	47%	See Figure 22
River Segment ID 129	21%***	8.5% (WQO exceeded about 1%)	13%****	5%*****
River Segment ID 159	6% (WQO exceeded < 0.1%)	6% (WQO exceeded < 0.1%)	<1%	<5%

*Ammonia WQO is based on a 30-day average concentration, not an instantaneous sample or a daily average value. The ammonia WQO for a daily average is approximately an order of magnitude greater than the CCC, such that these levels of ammonia would have no observable effect on even the most sensitive species. Thus, the percent exceedances in this table is conservative.

**During first significant storms of the winter, due to some episodic NPS load of ammonia and nitrate.

***Nitrate + nitrite concentrations rise in the upper segments of Reach 7 as ammonia is partially transformed to nitrite and nitrite to nitrate.

****Exceedances most likely at the end of the dry season or the first strong storm events

*****This is the tightest condition in the entire watershed and would require frequent monitoring to ensure compliance.

The first alternative considers PS effluent concentrations at the Numeric Targets for the respective nutrients. Results for EPA Reach 7 are presented in Figures 6-11 of Appendix F. Alternative 2 involves reducing the ammonia loading from the Saugus WRP, by reducing effluent concentrations to 2.0 mg/L as N-NH_3, leaving all other effluent concentrations equal to targets. The results for Reach 8 and the Reach 7 segment immediately above the Valencia WWTP are presented in Figures 12 and 13 in Appendix F. Alternative 3 considers the expected performance of upgraded WRPs. The LACSD and the Santa Paula WRP plants are in the process of upgrading to include a Nitrification-Denitrification (NDN) module. From practical experience with the NDN process at the Whittier Narrows WRP, CSDLAC considers that it can control ammonia effluent concentrations to below 2.0 mg/L as N-NH_3, 0.1 mg/L as N-NO_2 and around 8.0 mg/L as N-NO_3 at the Saugus WRP. Since the Valencia WRP treats solids generated at both plants, CSDLAC anticipates effluent concentrations may be 2 mg/L NH3 and 10 mg/L as NO2+NO3. The effluent conditions considered in this alternative are presented in Table 19. Although the alternative was evaluated with both current and future flowrates, only the higher future flowrate is presented here.

Table 19. Scenario Using Effluent Concentrations NDN process at Whittier Narrows WRP

POTW	NH_3 (mg/L)	NO_2 (mg/L)	NO_3 (mg/L)	Flowrate (m^3/s)
Saugus	3.15	0.1	8.0	0.28475
Valencia	2.00	0.1	8.0	0.94625
Santa Paula + Fillmore	1.84	0.1	8.0	0.18

Results for Alternative 3 are presented for selected segments Figures 14 to 16 in Appendix F. Based on the results of Alternative 3, an "Intermediate Scenario," Alternative 4, was constructed, with the goal of meeting the numeric targets and yet recognize the feasibility of performance of the upgraded NDN processes at the WRPs. Presented here is the result of many iterations to find a suitable balance between nitrogen compounds, as ammonia, nitrite and nitrate loading all contribute to the nitrate + nitrite numeric target. In addition, there is a need to balance the total nitrogen loading from the Saugus and Valencia WRP, since effluent from Saugus affects the levels of nitrate above and below the Valencia WRP in Reach 7. This is somewhat complicated due to the sharp change in the nitrate + nitrite WQO between Reach 7 and 8. The Intermediate alternative conditions are presented in Table 20.

Table 20. Effluent Concentrations for Intermediate alternative

POTW	NH_3 (mg/L)	NO_2 (mg/L)	NO_3 (mg/L)	Flow rate (m^3/s)
Saugus	2.00	0.1	7.00	0.28475
Valencia	1.75	0.1	6.70	0.94625
Santa Paula + Fillmore	2.00	0.1	8.00	0.18

*Note: Saugus and Valencia WRPs may not achieve these concentrations without construction of additional treatment at these facilities.

The simulation results are presented in Figures 17-28 of Appendix F. With the lower effluent concentrations from the Saugus WRP (below the numeric targets for Reach 8), the ammonia and numeric targets for Reach 8 and segment 129 (Reach 7 above Valencia) are met throughout the 11-year simulation (Figures 17-20) more than 95 % of the time. Nitrite + nitrite concentrations in segment 129 are below 4.34 mg/L 95% of the time.

The simulation of Alternative 4, the "Intermediate Scenario" shows ammonia concentrations below Valencia and down to the County Line (Figures 21 and 23 of the Analysis of Potential Load Allocation Report) would be well below the numeric target for these segments of Reach 7. Nitrate + nitrite in segment 129 is in compliance with the numeric target exactly 95% of the time (Figure 22). This is the tightest condition in the entire watershed and would require frequent monitoring to ensure compliance. Once the river flows down to the County Line, the nitrate + nitrite numeric target is met all the time throughout the 11-year simulation period (Figure 22).

Both the ammonia and nitrate + nitrite numeric targets are met above, at and below Santa Paula all the time throughout the 11-year simulation period under the Intermediate Scenario (Figures 25-28). The higher assimilative capacity in Reach 3 as well as reduced nitrogen loading relative to current operating conditions for the Santa Paula and Fillmore WRPs results in full compliance.

The nitrogen compound loads corresponding to the Intermediate Scenario can be divided into current and future load, as presented in Table 21.

Table 21. Current and future loads considering Alternative 4 (Intermediate Scenario)

POTW	Current Load			Future Load		
	NH_3 (kg/day)	NO_2 (kg/day)	NO_3 (kg/day)	NH_3 (kg/day)	NO_2 (kg/day)	NO_3 (kg/day)
Saugus	41.5	2.1	145.2	49.2	2.5	172.2
Valencia	75.6	4.3	289.4	143.1	8.2	547.8
Santa Paula + Fillmore	25.9	1.3	103.7	31.1	1.6	124.4

6.1.1 Minor Point Sources

Minor point sources are not considered to contribute loads ammonia, nitrite, or nitrate to the Santa Clara River that would have a significant effect on achievement of numeric targets. However, because these sources can potentially have localized effects on water quality, they are allocated concentration-based wasteloads equivalent to the water quality objective. These wasteloads will be implemented through the individual NPDES permits and the Monitoring and Reporting Programs associated with those permits.

6.1.2 MS4 and Stormwater Sources

Municipal separate storm sewer systems (MS4s) and other stormwater sources regulated under NPDES permits are considered minor loads of ammonia, nitrite, and nitrate to the Santa Clara River. However, because these sources can potentially have localized effects on water quality, they are allocated concentration-based wasteloads equivalent to the water quality objective. These wasteloads will be implemented through the stormwater NPDES permits and the Monitoring and Reporting Programs associated with those permits.

Wasteload allocations were set through analysis of different alternatives based on the WARMF model. One alternative evaluated modified ammonia, nitrite, and nitrate concentrations for wasteload allocations for the MS4 permittees in the upper reaches of the watershed. Large storm events can flush the landscape, resulting in infrequent peak concentrations (Report on Point and Non-Point Source Analysis for Segment 56 in Reach 7, below Valencia WRP, 2003). However, the overall load is insignificant. In addition, mass emission monitoring data conducted for MS4 NPDES Permit compliance indicate that the MS4 discharges are below the WLA in both wet and dry weather samples.

On November 22, 2002, the United States Environmental Protection Agency issued a Memorandum clarifying and providing guidance for establishing waste load allocations for storm water discharges in TMDLs. It is noted that TMDLs issued by the Regional Board prior to November 22, 2002 did not contain wasteload allocations for MS4 permittees. However, as the MS4 permittees are a minor load of ammonia, nitrite, and nitrate to the Santa Clara River, the compliance alternative is an iterative approach, which is consistent with the November 22, 2002 memorandum. This iterative, or adaptive management BMP approach, will be based on BMPs currently required in the NPDES permits for stormwater management.

6.1.3 Alternatives Considered by Regional Board

Four alternatives were considered for waste load allocations for ammonia in the Santa Clara River: 1) set concentrations of ammonia, nitrate, and nitrite in WRP effluent equal to the numeric targets; 2) keep point source loads equal to Alternative 1 except for the ammonia concentration in the Saugus WRP, where effluent is reduced to 2 mg/L; 3) anticipate performance of WRP upgrades for ammonia treatment, with nitrate + nitrite effluent concentration of 8.1 mg-N/L; and 4) anticipate performance of WRP upgrades, with nitrate + nitrite effluent concentration of 6.8 mg-N/L for Valencia WRP, 7.1 mg-N/L for Saugus WRP and 8.1 mg-N/L for Santa Paula + Fillmore WRP. The criteria used for selecting the recommended alternative included:

- attainment of numeric targets
- level of beneficial use protection; and

- consistency with the current science regarding water quality necessary to reasonably protect the beneficial uses.

Alternative 4 is the recommended alternative since the action would:

- Be consistent with State and federal water quality regulations;
- consider the expected performance of upgraded WRP (LACSD and Santa Paula WRP plants are in the process of upgrading to include a Nitrification-Denitrification (NDN) module);
- facilitate development of appropriate waste load allocations to meet numeric targets and yet recognize the feasibility of performance of the upgraded NDN processes at the WRPs; and
- improve the scientific basis upon which the waste load allocations are based.

Adoption of Alternatives 1 and 2 would be inconsistent with the scientific study of in-stream phenomenon and performance of upgraded WRPs. Nitrate plus nitrite concentrations in the segment of Reach 7 between Highway 5 and the Valencia WRP could exceed the numeric target based on Alternative 1. Alternative 2 involves reducing the ammonia loading from the Saugus WRP by reducing effluent concentrations. Under these conditions, without consideration of the expected performance upgrades at LACSD and the Santa Paula WRP, the ammonia, nitrate, and nitrite numeric targets are met most of the time. Under Alternative 3, with consideration of expected performance upgrades at the WRPs, and nitrate effluent concentrations for all segments set at 8 mg/L, the nitrate + nitrite concentrations would exceed the numeric target in some reaches.

6.2 Load Allocations: Nonpoint Source Loading Analysis

The previous analysis considers changes in nitrogen loading from the three major point sources while the NPS nitrogen (ammonia + nitrate + nitrite) loading remains at levels similar to existing conditions. However, the flowrates will be higher than in the calibration alternative, given that a significant increase in overall WRP flowrates is anticipated. Thus, the relative contribution of the NPS to overall in-stream loading varies with respect to the original calibration. One way to evaluate the role of these smaller sources, including the small PS as well as NPS such as atmospheric deposition, septic systems, fertilizer application in farms and residential areas, etc., is to set the nitrogen compound loading to zero and observe the resulting water quality.

Based on the above analysis, load allocations for nonpoint sources are set equivalent to the water quality objectives.

NPS loading in Reach 8 and above is significant, both for ammonia and nitrate. Nitrite NPS loading in general is very low throughout the watershed, given that there sources are very small, so it won't be discussed in specific, although the simulated nitrate + nitrite concentrations for an accurate comparison against the previous alternatives is presented. Atmospheric deposition of both ammonia and nitrate is important in Reaches 8 and 9 of the Santa Clara River, given the proximity to the greater Los Angeles basin, where a significant amount of these air pollutants is emitted, and the very large surface area of these two Reaches. Nitrate is produced from the transformation of nitrogen oxides (NOx) to nitric acid and then nitrate. Ammonia appears to be delivered to the river mostly in storm events, while nitrate loading is also through shallow groundwater flows, with an average nitrate + nitrite concentration in the river of 1.5 mg/L. Large storm events flush the landscape, resulting in some peak concentrations.

The contribution from NPS loading of ammonia and nitrate decreases in Reach 7, as these compounds are assimilated. The overall surface area of Reach 7 is smaller, decreasing the magnitude of the loading from atmospheric deposition. The population served by septic systems is also much smaller, given the higher level of urbanization in Reaches 8 and 9 in particular. Thus, the in-stream concentrations generally decrease going downstream. As in Reach 8, ammonia contributions are mostly driven by storm events, while nitrate has both groundwater and storm event contributions.

In Reach 3, NPS ammonia in-stream loading is negligible. Nitrate loading is quite significant above Santa Paula, with an average nitrate + nitrite concentration of 1.26 mg/L. The contributions from NPS nitrate loads decreases going downstream, both due to dilution in WRP effluent and assimilation or transformation of nitrate.

With respect to increases in NPS loading in the future, the conditions at and below the Valencia WRP dictate what can be done in Reaches 8 and 9. Additional NPS loading in these areas needs to be assimilated before it reaches the Valencia WRP, or be associated with sufficient flow to dilute the concentrations in the river.

In Reach 7 below segment 129, the proportion of farmland relative to other land uses increases to 7-8% of the total land surface, and is generally located close to the river. Although there is room for additional NPS loading in these segments, this region will be required to be monitored frequently to ensure compliance with the numeric targets, as outlined in the implementation plan. The TMDL includes monitoring of the effectiveness of Best Management Practices to ensure that NPS loading does not cause exceedances of numeric targets as urbanization of this region progresses.

Nitrate peaks from groundwater discharges in the upper watershed are attributed to NPS loading. Although infrequent, the model predicts in-stream nitrate levels in excess of numeric targets associated with wet weather discharge of groundwater. However, it may underestimate the loading to surface water, which should be attributed to groundwater because of limited groundwater data and modeling limitations on groundwater modeling. As a result, non attainment of modeled numeric targets may be due to NPS loading and measurement of shallow discharging groundwater is part of the implementation plan. NPS reductions to protect groundwater are necessarily an estimate.

An initial allocation of a 20% concentration reduction for future septic system leachate is considered sufficient to prevent groundwater impairments in Reach 7 and 8. Additional monitoring requirements associated with these new septic systems and other WDR permits issued by the Regional Board are expected to identify existing septic systems, which are failing for appropriate regulatory action, by the Regional Board or the Department of Health Services.

An allocation of 20% concentration reduction for agriculture is considered sufficient to achieve compliance in Brown/Todd Barranca and Torrey Canyon where loading is all from agricultural practices.

If shallow groundwater loading continues to show contributions to surface impairment, then additional allocation reductions would be recommended. These additional reductions should be developed on a site-specific basis depending on the location of the non-attainment of shallow groundwater conditions as per Table 22.

Table 22. Additional Reductions to Groundwater Contributions

Reach not attaining GW numeric target	Implementation Plan change
EPA Reach 6 or 7	Existing and future Septic System discharge concentrations reduced below GW numeric target
EPA Reach 3,4, or 5	Agricultural discharge concentration reduced to below GW numeric targets.

6.3 Margin of Safety

A Margin of Safety (MOS) is imposed to compensate for uncertainties in the analytical assessment of the linkage between the allocated source load and the targeted in-stream water quality. MOS can be implicit or explicit. For example, considering a 10% MOS for the WQO in determining the Numeric Targets is an explicit MOS. If an additional MOS is considered based on uncertainty in the model, due to data limitations and/or model assumptions, this is considered an implicit MOS.

An explicit 10% MOS has been considered in the numeric targets of this TMDL. For regions with frequent monitoring, such as segment 159 of Reach 8 and segments 56 and 129 of Reach 7, this safety level appears adequate. For the region below segment 129, as the river enters the farmland in the lower Reach 7, the 95 percentile of observed nitrate + nitrite concentration is 3.55 mg/L. Under current conditions, the difference between the WQO of 5 mg/L and this concentration is around 30%. This should be sufficiently ample difference to meet the WQO.

Increased frequency of monitoring during the critical conditions should result in higher confidence in model results, without the need to formally establish a higher MOS.

A 10% MOS assumes that the model represents the physical conditions present in the river such that the calibration of the model to fill data gaps has a level of accuracy similar to other models of its class. The WARMF model's strengths include the ability to predict chemical transformation of nutrient species with varying pH and dilution and to integrate large amounts of data and area. Based on this, it can be argued that the model accurately depicts the concentrations of nutrient species, especially the large difference between the nutrient load applied to land and the nutrient load transported in the river. As a result, model predictions of the reductions required in the nonpoint source loading of land-applied nutrients are likely to be accurate and consistent with a 10% MOS.

WARMF practitioners report that the model is not designed to model groundwater discharge and blends nonpoint source contributions to groundwater over an entire watershed unit. Model predictions of nonpoint source loading to groundwater and subsequent discharge to the river may be underestimated. However, these nitrogen sources appear minor relative to the nitrogen contained in the WRP discharges.

The modeled linkage analysis predicts that with a 10% explicit MOS, an implicit MOS from conservative assumptions, modeling calibration, and the allocations presented, the water quality objectives can be attained within all reaches of the Santa Clara River. The exception is Reach 7, adjacent to the Valencia WRP outfall where assumptions of unique local conditions (i.e., high in-stream denitrification rates) were made and the WQOs is attained 95% of the time. This TMDL sets forth special studies to determine the nitrification/denitrification rates in the vicinity of the Valencia WRP outfall.

There are a number of built-in assumptions in the Intermediate Alternative, which provide additional safety. For example, the simulations have been conducted at higher flowrates than the situation that will be present during the first few years of operation of the upgraded WRP. Thus, nitrogen loading will be lower than the alternative considers. Monthly ammonia numerical targets are met on a daily basis more than 95% of the time or better. Point source loading has been considered towards the upper range of the experience at the Whittier Narrows WRP, to provide an additional margin of safety. The calibration refinement tends to slightly overpredict concentrations in most cases.

An increased monitoring program, particularly in those segments where the concentrations are close to the numeric target, and during the critical conditions, should adequately provide information to make refinements in the load allocations in future years.

In addition, this TMDL includes special studies to address the follow assumptions:

- Rapid nitrogen compound disappearance in Reaches 7 and 8: the observed data imply a rapid disappearance of ammonia, nitrite and nitrate in the upper SCR. Whether this will continue to be the case when the WRP are upgraded to NDN needs to be monitored. Changes in conditions might result in the need to refine the model and revisit the load allocations.
- Atmospheric deposition: an important nonpoint source load in the upper watershed is atmospheric deposition. The magnitude of this load was estimated in the source analysis, but it would be of use to all the stakeholders in the upper watershed to know if the assumptions are correct, and it might lead to either increased or decreased loading from other sources.

- NPS loading: The NPS load to the river is predicted to increase during first storm events. Monitoring of all N compounds to verify this prediction is considered in the studies.
- Nitrate loading via groundwater discharge: The WARMF model uses prescribed groundwater discharge flows along the various segments. Nitrate concentrations in these groundwater discharges is based on the initial condition in 1989 (from the USGS report), incremented over time with N loading to the surface that migrates into the various layers of the aquifer. However, given the nature of the WARMF model, the nitrate concentrations are homogeneous for each layer of the aquifer, based on the assumption of immediate mixing in a layer. Thus, the nitrate loading via groundwater discharge might be underestimated in areas where the nutrient load is concentrated and is near the discharge area. A study to collect groundwater nitrate concentrations at the discharge points as well as corresponding surface water concentrations immediately above and below the discharge would reduce the uncertainty associated with this loading. The study should consider spatial and temporal variability.

7 FUTURE GROWTH

The population in the Santa Clarita Valley is expected to grow by nearly 80% from 2000 to 2015 based on 1994 studies by Southern California Association of Governments (SCAG). The SCAG studies indicate that the population in Ventura County is expected to grow by 20%. Population growth will impact Santa Clara River in the form of additional nutrient loads in POTW effluent and potentially, greater nonpoint source loads. The load will increase proportionally to the population increase if it is assumed that future domestic water use per person and future nutrient load per household are approximately equal to current water use and nutrient loads. Under those assumptions, the volume of wastewater discharged by the POTW is also projected to increase proportional to population increase.

Because impairments are based on in-stream nitrogen concentrations, increased loads (i.e. flows) from POTWs is not expected to result in impairment of the Santa Clara River because the relative nitrogen concentrations will remain unchanged as long as nitrogen compounds do not accumulate in the sediments or other areas within the watershed. Therefore, the projected future increase in nitrogen loads from current and future POTWs in the watershed due to population growth are expected to be assimilated adequately. WLAs for POTWs are specified proportional to discharge volume, such that the nutrient concentration in the discharge will equal the concentration based WLAs. However, future growth may result in increased nitrogen concentrations in groundwater in the Santa Clara River watershed. This TMDL includes a special study to evaluate the effects of future nitrogen loading on groundwater to determine whether there will be effects from, for example, use of reclaimed water for irrigation, .

Future growth that would exceed existing POTW capacity will be accommodated by increasing existing POTW capacity or construction of new POTWs. Either alternative entails the construction of new treatment capacity that will require a modification to existing or new NPDES permits. Revision of WLAs can be incorporated into the NPDES permits, if appropriate. The numeric targets for POTWs with increasing capacity or new POTWs will be set on a concentration basis, and the WLAs will be calculated based on the new design capacity and effluent concentrations needed to meet in-stream water quality standards.

Future Growth can be considered in several ways. For the two WRP in Los Angeles County, Saugus and Valencia, the information from the County Sanitation Districts of Los Angeles County (CSDLAC) indicates that these two plants will be upgraded to a capacity of 6.5 MGD and 21.6 MGD, respectively. For the Fillmore and Santa Paula area, the modeling considered that the Fillmore plant will be phased out and that all of its flow will be directed to the upgraded Santa Paula WRP. A growth factor of 1.2 was applied to their combined flow, considering the slower growth rate in this area relative to that of the upper reaches. The current and projected flowrates for these facilities is presented in Table 23. For agricultural NPS, no additional future growth was considered since the acreage devoted to agriculture is unlikely to increase, given the increasing urbanization of the watershed. There is the potential to convert orchards (e.g. citrus or avocado) to row crops, but this was not evaluated in this analysis given the lack of information on such plans.

Increased use of reclaimed water is a major component of future growth of the Santa Clarita Valley. The Castaic Lake Water Agency has proposed to use reclaimed water from the Saugus and Valencia WRPs. Although increased use of reclaimed water may reduce the loading of ammonia, nitrite, and nitrate to the Santa Clara River, the magnitude of this reduction has not been quantified. Use of reclaimed water system in the vicinity of the impaired reaches could remove diluting effects through local or temporary increases in groundwater concentrations through direct percolation or leaching. This TMDL includes evaluation of the effects of reclaimed water on the in-stream water quality and establishment of reclaimed water limits for ammonia, nitrite, and nitrate if required.

Table 23. Current and projected Flowrates of Major Point Sources in SCR

	Current (m^3/s)	Projected (m^3/s)	% Increase
Saugus	**0.24**	0.28475	18.6%
Valencia	**0.50**	0.94625	89.3%
Santa Paula & Fillmore	**0.15**	**0.18**	20 %

8 CRITICAL CONDITION AND SEASONALITY

Critical conditions and seasonality were analyzed by evaluating the conditions that lead to high concentrations of inorganic nitrogen species (i.e. ammonia, nitrite and nitrate) in the impaired reaches and tributaries of the Santa Clara River watershed. The analysis was divided into three sections: (1) an analysis of the low flow conditions and the correlation between low flow and high concentrations of these nitrogen species; (2) an evaluation of the timing of point and nonpoint source discharges of these nitrogen species to the river and tributaries, to determine the possibility of high concentration peaks during the initial storm events (first flush effect); and

(3) an analysis of conditions where rising groundwater might be a significant contribution to total loading.

The statistical correlation of flow and concentrations indicates that the highest concentrations are typically going to be found during low flow periods when there is reduced dilution. For these catchments, this is of particular importance given that in many instances there is practically no flow during significant periods of time. On the other hand, since there is no carrier medium, there is generally little or no loading occurring at this time from non point sources (NPS). Thus the concern is that point source (PS) loading be controlled during these low flow periods so that it does not exceed the desired numeric targets.

From the timing analysis it is concluded that for these catchments, NPS loading is very small in general, with only a few days in the 11-year simulation where the relative magnitude of NPS loading is of significance for water quality. These high NPS load days occur early in the rainy season, and typically follow a period of dry years. In the case of ammonia, this is mostly a concern if the NPS ammonia load is applied right before the rain events. These findings can be used to better design Best Management Practices, with regards to the timing of the NPS loading so that it is reduced in the months before the rainy season, and in particular after a number of dry years.

The analysis of contribution from groundwater to the observed nitrate concentrations in the Santa Clara River indicates that this is more likely to occur in the lower watershed (Reach 3), and be less important in the upper watershed (Reach 7). However, it is important to note that the groundwater component of the model is spatially very simplified. It is necessary to obtain time-series data of nitrate concentrations in several wells in the area, which can then be coupled to a groundwater flow model to estimate the magnitude of the contribution from groundwater.

In conclusion, the most critical conditions for water quality in the Santa Clara River are low-flow conditions, in particular at the end of the dry season. The first strong storm events can cause significant short-term increases in nitrate concentrations in the river. Groundwater may be an important contributor in the lower watershed to increasing nitrate concentrations during the dry season. The groundwater contribution needs additional studies to confirm the magnitude and temporal variation of this load. These results need to be confirmed with additional monitoring data, in particular for Reach 3 where the observed data is sparse in many locations.

9 SUMMARY OF TMDL

This TMDL sets Waste Load Allocations for ammonia, nitrate, nitrite, and Nitrate+Nitrite for POTWs discharging to the Santa Clara River and its tributaries. Effluent limits are designed to ensure compliance with the water quality standards for ammonia based on the updated ammonia criteria, and nitrate and nitrite based on the existing Basin Plan objective. Under this TMDL the ammonia loadings will be reduced from approximately 605 kg/day to approximately 61 kg/day (10%of 1998 load). This represents a 90% reduction in the total ammonia loads. Table 24 compares the proposed WLAs to the current loading estimates.

Table 24. Waste Load and Load Allocation Summary by Source

	Estimated Mean Loads (lb/day) (based on discharger effluent data for POTWs)				Proposed Future Waste Load Allocations (lb/day) ****				Reduction in current load due to WLAs and LAs			
Source	Saugus*	Valencia*	S+F*	NPS **	Saugus	Valencia	S+F	NPS ***	Saugus	Valencia	S+F	NPS
Ammonia as N	536	1226	329	12.8 (3.6)	109	316	69	10.2	80%	74%	80%	20%
Nitrate+ Nitrite as N	176	546	97	1584 (274)	385	1226	278	1267	+118%	+124%	+186%	20%
Total N from Point and Nonpoint	4507 lbs/day				3660 lbs/day				19%			

* Load from discharge monitoring reports in Appendix C where it is reported in kg/d, which can be multiplied by 2.205 to get lbs/day. S+F is a combined Santa Paula and Fillmore discharge

** Load from model calculation for wet year 1998 (and dry year 1991) when NPS contributions are large as quantified in "Source contributions" for NPS minus Point source in Appendix D which is a calculation of the non-assimilated nutrient load which is found in-stream.

***Load reductions set at 20% for agricultural BMPs

**** Includes additional flow (see Technical Support Document – Appendix A)

Table 25 presents the TMDL elements.

Table 25. Santa Clara River Nitrogen Compounds TMDL: Elements

Element	Santa Clara River Nitrogen Compounds TMDL
Problem Statement	Discharge of wastes containing nitrite, nitrate and ammonia to the Santa Clara River causes exceedances of water quality objectives for nitrate and nitrite established in the Basin Plan and of the water quality objectives for ammonia established in the U.S. Environmental Protection Agency 1999 ammonia criteria for Inland Surface Waters. Based on the 2002 303(d) list of impaired water bodies, the Santa Clara River is impaired by ammonia in reach 3 and nitrate plus nitrite in reach 7. Reach 8 of the Santa Clara River is included on the State Monitoring List for organic enrichment/dissolved oxygen. The State Monitoring List assigns a high priority for monitoring before the next section 303(d) list is completed. Nitrite and nitrate are biostimulatory substances that can cause or contribute to eutrophic effects such as low dissolved oxygen and algae growth in inland surface waters such as the Santa Clara River. Excessive ammonia can cause aquatic life toxicity in inland surface waters such as the Santa Clara River.

<table>
<tr><th>Element</th><th>Santa Clara River Nitrogen Compounds TMDL</th></tr>
<tr><td>Numeric Target (Interpretation of the numeric water quality objective, used to calculate the load allocations)</td><td>Numeric targets for this TMDL are listed as follows:

• Total ammonia as nitrogen (NH_3-N)
Based on the past five years of temperature and pH data, the ammonia numeric targets for the stream segments which receive the significant ammonia and nitrite + nitrate loads are provided below:
<table>
<tr><th>Reach</th><th>One-hour NT (mg-N/L)</th><th>Thirty-day NT (mg-N/L)</th></tr>
<tr><td>Reach 8</td><td>14.8</td><td>3.2</td></tr>
<tr><td>Reach 7 above Valencia</td><td>4.8</td><td>2.0</td></tr>
<tr><td>Reach 7 below Valencia</td><td>5.5</td><td>2.0</td></tr>
<tr><td>Reach 7 at County Line</td><td>3.4</td><td>1.2</td></tr>
<tr><td>Reach 3 above Santa Paula</td><td>2.4</td><td>1.9</td></tr>
<tr><td>Reach 3 at Santa Paula</td><td>2.4</td><td>1.9</td></tr>
<tr><td>Reach 3 below Santa Paula</td><td>2.2</td><td>1.7</td></tr>
</table>
• NO_3-N + NO_2-N
9.0 mg/L in Reach 8
4.5 mg/L in Reaches 3 and 7

Narrative objectives for biostimulatory substances and toxicity are based on the Basin Plan.. The TMDL analysis indicates that the numeric targets will implement the narrative objectives. The Implementation Plan includes monitoring and special studies to verify that the TMDL will implement the narrative objectives.</td></tr>
<tr><td>Source Analysis</td><td>The principal source of ammonia, nitrite, and nitrate to the Santa Clara River is discharges from the Saugus and Valencia Water Reclamation Plants and the Fillmore and Santa Paula Publicly Owned Treatment Works. Agricultural runoff, stormwater discharge and groundwater discharge may also contribute nitrate loads. Further evaluation of these sources is set forth in the Implementation Plan.</td></tr>
<tr><td>Linkage Analysis</td><td>Linkage between nitrogen sources and the in-stream water quality was established through hydrodynamic and water quality models. The Watershed Analysis Risk Management Framework was used to model the hydrodynamic characteristics and water quality of the Santa Clara River. The Linkage Analysis demonstrated that major point sources were the primary contributors to in-stream ammonia and nitrate plus nitrite loads. Nonpoint sources and minor point sources contributed a much smaller fraction of these in-stream loads.</td></tr>
<tr><td>Wasteload Allocations (for</td><td><u>Major point sources:</u></td></tr>
</table>

<table>
<tr><th>Element</th><th>Santa Clara River Nitrogen Compounds TMDL</th></tr>
<tr><td>point sources)</td><td>
Concentration-based wasteloads are allocated to major point sources of ammonia in Reach 3, which include the Fillmore and Santa Paula POTWs; concentration-based wasteloads are allocated are allocated to major point sources of nitrite+nitrate in Reaches 7 and 8 ,,which include the Valencia and Saugus WRPs. Based on the linkage analysis for this TMDL, the ammonia WLAs for the major POTWs are provided below. The Implementation Plan provides reconsideration of the WLAs by the Regional Board based on WER studies and updated data 5 years after the effective date of the TMDL.
Ammonia-nitrogen (NH_3-N):
<table>
<tr><th>POTW</th><th>One-hour WLA</th><th>Thirty-day WLA</th></tr>
<tr><td>Saugus WRP</td><td>5.6 mg/L</td><td>2.0 mg/L</td></tr>
<tr><td>Valencia WRP</td><td>5.2 mg/L</td><td>1.75 mg/L</td></tr>
<tr><td>Fillmore POTW</td><td>4.2 mg/L</td><td>2.0 mg/L</td></tr>
<tr><td>Santa Paula POTW</td><td>4.2 mg/L</td><td>2.0 mg/L</td></tr>
</table>
Although there is no 303(d) listing for Ammonia in Reaches 7 and 8, the TMDL analysis shows that the POTWs will be discharging at no more than 2.0 mg-N/L in Reach 8 and 1.75 mg-N/L in Reach 7, to achieve the nitrite + nitrate numerical targets for each of these reaches.
Nitrate-nitrogen (NO_3-N) + Nitrite-nitrogen (NO_2-N):
<table>
<tr><th>POTW</th><th>NO2-N</th><th>NO2-N+NO3-N</th></tr>
<tr><td>Saugus WRP</td><td>0.9 mg/L</td><td>7.1 mg/L</td></tr>
<tr><td>Valencia WRP</td><td>0.9 mg/L</td><td>6.8 mg/L</td></tr>
</table>
Minor Point Sources:
Concentration-based wasteloads are allocated to minor discharges enrolled under NPDES or WDR permits.. The allocations for minor point sources are based on the water quality objectives for ammonia, nitrite, nitrate and nitrite+nitrate. For minor dischargers discharging into Reach 7, the WLA for nitrate+nitrite is 6.8 mg/L. For minor dischargers discharging into Reach 3, the thirty-day WLA for ammonia is 2.0 mg/L and the one hour WLA for ammonia is 4.2 mg/L; the WLA for nitrate+nitrite is 8.1 mg/L.
MS4 and Stormwater Sources:
Concentration-based wasteloads are allocated to municipal, industrial and
</td></tr>
</table>

Element	Santa Clara River Nitrogen Compounds TMDL
	construction stormwater sources regulated under NPDES permits. The allocations for minor point sources are based on the water quality objectives for ammonia, nitrite, and nitrate. For stormwater permittees discharging into Reach 7, the thirty-day WLA for ammonia is 1.75 mg/L and the one-hour WLA for ammonia is 5.2 mg/L; the WLA for nitrate+nitrite is 6.8 mg/L. For minor dischargers discharging into Reach 3, the thirty-day WLA for ammonia is 2.0 mg/L and the one-hour WLA for ammonia is 4.2 mg/L; the WLA for nitrate+nitrite is 8.1 mg/L.
Load Allocation (for nonpoint sources)	Concentration-based loads for total inorganic nitrogen are allocated for nonpoint sources. For nonpoint sources discharging to Reach 7, the ammonia + nitrate + nitrite (NH_3-N + NO_2-N + NO_3-N) load is 8.5 mg-N/L. For non-point sources discharging into other reaches of the Santa Clara River the ammonia + nitrate + nitrite (NH_3-N + NO_2-N + NO_3-N)loads are 10 mg-N/L. Monitoring is established in the TMDL Implementation Plan to verify the nitrogen nonpoint source contributions from agricultural and urban runoff and groundwater discharge.
Implementation	• Ammonia, nitrite, and nitrate reductions will be regulated through effluent limits prescribed in POTW and minor point source NPDES Permits, Best Management Practices required in NPDES MS4 Permits, and SWRCB Management Measures for non point source discharges. • Refer to Table 29 of this document for the Implementation Schedule The Implementation Plan includes upgrades to the WRPs and POTWs discharging to Santa Clara River for removal of ammonia, nitrate, and nitrite. To allow time for completion of the nitrification/denitrification facilities and/or modifications of existing nitrification/denitrification facilities which are integral to this TMDL, the amendment to the Basin Plan made by this TMDL allows for higher interim loads which the Regional Board (at its discretion) can incorporate into NPDES permits as interim effluent limits for a period not to exceed five years from the effective date of the TMDL, as follows: Interim Limits for Nitrate + Nitrite POTW — Daily Maximum Saugus WRP — 10 mg-N/L Valencia WRP — 10 mg-N/L Interim Limits* for Ammonia + Nitrate +Nitrite POTW — Monthly Average — Daily Maximum Fillmore WRP — 32.8 mg-N/L — 38.9 mg-N/L Santa Paula WRP — 41.8 mg-N/L — 49.0 mg-N/L

Element	Santa Clara River Nitrogen Compounds TMDL
	The Implementation Plan also includes special studies and monitoring to evaluate the effectiveness of nitrogen reductions for ammonia, nitrite, and nitrate on implementing narrative objectives for biostimulatory substances and toxicity. Ammonia, nitrite, and nitrate reductions will be regulated through effluent limits prescribed in NPDES permits and best management practices for MS4 and non point source discharges. The Implementation Plan also includes special studies to address issues regarding water quality standards and site specific objectives and a reconsideration of waste load allocations based on monitoring data and special studies.
Margin of Safety	An explicit margin of safety of 10% of the nitrogen loads is allocated to address uncertainty in the source and linkage analyses. In addition, an implicit margin of safety is incorporated through conservative model assumptions and statistical analysis. Impairment is typically based on exceeding the single sample objective in more than 10% of the samples. By incorporating an implicit margin of safety, the number of samples exceeding the water quality objective will be less than 10% of the samples measured in-stream.
Future Growth	Plans for the upper watershed include urban growth, which will expand the capacity of the Valencia Water Reclamation Plan, construction of an additional water reclamation plant, and increased use of reclaimed water. Wasteload and load allocations will be developed for these new sources as required to implement appropriate water quality objectives for ammonia, nitrite, nitrate, and nitrite+nitrate.
Seasonal Variations and Critical Conditions	The critical condition identified for this TMDL is based on the low flow condition defined as the 7Q10. In addition, the driest six months of the year are identified as a more critical condition for nutrients because less surface flow is available to dilute effluent discharge. The linkage analysis also indicates a critical condition during the first major storm event after a dry period. The implementation plan includes monitoring to verify this potential critical condition.

10 IMPLEMENTATION

This section describes the proposed implementation plan to meet water quality objectives for nitrogen and effects in the Santa Clara River. The Implementation Plan includes the following elements:

- Wastewater treatment to remove ammonia, nitrate and nitrite from POTW effluent;
- Implementation and evaluation of agricultural best management practices (BMPs) in the Santa Clara River watershed;
- Implementation of modeling and evaluation of groundwater conditions in the Upper Santa Clara River watershed; and
- Monitoring for ammonia, nitrite, nitrate, toxicity, algae, dissolved oxygen, scum, and foam in the Santa Clara River.

10.1 Alternatives Considered by Regional Board

In addition to the alternatives developed and described in Section 6, Allocations, two alternatives were considered for developing an appropriate implementation schedule to meet the ammonia, nitrate, nitrite, nitrate + nitrite objectives. Alternative 1 would require that waste load allocations be applied to POTWs on the effective date of the TMDL. Under Alternative 2, interim waste load allocation would be considered for an interim period before WLAs for nitrate-N, nitrite-N, nitrate-N + nitrite-N would apply to POTWs

Alternative 2 is the recommended alternative since this alternative would allow the dischargers time to complete the implementation of treatment facilities without increasing current ammonia, nitrate and nitrite loads in the interim period. As the treatment facilities are commissioned, the reductions in ammonia and nitrate loads will alleviate the corresponding impairments in the Santa Clara River. Alternative 1 would not provide the time needed for the dischargers to complete implementation of nitrification/denitrification facilities.

10.2 Wastewater Treatment

The WLAs for ammonia, nitrite, and nitrate established in this TMDL will be implemented as effluent limits in the NPDES permits for the POTWs discharging in the Santa Clara River. These effluent limits can be achieved by incorporating additional treatment facilities, which may include modifications to existing nitrification and denitrification operations and installation of denitrification filters at the POTWs. Nitrification reduces the ammonia load by oxidizing it to nitrite and nitrate, and denitrification reduces the nitrite and nitrate loads by reducing these compounds to gaseous nitrogen.

The regulatory framework for achieving the ammonia objective is established by the Basin Plan. The Basin Plan provides that the compliance date for the inland surface water ammonia objective is June 13, 2002. Specifically, the Basin Plan states that, "timing of compliance with this objective will be determined on a case-by-case basis. Discharges will have up to 8 years following the adoption of this plan by the Regional Board to (i) make the necessary adjustments/improvements to meet these objectives or (ii) to conduct studies leading to an approved site-specific objective for ammonia. If there is an immediate threat or impairment of beneficial uses due to ammonia, the objectives in Tables 3-1 to 3-4 shall apply" (Basin Plan, p. 3-3). On May 31, 2001 Regional Board staff presented a Status Report on POTWs Timely Progress toward Compliance with Inland Surface Water Ammonia Objectives to Protect Aquatic Life, as Stipulated in the Basin Plan. Staff reported that most of the POTWs in the Santa Clara River were expected to be in compliance with the ammonia objective within one year of the June 13, 2002 deadline. Staff recommended that the Regional Board evaluate on a case-by-case basis the appropriateness of (1) issuing Time Schedule Orders for those POTWs that will not achieve compliance by the deadline and/or (2) finding the discharges in violation of permit conditions and taking other enforcement actions.

Compliance with oxidized nitrogen targets will involve both point source and nonpoint source controls. For POTWs, compliance with nitrate and nitrite targets is related to compliance with the ammonia target, because the preferred method of meeting the ammonia target is to oxidize ammonia to nitrate (i.e. nitrify effluent). The nitrified effluent will need to be denitrified to meet nitrate and nitrite objectives.

Regional Board staff also considered enhancement or construction of wetlands as an alternative to nitrification/denitrification meet wasteload and as a potential BMP. Wetlands construction can remove nutrient compounds while providing support for habitat and recreational uses. Dischargers would provide appropriate monitoring to verify the effectiveness of wetlands treatment in meeting the numeric targets.

10.3 Interim Nitrate Limits

The POTWs in the Santa Clara watershed may require additional time to meet the oxidized nitrogen (nitrate, nitrite, and nitrate + nitrite) WLAs. As POTWs implement nitrification/denitrification processes to comply with the ammonia objective and existing effluent limitations for nitrate + nitrite additional oxidized nitrogen will be generated in the POTW effluent. To allow time for completion of a site-specific objective and for planning, design, and construction of additional nitrification and denitrification facilities, if needed, which are integral to this TMDL, the amendment to the Basin Plan that includes this TMDL allows for interim limits listed in Tables 25 and 26 while the appropriate upgrades are effected to achieve full compliance, if needed.

The interim effluent limits are based on POTW performance and are based on the 99th percentile of effluent performance data for the daily maximum and 95th percentile of effluent performance data for the monthly average limits for nitrite-nitrogen, and nitrate-nitrogen concentrations in POTW effluent. These interim limits will apply to ammonia, nitrate, nitrite, and nitrate + nitrite for the Fillmore and Santa Paula POTWs, as shown in Table 26. For the Saugus and Valencia POTWs, only nitrate + nitrite interim limits apply, as shown in Table 27. The time periods for interim limits are based on information provided by the POTWs. Interim limits were calculated assuming the detection limit for nitrite is 0.01 mg/L.

Table 26. Interim Limits for Fillmore and Santa Paula POTWs

	Ammonia+ Nitrate+nitrite (mg/L)
Fillmore	

Monthly Average	32.8
Daily Maximum	38.9
Santa Paula	
Monthly Average	41.8
Daily Maximum	49.0

Table 27. Interim Limits for Saugus and Valencia POTWs

	Nitrate+nitrite (Daily Maximum)
Saugus	10 mg/L
Valencia	10 mg/L

10.4 Nonpoint Source Control

Load allocations will be implemented in accordance with the State's Nonpoint Source Management Plan which describes a three-tiered approach to address nonpoint source loads, including: (1) voluntary implementation of Best Management Practices (BMPs), (2) regulatory-based enforcement of BMPs, and (3) prescription of effluent limitations. The management plan generally prescribes the least stringent option that will restore and protect water quality.

The status of implementation of nonpoint source BMPs throughout the Santa Clara watershed was documented for this TMDL (Appendix E) and demonstrates that substantial efforts have been expended to provide educational and funding support for voluntary implementation of Best Management Practices as defined in the Basin Plan. The State Water Control Board Nonpoint Source Implementation Guidance Document (2002) states that sufficient voluntary implementation is not necessary to proceed to regulatory-based enforcement.

The Regional Board has initiated the organization of oversight committees or identified an existing stakeholder group willing to be tasked with assisting in the implementation of nonpoint source controls through the TMDL. Agricultural, reclaimed water and septic system loading, and wetlands elimination have been identified as nonpoint source issues which require more oversight, monitoring and modeling than can be provided by Regional Board Nonpoint staff during the implementation period to ensure success of the TMDL.

An agricultural oversight committee (AOC) was formed to monitor and track the development of BMPs in the watershed. This group is providing educational outreach to growers and has begun monitoring agricultural impacts and documenting the extent and impact of existing BMPs. The agricultural oversight committee is comprised of local agricultural organizations, Regional Board staff and interested stakeholders. The committee's first meeting took place on September 18, 2002 at the Ventura County Farm Bureau. The committee will participate in the following activities with Regional Board Staff; 1) quantify fertilizer application practices and loading rates to groundwater through leaching and surface waster through runoff, 2) describe BMPs to manage, 3) identify extent of BMPs usage, 4) provide outreach, education, and fiscal support targeted by BMP and by prioritized areas, and 5) install and overview BMPs. In cases of non-compliance with BMPs by some of these stakeholders, the Regional Board may issue discharge permits, time schedule orders, or waivers as appropriate. The Regional Board staff recommends that when progress is made on these implementation plan tasks, then growers participating with the AOC may not be subject to discharge permits.

Groundwater discharge to the Santa Clara River is a nonpoint source, (DWR 1993, USGS 2003) which can affect the results of the TMDL. Water purveyors and users in the upper and lower watershed have entered a Memorandum of Understanding and formed a "MOU" committee tasked with constructing a working surface and groundwater model to quantify and monitor water transfer and storage programs proposed to optimize the utilization of the Santa Clara River watershed resource. The model is expected to be completed in June 2003 with ongoing monitoring provided by the group members to update the model during its use. Regional Board staff met with representatives of this committee in December 16, 2002. This committee may model the impact of proposed reclaimed water systems and provide this information to the Regional Board for the purposes of permitting these discharges and ensuring the resulting in-stream water quality is consistent with the requirements of the TMDL. Additional monitoring by this committee and its members and updating of the model with this data and periodic model analysis were already planned as part of the MOU agreement and will be included in permit requirements to ensure that reclaimed water systems and groundwater management plans will not prevent the success of the TMDL.

The Septic Task Force is considering assisting Regional Board staff in monitoring the cumulative effects of septic system installation in the Upper Santa Clara River. The group was formed with the assistance of the Regional Water Quality Control Board and the Santa Monica Restoration Group to provide stakeholder guidance in the development of the Malibu nutrient and coliform TMDL.

10.5 Monitoring

The following describes key elements of the TMDL Monitoring Program.

10.5.1 Compliance Monitoring for POTWs

Effluent and receiving water monitoring requirements will be developed for the POTWs to ensure compliance with the limits for nitrogen species (including but not limited to ammonia, nitrate, nitrite, and nitrate plus nitrite). The frequency of sampling will be determined by the Regional Board to ensure that the effluent limits are met and that receiving water standards are not violated. Organic nitrogen will be included in the parameters to evaluate total nitrogen loadings to Santa Clara River and its tributaries.

POTW monitoring will include parameters to assess the narrative standards for nitrate, nitrite and ammonia in accordance with USEPA Protocol for Developing Nutrient TMDLS, 1999, #841 B 99 007, including, but not limited to water column measurements of temperature, pH and DO, ammonia, nitrate, nitrite, organic nitrogen, acute and chronic toxicity, algae mass and coverage, benthic invertebrates, macroinvertebrates, and fish surveys. The frequency of sampling will be determined by the Regional Board to statistically demonstrate that the sampling frequency is sufficient to ensure that the water quality standards are met. The monitoring program will also include sediment samples, if necessary, to ensure water quality standards for nutrients are attained. Observations for the presence of scum, odors, and the presence and extent of algal mats should be made at the same time the receiving waters are sampled, and coordinated, to the extent possible, with ongoing monitoring requirements for the WRPs and POTWs.

Additional monitoring will be required to refine the point source loading estimates from minor sources. The Regional Board will re-estimate the magnitude of minor point source loading and determine if additional monitoring of these sources is required to refine the point source load estimates and allocate waste loads to the minor point sources.

10.5.2 Nonpoint Source Monitoring

This TMDL includes monitoring to evaluate nutrient loadings associated with agricultural drainage and other nonpoint sources. The monitoring program will include both dry and wet weather discharges from agricultural, urban and open space sources. In addition, groundwater discharge will also be analyzed for nutrients to determine the magnitude of these loading and the need for load allocations. A key objective of these studies will be to determine the effectiveness of agricultural BMPs in reducing nutrient loadings. Consequently, flow and analytical data for nutrients will be required to estimate loadings from nonpoint sources.

10.5.3 MS4 Monitoring

MS4 Monitoring will be in accordance with Work Plans to be submitted by MS4 permittees in Los Angeles and Ventura Counties, respectively. The Work Plans can include a phased approach in which initial monitoring will be provided by existing mass emission monitoring stations and selected storm drains, if necessary, as proposed by the MS4 permittees and approved by the Regional Board Executive Officer. If, as a result of first phase monitoring, nitrogen loads from the storm sewer system are found to be a significant source or cause exceedances of applicable numeric targets for ammonia and/or nitrate + nitrite, the Work Plan will establish steps for further monitoring. Elements of future phased monitoring may include land use monitoring and tributary monitoring. BMPs, as established in the NPDES permits, will be implemented as necessary to reduce ammonia, nitrite, and nitrate loading, if required.

10.6 Special Studies

The Implementation Plan sets forth special studies to address issues associated with nutrient impairments that currently require more data to resolve. These special studies include:

- study of agricultural best management practices (BMPs) in the Santa Clara River watershed;
- study of groundwater conditions in the Upper Santa Clara River watershed; studies to address issues for which the data are insufficient to assess the nutrient influence in the Santa Clara River, including, but not limited to aquatic life , algae and dissolved oxygen.

Table 28 summarizes the Implementation Plan Milestones. The Implementation Plan provides a provision for reevaluating the TMDL five years after the effective date to consider revised water quality objectives, if appropriate.

Table 28. Implementation Schedule

Implementation Tasks, Milestones and Provisions	Responsible Party	Completion Date
1. Apply interim limits for NH_3-N and NO_3-N + NO_2-N to Fillmore and Santa Paula POTWs. 2. Apply interim limits for NO_3 to Saugus and Valencia WRPs. 3. Apply Wasteload Allocations (WLAs) to minor point source dischargers and MS4 permittees. 4. Include monitoring for nitrogen compounds in NPDES and WDR permits for minor dischargers as permits are renewed.	Fillmore and Santa Paula POTWs; NPDES and WDR permittees	Effective Date of TMDL
5. Submittal of Work Plans by Los Angeles County and Ventura County MS4 permittees to estimate nitrogen loadings associated with runoff loads from the storm sewer system for approval by the Regional Board's Executive Officer. If, as a result of carrying out the Work Plan, ammonia or nitrogen loads from the storm sewer system are found to be a significant source, the Work Plan will be modified to include determination of the effectiveness of BMPs in addressing nutrient loading in runoff from urban and suburban areas,	Los Angeles and Ventura Counties MS4 Permittees	1 year after the Effective Date of TMDL
6. Submittal of Work Plan by major NPDES permittees to assess and monitor the receiving water quality for organic enrichment and other nitrogen effects in the Santa Clara River for approval by the Regional Board's Executive Officer. The Work Plan will include evaluation of the effectiveness of the POTW in meeting WLAs.	Cities of Fillmore and Santa Paula, and County Sanitation Districts of Los Angeles County	1 year after Effective Date of TMDL
7. Submittal of special studies Work Plan by County Sanitation Districts of Los Angeles County to evaluate site-specific objectives (SSOs) for nitrate for approval by the	County Sanitation Districts of Los Angeles County	1 year after Effective Date of TMDL

Implementation Tasks, Milestones and Provisions	Responsible Party	Completion Date
Regional Board's Executive Officer		
8. Submittal of results from water effects ratio study for ammonia by County Sanitation Districts of Los Angeles County.	County Sanitation Districts of Los Angeles County	Effective Date of TMDL
9. Evaluation of feasibility of including stakeholders in the Upper Santa Clara River watershed in the Regional Board Septic Tank task force.	Regional Board	1 year after Effective Date of TMDL
10. Submittal of Work Plan by Stakeholder Group for nitrogen trading in the Santa Clara River watershed for approval of the Executive Officer.	Interested Stakeholders	2 years after Effective Date of TMDL
11. Regional Board considers a Basin Plan Amendment for site-specific objectives for ammonia and nitrite-nitrogen + nitrate-nitrogen based on results of Tasks 7 and 8.	Regional Board	1 year after Effective Date of TMDL for ammonia; 4 years after the Effective Date of the TMDL for nitrite-nitrogen + nitrate-nitrogen.
12. Based on the results Task 5-11 and NPDES Monitoring, complete implementation of advanced treatment or additional treatment modifications to achieve WLAs for POTWs, if necessary.	POTW Permittees	8 years after Effective Date of TMDL
13. Interim limits for ammonia, and nitrate expire and WLAs apply to POTWs. The Regional Board will consider extending the duration of the remaining schedule and re-evaluating interim limits if WLAs for POTWs are reduced after SSO considerations.	POTW Permittees Regional Board	Based on results of Tasks 6 and 11: if additional modifications or advanced nitrification/denitrification facilities are required interim limits will expire 8 years after the Effective Date of TMDL; if advanced treatment is not required, interim limits will expire 5 years after the Effective Date of the TMDL.

10.7 Cost Analysis

Regional Board staff analyzed the costs of implementation of the TMDL. Analysis of TMDL costs is complicated because the Saugus and Valencia WRPs and the Fillmore and Santa Paula POTWs are currently undergoing plant expansions and upgrades. These upgrades will expand capacity and comply with the criteria specific Basin Plan objective for ammonia through implementation of nitrification/denitrification. The Fillmore plant is under plans to be phased-out and sewage is planned to be treated a new regional facility wastewater treatment facility in Santa Paula. The Saugus and Valencia WRPs will be modified to include nitrification and denitrification of effluent. The City of Fillmore provided cost information, but Regional Board staff could not identify costs for compliance with this TMDL in the data provided. CSDLAC provided a cost study that focused on determining the effects of different averaging periods for the nitrite + nitrate objective. The cost study, described below, contains an analysis of costs for additional nitrification/denitrification to comply with a 5 mg/L effluent limit on a daily, monthly, and annual average. Because the WLAs for this TMDL are 6.8 mg/L, Regional Board staff used the methodology described below to estimate the magnitude of costs for implementation of this TMDL.

The cost analysis considers both effluent treatment at the Saugus and Valencia WRPs and implementation of agricultural best management practices. The cost analysis for effluent treatment is based on the estimated costs for upgrading the N/DN facilities as reported by the CSDLAC in a report by Montgomery Watson Harza, "Nitrogen Removal Evaluation for the Saugus and Valencia Water Reclamation Plants," December 2002. The Montgomery Watson Harza cost estimate is based on achievement of 5 mg/L for nitrate+nitrite as a daily maximum, monthly average and annual average for both Valencia and Saugus WRPs. The CSDLAC cost estimate provides the basis for Regional Board staff conclusion that the costs for advanced N/DN will have a minor impact on current sewage rates in Santa Clarita.

The costs associated with this TMDL for effluent treatment include additional treatment for ammonia and oxidized nitrogen removal from WRP discharge. The costs are based on Alternative No. 2 of the MWH report: 28.1 MGD combined capacity at Saugus and Valencia

WRPs with denitrification Filters. Table 4-3 of the MWH study reports a present worth of Alternative 2 ranging from $24.1 million to $78.2 million. Based on the MWH study, the cost estimate for the present worth of implementing advanced N/DN treatment is $34.7 million.

It is noted that the MWH reports correlates the N/DN costs to the interpretation of the numeric limit for nitrate+nitrite: annual average, monthly average, and instantaneous maximum. However, the correlation is not applicable to this TMDL, which contains concentration-based because the correlation is based on an analysis of mass loads. Because the Saugus and Valencia WRPs are currently undergoing upgrades at the present time that will reportedly achieve nitrate+nitrite effluent concentrations of 10 mg/L, the most representative cost estimate should be based on facility upgrades that will further reduce nitrate+nitrite by approximately 4 mg/L. This cost estimate corresponding to this performance objective is interpolated between the value for "annual average," $24.1 million which is based on a 1.9 mg-N/L nitrate+nitrite reduction and the value for "monthly average," $46.3 million which is based on a is 6.3 mg-N/L nitrate+nitrite reduction.

The costs of applying the TMDL remedies in the upper Santa Clara River watershed are relatively minor. The estimated costs for evaluating affordability are based on the present worth cost estimate above normalized to the number of connections and compared to state-wide sewage rates. For 28.1 MGD, the estimated number of people served are based a nominal rate of 100 gallons per day per person. The number of households is estimated based on an average of 4.5 persons per household. Therefore, the estimated number of connections is approximately 62,500. Consequently, the annualized cost per household, based on amortizing the present worth for 20 years at 5% interest is approximately $3.71 per month, an increase of approximately 40% over the current sewer rates.

Table 29 indicates sewage rates for major cities in California and allows comparison of the costs of TMDL implementation to the current monthly household sewer rates. The estimated sewage rates that would result from most costly TMDL (advanced nitrification/denitrification) remedy are well below the average in California, which is $19.82 for 2001.

Potential cost savings to community residents, which could be acquired through the sale of treated water, funding programs to assist in the construction costs, and avoidance of additional treatment costs for other pollutants (i.e. future TMDL requirements) are not included.

Table 29. Ranking of Sewage Rates for Major Cities (State Water Resources Control Board Wastewater user Charge Survey Report May 2001)

Location	Rate per Month per Household	Notes
California Low	$4.25	
City of Santa Clarita	$10.96	Existing rate
Santa Clarita with Enhanced Nitrification/Denitrification	**$12.71**	
Los Angeles County Average	$15.01	
California Average	$19.82	
Ventura County Average	$23.15	
San Diego County Average	$26.24	
Average of all California County Highs	$39.86	
San Luis Obispo County High	$55	
Ventura County High	$73.75	
San Diego County High	$75	
California High/Los Angeles County High	$145.50	

10.7.1 Agricultural Best Management Practices

Costs to implement agricultural BMPs are dependent on the extent to which BMPs have already been implemented in the watershed. Because this information is not readily available, several assumptions were made to estimate agricultural BMP costs. First, it is assumed that there is minimal implementation of agricultural BMPs. Although it is known that some farms likely employ some of these measures already, there is no way to estimate the number that do at this time. Secondly, each BMP listed was assumed to have been implemented separately from the other BMPs. In reality, some BMPs may be implemented together and therefore reduce the costs. Finally, implementation of the BMPs was assumed to occur concurrently and consistently across all of the agricultural acreage in the watershed.

Table 30 summarizes the estimated unit costs for each BMP. Since the acreage to be applied is to be determined by the AOC, it is premature to determine the estimated watershed costs. Watershed costs for each BMP were determined based on the acreage in the watershed to which the BMP could be applied. Tillage, crop residue, and irrigation systems were assumed to be implemented on all the agricultural acreage in the watershed. Contour farming, contour orchards, and hillside benches were estimated for agricultural acreage in hilly areas. Filter strips were assumed to be installed along the main channel and tributaries in agricultural areas for a total of 157 miles in the watershed. For simplicity, grassed waterways were assumed to be applied to the same miles of the waterways as the filter strips. The number of sediment basins, infiltration trenches, and sediment traps depend greatly on the amount of space available to install these devices. This information was not readily available, so watershed costs were not estimated for these BMPs. Because the number of individual farms in the watershed was not known, it was not possible to estimate the watershed cost for tail water recovery systems.

Table 30. Estimated Agricultural BMP Costs

Best Management Practice	Cost per acre[1]
Conservation Tillage	
No Till	($2.90)
Mulch Till	$17.20
Contour Farming	$61.90
Contour Orchard and Other Fruit Area	$131.80
Crop Residue Use	
Chopping and Chopping Waste	$48.75
Mulching using min. Tillage	$20.10
Filter Strip	

Best Management Practice	Cost per acre[1]
Filter Strip	$7,377.75
Filter Strip	$7,377.75
Filter Strip	$7,377.75
Buffer Strip	$1,217.70
Landscaping	$2,263.45
Grassed Waterway	$7,377.75
Hillside Bench	$1,080.15
Irrigation System: Sprinkler	$830.90
Irrigation System: Trickle	
Microspray System	$2,320.80
Drip Irrigation	$3,123.00
Irrigation System	
Tail water Recovery	$16,904.40
Irrigation Water Management	$458.40
Runoff Management system	
Sediment Basin	$573,430.70
Infiltration Trench	$51.60
Sediment Trap, Box Inlet	$593.10

1. Based on average costs presented in "Calleguas Creek Watershed Erosion and Sediment Control Plan for Mugu Lagoon", National Resources Conservation Service, May 1995.

As shown in Table 30, the BMP costs for agricultural on a watershed basis range widely, depending on the BMP. However, most of these BMPs would provide treatment benefits for constituents other than just nitrogen compounds. The overall costs will depend on the BMPs selected as well as extent of BMP implementation.

10.8 Pollutant Trading

Water quality trading is a market-based approach to improve and preserve water quality. Trading can provide greater efficiency in achieving water quality goals in watersheds by allowing one source to meet its regulatory obligations by using pollutant reductions created by another source that has lower pollution control costs. This TMDL includes a study to evaluate the feasibility of trading nitrogen load allocations in the Santa Clara River. A pollutant trading program for nitrogen in the Santa Clara River would require approval by US EPA.

In order to meet the EPA Trading Policy requirements, the TMDL will include a Trading Committee with representative stakeholders and interested parties that will perform the following tasks for the purposes of generating recommendations and a plan:

- Identify how trading will occur, trade administration, and eligible participants in trading;
- determine requirements to attain all necessary permits before entering a trade, including permit language that identifies the trade, provides notice to the public, and indicates any modified permit limits;
- ensure accountability;
- develop methods and procedures to determine compliance, such as the use of a baseline condition and how credits are generated beyond the baseline, and pollution reduction performance;
- identify when backsliding or anti-degradation is triggered in the context of a trade;
- determine appropriate trade ratios in light of the uncertainty of pollutant reduction performance; and
- establish a method for technical assistance for non-point best management practices.

The Committee will also follow the guidance for stakeholder-led studies described in the 2002 TMDL Strategy documents.

The Trading Committee will develop recommendations for a program to be implemented watershed wide. These recommendations and plan, upon approval of the Regional Board, will be initiated as an alternative compliance measure for the TMDL.

Upon approval and implementation of the trading program and within the first 2 years of the implementation plan, the Trading Committee, will evaluate the environmental effectiveness of the program so that adjustments can be made if necessary. The evaluations will include the following information:

- Ambient monitoring to ensure that impairments of designated uses (including existing uses) do not occur and to document water quality conditions;
- quantify nonpoint source pollutant removal efficiencies such as agricultural BMP studies; and
- determine whether the water quality objectives have been achieved.

11 REFERENCES

Borgmann, Uwe, 1994. Chronic Toxicity of Ammonia to the Amphipod Hyalella azteca; Importance of Ammonium Ion and Water Hardness. Environmental Pollution 86, 329-335. 1994.

Borgmann, Uwe and Borgmann, A.I., 1997. Control of Ammonia Toxicity to Hyalella Azteca by Sodium, Potassium and pH. Environmental Pollution vol. 95, No. 3 pp 325-331. 1997.

California Resources Agency. "CWIS 'Mugu Lagoon.'" December 1997. California Environmental Resources Evaluation System (CERES), January 8, 2001. <http://ceres.ca.gov/wetlands/geo_info/so_cal/mugu_lagoon.html>

Montgomery Watson Americas, Inc., 1995. Simi Valley County Sanitation District Report on Arroyo Simi Characterization. September 1995.

National Research Council. 1993. Managing Wastewater in Coastal Urban Areas. National Academy Press, Washington, D.C. 1993.

Regional Water Quality Control Board Los Angeles Region. 1994. Water Quality Control Plan: Los Angeles Region Basin Plan for the Coastal Watersheds of Los Angeles and Ventura Counties. June 1994.

Regional Water Quality Control Board- Los Angeles Region, 1996a. 1996 Water Quality Assessment Data Summaries.

Regional Water Quality Control Board- Los Angeles Region, 1996b. Aesthetic Stressor Worksheet and Surface Water Quality Field Notes 1991-1996.

Schiff Kenneth and Kamer Krista, for Southern California Coastal Water Research Project. 2000. Comparison of Nutrient Inputs, Water Column Concentrations, and Macroalgal Biomass in Upper Newport Bay, California. December 21, 2000.

State Water Resources Control Board. 1988. Adoption of Policy Entitled "Sources of Drinking Water." May 1998.

State Water Resources Control Board, 1999. 1998 California 303(d) List and TMDL Priority Schedule. Approved by the USEPA in May, 1999.

Thomas, Mary Ann. 2000. The Effect of Residential Development on Ground-Water Quality Near Detroit, Michigan. Journal of the American Water Resources Association. Vol. 36, no. 5. October 2000.

United States Environmental Protection Agency. 2000a. 40 Code of Federal regulations Part 130 (TMDL Rule). 2000.

United States Environmental Protection Agency Office of Air Quality. 1997. Deposition of Air Pollutants to the Great Waters, Second Report to Congress. June 1997.

United States Environmental Protection Agency Office of Water. 1985. Ambient Water Quality Criteria for Ammonia-1984. January 1985.

United States Environmental Protection Agency Office of Water. 1990. The Drinking Water Criteria Document on Nitrate/Nitrite. December 1990.

United States Environmental Protection Agency Office of Water. 1998. National Strategy for the Development of Regional Nutrient Criteria. June 1998.

United States Environmental Protection Agency. Office of Water. 1999a. Protocol for Developing Sediment TMDLs. EPA 841-B-99-004. (4503F), United States Environmental Protection Agency, Washington D.C. 132 pp.

United States Environmental Protection Agency Office of Water. 1999b. Protocol for Developing Nutrient TMDLs First Edition. November 1999.

United States Environmental Protection Agency Office of Water. 1999c. 1999 Update of Ambient Water Quality Criteria for Ammonia. December 1999.

United States Environmental Protection Agency Office of Water. 2000b. Nutrient Criteria Technical Guidance Manual: Rivers and Streams. July 2000.

United States Environmental Protection Agency Office of Water. 2000c. National Management Measures to Control Nonpoint Source Pollution from Agriculture. August 2000.

United States Environmental Protection Agency Office of Water. 2000d. Ecoregional Nutrient Criteria Fact Sheet. December 2000.

United States Environmental Protection Agency Office of Water. 2000e. Ambient Water Quality Criteria Recommendations- Rivers and Streams in Ecoregion III. December 2000.

United States Department of Agriculture, Natural Resources Conservation Service and Forest Service, 1995. 'Calleguas Creek Watershed Erosion and Sediment Control Plan for Mugu Lagoon. Davis, CA. May 1995.

United Water Conservation District, 2000, Surface and Groundwater Conditions Report, Water Year 1999 Supplement.

TECHNICAL APPENDICES

Santa Rosa Animal Waste Control Demonstration Project Annual Report at Region 1

Wetlands at your service: Reducing Impacts of Agriculture at the Watershed Scale
By Joy B. Zedler

Ammonia Numeric Targets for Santa Clara River

Figure 84-Annual Average Discharge-Frequency Weighted Chloride Concentrations, Santa Clara River, Los Angeles-Ventura County Line

Figure 85- Annual Average Discharge-Frequency Weighted Nitrogen Concentrations, Santa Clara River, Los Angeles-Ventura County Line

Public Data Set, 303(d) assessment 2002, Santa Clara River Reach 5 (EPA Reach 7)

Expected Performance of Upgraded WWTP's

Stream Health Studies

Stickleback Health

Simulation of Ground-Water/Surface-Water Flow in the Santa Clara-Calleguas Basin, Ventura County, California

TECHNICAL SUPPORT DOCUMENTS

Analysis of pH variation in the impaired reaches of the Santa Clara River, Arturo A. Keller and Yi Zheng, Bren School of Environmental Science & Management, UCSB

WARMF model Calibration refinement for Nitrogen Compounds, Arturo A. Keller and Yi Zheng, Bren School of Environmental Science & Management, UCSB

Determination of the Critical Water Quality Conditions for the Impaired Reaches of the Santa Clara River Watershed, Arturo A. Keller and Yi Zheng, Bren School of Environmental Science & Management, UCSB

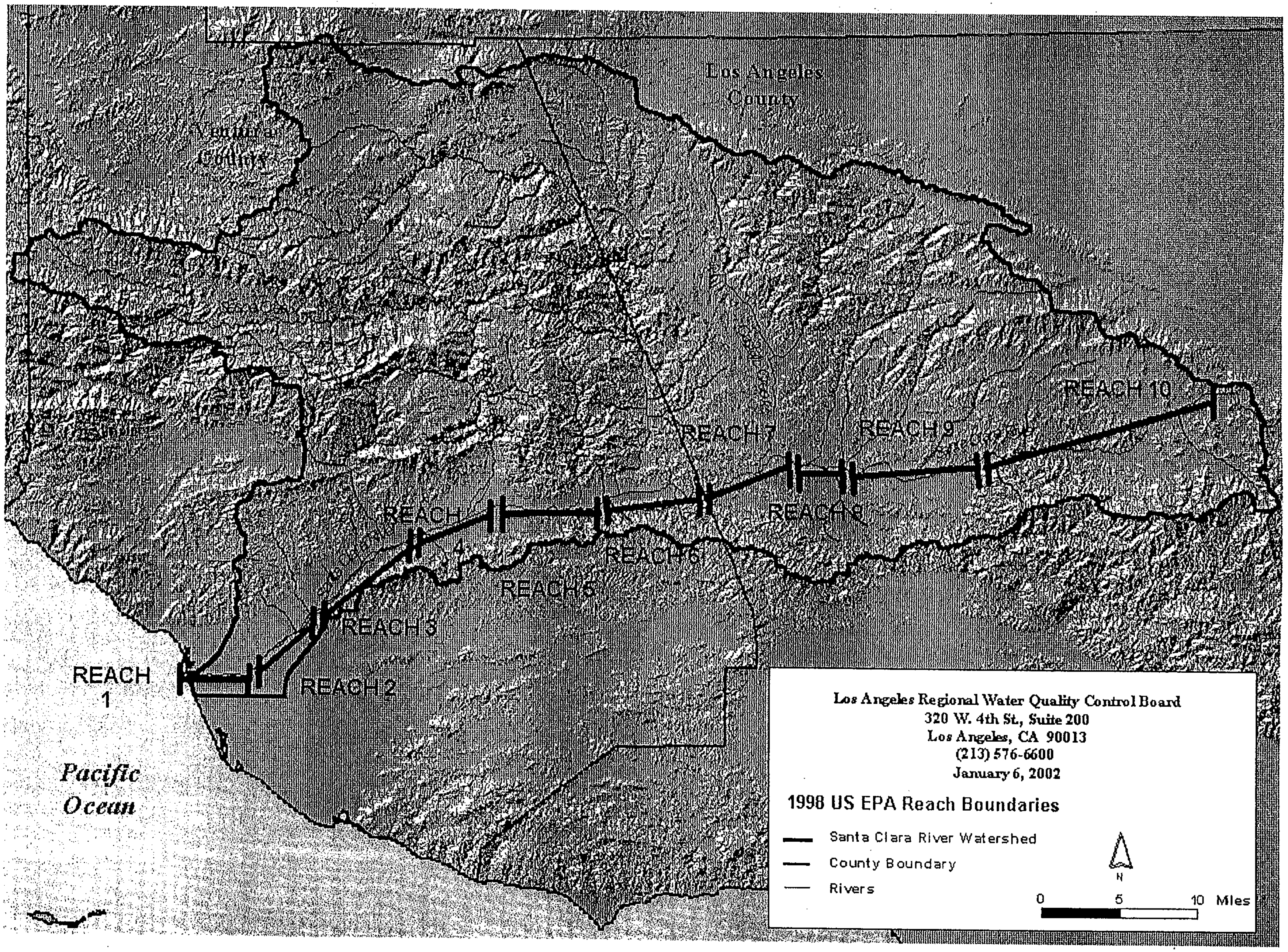
Report on Point and Non-Point Source Analysis for Segment 56 in Reach 7, below Valencia WRP, Arturo A. Keller and Yi Zheng, Bren School of Environmental Science & Management, UCSB

Analysis of Potential Nutrient Load allocation for the reaches of the Santa Clara River Considered in the 1998 303(d) list, Arturo A. Keller and Yi Zheng, Bren School of Environmental Science & Management, UCSB

Final Linkage Analysis-Santa Clara River Nutrient TMDL Analysis Parts I and II: Hydrology and Water Quality, Systech Engineering, Inc. for the SCR N TMDL Steering Committee.

Final Task I Report for Santa Clara River Nutrient TMDL Analysis: Source Identification and Characterization, Systech Engineering, Inc. for the SCR N TMDL Steering Committee.

Figure 1
Santa Clara River Watershed
Topography



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WARMF model Calibration refinement for Nitrogen Compounds

By Arturo A. Keller and Yi Zheng
Bren School of Environmental Science & Management
University of California, Santa Barbara

The original calibration of the WARMF model application for the Santa Clara River was presented in the Task 2 report prepared by Systech Engineering, Inc. The original calibration was generally based on standard rates of nitrification and denitrification in the various segments of the river. However, in some regions the apparent rate of disappearance of ammonia, nitrite and/or nitrate is faster or slower, based on an evaluation of the observed data. This could be due to additional assimilation of these nitrogen compounds by in-stream and riparian vegetation, increased volatilization of ammonia due to the relatively high surface area and mixing energy of the rocky river bottom, or slightly anoxic conditions which would reduce the rate of nitrification and increase denitrification in some regions. Given the length of the river segments, from a few hundred meters to several kilometers, it is not inconceivable that all of these processes can be taken place within a river segment. Thus, it seems appropriate to adjust the first-order rate constants for the rate of ammonia, nitrite and nitrate disappearance. After several iterations to minimize relative and absolute errors, a set of best fit rate constants were developed (Table 1).

Some of the guiding concepts in the calibration refinement were:

- Slightly overpredict concentrations relative to observed data, to provide a small additional margin of safety;
- Calibrate nitrate and nitrite together, given that any nitrite is likely to rapidly convert to nitrate, and that adjustment of nitrite concentrations alone is difficult given the dependence on both the rate of nitrification and denitrification;
- Consistently adjust rate constants throughout a region;
- For those segments where no observed data is available, adjust the rate constants by interpolating the values from segments where data is available.

The results of the calibration refinement are presented in the following figures for those river segments where there is adequate observed data. Tables 2 to 4 present the statistics of the calibration, in terms of concentrations at 50, 90, 95, 99 and 99.9 percentiles, as well as relative error (RE), absolute error (AE) and root mean square error (RMSE), as defined here:

$$RE = \frac{1}{n}\sum_{i=1}^{n}(x_i - c_i)$$

$$AE = \frac{1}{n}\sum_{i=1}^{n}\left|(x_i - c_i)\right|$$

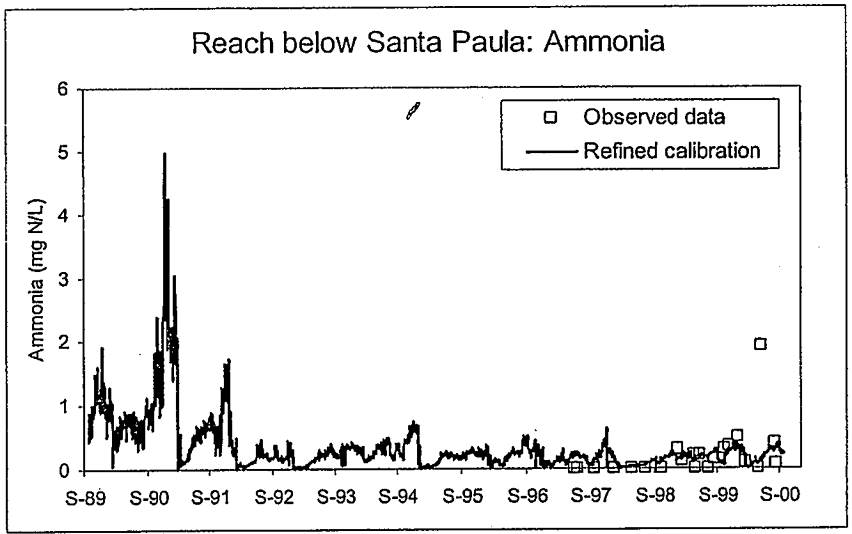
$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_i - c_i)^2}$$

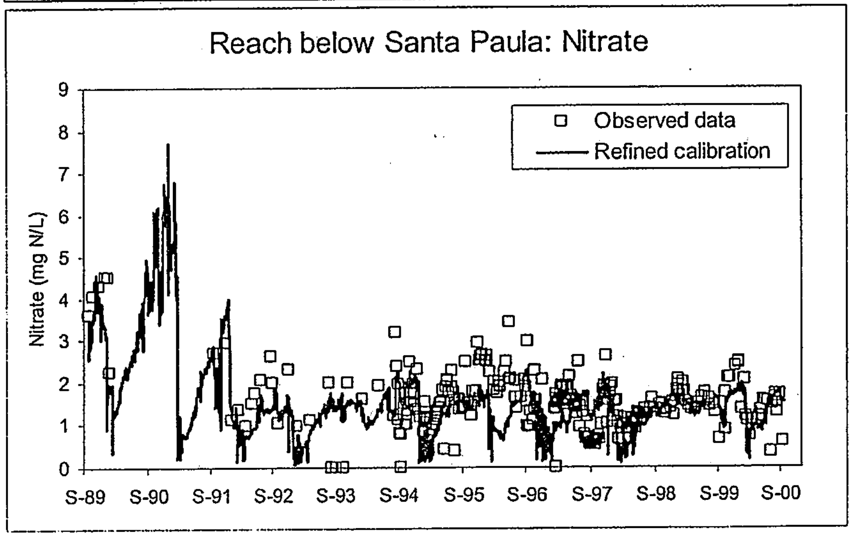
where x_i is the simulated value, c_i is the observed value and n is the number of observations. RE is the average of all errors over all time steps (11-year at a daily time step or 4018 time steps). It is a measure of model accuracy and any consistent bias. However, over-predictions can cancel out under-predictions. AE is the absolute value of the average of all errors over all time steps, and provides another measure of model accuracy, indicating whether the simulated values are generally close to the observed values. RMSE is a measure of model precision, and magnifies the effect of larger than average errors.

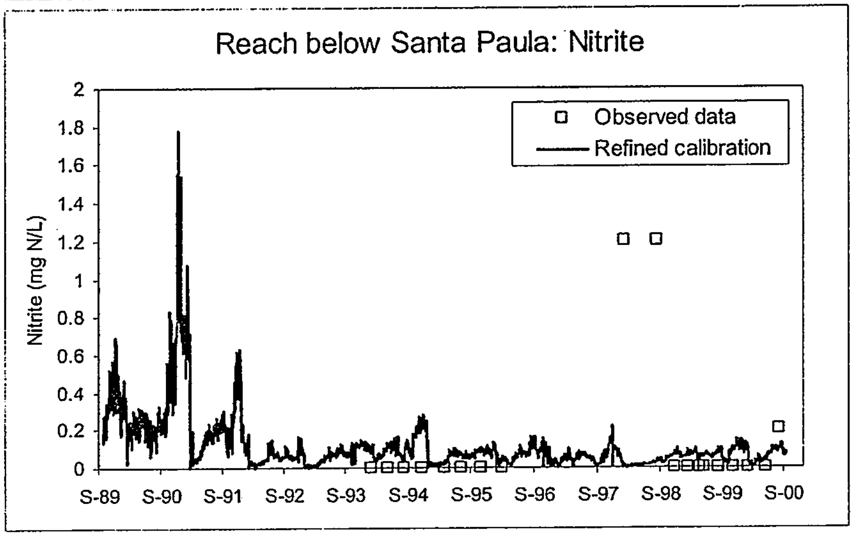
Table 1 Nitrification and denitrification rates (in day^{-1}) for the refined calibration. Segment Ids are presented from lower to upper watershed.

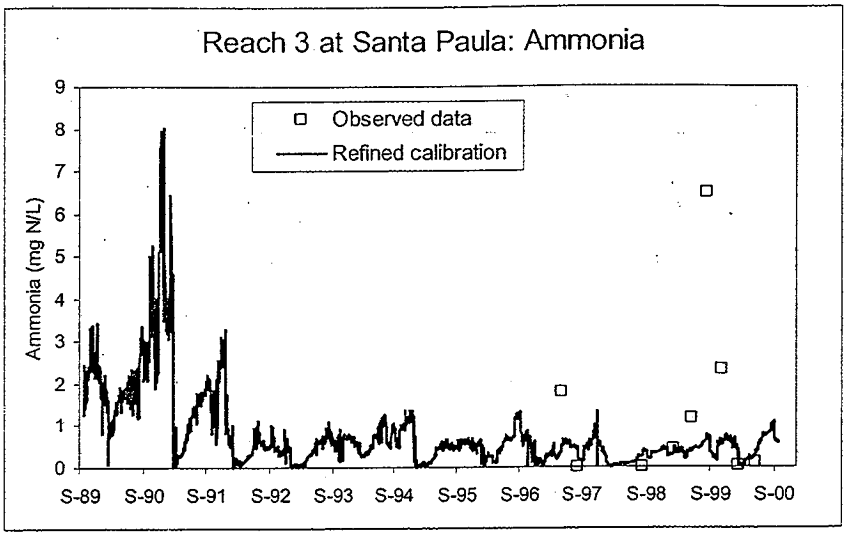
Reach	3	3	3	7	7	7	7	7	7	8	8	8	9
Segment ID	7	9	69	111	113	115	56	137	129	47	149	159	167
Nitrification rate	1.0	0.8	0.7	0.8	0.6	0.4	0.35	0.035	1.0	0.65	0.35	0.0	0.2
Denitrification rate	0.4	0.4	0.3	0.05	0.1	0.2	0.3	0.0	0.3	0.3	0.3	0.15	0.0

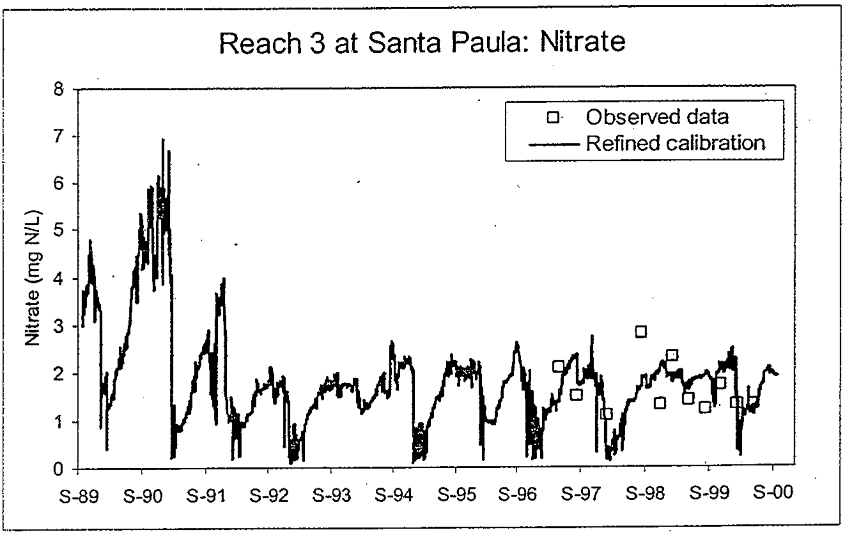
Note that common values for nitrification rates range from 0 to 1.0 day^{-1} and for denitrification from 0 to 0.5 day^{-1}, depending on redox conditions (aerobic or anaerobic).

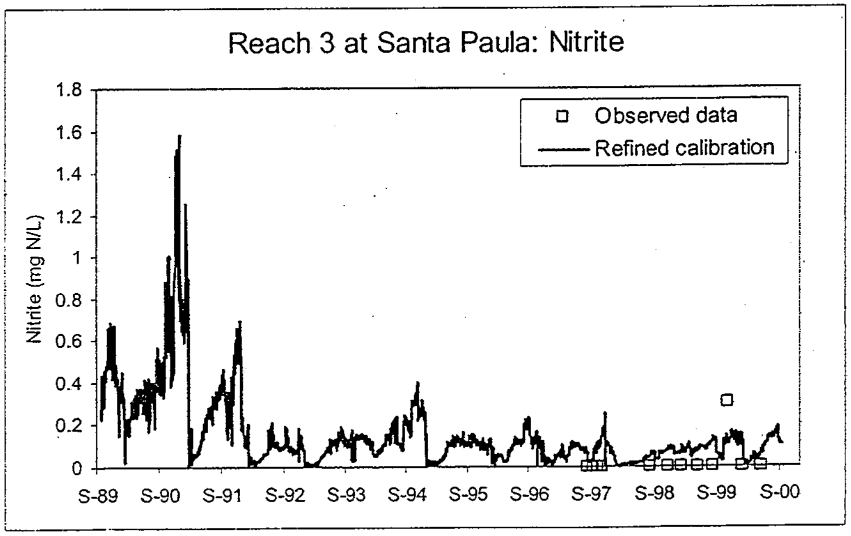

Reach below Santa Paula: Ammonia

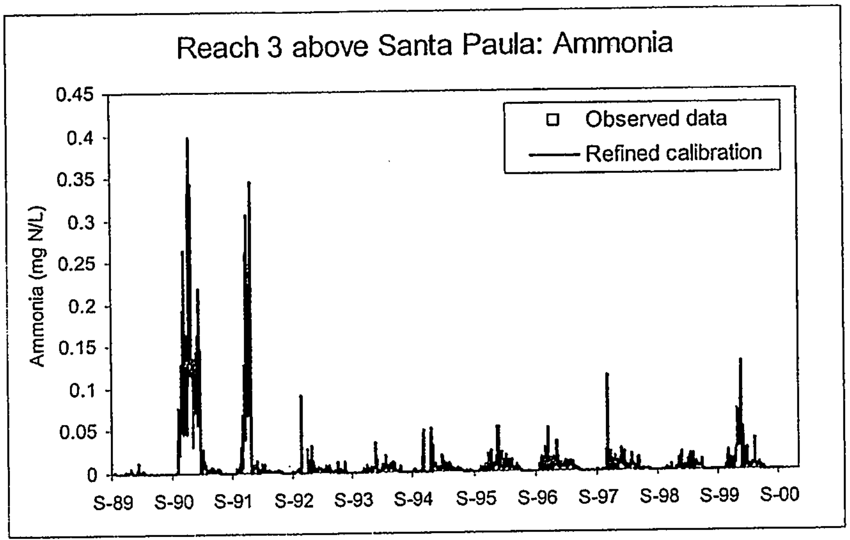

Reach below Santa Paula: Nitrate

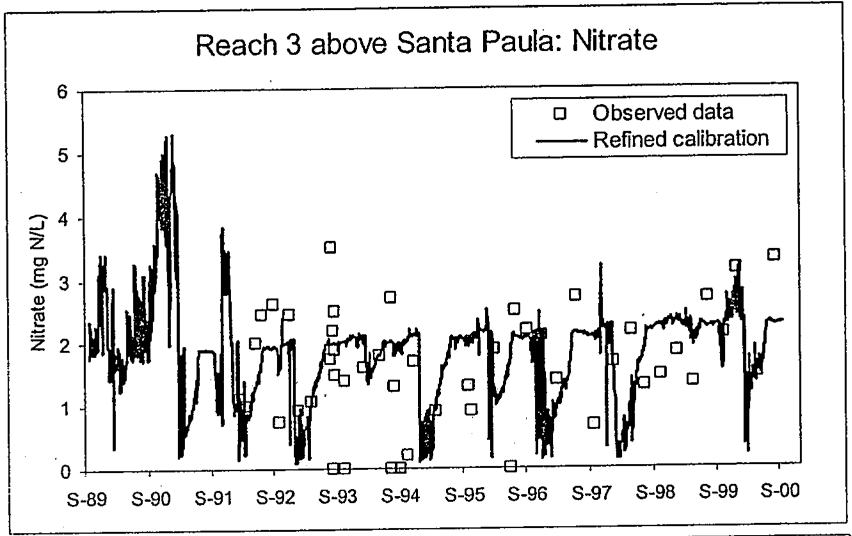

Reach below Santa Paula: Nitrite

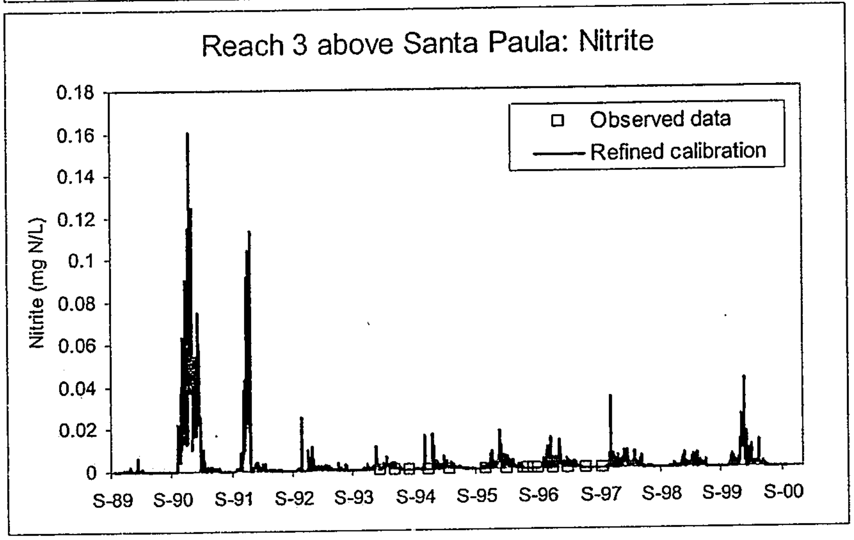

Reach 3 at Santa Paula: Ammonia
Ammonia (mg N/L)
0
1
2
3
4
5
6
7
8
9
Observed data
Refined calibration
S-89
S-90
S-91
S-92
S-93
S-94
S-95
S-96
S-97
S-98
S-99
S-00

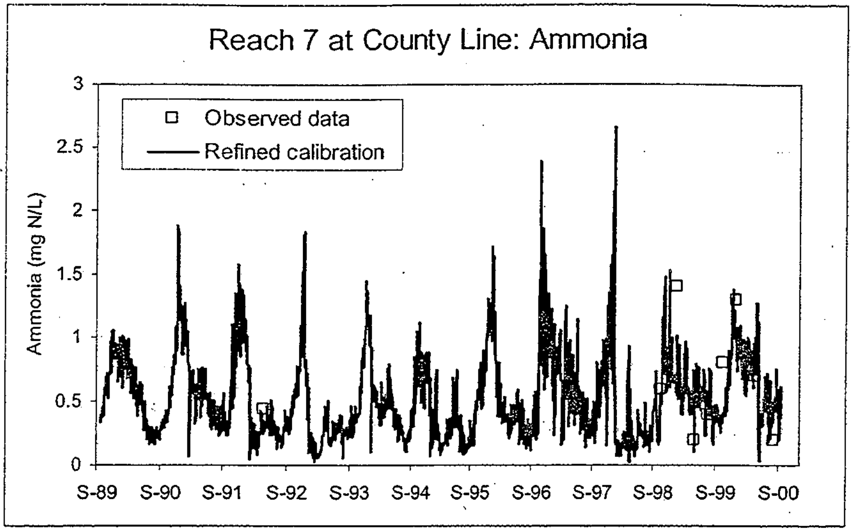

Reach 3 at Santa Paula: Nitrate
Nitrate (mg N/L)
0
1
2
3
4
5
6
7
8
Observed data
Refined calibration
S-89
S-90
S-91
S-92
S-93
S-94
S-95
S-96
S-97
S-98
S-99
S-00

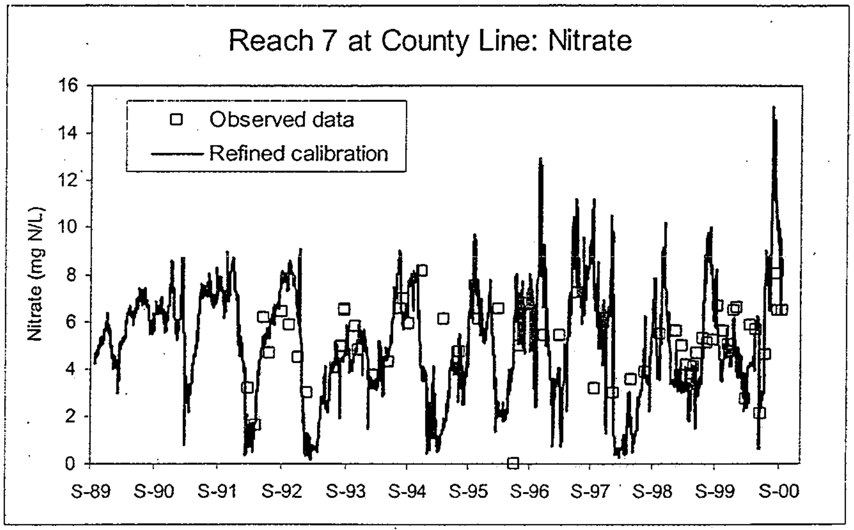

Reach 3 at Santa Paula: Nitrite
Nitrite (mg N/L)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
Observed data
Refined calibration
S-89
S-90
S-91
S-92
S-93
S-94
S-95
S-96
S-97
S-98
S-99
S-00

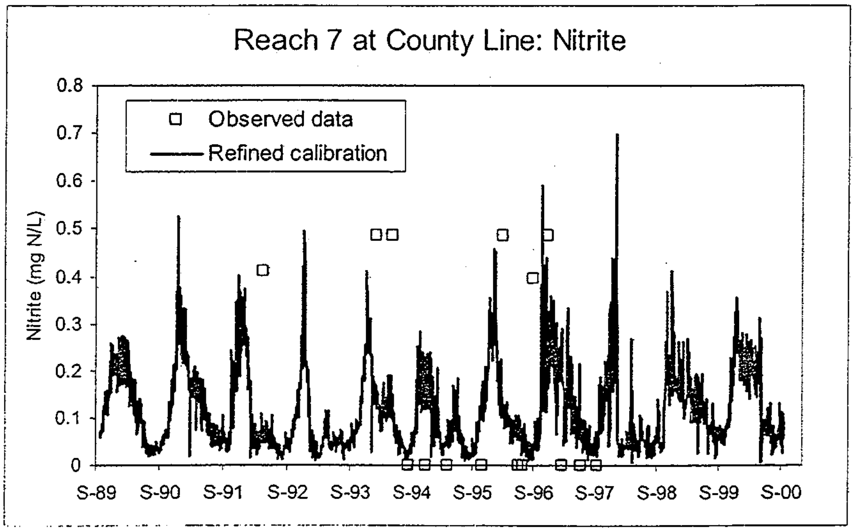

Reach 3 above Santa Paula: Ammonia

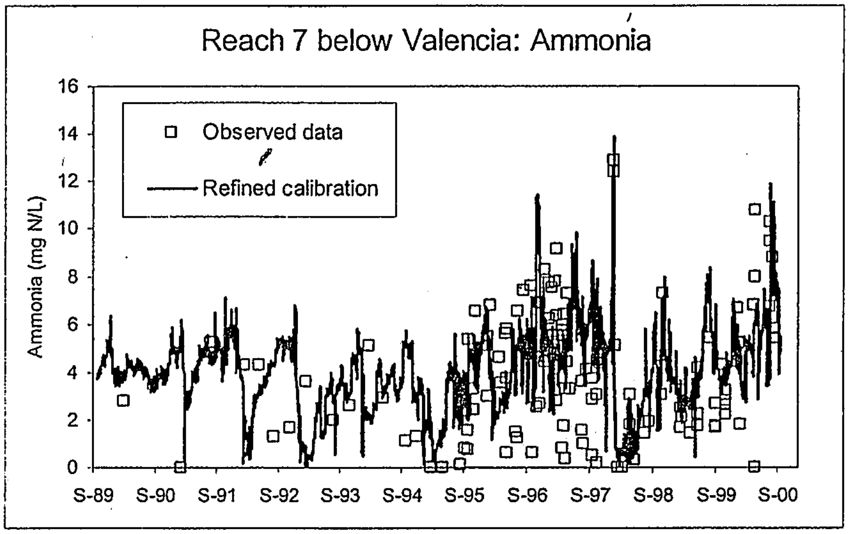

Reach 3 above Santa Paula: Nitrate

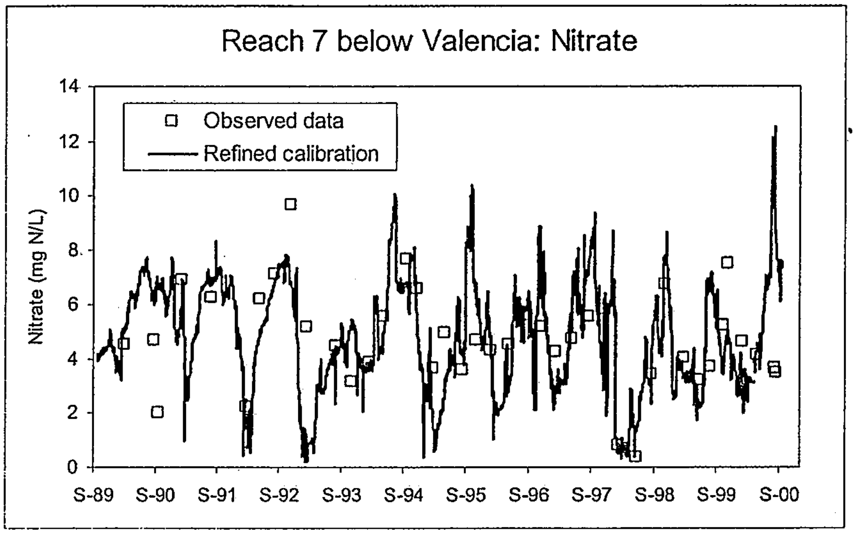

Reach 3 above Santa Paula: Nitrite

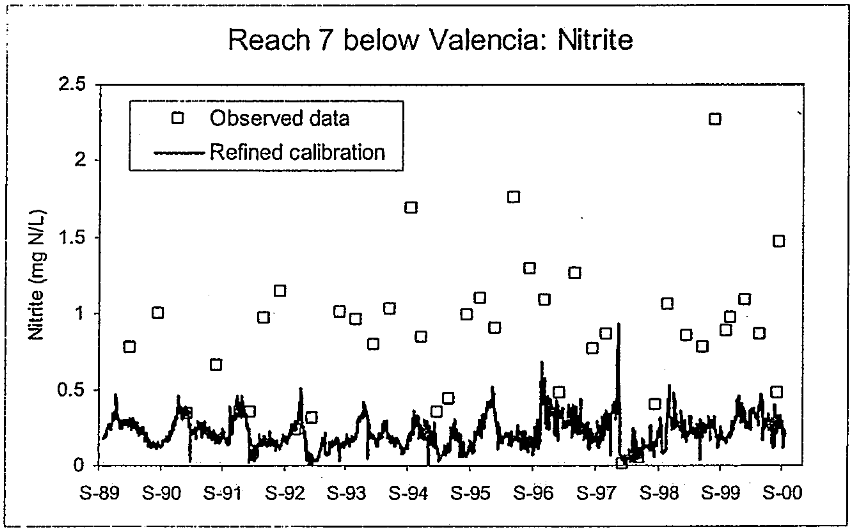

Reach 7 at County Line: Ammonia

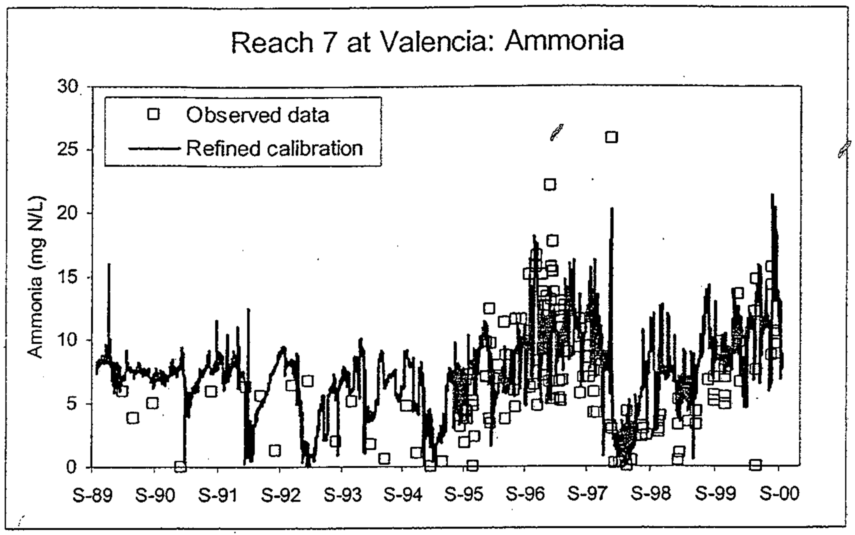

Reach 7 at County Line: Nitrate

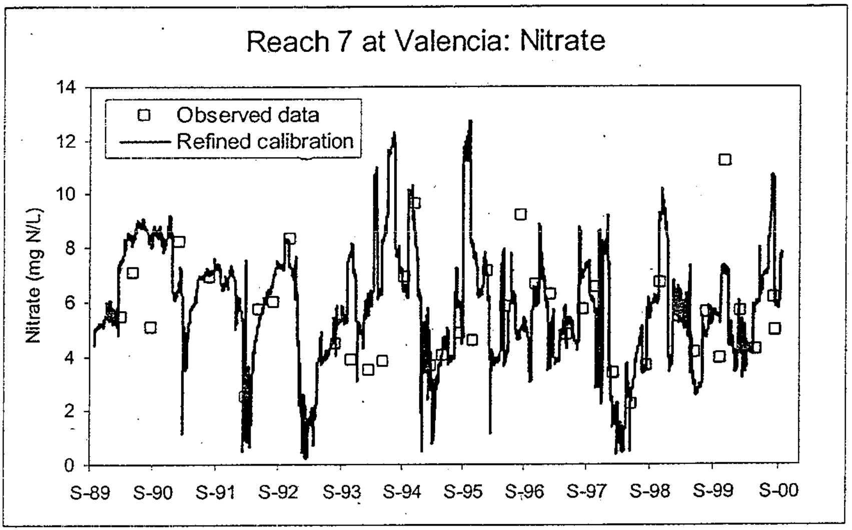

Reach 7 at County Line: Nitrite

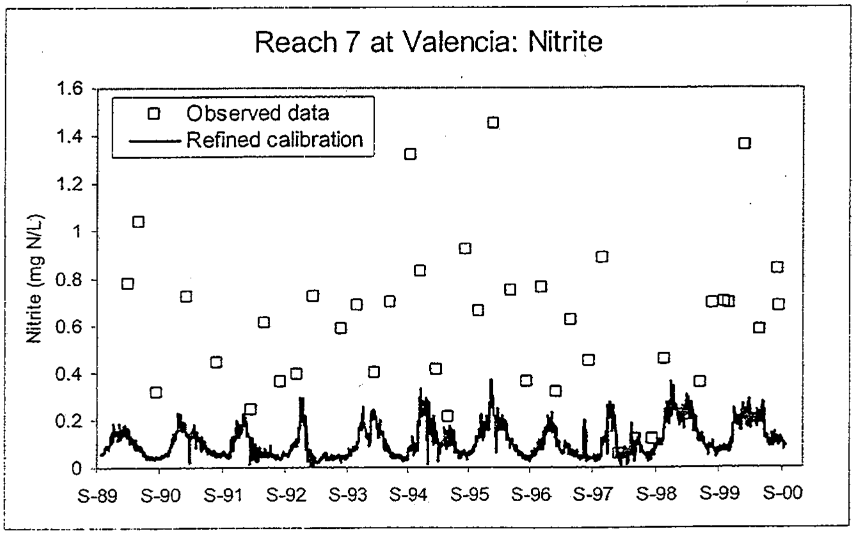

Reach 7 below Valencia: Ammonia

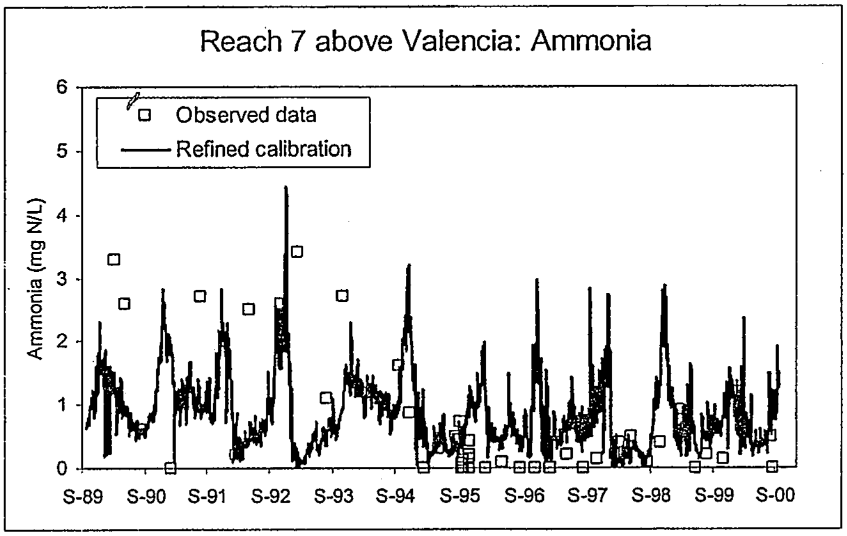

Reach 7 below Valencia: Nitrate

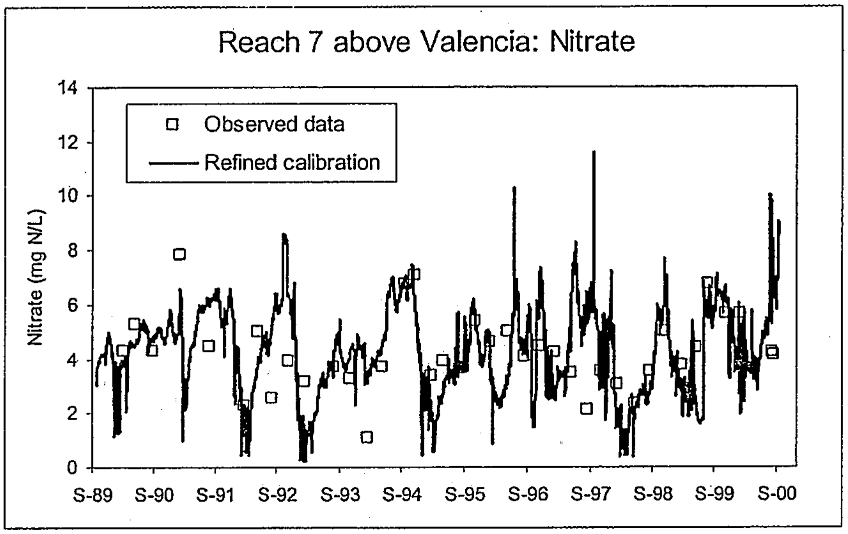

Reach 7 below Valencia: Nitrite

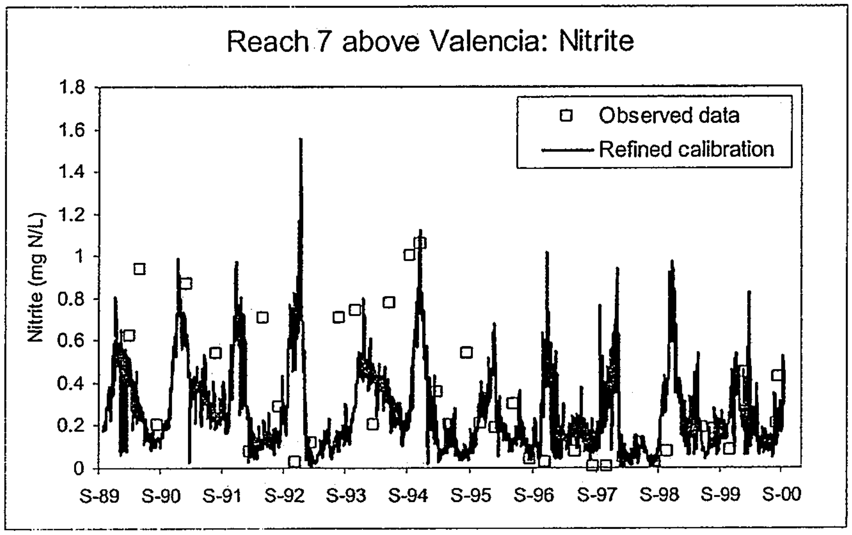

Reach 7 at Valencia: Ammonia

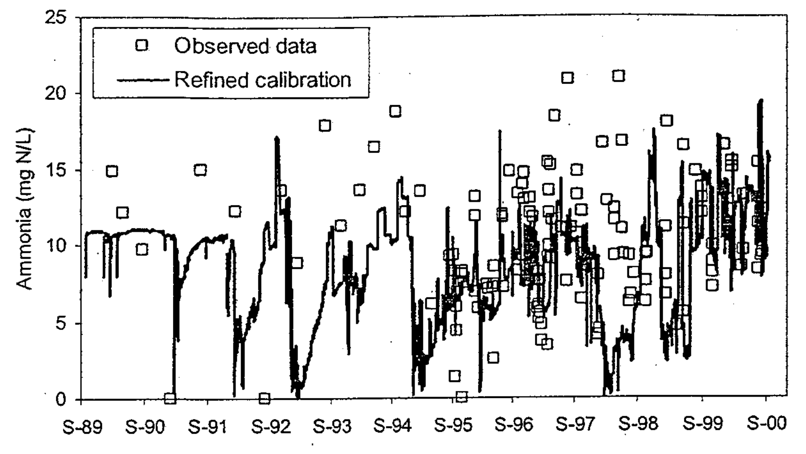

Reach 7 at Valencia: Nitrate


Reach 7 at Valencia: Nitrite

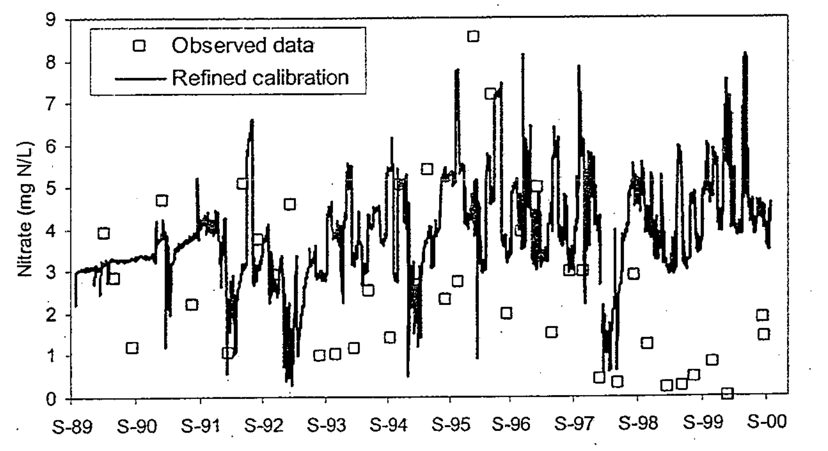

Reach 7 above Valencia: Ammonia
Observed data
Refined calibration
Ammonia (mg N/L)
0
1
2
3
4
5
6
S-89
S-90
S-91
S-92
S-93
S-94
S-95
S-96
S-97
S-98
S-99
S-00


Reach 7 above Valencia: Nitrate
Observed data
Refined calibration
Nitrate (mg N/L)
0
2
4
6
8
10
12
14
S-89
S-90
S-91
S-92
S-93
S-94
S-95
S-96
S-97
S-98
S-99
S-00

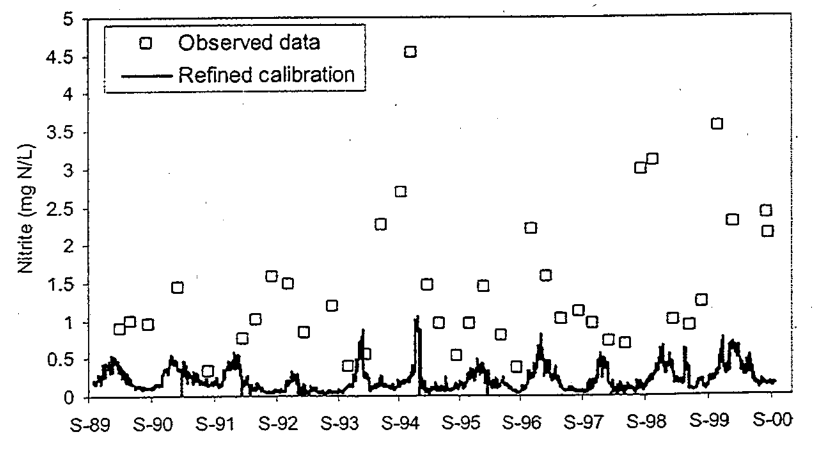

Reach 7 above Valencia: Nitrite
Observed data
Refined calibration
Nitrite (mg N/L)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
S-89
S-90
S-91
S-92
S-93
S-94
S-95
S-96
S-97
S-98
S-99
S-00



Reach 8 at Saugus: Ammonia



Reach 8 at Saugus: Nitrate



Reach 8 at Saugus: Nitrite

Table 2 Statistics of Ammonia calibration refinement

Reach ID	7	9	69	111	56	137	129	159
Number of Observations	22	9	0	10	136	138	50	138
Observed 50 percentile	0.08	0.43	N.D.	0.65	3.62	6.39	0.35	9.52
Observed 90 percentile	0.39	3.14	N.D.	1.31	7.46	13.56	2.70	15.40
Observed 95 percentile	0.50	4.81	N.D.	1.36	8.43	15.36	3.36	16.76
Observed 99 percentile	1.61	6.15	N.D.	1.39	11.84	20.44	10.05	20.86
Observed 99.9 percentile	1.88	6.46	N.D.	1.40	12.83	25.29	11.62	22.45
Simulated 50 percentile	0.22	0.52	0.00	0.46	4.00	7.42	0.75	9.56
Simulated 90 percentile	0.76	1.85	0.01	0.96	5.88	11.17	1.68	12.72
Simulated 95 percentile	1.11	2.67	0.04	1.14	6.75	12.36	2.04	14.13
Simulated 99 percentile	2.31	5.05	0.17	1.48	9.27	16.23	2.69	16.98
Simulated 99.9 percentile	4.39	7.44	0.36	2.08	12.59	18.93	4.12	19.22
Relative error	-0.020	-0.968	N.D.	-0.034	0.677	2.011	-0.338	-1.972
Absolute error	0.214	1.158	N.D.	0.281	1.938	3.367	1.071	3.618
Root mean square	0.404	2.068	N.D.	0.326	2.486	4.192	2.172	5.022

N.D. = No data

Table 3 Statistics of Nitrate calibration refinement

Reach ID	7	9	69	111	56	137	129	159
Number of Observations	276	11	48	58	41	41	39	38
Observed 50 percentile	1.51	1.40	1.73	5.26	4.61	5.59	4.15	2.32
Observed 90 percentile	2.39	2.30	2.70	6.67	6.90	8.33	5.90	5.05
Observed 95 percentile	2.64	2.55	3.07	7.25	7.54	9.62	6.78	5.58
Observed 99 percentile	4.13	2.75	3.41	8.06	8.88	11.38	7.56	8.02
Observed 99.9 percentile	4.52	2.80	3.49	8.12	9.62	11.49	7.82	8.48
Simulated 50 percentile	1.45	1.75	1.99	5.10	4.73	5.88	4.37	3.73
Simulated 90 percentile	2.71	2.85	2.36	7.98	7.25	8.53	6.33	5.38
Simulated 95 percentile	3.89	4.15	3.06	8.77	7.82	9.09	6.74	5.83
Simulated 99 percentile	5.74	5.54	4.60	11.24	9.77	11.79	8.55	7.63
Simulated 99.9 percentile	6.73	6.17	5.21	12.98	10.93	12.50	9.93	8.03
Relative error	-0.189	-0.025	0.104	0.29	0.128	0.0247	0.0393	1.331
Absolute error	0.491	0.488	0.566	1.65	1.503	1.722	1.262	2.105
Root mean square	0.621	0.589	0.728	2.162	1.987	2.429	1.509	2.543

Table 4 Statistics of Nitrite calibration refinement

Reach ID	7	9	69	111	56	137	129	159
Number Observations	19	12	14	16	40	41	39	38
Observed 50 percentile	0.00	0.00	0.00	0.00	0.88	0.62	0.21	1.02
Observed 90 percentile	0.40	0.00	0.00	0.49	1.31	0.92	0.80	2.74
Observed 95 percentile	1.20	0.14	0.00	0.49	1.69	1.32	0.95	3.14
Observed 99 percentile	1.20	0.27	0.00	0.49	2.07	1.41	1.04	4.16
Observed 99.9 percentile	1.20	0.30	0.00	0.49	2.25	1.45	1.06	4.50
Simulated 50 percentile	0.07	0.10	0.00	0.09	0.21	0.09	0.21	0.16
Simulated 90 percentile	0.25	0.35	0.00	0.24	0.35	0.21	0.56	0.43
Simulated 95 percentile	0.38	0.50	0.01	0.29	0.39	0.24	0.67	0.51
Simulated 99 percentile	0.81	0.97	0.06	0.39	0.48	0.29	0.91	0.72
Simulated 99.9 percentile	1.55	1.46	0.14	0.53	0.80	0.34	1.44	0.99
Relative error	-0.063	0.0624	0.0007	-0.069	-0.649	-0.497	-0.1	-1.251
Absolute error	0.195	0.0932	0.0007	0.183	0.655	0.497	0.228	1.27
Root mean square	0.393	0.105	0.0011	0.226	0.786	0.583	0.3	1.55

Determination of the Critical Water Quality Conditions for the Impaired Reaches of the Santa Clara River Watershed

By Arturo A. Keller and Yi Zheng

Bren School of Environmental Science & Management
University of California, Santa Barbara

1. Introduction

In this study, we evaluated the conditions that lead to high concentrations of inorganic nitrogen species (i.e. ammonia, nitrite and nitrate) in the impaired reaches and tributaries of the Santa Clara River watershed. The analysis was divided into three sections: (1) an analysis of the low flow conditions and the correlation between low flow and high concentrations of these nitrogen species; (2) an evaluation of the timing of point and non-point source discharges of these nitrogen species to the river and tributaries, to determine the possibility of high concentration peaks during the initial storm events (first flush effect); and (3) conditions where rising groundwater might be a significant contribution to total loading.

2. Low-flow analysis

The analysis focused on three reaches and a number of tributaries of the Santa Clara River where the Regional Water Quality Control Board (RWQCB) has determined that the water quality objectives have been exceeded, resulting in potential impairment of the designated beneficial uses. The low flow conditions were characterized using three different criteria:

1Q10: the lowest one-day flow with a recurrence of 10 years;

7Q10: the lowest seven-day flow with a recurrence of 10 years;

30Q3: the lowest thirty-day flow with a recurrence of 3 years.

Although the most common criterion for low flow conditions is the 7Q10, given the climatic conditions of the SCR watershed, typical of Coastal Mediterranean regions with a long dry summer and fall, followed by short intense rainfall events in the winter and early spring, we considered the 30Q3 as an additional criterion, since many of the tributaries do not have any flow for a considerable part of the year. For this study, the eleven-year period between Water Year (WY) 1989 and WY 2000 was considered, given the availability of data. Daily flow data was available at a number of gauging stations in the SCR reaches. However, there was little or no flow data for a number of the tributaries. Thus, simulation results from the WARMF model were used to estimate the daily flows for these tributaries, as well as for those time periods where the flow gauges were not operational in the SCR reaches.

The results of the low flow analysis are presented in Table 1. The 1-day, 7-day and 30-day low flows for each segment are presented in the Appendix, as well as the corresponding 1-day, 7-day and 30-day average concentrations of ammonia, nitrite and nitrate as simulated by the WARMF model. The details of the calibration of the WARMF model have been presented in the Task 2 Linkage Analysis report and the Task 3 TMDL Analysis report. As expected, most of the watershed has no flow conditions at some point of the 11-year period, and only the main segments of the SCR have some flow under the 7Q10 criterion. Even the 30-day flows in the tributaries are very low or zero.

Table 1. Low flow conditions in the SCR watershed (m3/s)

River segments	1Q10	7Q10	30Q3
SCR reach 3 (downstream)	0.16	0.17	0.7978
SCR reach 3 (upstream)	0.16	0.17	0.7976
SCR reach 7 (downstream)	0	0.02	0.5009
SCR reach 7 (mid-stream)	0	0.05	0.642
SCR reach 7 (upstream)	0	0.39	0.4724
SCR reach 8	0	0.0002	0.1447
Mint Canyon	0	0	0
Wheeler Canyon	0	0	0.0008
Todd Barranca	0	0	0.0026
Brown Barranca/Long Canyon	0	0	0

Typically, low flow conditions such as 7Q10 flows have been used in steady state models to simulate water quality under such conditions. Given that the WARMF model performs a dynamic calculation at a daily time step with variable inputs, it is not as critical to choose a particular low-flow criterion. However, we decided to evaluate the observed and simulated water quality during these periods, when there is less water to dilute any nutrient load.

Figure 1 presents a graphical representation of the correlation of simulated water quality (ammonia, nitrite and nitrate concentrations on the left column, both the original values and the natural logarithm of the concentrations) vs. simulated flow and the natural logarithm of flow (on the top row), for Reach 3 of the SCR. There is a tendency to have high nitrogen concentrations during low flow conditions. The corresponding statistical analysis, presented in Table 2, corroborates the visual interpretation.

The results presented in Table 2 indicate that the strongest correlation is between ln(flow) and ln(concentration), suggesting a power law relationship:

$$\ln(\text{flow}) = a \ln[\text{concentration}] + b \qquad (1)$$

or

$$\text{Flow} = a\,[\text{Concentration}]^{b} \qquad (2)$$

Figure 1. Correlation Analysis between Simulated Flow and Concentration for Reach 3

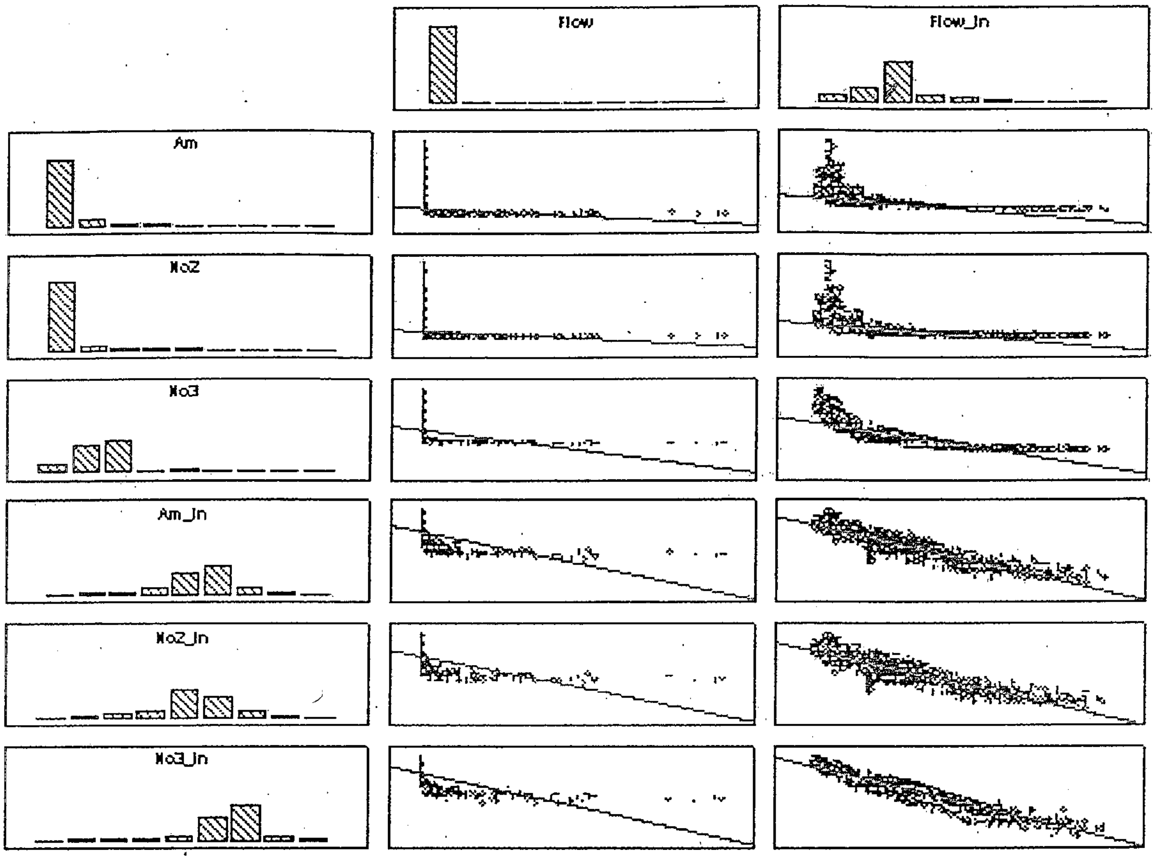


Table 2. Correlation between simulated nitrogen concentration and flow for Reach 3

	$[NH_3]$	$[NO_2]$	$[NO_3]$	$\ln[NH_3]$	$\ln[NO_2]$	$\ln[NO_3]$
Flow	-0.11	-0.11	-0.24	-0.40	-0.38	-0.49
ln(flow)	-0.54	-0.51	-0.75	-0.87	-0.83	-0.92

The corresponding coefficients (a and b) are presented in Table 3. The strongest correlation is for nitrate, followed by ammonia and nitrite. All three concentrations in general decrease with flow, indicating that the highest concentrations are typically found at the low flow conditions.

Table 3. Power law coefficients for Reach 3 of the SCR

	NH_3	NO_2	NO_3
a	0.2651	0.0954	1.7083
b	-0.7437	-0.7012	-0.456
r^2	0.749	0.6869	0.8451

Table 4 presents the power law coefficients for Reach 7 of the SCR, where one more time the relationship is one of decreasing concentration with increasing flow. The complete statistical analysis for these two reaches is presented in the Appendix.

Table 4. Power law coefficients for Reach 7 of the SCR

	NH_3	NO_2	NO_3
a	1.8899	0.4679	4.6047
b	-0.5726	-0.4178	-0.6581
r^2	0.4939	0.2615	0.8327

The reason for using simulated results (after the calibration of the model) is that the actual dataset is sparse. For example, the statistical analysis of the observed nitrate concentrations in Reach 3 of the SCR is presented graphically in Figure 2, with the corresponding statistics in Table 5. As can be seen, even with 273 data points, the correlation is weak. Nevertheless, the correlation coefficients are negative, suggesting a decreasing concentration with increasing flow, with the power law coefficients presented in Table 6.

Figure 2. Correlation Analysis between observed flow and NO3 for Reach 3

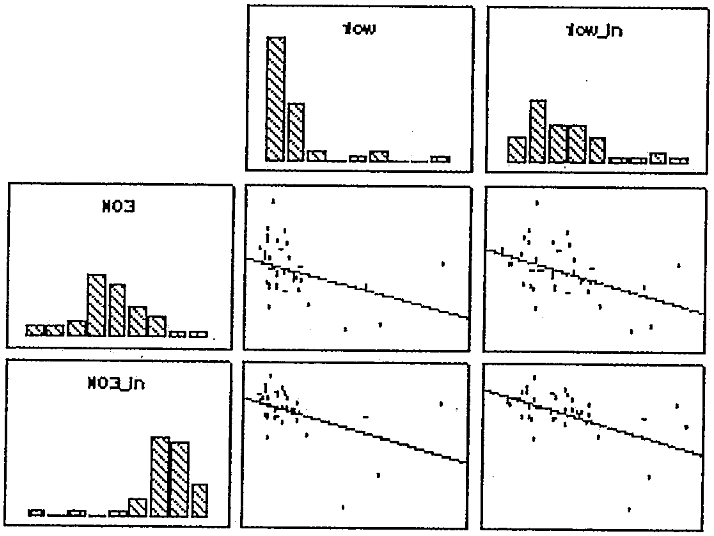


Table 5. Correlation between observed nitrogen concentration and flow for Reach 3

	$[NO_3]$	$\ln[NO_3]$
Flow	-0.38	-0.45
ln(flow)	-0.46	-0.51

Table 6. Power law coefficients for observed nitrate in Reach 3 of the SCR

a	4.3231
b	-0.5121
r^2	0.2603

3. Timing of Point and Non-Point Source Loads

Although the previous analysis indicates that there is a strong negative correlation between flow and concentration (i.e. low flow experiences the highest concentrations), we decided to evaluate whether timing of the Point Source (PS) and Non Point Source (NPS) loads would have made an important distinction at some point in the determination of critical conditions. For this analysis, we compared NPS loading to the river from the catchment to the total load in the river, to determine if and when the magnitude of the NPS could be significant to raise the overall load.

Figures 3, 4 and 5 present the magnitude of the NPS ammonia load and the total ammonia load for Reaches 3, 7 and 8 respectively. The scale of the y-axis (load) is logarithmic, given the wide differences in load magnitudes. As can be observed, the ammonia load from the catchments is usually very small relative to the total ammonia load, with a few exceptional days in Reach 7, given that any NPS ammonia loading is relatively rapidly converted to nitrate on the land surface and only reaches the river as ammonia when the NPS load is applied a few days before a significant storm event.

Figure 3. NPS and Total Ammonia Loading in Reach 3

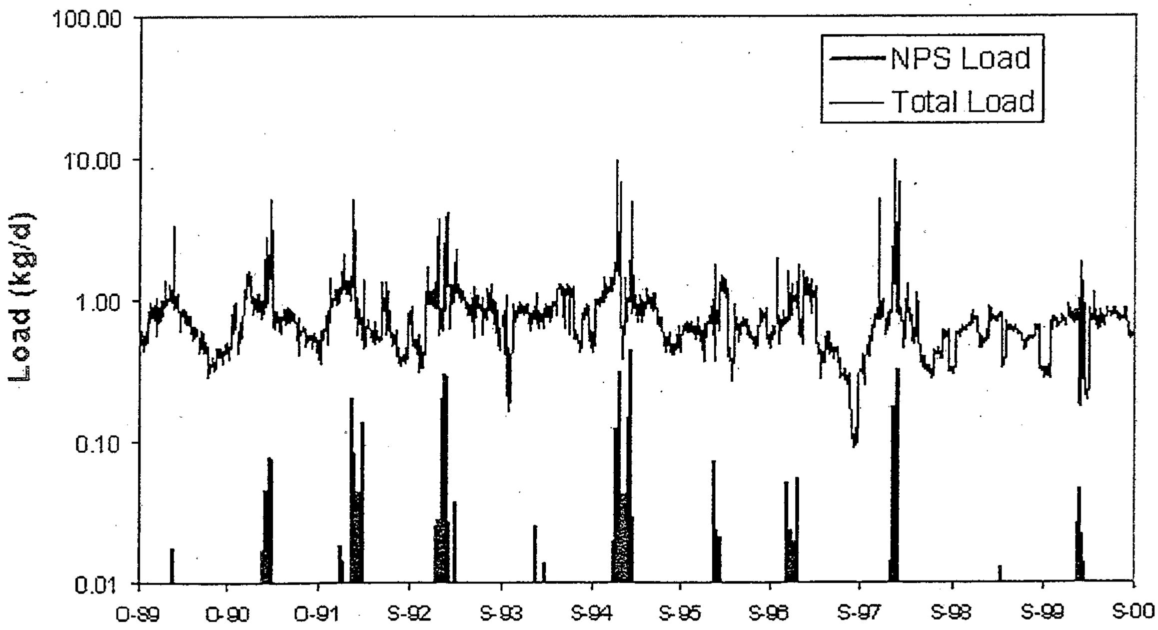


Figure 4. NPS and Total Ammonia Loading in Reach 7

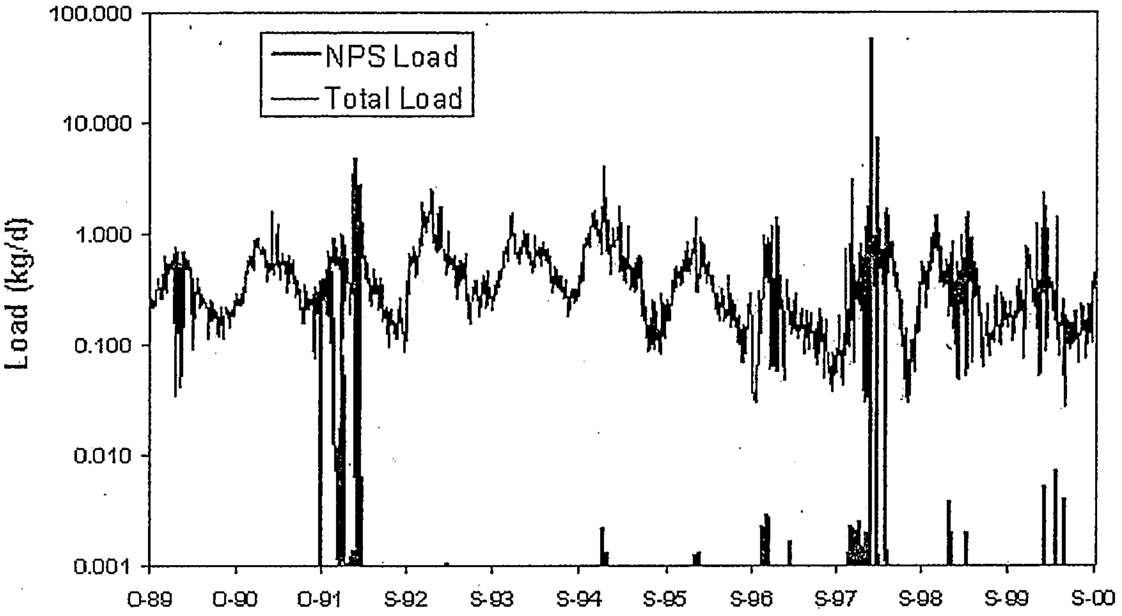
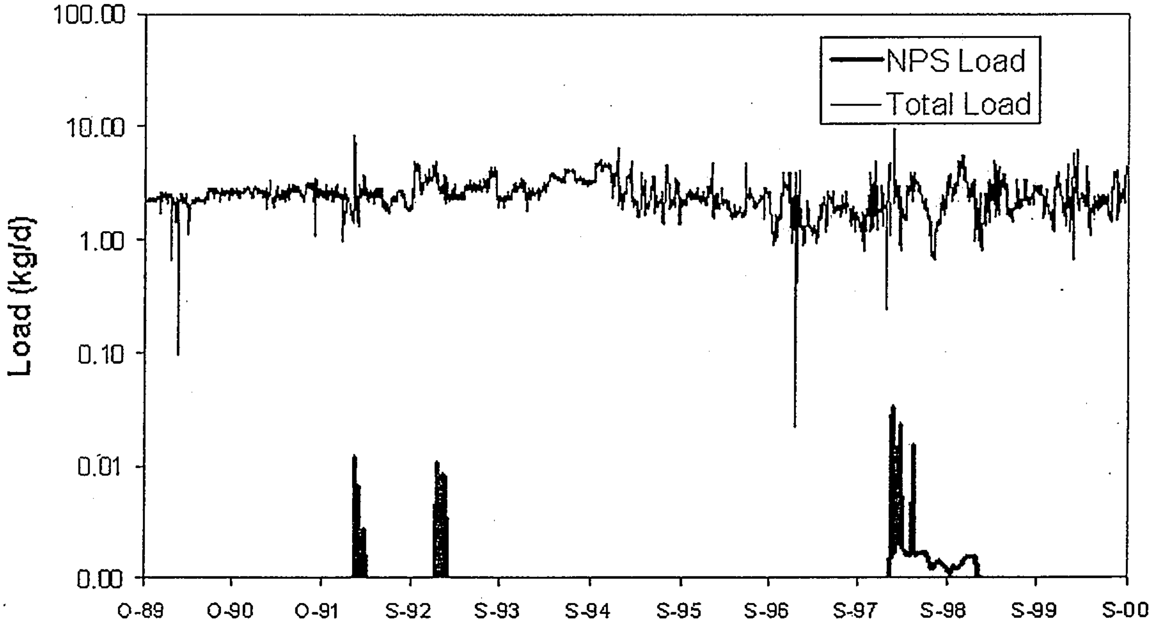


Figure 5. NPS and Total Ammonia Loading in Reach 8



Thus, nitrate loading is of more significance for evaluating critical conditions. In Figures 6, 7 and 8, the NPS and total nitrate loads in Reaches 3, 7 and 8 are presented.

Figure 6. NPS and Total Nitrate Loading in Reach 3

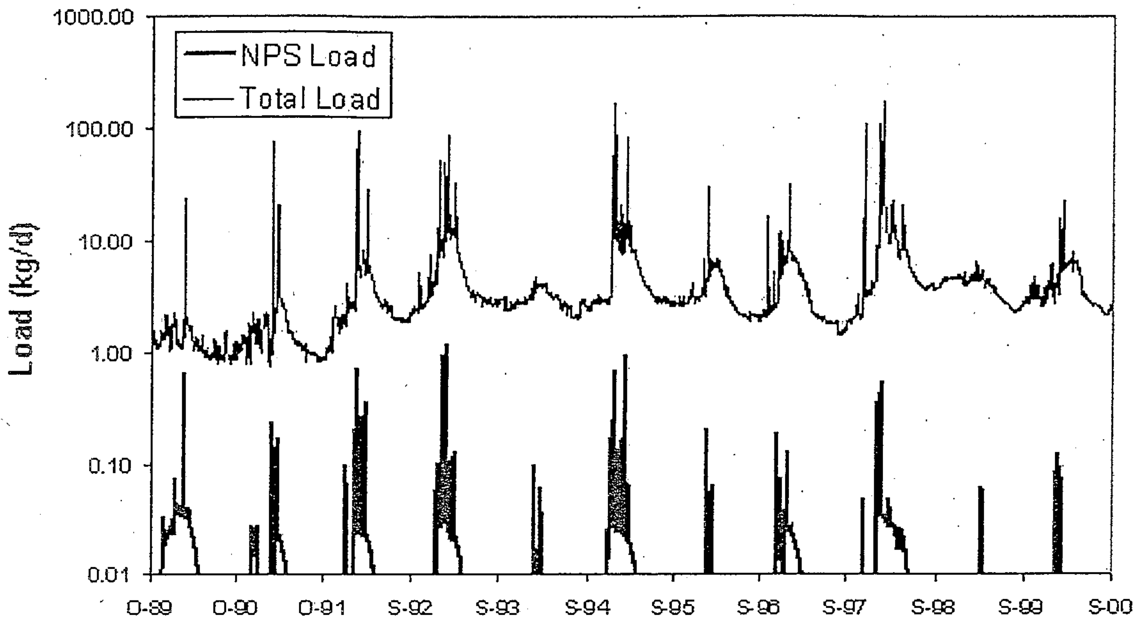


Figure 7. NPS and Total Nitrate Loading in Reach 7

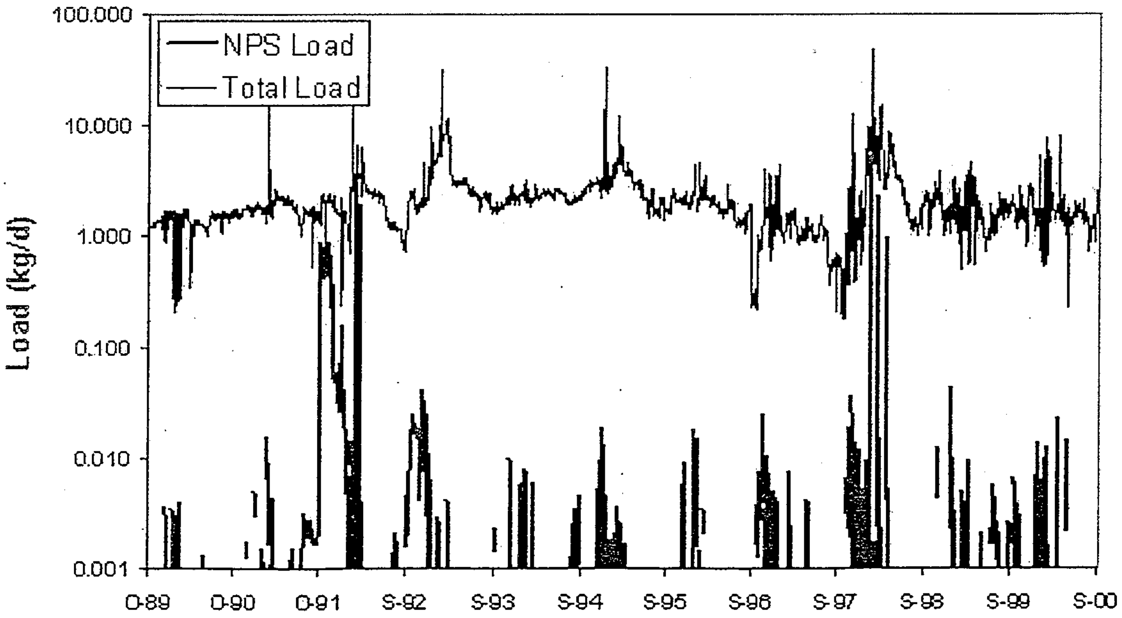
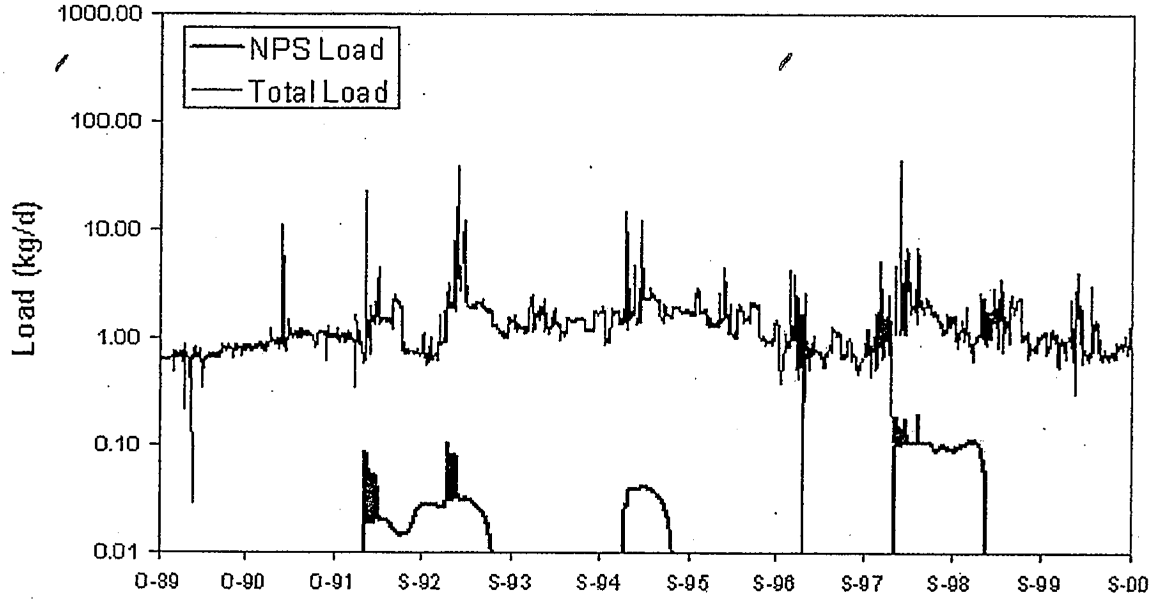


Figure 8. NPS and Total Nitrate Loading in Reach 8



To further analyze the relative magnitude of the loads, in Figures 9, 10 and 11 we present the percent contribution of NPS nitrate load to the total nitrate load for the same three reaches. From Figure 9, NPS nitrate load for Reach 3 is typically less than 1% of the total load, except for the winter months, when NPS nitrate load is typically up to 2% of the load, with an exceptional year in winter 1990, where due to the prolonged dry conditions a storm event actually contributed up to 11% of the load during a couple of days.

Figure 9. Percent NPS Nitrate Loading relative to total nitrate load in Reach 3

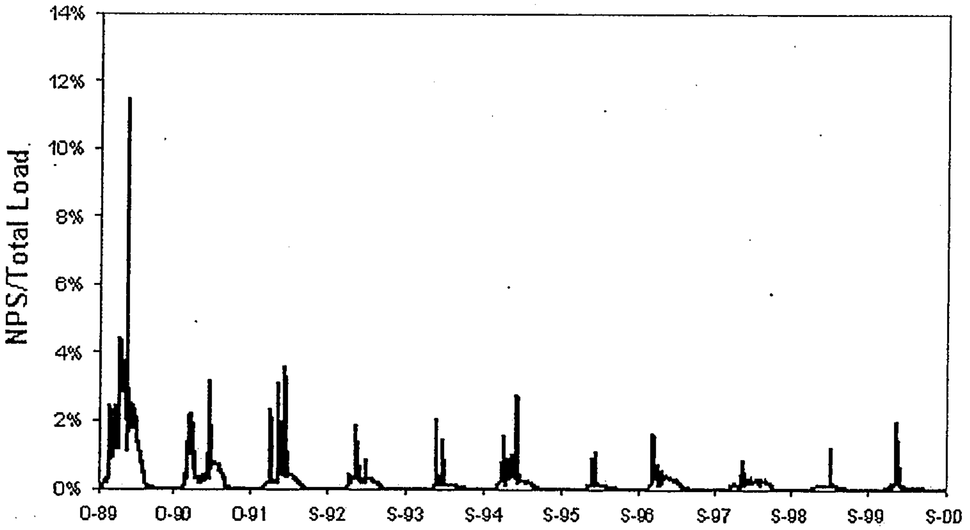


Figure 10. Percent NPS Nitrate Loading relative to total nitrate load in Reach 7

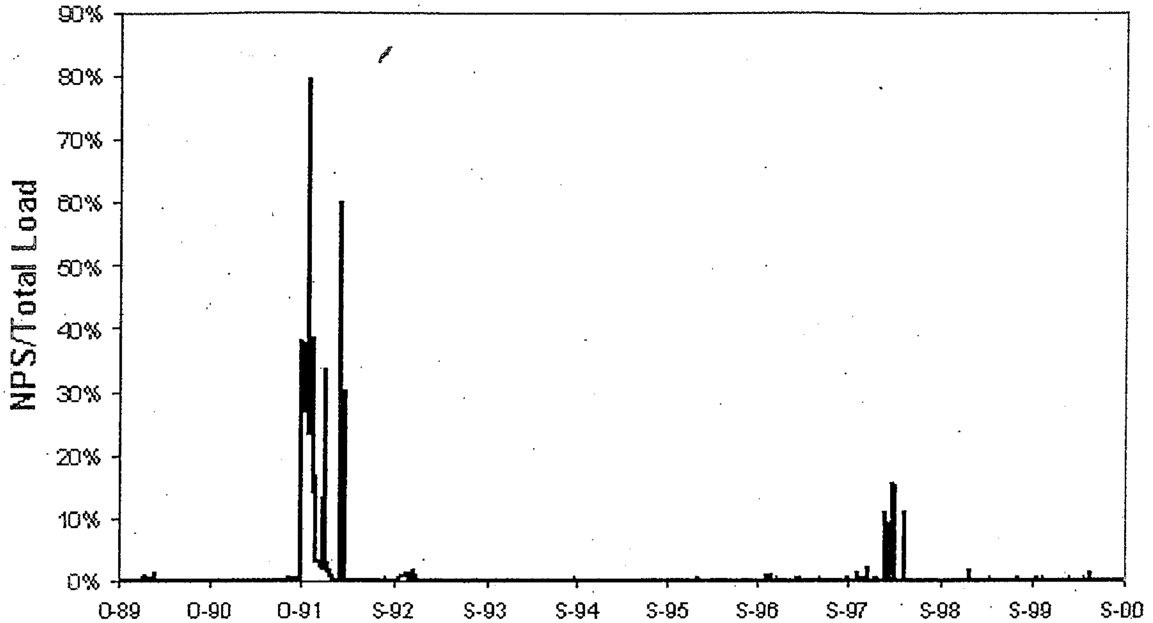
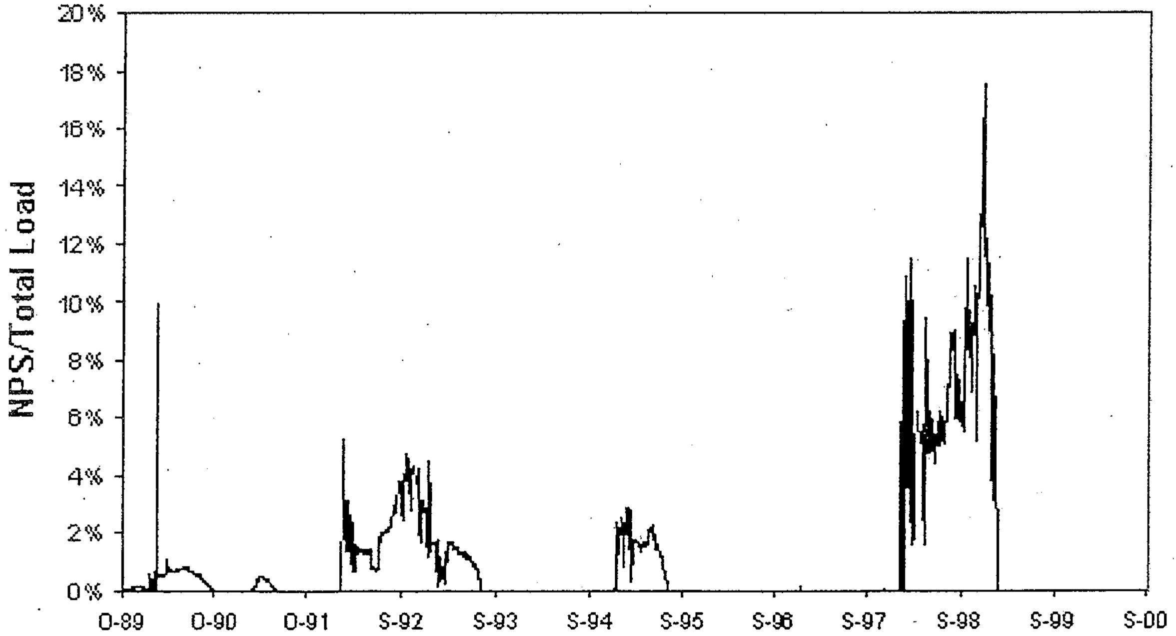


Figure 11. Percent NPS Nitrate Loading relative to total nitrate load in Reach 8



The situation is similar in Reach 7 (Figure 10), with NPS nitrate load typically less than 1% of the total load and some peak loading during storm events reaching a few more percent, with a significant exception in late 1991/early 1992, where there is a combination of high NPS loading and decreased PS loading for a few days (see Figure 7). This event again occurs at the beginning of the rainy season, and following a period of very dry rain years. This is corroborated by similar observations in Reach 8 (Figure 11), where it can be seen that the timing of the NPS loading is generally during the rainy (winter) season, with some peak NPS loads due to specific storm events. A similar peak loading occurs in late 1991/early 1992, although in Reach 8 there is also significant NPS loading during the rainy season of the 1998 El Niño year.

4. Locations with "Rising" Groundwater

There are a number of locations within the Santa Clara River where shallow groundwater surfaces at the river on a regular basis, contributing significantly to flow and water quality. There is a possibility that groundwater in some areas might have nitrate concentrations sufficiently high to increase the concentrations in the Santa Clara River. Certain areas in Reaches 3 and 7 are more likely to have such contributions, where significant Non-Point Source nitrogen loading from agriculture reaches the groundwater and then is transported towards the river.

We analyzed two regions in specific: (1) in Reach 7, the region below Old Road, through Blue Cut (County Line) and below Blue Cut; and (2) in Reach 3, the river segments between Pole Creek and Todd Barranca, passing through Fillmore and Santa Paula.

Rising Groundwater in Reach 7

The segments between Old Road and Blue Cut are generally dominated by the effluent flow and loading from the Valencia WWTP. Surface water quality in this region is available from the LA County Sanitary Districts stations RC, RD, RE and RF. Nitrate concentrations have been observed to exceed 5 mg N/L as NO3 in the past, and the simulation results for these segments indicate that under the current conditions, there are a number of instances where this level is exceeded (Figures 12-14).

Figure 12. Nitrate concentrations at the Old Road

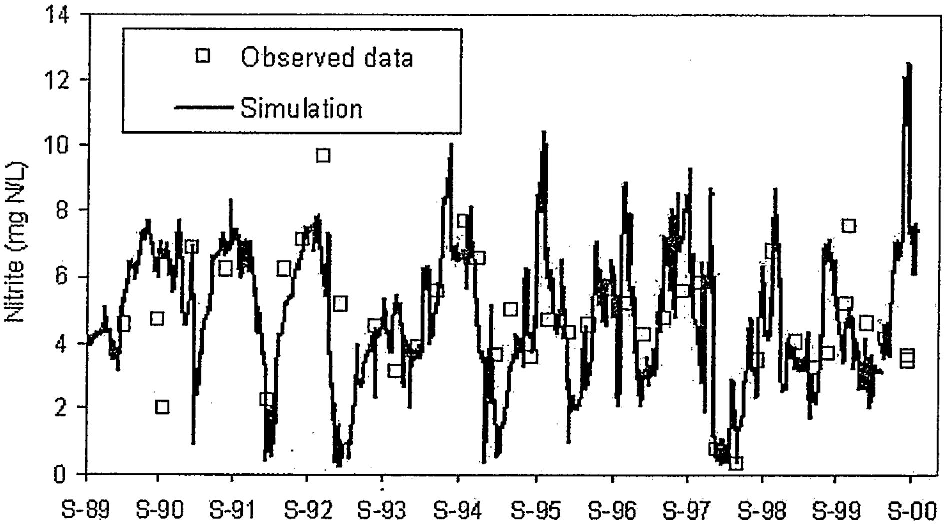


Figure 13. Nitrate concentrations at the County Line

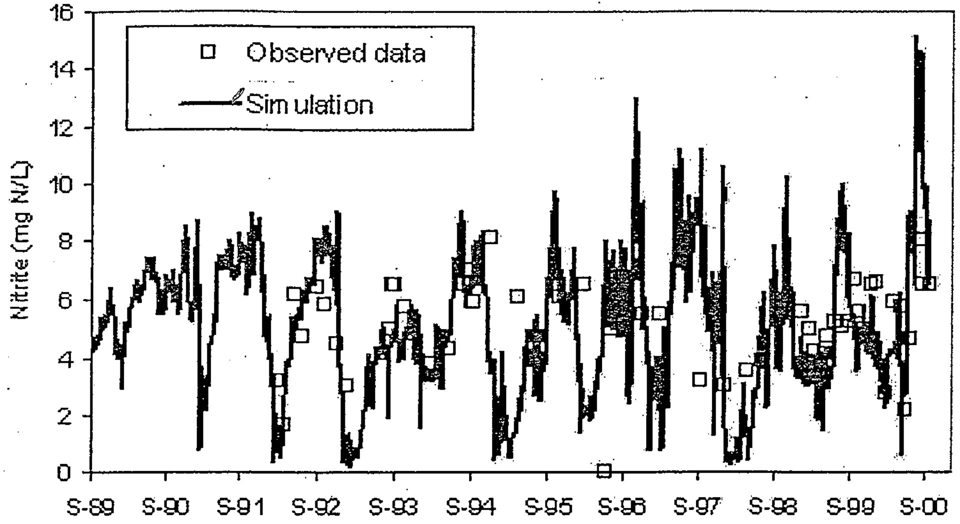
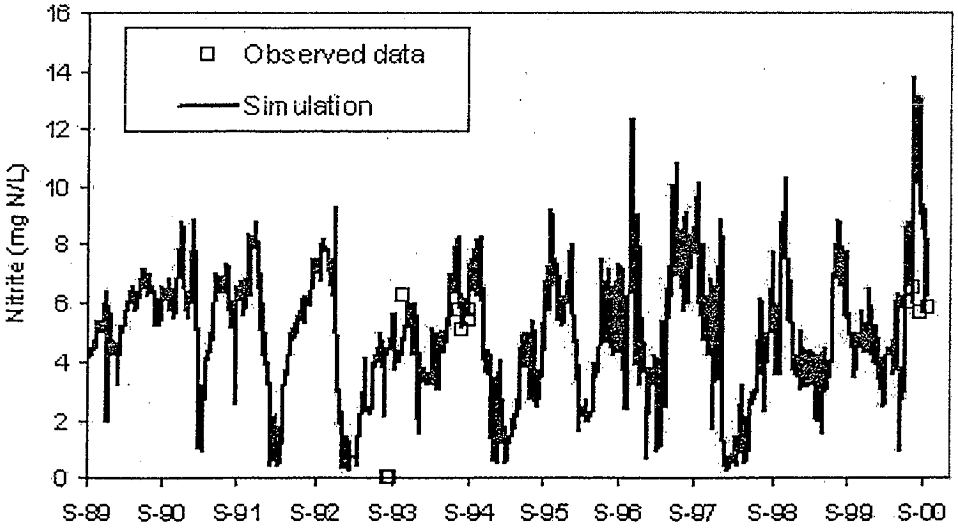


Figure 14. Nitrate concentrations below Blue Cut



The nitrate pattern at the County Line and below Blue Cut follows closely the pattern observed at the Old Road, indicating that in general the point source dominates to a large extent the nitrate concentrations. In fact, there is an increase in nitrate concentrations as the river flows downstream, which can be best seen in a comparison of the simulation results between Old Road and County Line (Figure 15) or between County Line and below Blue Cut (Figure 16).

Figure 15. Difference between simulated NO_3 at Old Road and County Line

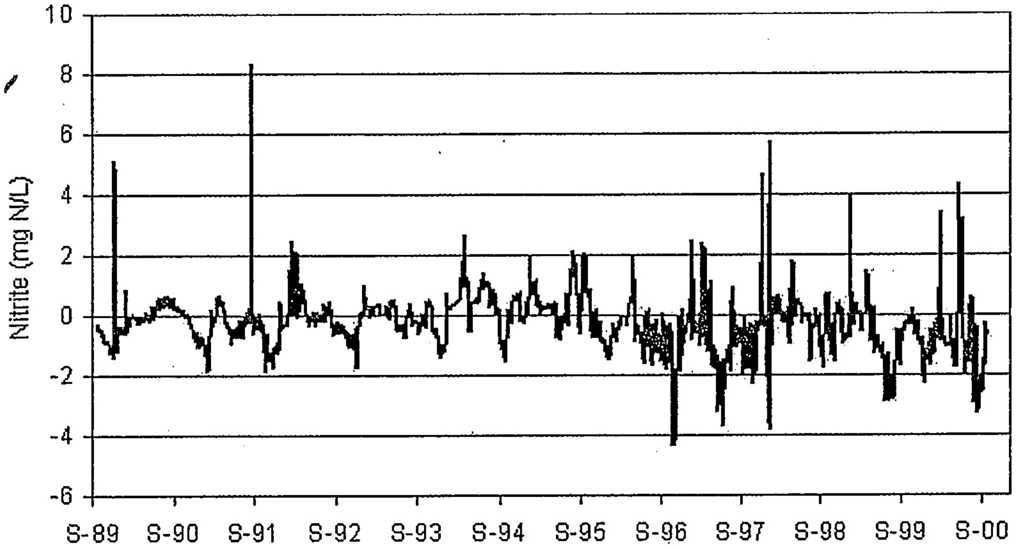
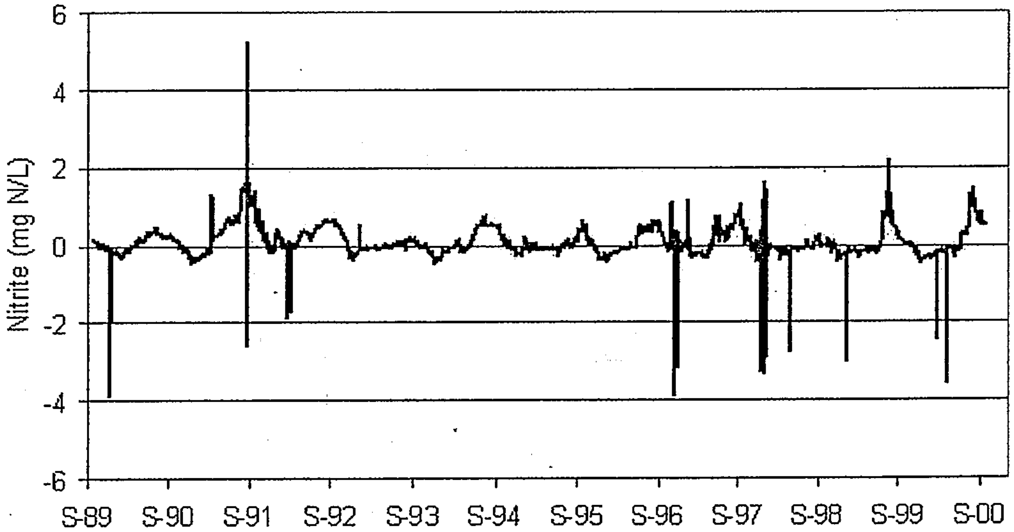


Figure 16. Difference between simulated NO_3 at County Line and below Blue Cut



Based on assimilation and other transformations, one would expect that the concentrations would decrease from upstream to downstream locations. In fact, Figure 15 indicates that most of the time nitrate concentrations increase at the County Line, with periodic dilution every winter. In the region below Blue Cut, nitrate concentrations remain fairly constant, with some periodic pulses that increase the concentrations and to a lesser degree some winter dilution. However, the increase in nitrate observed at the County Line can easily be explained by the transformation of ammonia to nitrate (Figures 17-19). About 2-4 mg N/L as NH_3 transform to nitrate in the segments between Old Road and the County Line, with some possible losses of N to assimilation and denitrification. These processes continue below Blue Cut, but there is considerably less ammonia in that region, so the effect is much smaller. Thus, without further groundwater monitoring data, it would be difficult to differentiate between these various processes.

Figure 17. Ammonia concentrations at the Old Road

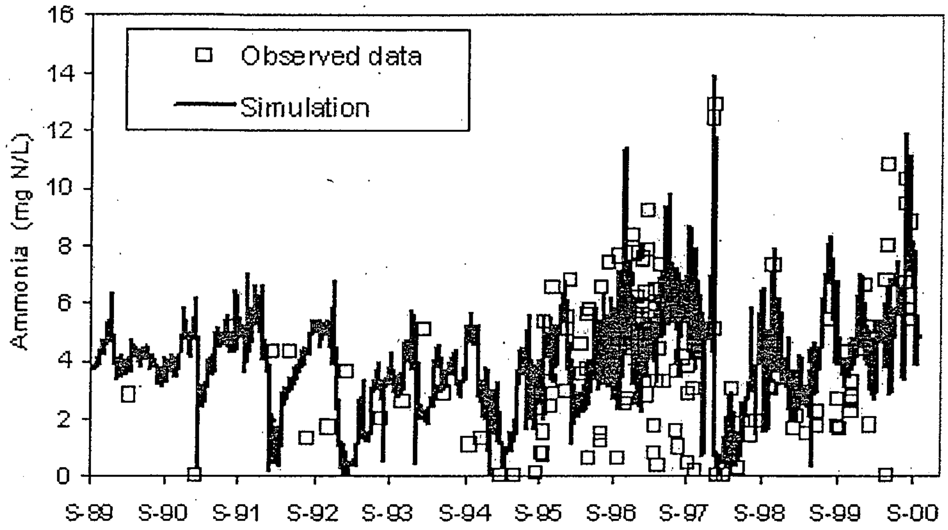


Figure 18. Ammonia concentrations at the County Line

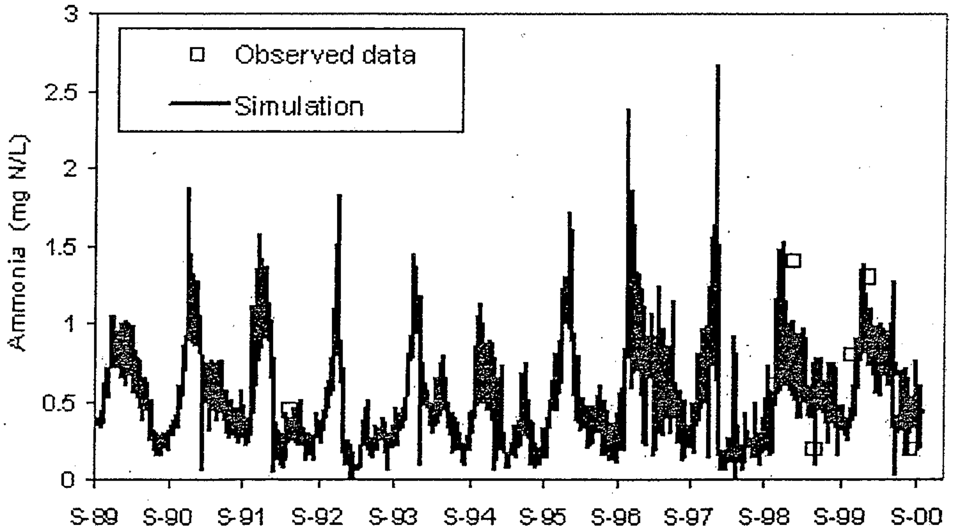
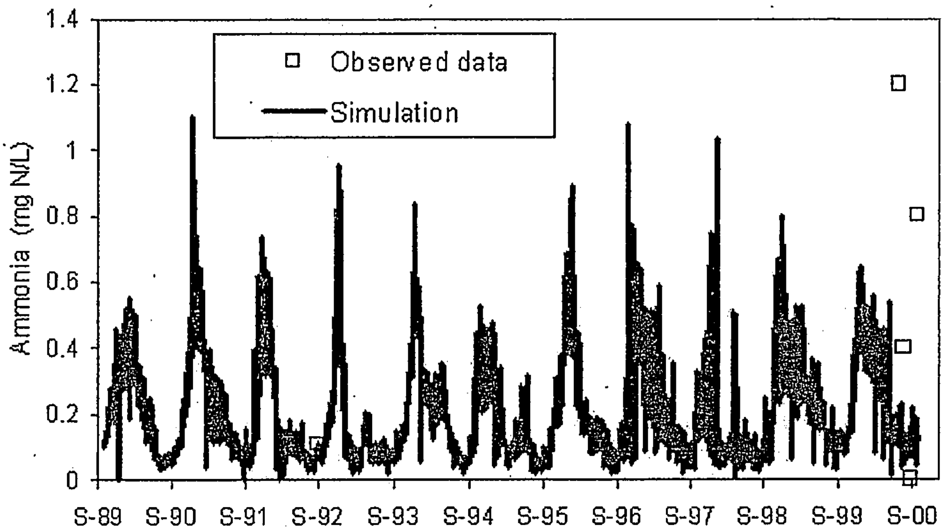


Figure 19. Ammonia concentrations at below Blue Cut



Rising Groundwater in Reach 3

Groundwater "rises" between the region above Fillmore and Santa Paula, in the vicinity of the Fillmore Fish Hatchery. The effect is captured in Figure 20, where flow in the reach above Fillmore (blue line) is significantly lower than flow at the end of the reach above Santa Paula (red line). Note that the scale on this figure is logarithmic, indicating a significant difference in flow between these two regions, due mostly to groundwater contributions. Water flow increases again at Santa Paula due to the contribution from the point source, the Santa Paula Wastewater Treatment Plant. There is essentially no difference between flow at Santa Paula and the next segment below Santa Paula. All of these river segments are within Reach 3.

Nitrate concentrations increase in late spring, summer and through the fall within these river segments, suggesting that NPS contributions in this region are important (Figures 21-24). There is a common dilution effect every winter and into early spring, which is probably due to winter storm events and delayed groundwater contributions. We present both observed data and simulation results to emphasize that this is not just a simulated condition, but that even with the relative sparseness of the observed data at some locations, the effect is relatively general with few exceptions.

In general, nitrate concentrations in the segment above Fillmore are below 5 mg N/L as NO_3, while the nitrate concentrations increase in the segment above Santa Paula and remain at the higher level through Santa Paula and below. The increase is on the order of 1-2 mg N/L as NO_3, which is sufficient to result in some exceedances of the water quality objective for this Reach. Groundwater is likely contributing to the rise of nitrate concentrations in this region. Given that ammonia loading above Fillmore is rather low, ammonia conversion to nitrate is not likely to be an important process in Reach 3. Additional studies with isotopic tracers and other dating methods should be considered to establish the contribution of nitrate from the upper watershed to the lower watershed. There is also important NPS loading in this Reach, which would by itself be an important contributor.

Figure 20. Flow in Reach 3

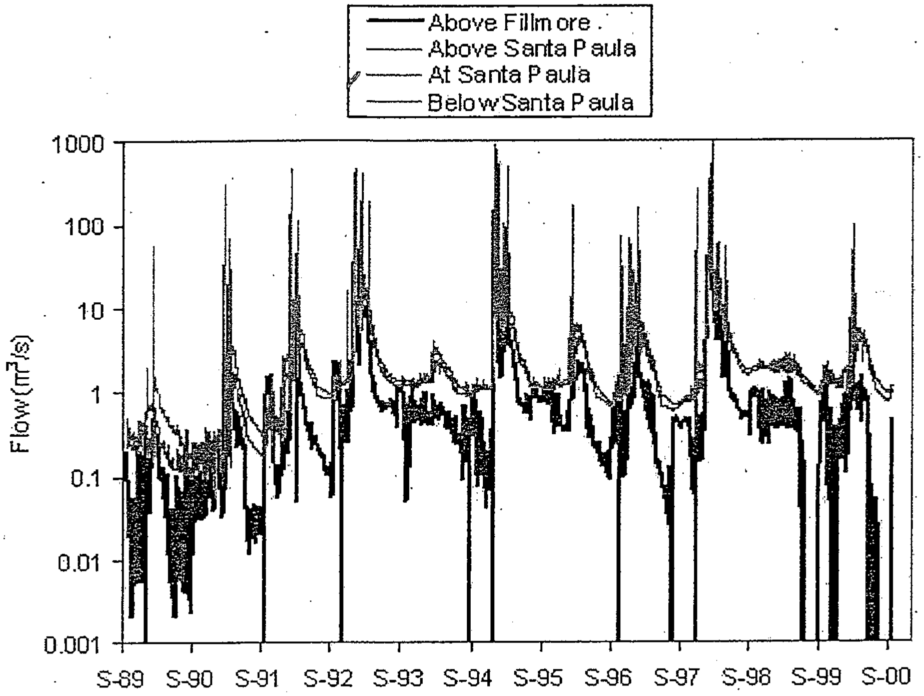


Figure 21. Nitrate concentrations above Fillmore

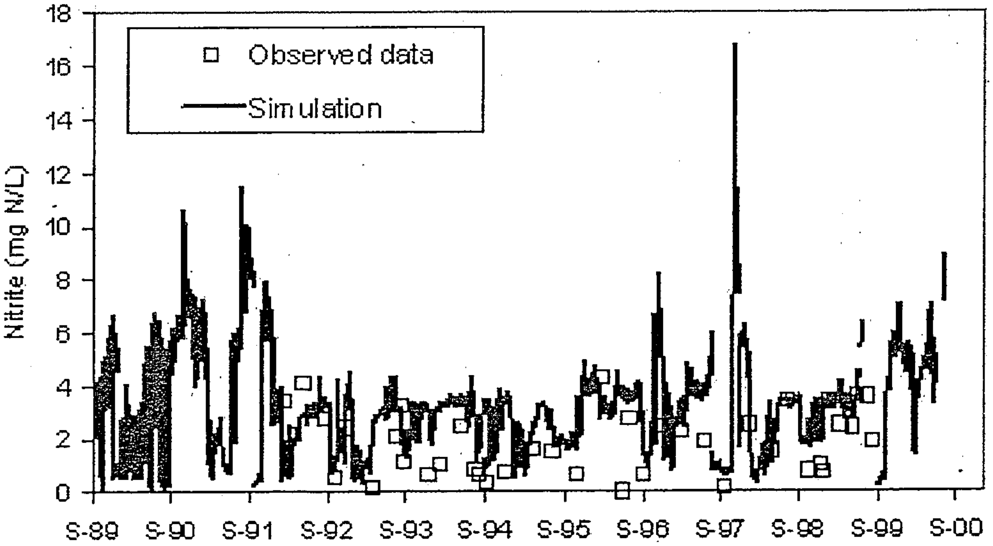


Figure 22. Nitrate concentrations above Santa Paula

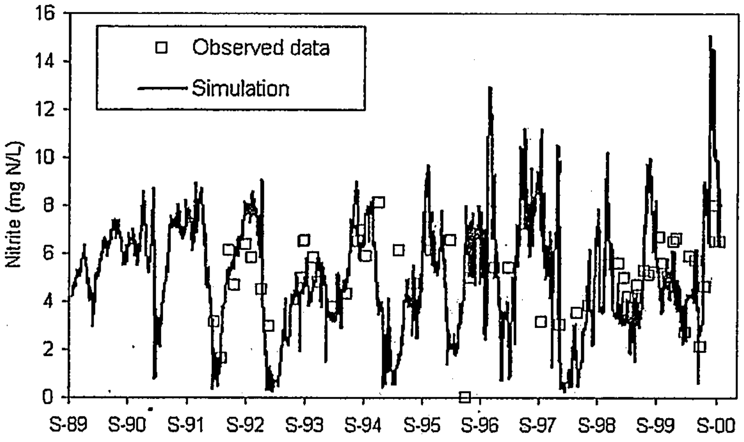


Figure 23. Nitrate concentrations at Santa Paula

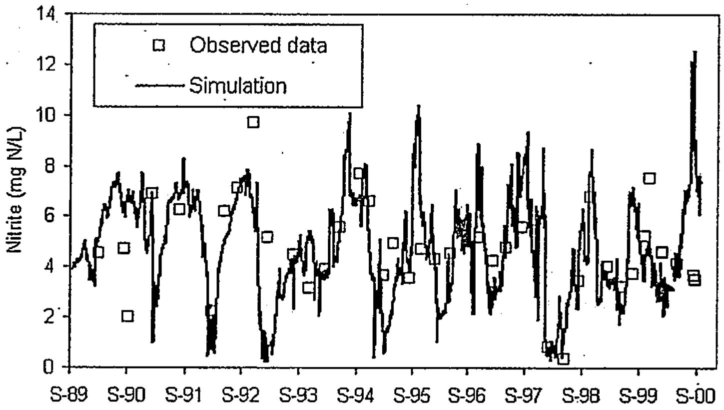
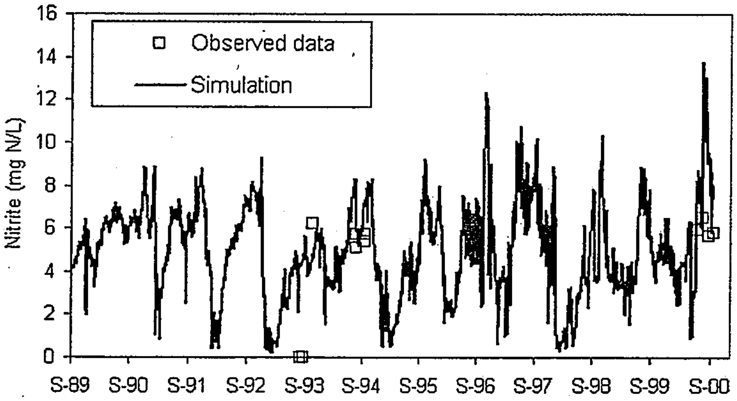


Figure 24. Nitrate concentrations below Santa Paula



5. Conclusions

The statistical correlation of flow and concentrations indicates that the highest concentrations are typically going to be found during low flow periods when there is reduced dilution. For these catchments, this is of particular importance given that in many instances there is practically no flow during significant periods of time. On the other hand, since there is no carrier medium, there is generally little or no loading occurring at this time from NPS. Thus the concern is simply that PS loading be controlled during these low flow periods so that it does not exceed the desired numerical targets.

From the timing analysis we conclude that for these catchments, NPS loading is very small in general, with only a few days in the 11-year simulation where the relative magnitude of NPS loading is of significance for water quality. These exceptionally high NPS load days occur early in the rainy season, and typically follow a period of dry years. In the case of ammonia, this is mostly a concern if the NPS ammonia load is applied right before the rain events. These findings can be used to better design Best Management Practices, with regards to the timing of the NPS loading so that it is reduced in the months before the rainy season, and in particular after a number of dry years.

The analysis of contribution from groundwater to the observed nitrate concentrations in the Santa Clara River indicates that this is more likely to occur in the lower watershed (Reach 3), and be less important in the upper watershed (Reach 7). However, it is important to note that the groundwater component of the model is spatially very simplified. It is necessary to obtain time-series data of nitrate concentrations in several wells in the area, which can then be coupled to a groundwater flow model to estimate the magnitude of the contribution from groundwater.

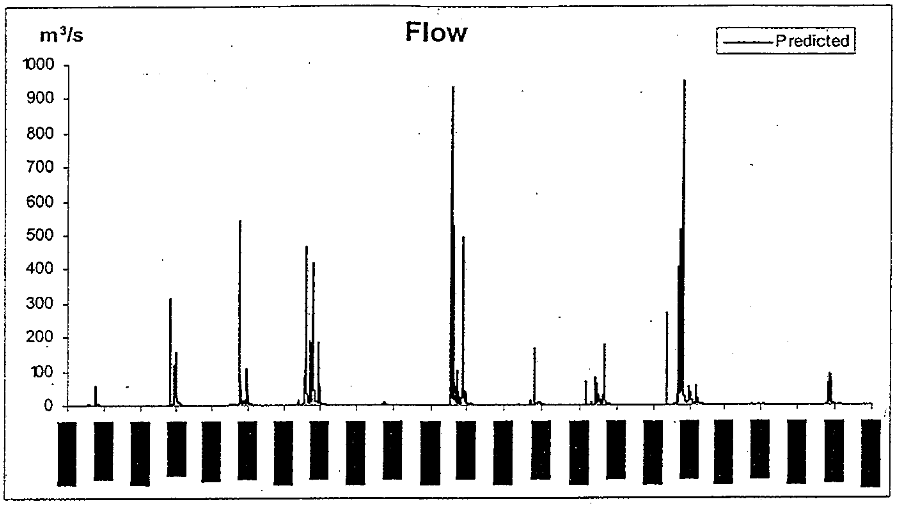
In conclusion, the most critical conditions for water quality in the Santa Clara River are low-flow conditions, in particular at the end of the dry season. The first strong storm events can cause significant short-term increases in nitrate concentrations in the river. Groundwater may be an important contributor in the lower watershed to increasing nitrate concentrations during the dry season. The groundwater contribution needs additional studies to confirm the magnitude and temporal variation of this load. These results need to be confirmed with additional monitoring data, in particular for Reach 3 where the observed data is sparse in many locations.

Appendix 1: Santa Clara River Reach 3 (downstream)

- Critical condition----Low flows and corresponding water quality data

	Water year	Flow (m³/s)	Ammonia (mg/L N)	pH	T (°C)	Nitrite (mg/L N)	Nitrate (mg/L N)
1Q	89-90	0.2112	0.6152	9.6012	20.3722	0.1945	3.1651
	90-91	0.1536	1.1604	9.0677	18.5983	0.4049	4.4495
	91-92	0.3598	0.4523	9.1541	20.5063	0.1454	2.1073
	92-93	1.1957	0.1347	9.0037	18.8071	0.0466	1.3051
	93-94	1.0365	0.2910	8.6473	18.6614	0.1085	1.9669
	94-95	1.1336	0.5549	8.9348	14.8687	0.2170	2.0534
	95-96	0.7691	0.3577	8.5439	19.5447	0.1172	2.0702
	96-97	0.7154	0.1308	9.1645	20.4832	0.0409	1.6290
	97-98	0.8984	0.1773	8.9144	18.7138	0.0604	1.5648
	98-99	0.9993	0.2597	9.0745	18.0393	0.0907	1.6810
	99-00	0.9532	0.3148	8.9522	19.7660	0.1020	1.7498
7Q	89-90	0.2254	0.5937	9.5318	21.2511	0.1786	3.1012
	90-91	0.1623	1.4301	9.0628	18.0151	0.5131	4.9640
	91-92	0.5248	0.3288	9.1374	20.3197	0.1072	1.5504
	92-93	1.2188	0.1556	9.0249	18.1442	0.0553	1.3537
	93-94	1.0996	0.2905	8.6357	18.9679	0.1066	1.9603
	94-95	1.1432	0.5444	8.8858	14.4628	0.2170	2.0630
	95-96	0.8208	0.3277	8.6478	20.0872	0.1046	1.9891
	96-97	0.7556	0.1317	9.1544	20.1883	0.0420	1.5806
	97-98	0.9470	0.1936	8.9151	17.8170	0.0684	1.5614
	98-99	1.0168	0.2432	9.0689	18.5179	0.0836	1.6609
	99-00	0.9661	0.3155	8.9540	19.6560	0.1028	1.7433
30Q	89-90	0.2434	0.5918	8.8406	20.8670	0.1819	3.0511
	90-91	0.1983	1.0550	8.5805	19.7925	0.3458	4.4488
	91-92	0.6343	0.3504	9.0751	19.0431	0.1221	1.4163
	92-93	1.3974	0.1304	9.0625	16.7667	0.0493	1.3764
	93-94	1.1821	0.1582	8.9818	20.2025	0.0518	1.3016
	94-95	1.2004	0.5373	8.9159	13.7490	0.2179	2.0374
	95-96	0.8593	0.3103	8.7114	19.5376	0.1018	1.8848
	96-97	0.7978	0.1502	9.1525	19.7172	0.0489	1.5834
	97-98	0.9725	0.1488	8.8935	19.1528	0.0509	1.4171
	98-99	1.0997	0.2025	9.0914	18.3010	0.0711	1.5738
	99-00	1.0440	0.2270	9.0720	18.9763	0.0767	1.5984

❖ Predicted flows



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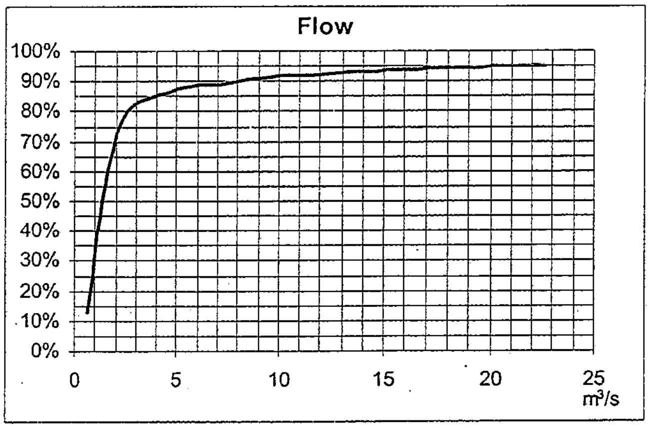
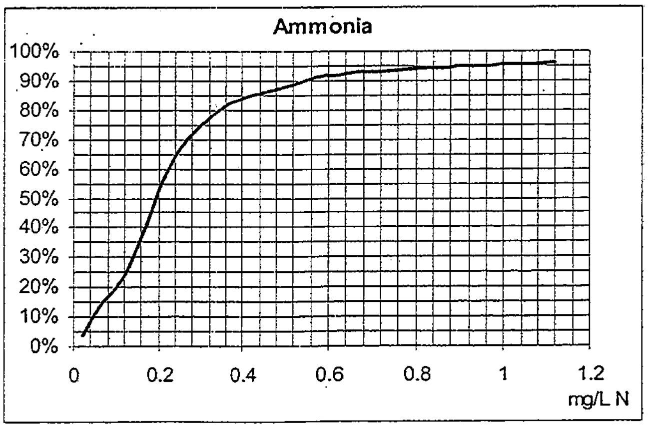
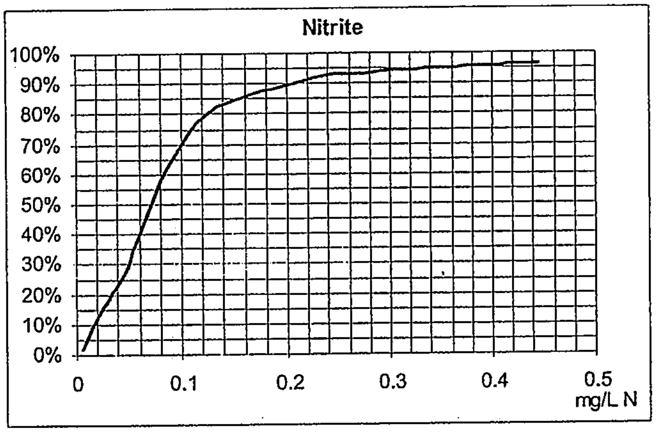
❖ Cumulative probabilities



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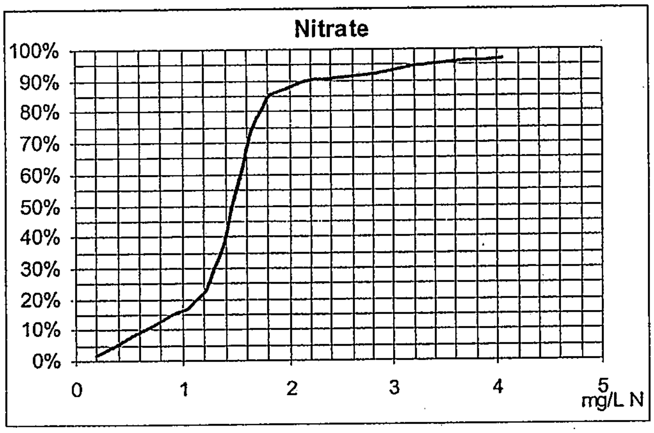
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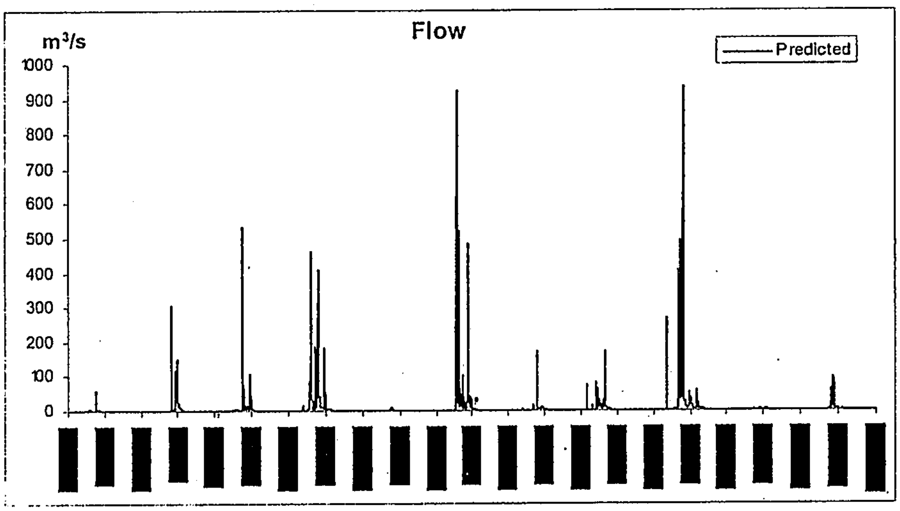
Appendix 2: Santa Clara River Reach 3 (upstream)

- Critical condition----Low flows and corresponding water quality data

	Water year	Flow (m³/s)	Ammonia (mg/L N)	pH	T (°C)	Nitrite (mg/L N)	Nitrate (mg/L N)
1Q	89-90	0.2107	1.8381	9.6211	20.4844	0.4424	4.0303
	90-91	0.1533	2.9891	9.1365	18.5656	0.7728	5.1280
	91-92	0.3536	1.0902	9.1334	22.5380	0.2576	2.5489
	92-93	1.1957	0.3461	8.9402	18.5626	0.0904	1.8829
	93-94	1.0352	0.7438	8.3951	18.6761	0.2408	2.6314
	94-95	1.1323	0.3727	8.7599	20.8299	0.1488	2.1055
	95-96	0.7683	0.9781	8.2719	19.4822	0.2340	2.7264
	96-97	0.7154	0.3835	9.1004	20.2221	0.0896	2.4813
	97-98	0.8939	0.4573	8.8191	18.6886	0.1117	2.2492
	98-99	0.9990	0.6408	9.0419	18.0622	0.1582	2.2816
	99-00	0.9530	0.8749	8.9373	19.6223	0.2081	2.2767
7Q	89-90	0.2253	1.8835	9.5575	21.3534	0.4360	3.9077
	90-91	0.1621	3.4999	9.1524	18.2539	0.9072	5.5910
	91-92	0.5259	0.9669	9.1705	20.2008	0.2543	1.8855
	92-93	1.2190	0.3830	8.9703	18.0513	0.1011	1.9176
	93-94	1.0995	0.7601	8.3744	18.9335	0.2436	2.6285
	94-95	1.1433	1.0761	8.8753	14.4604	0.3040	2.4803
	95-96	0.8204	0.9339	8.4542	19.9618	0.2198	2.6538
	96-97	0.7557	0.3762	9.0921	20.0073	0.0885	2.3937
	97-98	0.9468	0.4673	8.8259	17.8948	0.1161	2.1917
	98-99	1.0170	0.6149	9.0327	18.4481	0.1507	2.2753
	99-00	0.9659	0.8692	8.9392	19.5357	0.2073	2.2661
30Q	89-90	0.2435	1.8222	8.2293	20.9918	0.4274	3.8438
	90-91	0.1981	2.9700	8.1195	19.9988	0.7218	5.2843
	91-92	0.6347	0.9171	9.1194	19.0137	0.2422	1.6745
	92-93	1.3952	0.2931	9.0012	16.8148	0.0819	1.9644
	93-94	1.1820	0.4502	8.9177	20.0030	0.1158	1.8539
	94-95	1.2003	1.0257	8.9017	13.9282	0.2956	2.4567
	95-96	0.8595	0.8479	8.5711	19.4506	0.2026	2.5162
	96-97	0.7976	0.4155	9.0982	19.5833	0.0990	2.3466
	97-98	0.9725	0.3860	8.7885	19.1191	0.0963	2.0645
	98-99	1.0994	0.5051	9.0489	18.2575	0.1299	2.1968
	99-00	1.0443	0.5965	9.0384	18.9127	0.1475	2.1977

- Predicted flows



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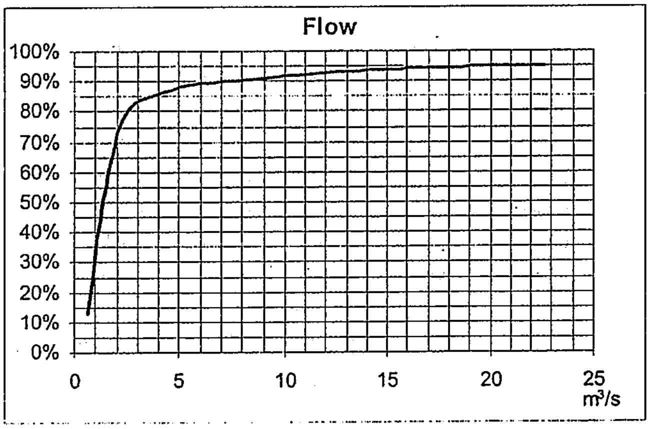
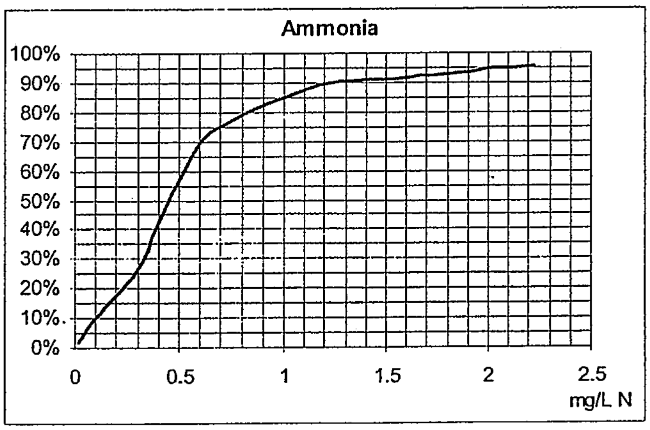
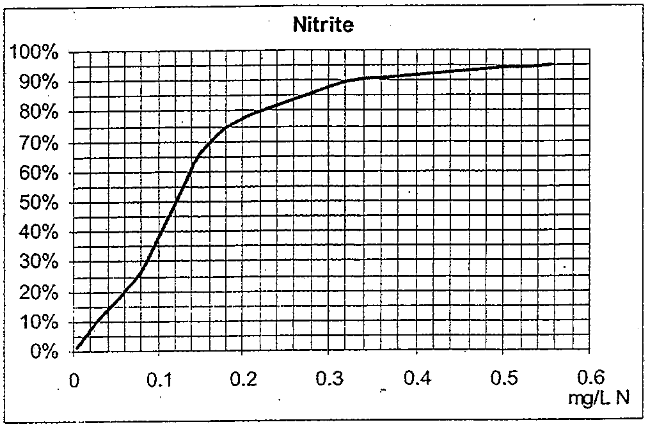
- Cumulative probabilities



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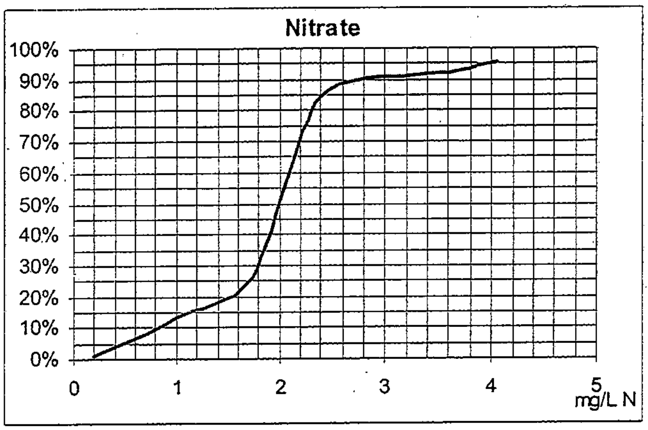
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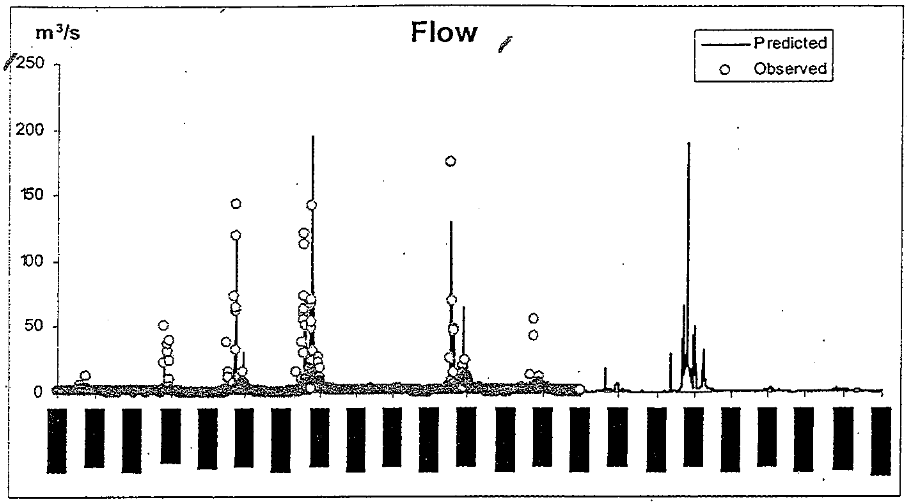
Appendix 3: Santa Clara River Reach 7 (downstream)

- Critical condition----Low flows and corresponding water quality data

	Water year	Flow (m^3/s)	Ammonia (mg/L N)	pH	T (°C)	Nitrite (mg/L N)	Nitrate (mg/L N)
1Q	89-90	0					
	90-91	0.0308	0.0220	8.6885	23.9453	0.0055	7.3480
	91-92	0					
	92-93	0.4941	0.0223	9.0395	24.3543	0.0055	6.6007
	93-94	0.5897	0.0201	9.1843	23.8311	0.0052	5.6631
	94-95	0.5480	0.0395	8.5165	23.0638	0.0110	6.9574
	95-96	0.7111	0.0239	9.0833	22.5835	0.0069	4.3463
	96-97	0					
	97-98	0					
	98-99	0					
	99-00	0					
7Q	89-90	0					
	90-91	0.1031	0.0297	8.6642	23.1958	0.0081	6.8796
	91-92	0.2004	0.0194	8.7474	24.5338	0.0047	6.2386
	92-93	0.5251	0.0334	8.9784	23.2152	0.0093	6.5930
	93-94	0.6342	0.0144	9.1441	24.7425	0.0034	5.4448
	94-95	0.6962	0.0709	8.4388	21.5380	0.0233	7.1626
	95-96	0.7339	0.0234	8.7681	24.1650	0.0058	5.8517
	96-97	0.3719	0.1295	8.4196	21.8592	0.0425	11.9291
	97-98	0.5485	0.0400	9.1492	23.3260	0.0129	6.4223
	98-99	0.2316	0.0287	8.5996	24.5809	0.0069	7.8651
	99-00	0.6714	0.0237	8.8768	24.7377	0.0061	6.7540
30Q	89-90	0.6048	0.1712	8.3349	17.8444	0.0714	6.1238
	90-91	0.2021	0.0298	8.6620	23.4790	0.0082	6.6119
	91-92	0.2103	0.0397	8.6555	23.1027	0.0122	6.7918
	92-93	0.6384	0.0457	8.9602	22.4985	0.0137	7.1010
	93-94	0.6529	0.0457	8.9602	22.4985	0.0137	7.1010
	94-95	0.8396	0.0828	8.6184	20.6601	0.0294	7.3065
	95-96	0.7778	0.0174	8.7878	25.1934	0.0043	5.6839
	96-97	0.5009	0.0182	8.9246	25.7368	0.0040	8.2567
	97-98	0.5592	0.0587	8.9580	21.8451	0.0196	6.8040
	98-99	0.4911	0.0320	8.6506	24.3247	0.0084	7.2744
	99-00	0.7054	0.0394	8.6644	23.9935	0.0105	8.1936

- Predicted and observed flows



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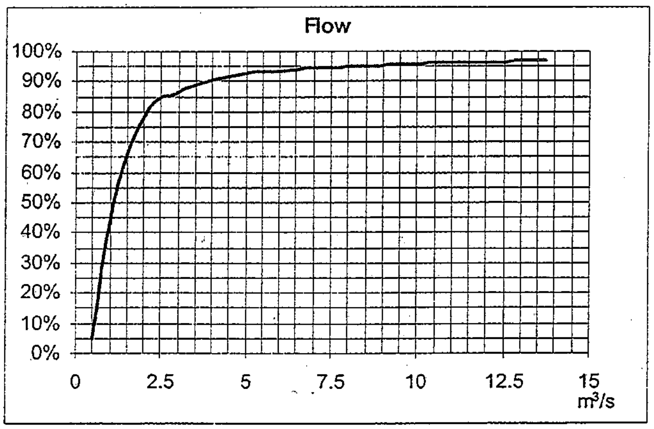
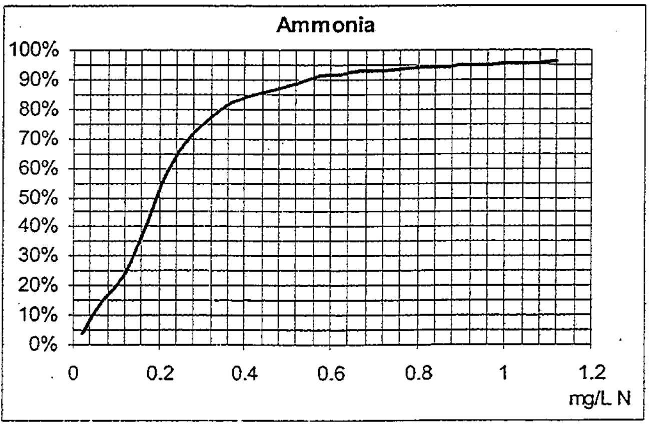
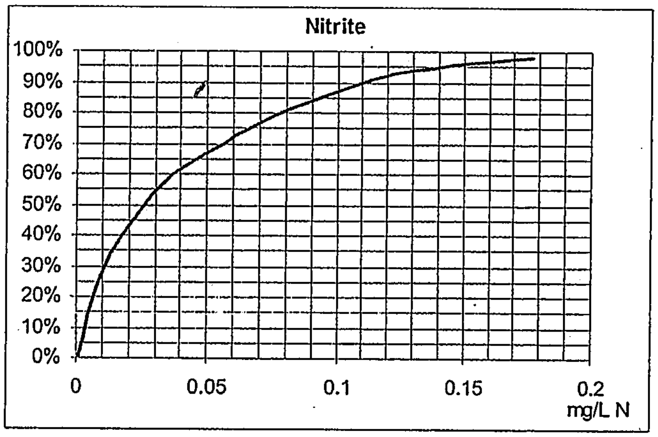
- Cumulative probabilities



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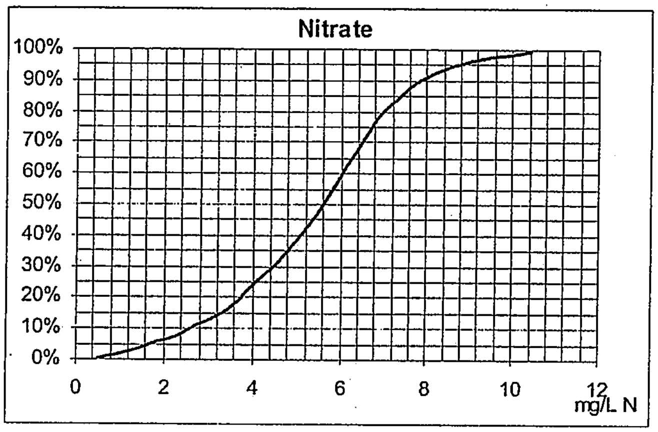
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6
8
10
12
mg/L N

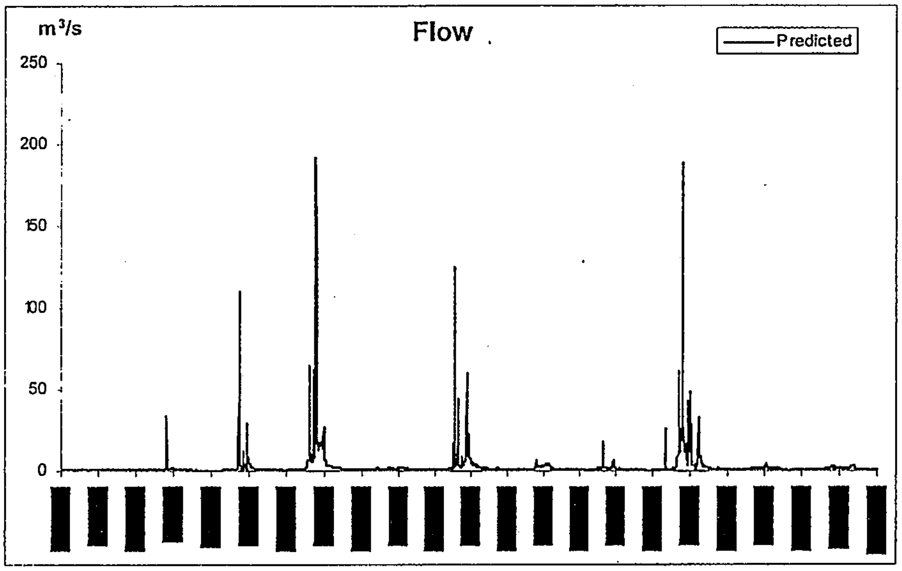
Appendix 4: Santa Clara River Reach 7 (mid-stream)

- Critical condition----Low flows and corresponding water quality data

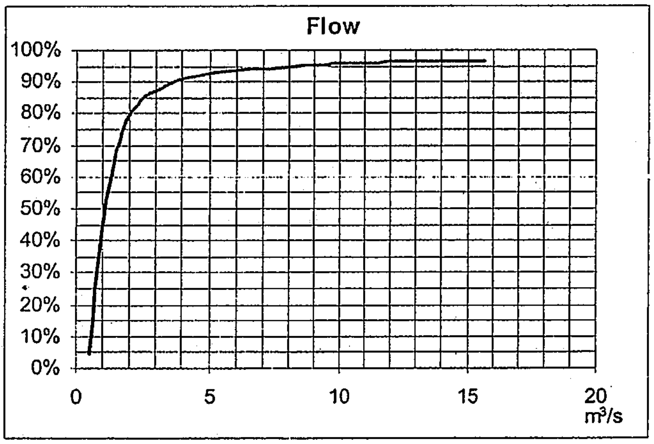
	Water year	Flow (m³/s)	Ammonia (mg/L N)	pH	T (°C)	Nitrite (mg/L N)	Nitrate (mg/L N)
1Q	89-90	0					
	90-91	0.0891	0.0907	8.4610	24.9225	0.0207	7.8597
	91-92	0					
	92-93	0.5117	0.0928	8.9845	24.5485	0.0222	6.9234
	93-94	0.6008	0.0636	9.1470	24.8120	0.0147	5.6300
	94-95	0.5641	0.1435	8.1393	23.4127	0.0384	7.2623
	95-96	0.7093	0.0830	9.0761	22.9591	0.0230	4.5213
	96-97	0					
	97-98	0					
	98-99	0					
	99-00	0					
7Q	89-90	0					
	90-91	0.1571	0.1112	8.4546	23.9490	0.0283	7.2935
	91-92	0.2451	0.0817	8.6031	24.8232	0.0191	6.5997
	92-93	0.5384	0.1224	8.9382	23.4200	0.0329	6.8879
	93-94	0.6415	0.0616	9.1051	25.1314	0.0140	5.7476
	94-95	0.6986	0.2177	8.0567	21.7978	0.0685	7.3993
	95-96	0.7321	0.0953	8.5892	24.5351	0.0226	6.1374
	96-97	0.3915	0.4011	7.8257	22.0960	0.1236	12.2573
	97-98	0.5455	0.1314	9.1338	23.5008	0.0387	6.7191
	98-99	0.2946	0.1218	8.2483	25.0734	0.0276	8.2389
	99-00	0.6705	0.0961	8.7272	24.9948	0.0234	7.0782
30Q	89-90#	0.5926	0.4219	8.0965	17.8675	0.1686	6.1985
	90-91	0.2471	0.1118	8.4621	23.9151	0.0290	6.9674
	91-92	0.2510	0.1346	8.4600	23.4604	0.0381	7.1226
	92-93	0.6420	0.1549	8.9236	22.6996	0.0447	7.3912
	93-94	0.6582	0.0817	8.7892	24.7553	0.0194	6.2494
	94-95	0.8319	0.2361	8.4584	20.9198	0.0794	7.5613
	95-96	0.7749	0.0741	8.6033	25.6139	0.0169	5.9906
	96-97	0.5007	0.0860	8.7655	26.0746	0.0178	8.7477
	97-98	0.5505	0.1826	8.8758	22.1358	0.0565	7.0854
	98-99	0.5255	0.1247	8.3807	24.7377	0.0308	7.6102
	99-00	0.7044	0.1515	8.3315	24.2267	0.0387	8.5454

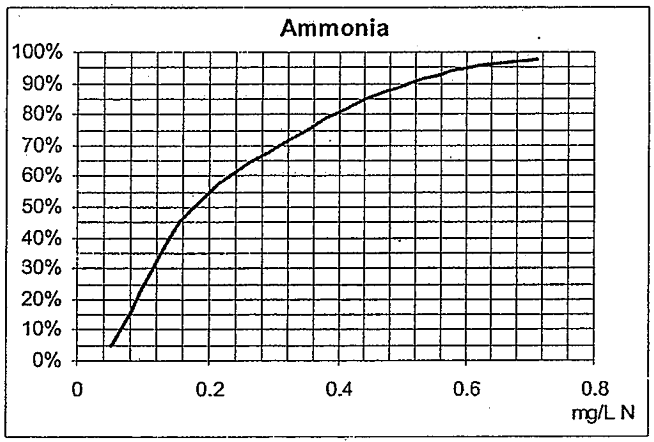
The predicted water quality data are incomplete during these periods due to the zero predicted flows

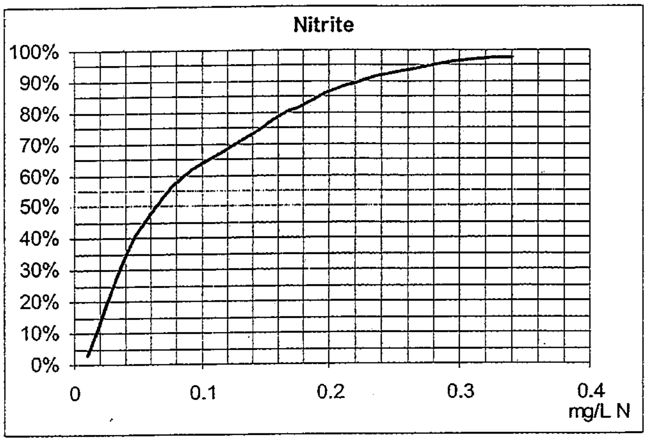
- Predicted flows

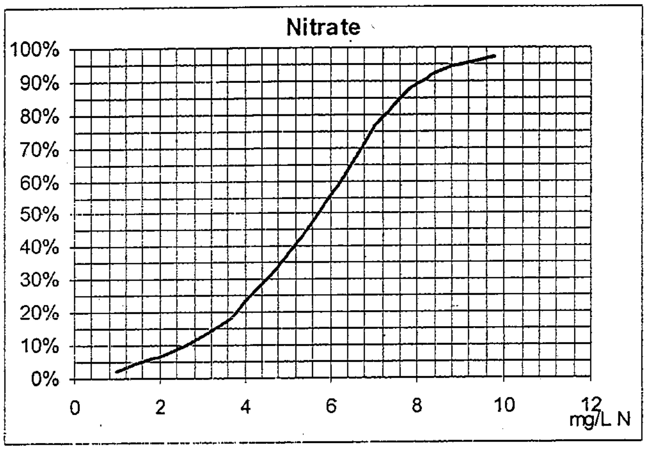


- Cumulative probabilities






Nitrite
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
0.1
0.2
0.3
0.4
mg/L N


Nitrate
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
2
4
6
8
10
12
mg/L N

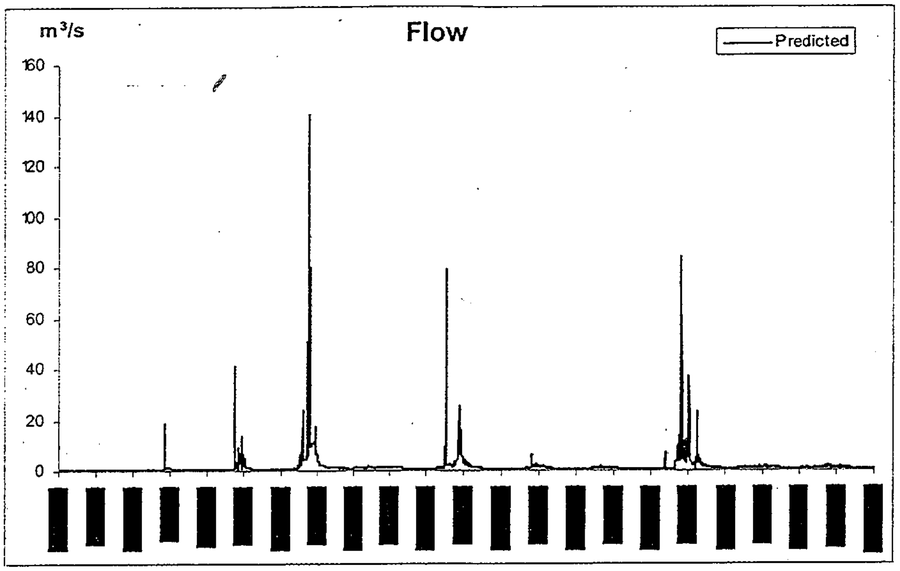
Appendix 5: Santa Clara River Reach 7 (upstream)

- Critical condition----Low flows and corresponding water quality data

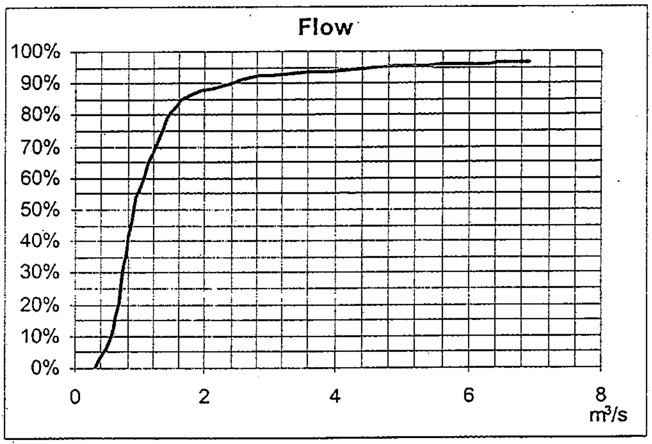
	Water year	Flow (m^3/s)	Ammonia (mg/L N)	pH	T (°C)	Nitrite (mg/L N)	Nitrate (mg/L N)
1Q	89-90	0					
	90-91	0.3416	2.1567	9.2623	26.09	0.3744	7.5204
	91-92	0					
	92-93	0.547	1.9069	9.4406	23.608	0.4137	5.8956
	93-94	0.6225	1.3096	9.4552	25.23	0.2454	5.1174
	94-95	0.6217	2.2126	9.1136	24.083	0.4811	5.9877
	95-96	0.669	2.2400	9.3032	25.171	0.4168	5.7803
	96-97	0.0293	2.3275	9.3304	18.793	0.6593	5.6124
	97-98	0					
	98-99	0.5172	2.2166	9.3884	15.949	0.7352	4.5716
	99-00	0					
7Q	89-90	0.3969	3.2000	9.3152	17.6089	0.8914	4.8550
	90-91	0.3894	2.0838	9.2820	24.9761	0.3985	6.7441
	91-92	0.3972	2.5558	9.3239	23.733	0.5362	7.16
	92-93	0.5770	1.9042	9.4439	23.967	0.4025	6.0346
	93-94	0.6530	1.3344	9.4241	25.386	0.2468	5.2386
	94-95	0.6848	2.4576	9.1577	22.834	0.5843	5.9131
	95-96	0.6949	1.8882	9.3293	25.03	0.3575	5.1646
	96-97	0.4412	2.3305	9.4367	26.253	0.386	7.9028
	97-98	0.4573	2.9409	9.4785	23.997	0.5653	7.4574
	98-99	0.5684	2.8474	9.232	24.776	0.5682	6.7423
	99-00	0.6369	1.9557	9.3593	25.25	0.4066	6.0859
30Q	89-90#	0.6181	2.8923	9.276	18.585	0.7814	4.7398
	90-91	0.436	1.9785	9.2873	24.585	0.3931	6.3131
	91-92	0.4209	2.0698	9.3089	24.505	0.4159	6.3858
	92-93	0.6323	2.0751	9.4948	23.427	0.4582	6.4096
	93-94	0.6612	1.6121	9.3419	25.173	0.3139	5.4867
	94-95	0.7676	2.3376	9.3372	21.84	0.5479	6.5303
	95-96	0.7315	1.6401	9.1923	26.086	0.2864	5.0393
	96-97	0.4664	2.3625	9.4239	26.337	0.3893	7.9773
	97-98	0.4724	2.4367	9.5315	23.638	0.494	6.3306
	98-99	0.6669	2.3473	9.2406	25.061	0.4618	6.2373
	99-00	0.6702	2.6661	9.2957	24.737	0.5584	6.998

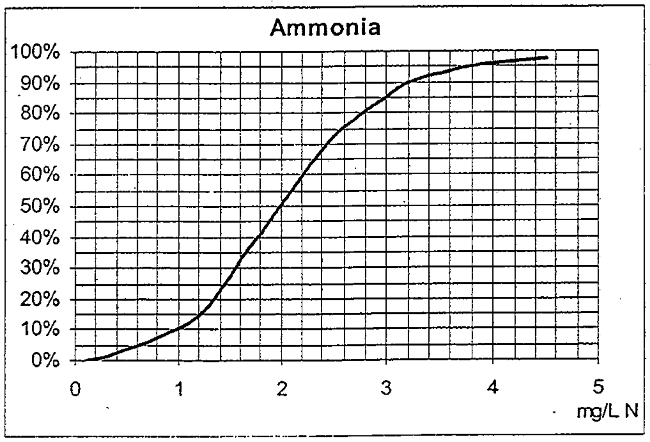
The predicted water quality data are incomplete during these periods due to the zero predicted flows

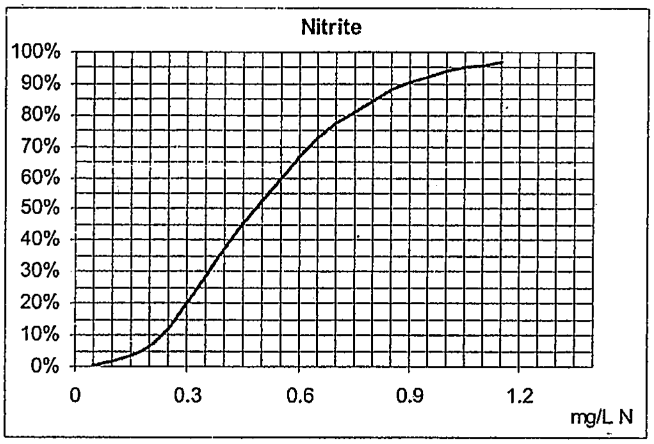
- Predicted flows

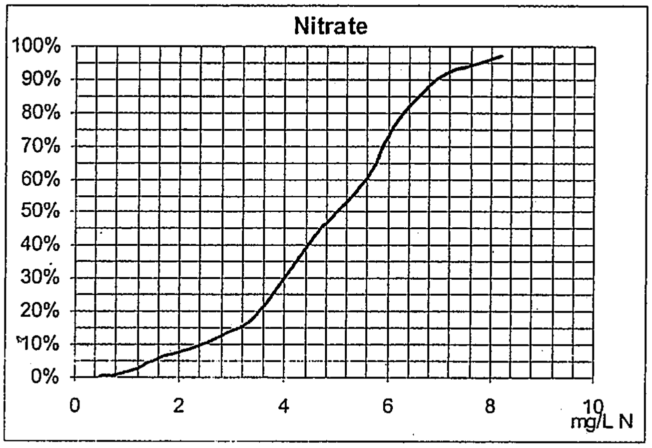


- Cumulative probabilities






Nitrite
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
0.3
0.6
0.9
1.2
mg/L N


Nitrate
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
2
4
6
8
10
mg/L N

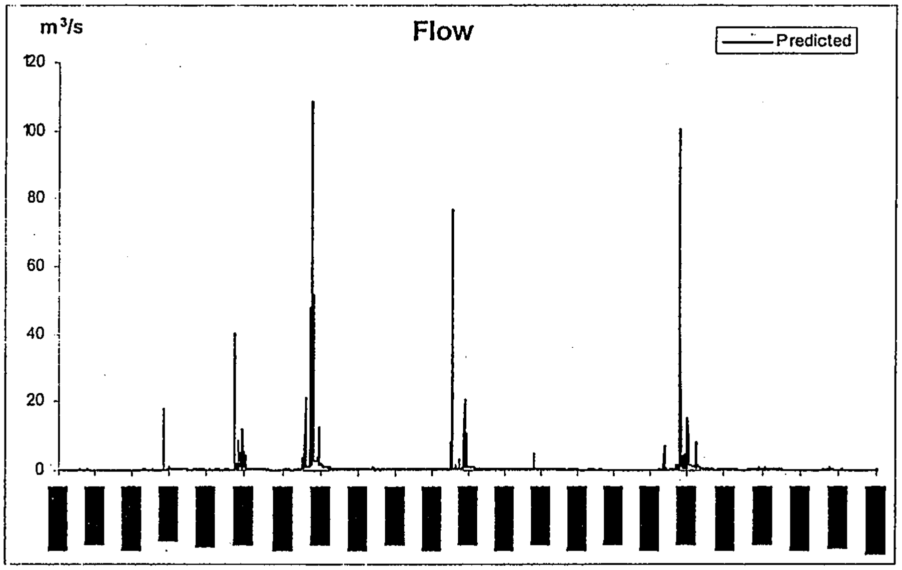
Appendix 6: Santa Clara River Reach 8

- Critical condition----Low flows and corresponding water quality data

	Water year	Flow (m^3/s)	Ammonia (mg/L N)	pH	T (°C)	Nitrite (mg/L N)	Nitrate (mg/L N)
1Q	89-90	0					
	90-91	0.1191	0.7872	8.6367	22.2290	0.2312	5.1689
	91-92	0					
	92-93	0.2233	2.3106	7.5719	16.7125	0.8845	5.6653
	93-94	0.2679	2.8381	7.6958	13.1983	1.2390	5.7421
	94-95	0.2491	2.1822	7.7652	15.3356	1.0313	6.4279
	95-96	0.2322	0.3082	8.7767	25.2984	0.0676	3.2945
	96-97	0					
	97-98	0					
	98-99	0					
	99-00	0					
7Q	89-90	0.0981	1.6850	7.6919	18.2668	0.6341	5.3609
	90-91	0.1811	2.4207	7.5788	14.3615	1.0420	5.3361
	91-92	0.0907	2.2442	7.6549	15.6949	0.9339	5.7030
	92-93	0.2438	1.6511	7.6679	19.3045	0.5656	5.5294
	93-94	0.3001	1.9441	8.0006	14.4933	0.9185	5.6980
	94-95	0.3015	1.2182	8.0494	21.1301	0.3835	6.0452
	95-96	0.2593	0.4235	8.6637	24.6419	0.1008	3.7708
	96-97	0					
	97-98	0					
	98-99	0.1090	1.1727	8.1289	22.5875	0.3343	6.9041
	99-00	0.0343	2.4911	7.7020	16.5438	1.0316	7.1370
30Q	89-90#	0.1584	2.4988	7.5651	14.6482	1.0642	5.2274
	90-91	0.2256	0.9910	8.0518	21.6100	0.3080	5.0142
	91-92	0.1447	0.8939	8.2521	22.0183	0.2609	4.6978
	92-93	0.2535	1.8987	7.5441	20.0405	0.6133	6.5734
	93-94	0.3161	0.8288	8.4448	22.7147	0.2353	5.4837
	94-95	0.3094	1.7267	7.7377	19.7504	0.5926	6.3323
	95-96	0.2680	0.3812	8.6822	25.3338	0.0843	3.6582
	96-97#	0.0158	1.1280	8.1630	18.4177	0.4385	4.6391
	97-98#	0.0507	0.9461	8.5441	21.3022	0.3027	5.5547
	98-99	0.1497	1.0118	8.1554	22.6470	0.2880	5.9150
	99-00	0.0644	1.3181	8.3092	20.1914	0.4553	6.7423

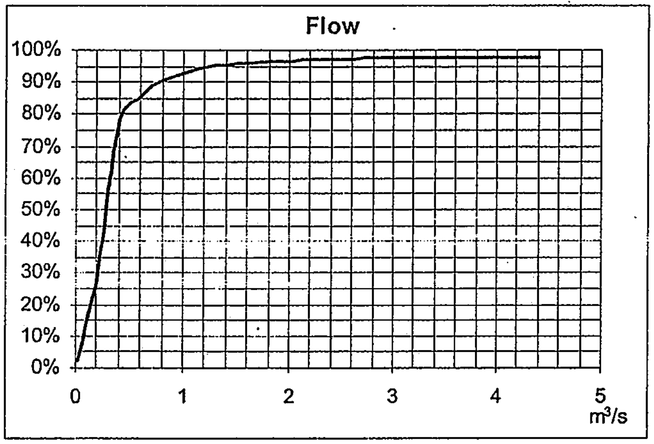
The predicted water quality data are incomplete during these periods due to the zero predicted flows

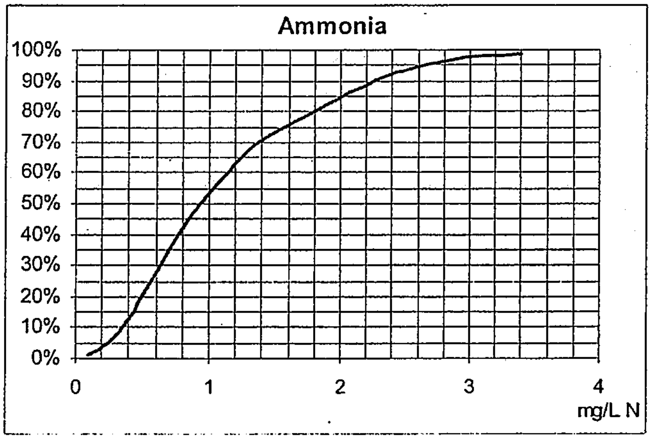
- Predicted flows

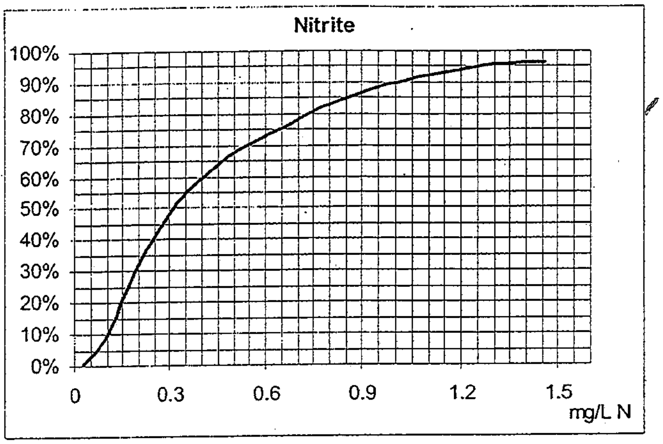


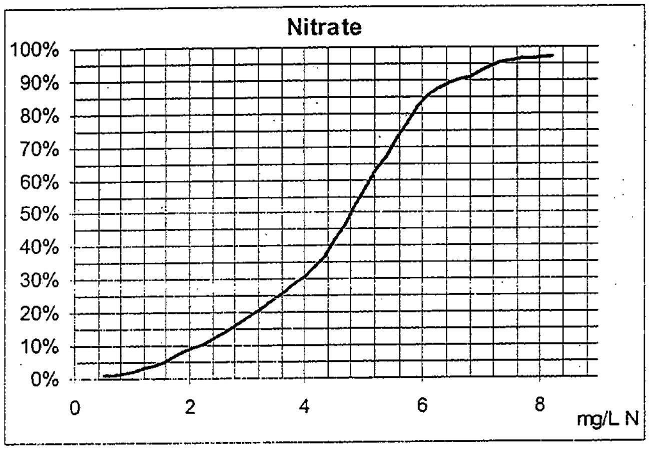
[redacted]

- Cumulative probabilities






Nitrite
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
0.3
0.6
0.9
1.2
1.5
mg/L N

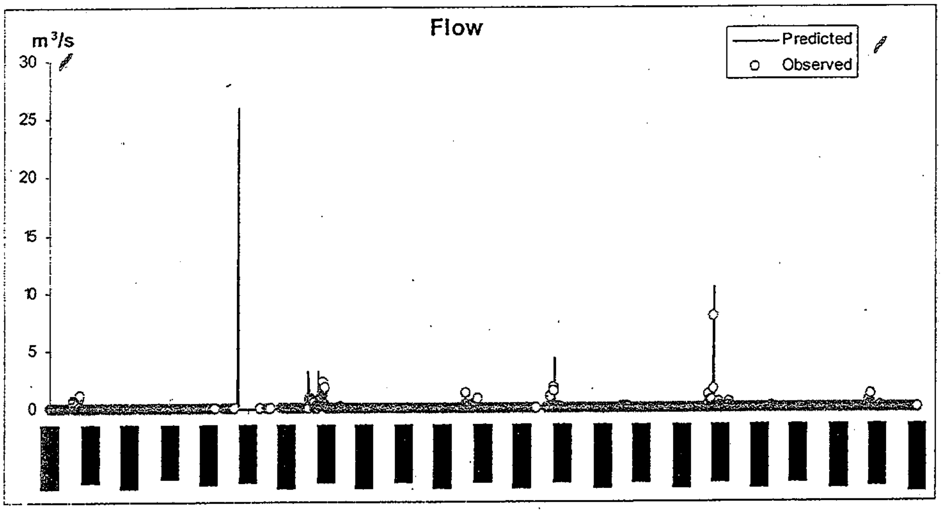

Nitrate
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
2
4
6
8
mg/L N

Appendix 7: Mint Canyon

- Critical condition----Low flows and corresponding water quality data

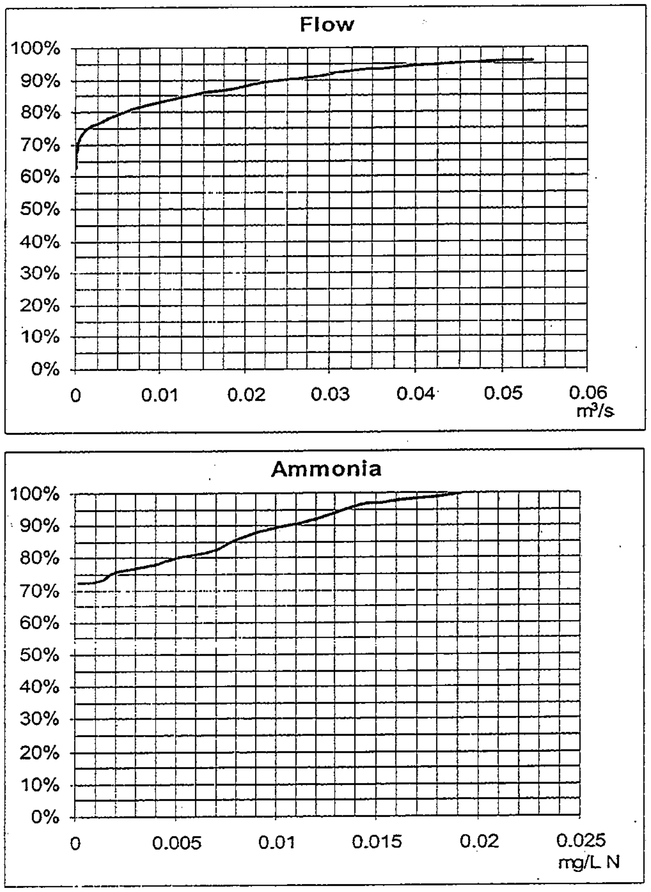
	Water year	Flow (m^3/s)	Ammonia (mg/L N)	pH	T (°C)	Nitrite (mg/L N)	Nitrate (mg/L N)
1Q	89-90	0					
	90-91	0					
	91-92	0					
	92-93	0					
	93-94	0					
	94-95	0					
	95-96	0					
	96-97	0					
	97-98	0					
	98-99	0					
	99-00	0					
7Q	89-90	0					
	90-91	0					
	91-92	0					
	92-93	0					
	93-94	0					
	94-95	0					
	95-96	0					
	96-97	0					
	97-98	0					
	98-99	0					
	99-00	0					
30Q	89-90	0					
	90-91	0					
	91-92	0					
	92-93	0					
	93-94	0					
	94-95	0					
	95-96	0					
	96-97	0					
	97-98	0					
	98-99	0					
	99-00	0					

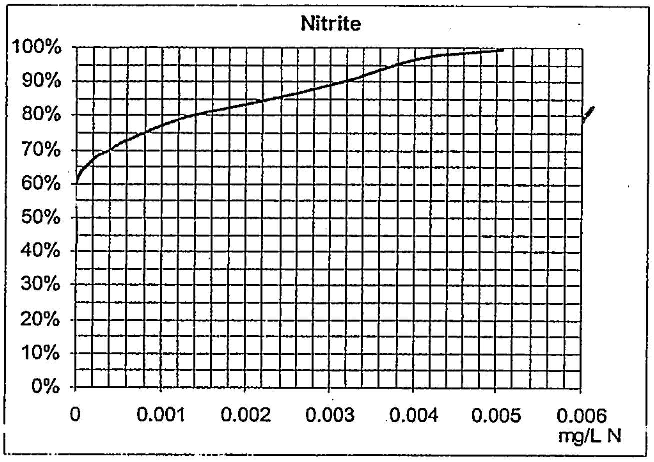
- Predicted and observed flows



[redacted]

- Cumulative probabilities




Nitrite
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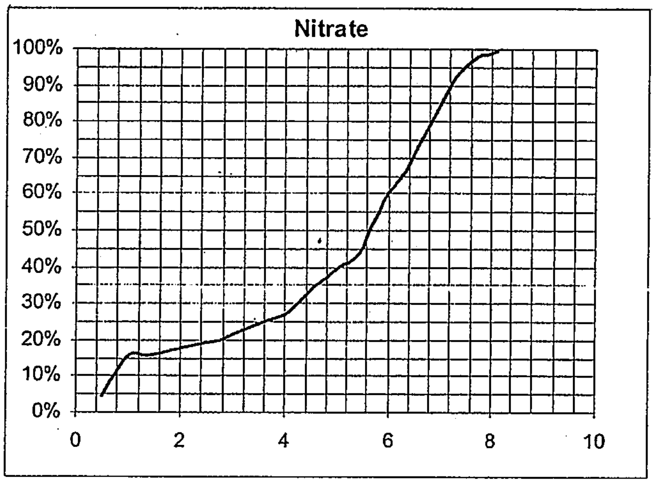
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
0.001
0.002
0.003
0.004
0.005
0.006
mg/L N

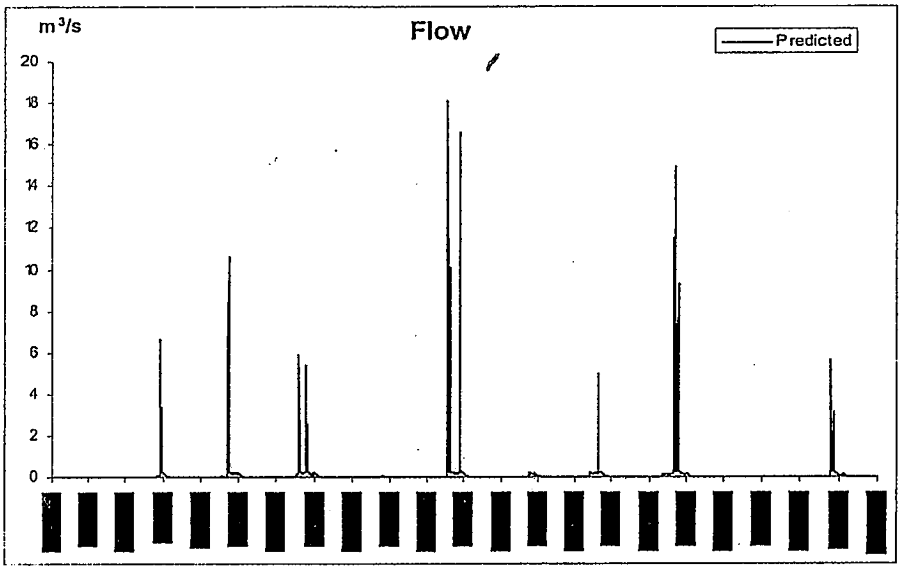

Nitrate
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
2
4
6
8
10

Appendix 8: Wheeler Canyon

- Critical condition----Low flows and corresponding water quality data

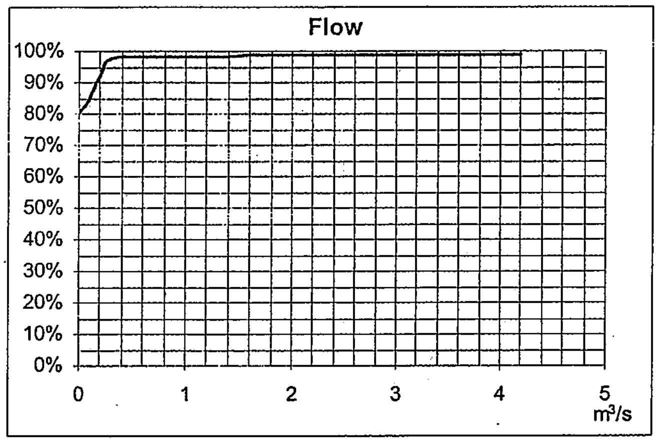
	Water year	Flow (m³/s)	Ammonia (mg/L N)	pH	T (°C)	Nitrite (mg/L N)	Nitrate (mg/L N)
1Q	89-90	0					
	90-91	0					
	91-92	0.0025	0.0001	8.4458	14.9314	0.00003	0.2803
	92-93	0.0023	0.0001	8.5168	12.8516	0.00004	0.3870
	93-94	0.0021	0.0001	8.5812	11.8287	0.00004	0.4800
	94-95	0.0022	0.0001	8.6111	11.8475	0.00004	0.4285
	95-96	0.0022	0.0001	8.6069	16.4800	0.00003	0.4819
	96-97	0.0023	0.0001	8.6087	20.8684	0.00003	0.5215
	97-98	0.0020	0.0001	8.6500	15.7473	0.00004	0.5234
	98-99	0.0006	0.0001	8.6983	19.6486	0.00003	0.6328
	99-00	0.0002	0.0002	8.7873	12.8913	0.00005	0.6640
7Q	89-90	0					
	90-91	0					
	91-92	0.0025	0.0001	8.4521	14.2461	0.00004	0.2800
	92-93	0.0023	0.0001	8.5210	12.6508	0.00004	0.3869
	93-94	0.0021	0.0001	8.5569	14.3502	0.00004	0.4797
	94-95	0.0022	0.0001	8.5945	13.5916	0.00004	0.4280
	95-96	0.0022	0.0001	8.5954	16.8640	0.00003	0.4813
	96-97	0.0023	0.0001	8.6022	21.3824	0.00002	0.5214
	97-98	0.0020	0.0001	8.6669	14.5872	0.00004	0.5228
	98-99	0.0007	0.0001	8.7110	18.5372	0.00003	0.6323
	99-00	0.0002	0.0002	8.7758	14.3077	0.00005	0.6636
30Q	89-90	0					
	90-91	0					
	91-92	0.0025	0.0001	8.4469	14.6844	0.00003	0.2789
	92-93	0.0024	0.0001	8.5105	13.5899	0.00004	0.3854
	93-94	0.0021	0.0001	8.5519	14.8375	0.00004	0.4756
	94-95	0.0022	0.0001	8.5935	13.7508	0.00004	0.4266
	95-96	0.0023	0.0001	8.6105	14.9006	0.00003	0.4775
	96-97	0.0025	0.0001	8.6207	16.0060	0.00003	0.5177
	97-98	0.0021	0.0001	8.6492	16.3416	0.00003	0.5213
	98-99	0.0008	0.0001	8.7159	17.4621	0.00004	0.6301
	99-00	0.0003	0.0002	8.7768	13.6691	0.00005	0.6582

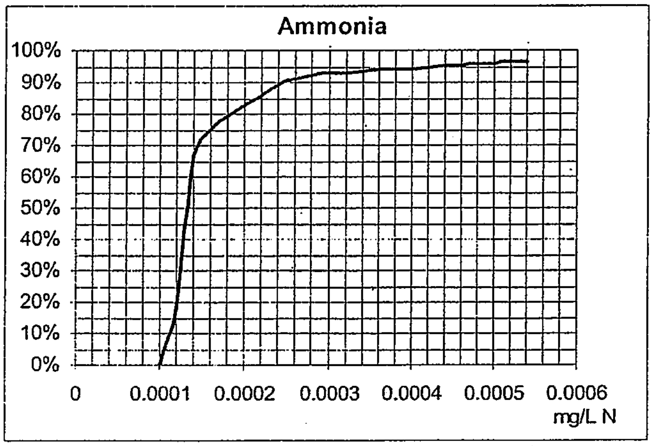
- Predicted flows

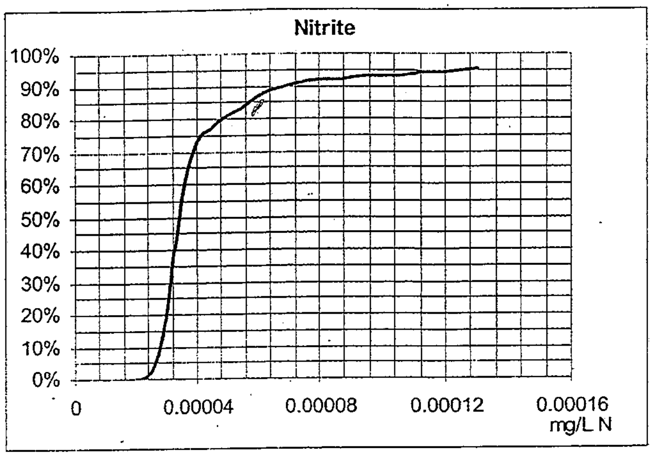


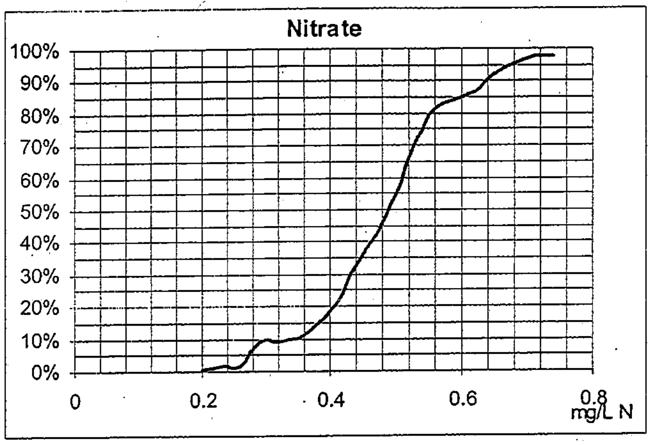
[redacted]

- Cumulative probabilities






Nitrite
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
0.00004
0.00008
0.00012
0.00016
mg/L N


Nitrate
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
0.2
0.4
0.6
0.8
mg/L N

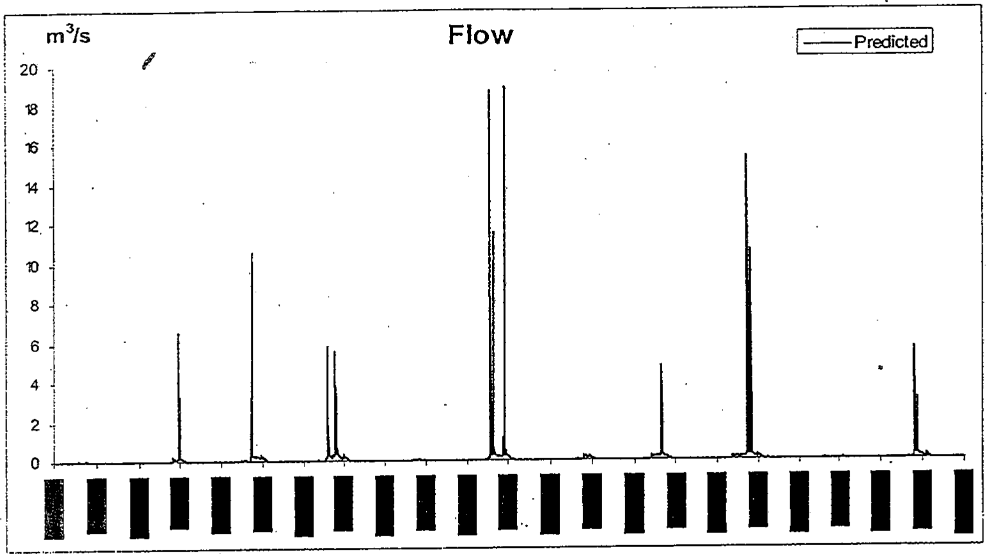
Appendix 9: Todd Barranca

- Critical condition----Low flows and corresponding water quality data

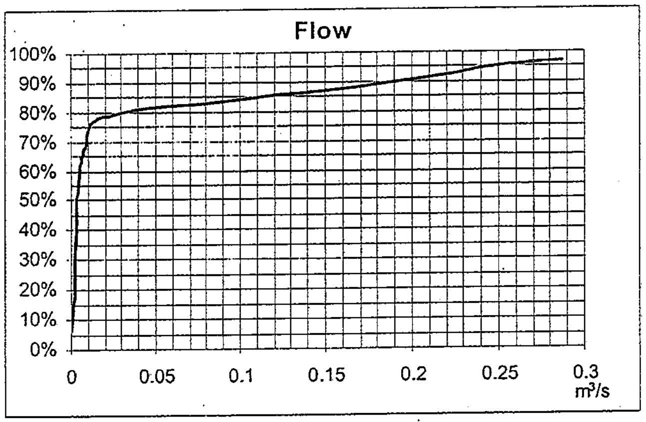
	Water year	Flow (m^3/s)	Ammonia (mg/L N)	pH	T (°C)	Nitrite (mg/L N)	Nitrate (mg/L N)
1Q	89-90	0					
	90-91	0.000003	0.0027	8.5857	17.3775	0.0009	6.9787
	91-92	0.0026	0.0002	8.6226	20.2618	0.0001	0.3834
	92-93	0.0025	0.0006	8.6155	20.9501	0.0002	0.3970
	93-94	0.0024	0.0003	8.6776	17.5237	0.0001	0.4661
	94-95	0.0025	0.0034	8.7337	14.4922	0.0855	2.8210
	95-96	0.0025	0.0072	8.7301	15.6771	0.0029	0.5073
	96-97	0.0023	0.0002	8.7119	22.5720	0.0000	0.5216
	97-98	0.0021	0.0202	8.7653	16.1378	0.0082	0.6744
	98-99	0.0007	0.0002	8.8013	20.3100	0.0001	0.6313
	99-00	0.0004	0.0003	8.8548	14.9445	0.0001	0.6254
7Q	89-90	0					
	90-91	0.000005	0.0023	8.5192	17.3643	0.0008	5.4010
	91-92	0.0027	0.0002	8.6197	20.4508	0.0001	0.3833
	92-93	0.0025	0.0010	8.6363	18.7670	0.0007	0.6956
	93-94	0.0024	0.0093	8.6824	17.1810	0.0035	0.4998
	94-95	0.0025	0.0032	8.7218	15.3828	0.0770	2.7980
	95-96	0.0025	0.0279	8.7306	15.7261	0.0162	0.9284
	96-97	0.0023	0.0002	8.7092	23.0214	0.0000	0.5216
	97-98	0.0021	0.0909	8.7718	14.7029	0.0909	1.3621
	98-99	0.0007	0.0003	8.8083	19.1372	0.0001	0.6302
	99-00	0.0004	0.0162	8.8592	14.4072	0.1653	2.0548
30Q	89-90	0					
	90-91#	0.000006	0.0015	8.3975	16.9546	0.0005	2.6078
	91-92	0.0028	0.0176	8.6051	18.6526	0.0505	3.2312
	92-93	0.0026	0.0105	8.6386	17.9941	0.0065	0.7104
	93-94	0.0025	0.0316	8.6964	15.6735	0.1201	5.0736
	94-95	0.0025	0.0107	8.7031	17.3636	0.0800	3.1531
	95-96	0.0025	0.0300	8.7320	15.7864	0.0155	0.8286
	96-97	0.0025	0.0002	8.7137	22.0644	0.00005	0.5205
	97-98	0.0022	0.1091	8.7578	16.2723	0.1940	2.4299
	98-99	0.0008	0.0003	8.8158	17.7333	0.0001	0.6284
	99-00	0.0005	0.1026	8.8422	14.8816	0.5948	6.5001

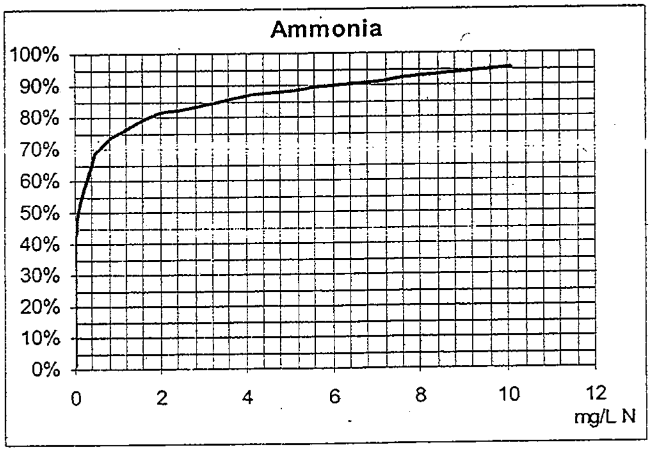
The predicted water quality data are incomplete during these periods due to the zero predicted flows

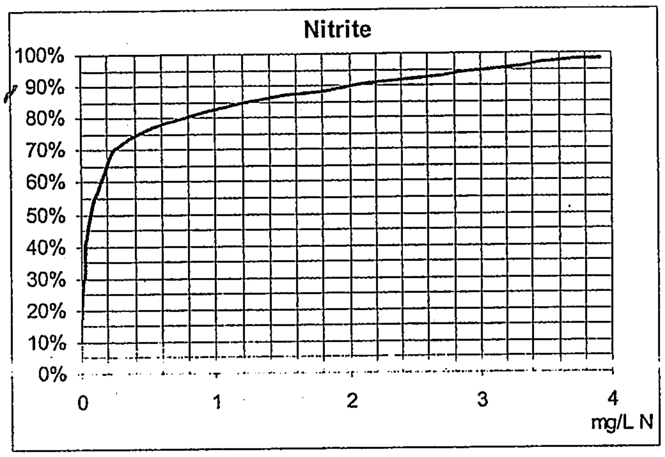
- Predicted flows

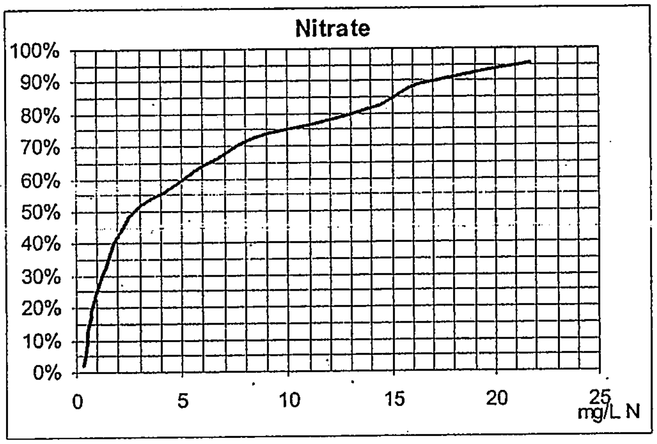


- Cumulative probabilities






Nitrite
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
mg/L N

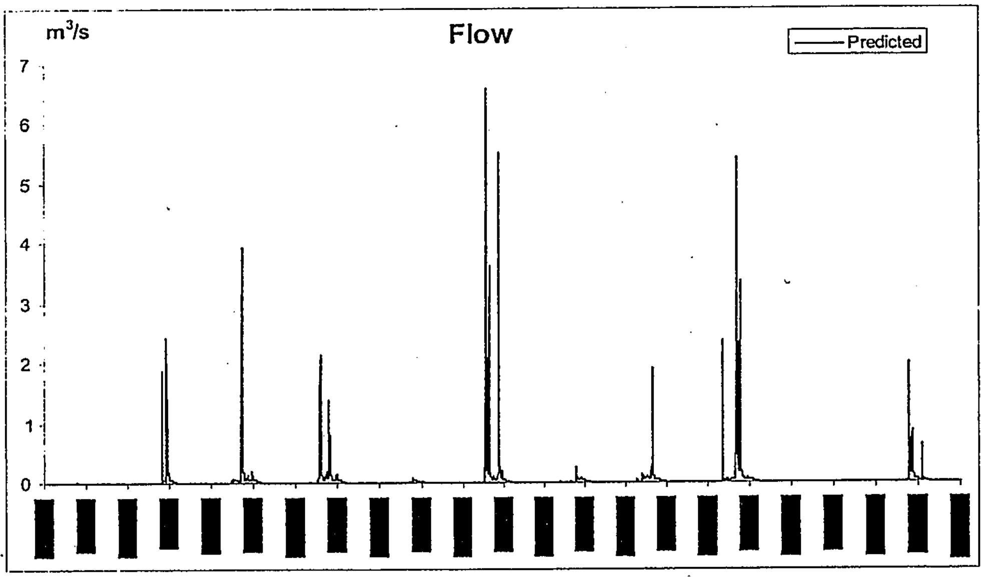

Nitrate
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
5
10
15
20
25
mg/L N

Appendix 10: Brown Barrance / Long Canyon

- Critical condition----Low flows and corresponding water quality data

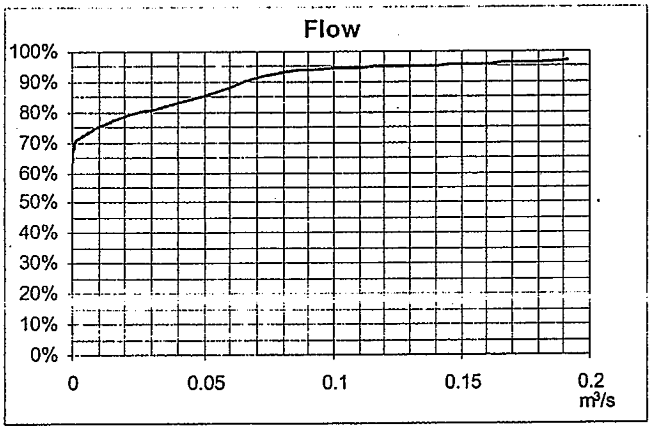
	Water year	Flow (m^3/s)	Ammonia (mg/L N)	pH	T (°C)	Nitrite (mg/L N)	Nitrate (mg/L N)
1Q	89-90	0					
	90-91	0					
	91-92	0					
	92-93	0					
	93-94	0					
	94-95	0					
	95-96	0					
	96-97	0					
	97-98	0					
	98-99	0					
	99-00	0					
7Q	89-90	0					
	90-91	0					
	91-92	0					
	92-93	0					
	93-94	0					
	94-95	0					
	95-96	0					
	96-97	0					
	97-98	0					
	98-99	0					
	99-00	0					
30Q	89-90	0					
	90-91	0					
	91-92	0					
	92-93	0					
	93-94	0					
	94-95	0					
	95-96	0					
	96-97	0					
	97-98	0					
	98-99	0					
	99-00	0					

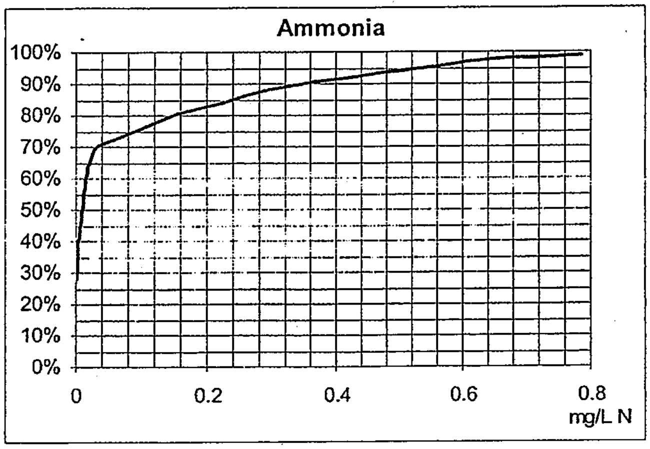
- Predicted flows

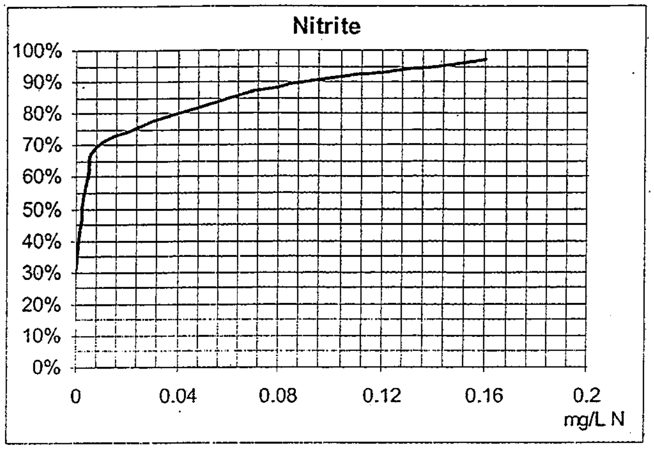


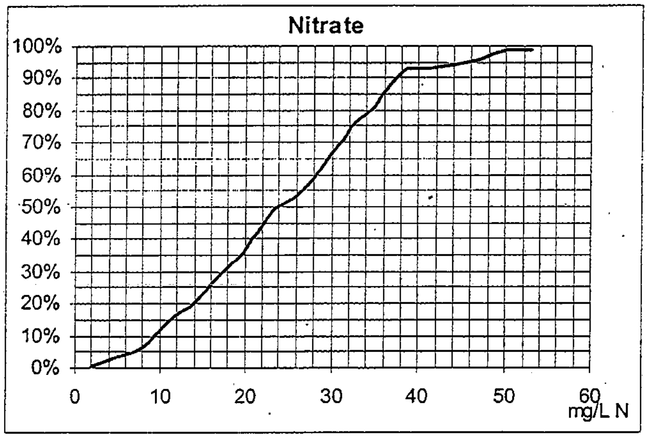
[redacted]

- Cumulative probabilities






Nitrite
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
0.04
0.08
0.12
0.16
0.2
mg/L N


Nitrate
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
10
20
30
40
50
60
mg/L N

Analysis of potential nutrient load allocation for the reaches of the Santa Clara River considered in the 1998 303(d) list

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University of California, Santa Barbara

1. Introduction

This study evaluates a number of nutrient load allocations from Point and Non-Point Sources (PS and NPS) present in the reaches of the Santa Clara River (SCR) considered in the 1998 303(d) listing, namely Reaches 3, 7 and 8 based on the US EPA designation (Figure 1 and 2). For modeling purposes, these reaches have been segmented further, providing an opportunity to consider water quality monitoring data for a number of segments, and to evaluate the PS and NPS loads for each segment. The segments are presented in Figures 1 and 2, using the identification number used in the WARMF model; the approximate location of the segment boundaries is presented in Table 1 for reference, as well as a descriptor of each segment. For this analysis, the WARMF model was used as described in the Task 2 Linkage Analysis, with a refined calibration of the nitrogen processes as described in Appendix A.

Table 1. Identification of river segments in Santa Clara River

ID	Segment Designation	Approximate boundaries of SCR segment
7	Reach 3 below Santa Paula	Between Adams Canyon and Todd Barranca
9	Reach 3 at Santa Paula	Between Todd Barranca and Santa Paula Creek
69	Reach 3 above Santa Paula	Above Santa Paula Creek and below Reach 4
111	Reach 7 at County Line	Between Salt Canyon and Potrero Canyon Creeks
56	Reach 7 below Valencia	Between Castaic Creek and Valencia WWTP*
129	Reach 7 above Valencia	Between Valencia WWTP and Highway 5
159	Reach 8	Between Bouquet Canyon Creek and the South Fork

*WWTP = Waste Water Treatment Plant

The load allocations require a consideration of the Water Quality Objectives (WQO), which are defined in the LA RWQCB Basin Plan. In addition, Numerical Targets have been defined by the LA RWQCB based on the WQO, with the intent of serving as an early warning system and thus prevent the exceedence of the WQO. For example, in most reaches the combined nitrate plus nitrite WQO is 5.0 mg/L as $N\text{-}NO_3 + N\text{-}NO_2$, except in Reach 8 where the WQO is 10.0 mg/L as $N\text{-}NO_3 + N\text{-}NO_2$. The Numerical Target has been set with a 10% explicit Margin of Safety (MOS), such that it is 4.5 mg/L as $N\text{-}NO_3 + N\text{-}NO_2$ in most reaches except Reach 8 where it is 9.0 mg/L as $N\text{-}NO_3 + N\text{-}NO_2$. The LA RWQCB expects that the Numerical Target will be met 95% of the time or better.

In the case of ammonia, the WQO is based on the US EPA 1999 Update of Ambient

Water Quality Criteria for Ammonia (ref.), which indicates that the thirty-day average concentration of total ammonia as nitrogen (in mg N/L) shall not exceed (more than once every three years on average) the criteria continuous concentration (CCC) calculated as follows:

Where early life stage fish are present:

$$CCC = \left(\frac{0.0577}{1+10^{7.688-pH}} + \frac{2.487}{1+10^{pH-7.688}} \right) * MIN(2.85, 1.45x10^{0.028*(25-T)})$$

Where early life stage fish are not present:

$$CCC = \left(\frac{0.0577}{1+10^{7.688-pH}} + \frac{2.487}{1+10^{pH-7.688}} \right) * 1.45x10^{0.028*(25-MAX(T,7))}$$

with T = temperature in °C.

The statistics of observed pH and temperature in the SCR are presented in Tables 2 and 3. For calculation of the CCC, the appropriate statistics are the 50-percentile pH and temperature. The 50-percentile pH generally increases while the 50-percentile temperature generally decreases from upstream to downstream locations. Using this information, the CCC for each segment are calculated using the two equations and are presented in Table 4. A 10% MOS is considered for the Ammonia Numerical Target, using the same rationale as for the Nitrate plus Nitrate Numerical Target. Note that based on the temperature in these segments of the SCR, there is no need to differentiate between the two CCC.

Table 2. Statistics of observed pH data

Statistic	Reach 8	Reach 7 above Valencia	Reach 7 below Valencia	Reach 7 at County Line	Reach 3 above Santa Paula	Reach 3 at Santa Paula	Reach 3 below Santa Paula
50 percentile	7.33	7.89	7.78	8.20	8.00	8.00	8.08
90 percentile	7.53	8.16	8.04	8.30	8.30	8.30	8.35
95 percentile	7.62	8.24	8.17	8.41	8.37	8.37	8.43
Mean	7.31	7.85	7.73	8.15	8.00	8.00	8.03
Std. deviation	0.22	0.29	0.31	0.21	0.26	0.26	0.31
CV*	0.03	0.04	0.04	0.03	0.03	0.03	0.04

*CV = coefficient of variation

Table 3. Statistics of temperature data (in °C)

Statistic	Reach 8	Reach 7 above Valencia	Reach 7 below Valencia	Reach 7 at County Line	Reach 3 above Santa Paula	Reach 3 at Santa Paula	Reach 3 below Santa Paula
50 percentile	19.89	18.23	20.22	19.03	16.68	16.81	16.81
90 percentile	24.34	23.68	25.32	24.59	19.00	19.73	19.87
95 percentile	25.02	24.58	25.90	25.41	19.48	20.44	20.57
Mean	19.55	18.43	20.21	19.22	16.39	16.52	16.52
Std. deviation	3.92	4.05	3.97	4.15	2.32	2.78	2.85
CV*	0.20	0.22	0.20	0.22	0.14	0.17	0.17

Table 4. Ammonia Water Quality Objective and Numerical Target (mg/L as N-NH_3)

	Reach 8	Reach 7 above Valencia	Reach 7 below Valencia	Reach 7 at County Line	Reach 3 above Santa Paula	Reach 3 at Santa Paula	Reach 3 below Santa Paula
CCC w/early life stages	3.50	2.19	2.23	1.29	2.06	2.04	1.80
CCC w/o early life stages	3.50	2.19	2.23	1.29	2.06	2.04	1.80
Numerical Target	3.15	1.97	2.00	1.16	1.85	1.84	1.62

The Total Maximum Daily Load (TMDL) for each segment must be divided into a Waste Load Allocation (WLA) from point sources and a Load Allocation (LA) from non-point sources. In addition, the TMDL must consider an MOS and Future Growth (FG), such that:

TMDL = WLA + LA + MOS + FG

MOS can be implicit or explicit. For example, considering a 10% MOS for the WQO in determining the Numerical Targets is an explicit MOS. If an additional MOS is considered based on uncertainty in the model, due to data limitations and/or model assumptions, this is considered an implicit MOS.

FG can be considered in several ways. For the two WWTP in LA County, Saugus and Valencia, the information from the LA County Sanitation Districts (LACSD) indicates that these two plants will be upgraded to a capacity of 6.5 MGD and 21.6 MGD, respectively. For the Fillmore and Santa Paula area, we have considered that the Fillmore plant will be phased out and that all of its flow will be directed to the upgraded Santa Paula WWTP. We then applied a growth factor of 1.2 to their combined flow, considering the slower growth rate in this area. The current and projected flowrates for these facilities is presented in Table 5. For agricultural NPS, no additional future growth was considered since the acreage devoted to agriculture is unlikely to increase, given the increasing urbanization of the watershed. There is the potential to convert orchards (e.g. citrus or avocado) to row crops, but this was not evaluated in this analysis given the lack of information on such plans.

Table 5. Current and projected flowrates of major point sources in SCR (in m^3/s)

	Current	Projected	Increase
Saugus	0.24	0.28475	18.6%
Valencia	0.50	0.94625	89.3%
Santa Paula & Fillmore	0.15	0.18	20 %

2. PS Loading Analysis

The scenarios were constructed using observed meteorological conditions, from 10/01/1989 to 9/30/2000, based on the calibrated WARMF model. Several PS loading scenarios were considered by modifying the ammonia, nitrate and nitrate concentrations in the treated WWTP effluent at the flowrates indicated in Table 5. One important consideration is the interaction between various nitrogen species, since ammonia oxidizes to nitrite which then oxidizes to nitrate. Ammonia, nitrite and nitrate can also be assimilated by the in-stream and riparian vegetation, and ammonia may also be lost to the atmosphere due to volatilization. Nitrate might be reduced to nitrogen gas under low oxygen conditions, such as those that might exist in some sediments and in slow-flowing pools along the river. Thus, loading scenarios have to consider all these interactions.

One possible scenario would be to consider PS effluent concentrations at the Numerical Targets for the respective nutrients. Simulations for various segments of the SCR are presented in Figures 3-16, considering the effluent concentrations presented in Table 6.

Table 6. Effluent Concentrations at Numerical Targets for each segment

	NH_3 (mg/L)	NO_2 (mg/L)	NO_3 (mg/L)	Flowrate (m^3/s)
Saugus	3.15	0.1	9.0	0.28475
Valencia	2.00	0.1	4.5	0.94625
Santa Paula + Fillmore	1.84	0.1	4.5	0.18

This scenario results in concentrations in the SCR below the Numerical Targets at all times for all segments below the Valencia WWTP. However, due to some episodic NPS load of ammonia and nitrate entering Reach 8, the ammonia Numerical Target could be exceeded 10 % of the time, during the first significant storms of the winter (Figure 3). It is important to note that the ammonia WQO is based on a 30-day average concentration, not an instantaneous sample or even a daily average value. The ammonia WQO for a daily average is approximately an order of magnitude greater than the CCC, such that these levels of ammonia would have no observable effect on even the most sensitive species. Nitrate + nitrite concentrations would exceed the Numerical Target 6 % of the time, generally during the same rain events (Figure 4). The nitrate + nitrite WQO would only be exceeded less than 0.1 % of the time in Reach 8. Ammonia concentrations decrease noticeably in the upper part of Reach 7, such that in the segment between Highway 5 and the Valencia WWTP the Numerical Target is only exceeded one day (Figure 5) through the eleven-year simulation period (compliance better than 99.9% of the time). Nitrate + nitrite concentrations in this segment of Reach 7 above the Valencia WWTP could exceed the Numerical Target around 21 % of the time, at the end of the dry-weather season and during the first significant storms. Nitrate + nitrite concentrations rise in these upper segments of Reach 7 as ammonia is partially transformed to nitrite and nitrite to nitrate.

One alternative scenario involves reducing the ammonia loading from the Saugus WWTP, by reducing effluent concentrations for example to 2.0 mg/L as N-NH_3, leaving all other effluent concentrations as shown in Table 6. The results for Reach 8 and the Reach 7 segment immediately above the Valencia WWTP are presented in Figures 17 and 18. Under these conditions, the ammonia Numerical Target is met at all times with only one exceedence through the 11-year simulation period. Nitrate + nitrite concentrations would still exceed the Numerical Target around 6 % of the time, although the nitrate + nitrite WQO might only be exceeded less than 0.1 % of the time in Reach 8. The concentrations of ammonia and nitrate + nitrite at the segment above Valencia WWTP would decrease, with only one day of exceedence of the ammonia Numerical Target and WQO, and compliance with the nitrate + nitrite Numerical Target 91.5% of the time. However, the nitrate + nitrite WQO would be exceeded about 1 % of the time during the eleven years. Concentrations of ammonia and nitrate + nitrate are slightly lower in the lower segments of the SCR, since the overall nitrogen loading is reduced upstream.

Another scenario considers the expected performance of upgraded WWTPs. The LACSD and the Santa Paula WWTP plants are in the process of upgrading to include a Nitrification-Denitrification (NDN) module. From practical experience with the NDN process at the Whittier WWTP, the LACSD considers that it can control ammonia effluent concentrations to below 2.0 mg/L as $N\text{-}NH_3$, 0.1 mg/L as $N\text{-}NO_2$ and around 8.0 mg/L as $N\text{-}NO_3$. The statistics of the performance of the Whittier WWTP for the last two years (January 2001-January 2003) are presented in Table 7. Nitrate concentrations in the Whittier effluent varied significantly, possibly due to seasonal variations in performance. It is assumed that the upgraded Santa Paula facility can also meet these conditions.

Table 7. Performance of Whittier WWTP

	NH_3 (mg/L)	NO_2 (mg/L)	NO_3 (mg/L)
Number of observations	112	33	32
50 percentile	1.13	0.03	6.36
90 percentile	1.73	0.09	7.55
95 percentile	1.86	0.11	7.83
99 percentile	1.99	0.16	8.03

The effluent conditions considered in this scenario are presented in Table 8. Although the scenario was evaluated with both current and future flowrates, only the higher flowrate is presented here.

Table 8. Effluent Concentrations considering Whittier WWTP experience

	NH_3 (mg/L)	NO_2 (mg/L)	NO_3 (mg/L)	Flowrate (m^3/s)
Saugus	3.15	0.1	8.0	0.28475
Valencia	2.00	0.1	8.0	0.94625
Santa Paula + Fillmore	1.84	0.1	8.0	0.18

Based on this scenario, ammonia concentrations in Reach 8 remain at the same level as presented in Figure 3, with a 10% exceedence of the numerical target. Nitrate + nitrite concentrations in Reach 8 (Figure 21) decrease to a level where the numerical target is achieved more than 99% of the time and the WQO is not exceeded in the 11-year simulation.

Ammonia concentrations in the segment of Reach 7 above the Valencia WWTP are the same as presented in Figure 5. Nitrate + nitrite are under the numerical target 87% of the time, with exceedences most likely at the end of the dry season or the first strong storm events (Figure 22). Ammonia concentrations below Valencia are the same as in Figures 7. Nitrate + nitrite concentrations below Valencia would exceed the numerical target in this reach (ID 56) around 47% of the time (Figure 23). The 90-percentile concentration is 5.43 mg/L. In the segment at the County Line (ID 111), the concentrations of ammonia are the same as in Figure 9; nitrate + nitrite concentrations are under the numerical target more than 99% of the time (Figure 24).

Ammonia concentrations in all segments of Reach 3 are the same as presented in Figures 11, 13 and 15. Nitrate + nitrite concentrations above Santa Paula are only slightly increased from Figure 12, due to the higher nitrate loading upstream, but are well under the numerical target all of the time. At Santa Paula, nitrate + nitrite concentrations increase by around 22% (Figure 25), but would still be well below the numerical target, with compliance throughout the entire 11-year simulation period. The situation below Santa Paula is also under compliance with the numerical target.

Based on these initial results, an Intermediate scenario was constructed, with the goal of meeting the numerical targets and yet recognize the feasibility of performance of the upgraded NDN processes at the WWTPs. Presented here is the result of many iterations to find a suitable balance between nitrogen compounds, as ammonia, nitrite and nitrate loading all contribute to the nitrate + nitrite numerical target. In addition, there is a need to balance the total nitrogen loading from the Saugus and Valencia WWTP, since effluent from Saugus affects the levels of nitrate below Valencia. This is somewhat complicated due to the sharp change in the nitrate + nitrite WQO between Reach 7 and 8. The Intermediate scenario conditions are presented in Table 9.

Table 9. Effluent Concentrations for Intermediate scenario

	NH_3 (mg/L)	NO_2 (mg/L)	NO_3 (mg/L)	Flowrate (m^3/s)
Saugus	2.00	0.1	7.00	0.28475
Valencia	1.75	0.1	6.70	0.94625
Santa Paula + Fillmore	2.00	0.1	8.00	0.18

The simulation results are presented in Figures 26-37. With the lower effluent concentrations from the Saugus WWTP (even below the numerical targets for Reach 8), the ammonia and numerical targets for Reach 8 and segment 129 (Reach 7 above Valencia) are met throughout the 11-year simulation (Figures 26-29) more than 95 % of the time. Nitrite + nitrite concentrations in segment 129 are below 4.34 mg/L 95% of the time.

Ammonia concentrations below Valencia and down to the County Line (Figures 30 and 32) are well below the numerical target for these segments of Reach 7. Nitrate + nitrite in segment 129 is in compliance with the numerical target exactly 95% of the time (Figure 31). This is the tightest condition in the entire watershed and would require frequent monitoring to ensure compliance. Once the river flows down to the County Line, the nitrate + nitrite numerical target is met all the time throughout the 11-year simulation period (Figure 33).

Both the ammonia and nitrate + nitrite numerical targets are met above, at and below Santa Paula all the time throughout the 11-year simulation period under the Intermediate Scenario (Figures 34-37). The higher assimilative capacity in Reach 3 as well as reduced nitrogen loading relative to current operating conditions for the Santa Paula and Fillmore WWTPs results in full compliance.

The nitrogen compound loads corresponding to the Intermediate Scenario can be divided into current and future load, as presented in Table 10.

Table 10. Current and future loads considering Intermediate scenario

	Current Load			Future Load		
	NH_3 (kg/day)	NO_2 (kg/day)	NO_3 (kg/day)	NH_3 (kg/day)	NO_2 (kg/day)	NO_3 (kg/day)
Saugus	41.5	2.1	145.2	49.2	2.5	172.2
Valencia	75.6	4.3	289.4	143.1	8.2	547.8
Santa Paula + Fillmore	25.9	1.3	103.7	31.1	1.6	124.4

3. NPS Loading Analysis

The previous analysis considers changes in nitrogen loading from the three major point sources while the NPS nitrogen loading remains at levels similar to existing conditions. However, the flowrates will be higher than in the calibration scenario, given that we are considering a significant increase in overall WWTP flowrates (Table 5). Thus, the relative contribution of the NPS to overall in-stream loading varies with respect to the original calibration. One way to evaluate the role of these smaller sources, including the small PS as well as NPS such as atmospheric deposition, septic tanks, fertilizer application in farms and residential areas, etc., is to set the nitrogen compound loading to zero and observe the resulting water quality. The results of this simulation are presented in Figures 38-51.

NPS loading in Reach 8 and above is significant, both for ammonia and nitrate. Nitrite NPS loading in general is very low throughout the watershed, given that there sources are very small, so it won't be discussed in specific, although we do present the simulated nitrate + nitrite concentrations for an accurate comparison against the previous scenarios. Atmospheric deposition of both ammonia and nitrate is important in Reaches 8 and 9 of the Santa Clara River, given the proximity to the greater Los Angeles basin, where a significant amount of these air pollutants is emitted, and the very large surface area of these two Reaches. Nitrate is produced from the transformation of nitrogen oxides (NOx) to nitric acid and then nitrate. Ammonia appears to be delivered to the river mostly in storm events (Figure 38), while nitrate loading is also through shallow groundwater flows, with an average nitrate + nitrite concentration in the river of 1.5 mg/L (Figure 39). Large storm events flush the landscape, resulting in some peak concentrations.

The contribution from NPS loading of ammonia and nitrate decreases in Reach 7, as these compounds are assimilated. The overall surface area of Reach 7 is smaller, decreasing the magnitude of the loading from atmospheric deposition. The population served by septic systems is also much smaller, given the higher level of urbanization than in Reaches 8 and 9 in particular. Thus, the in-stream concentrations generally decrease going downstream. As in Reach 8, ammonia contributions are mostly driven by storm events (Figures 40, 42 and 44), while nitrate has both groundwater and storm event contributions (Figures 41, 43 and 45).

In Reach 3, NPS ammonia loading is negligible (Figures 46, 48 and 50). Nitrate loading is quite significant above Santa Paula (Figure 47), with an average nitrate + nitrite concentration of 1.26 mg/L. The contributions from NPS nitrate loads decreases going downstream, both due to dilution in WWTP effluent and assimilation or transformation of nitrate.

With respect to increases in NPS loading in the future, the conditions at and below the Valencia WWTP dictate what can be done in Reaches 8 and 9. Additional NPS loading in these areas needs to be assimilated before it reaches the Valencia WWTP, or be associated with sufficient flow to dilute the concentrations in the river.

In Reach 7 below segment 129, the proportion of farmland relative to other land uses increases to 7-8% of the total land surface, and is generally located close to the river. Although there is room for additional NPS loading in these segments (Figures 32 and 33), this region should also be monitored frequently to ensure compliance with the numerical targets. If urbanization of this region is approved, a reevaluation of loading should be considered, even if most of the loading is in the form of subsurface discharges.

4. Margin of Safety

An explicit 10% MOS has been considered in all the numerical targets. For regions with frequent monitoring, such as segment 159 of Reach 8 and segments 56 and 129 of Reach 7, this safety level appears adequate. Monitoring in these segments should be increased during the critical conditions, namely at the end of the dry season and during the first strong storm events. It would also be recommendable to increase monitoring above the Saugus WWTP, to have a better picture of NPS loading from Reach 9 and tributaries in that area. Given the sparseness of monitoring data in this upper part of the watershed, partially as a result of very low flows during most of the year, these segments of the river could not be calibrated in the WARMF model. Additional information might allow for a reassessment of PS and NPS loading in Reaches 7 and 8.

For the region below segment 129, as the river enters the farmland in the lower Reach 7, the 95 percentile nitrate + nitrite concentration is 3.55 mg/L. Under current conditions, the difference between the WQO of 5 mg/L and this concentration is around 30%. This should be sufficiently ample difference to meet the WQO. Increased frequency of monitoring during the critical conditions should result in higher confidence in model results, without the need to formally establish a higher MOS.

In Reach 3, the simulation results indicate that ammonia and nitrate + nitrite concentrations will be more than 30% below the WQO, and in some cases even 80 or 90% below the WQO. Thus, there is no need to formally establish a larger MOS. However, monitoring data in Reach 3 has been sparse in the past, so an increased monitoring frequency is recommendable, particularly during the critical conditions.

5. Discussion and Recommendations

The guiding objective of this load allocation analysis was to meet the Water Quality Objectives. To ensure that the objectives are met, a 10% explicit Margin of Safety was incorporated into the Numerical Targets. A 95% compliance of the Numerical Targets or better was considered appropriate. There are a number of approaches to developing scenarios, and the interests of the various stakeholders must be taken into consideration. The Intermediate Scenario attempts to strike a balance, providing the desired environmental benefit by protecting the intended uses of the Santa Clara River at a reasonable cost, which will be borne mostly by the residents of the Santa Clara River watershed.

There are a number of built-in assumptions in the Intermediate Scenario, which provide additional safety. For example, the simulations have been conducted at higher flowrates than the situation that will be present during the first few years of operation of the upgraded WWTP. Thus, nitrogen loading will be lower than the scenario considers. PS loading has been considered towards the upper range of the experience at the Whittier WWTP, to provide an additional margin of safety. The calibration refinement tends to slightly overpredict concentrations in most cases.

In addition, an increased monitoring program, particularly in those segments where the concentrations are close to the numerical target, and during the critical conditions, should adequately provide information to make refinements in the load allocations in future years.

In addition, studies should be conducted to address the follow assumptions:

- **Rapid nitrogen compound disappearance in Reaches 7 and 8**: the observed data implies a rapid disappearance of ammonia, nitrite and nitrate in the upper SCR. Whether this will continue to be the case when the WWTP are upgraded to NDN needs to be monitored. Changes in conditions might result in the need to refine the model and revisit the load allocations.
- **Atmospheric deposition**: an important NPS load in the upper watershed is atmospheric deposition. The magnitude of this load was estimated in the source analysis, but it would be of use to all the stakeholders in the upper watershed to know if the assumptions are correct, and it might lead to either increased or decreased loading from other sources.
- **Nitrate loading via groundwater discharge**: The WARMF model uses prescribed groundwater (GW) discharge flows along the various segments. Nitrate concentrations in these GW discharges is based on the initial condition in 1989 (from the USGS report), incremented over time with N loading to the surface that migrates into the various layers of the aquifer. However, given the nature of the WARMF model, the nitrate concentrations are homogeneous for each layer of the aquifer, based on the assumption of

immediate mixing in a layer. Thus, the nitrate loading via GW discharge might be underestimated in areas where the nutrient load is concentrated and is near the discharge area. A study to collect GW nitrate concentrations at the discharge points as well as corresponding surface water concentrations immediately above and below the discharge would reduce the uncertainty associated with this loading. The study should consider spatial and temporal variability.

Other studies might be recommended in the future, but these three issues are key for the current load allocation.

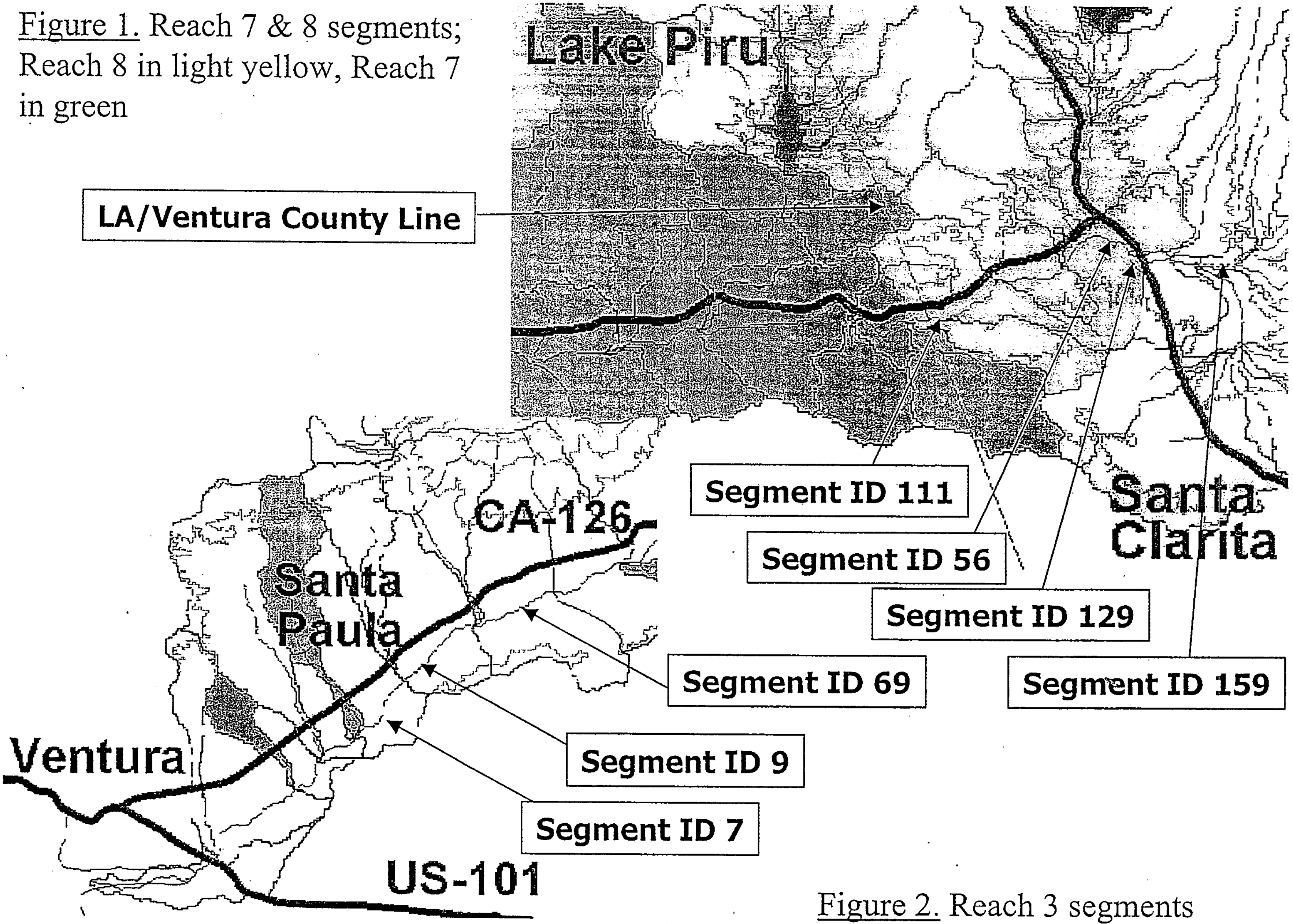


Figure 1. Reach 7 & 8 segments; Reach 8 in light yellow, Reach 7 in green

Figure 2. Reach 3 segments

Figure 3. Simulated ammonia concentrations in Reach 8 considering Saugus effluent at numerical targets

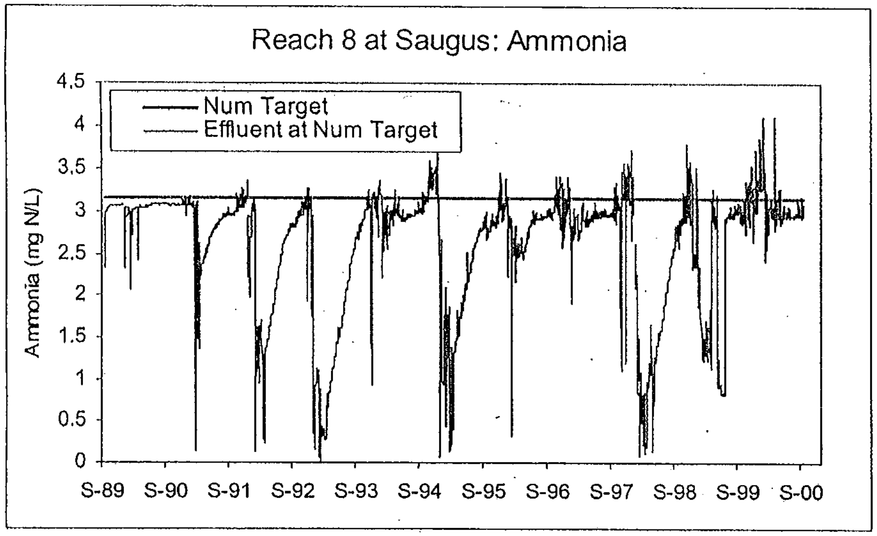


Figure 4. Simulated nitrate + nitrite concentrations in Reach 8 considering Saugus effluent at numerical targets

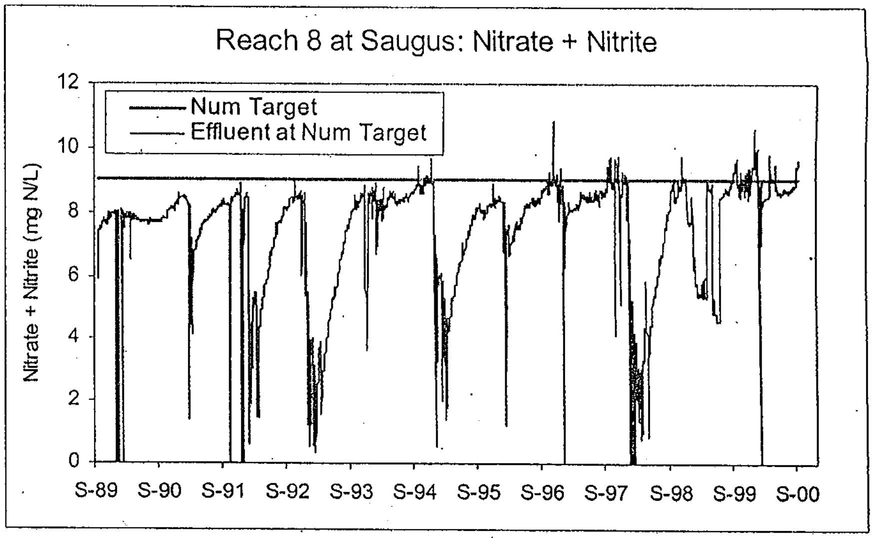


Figure 5. Simulated ammonia concentrations in Reach 7 above Valencia considering Saugus effluent at numerical targets

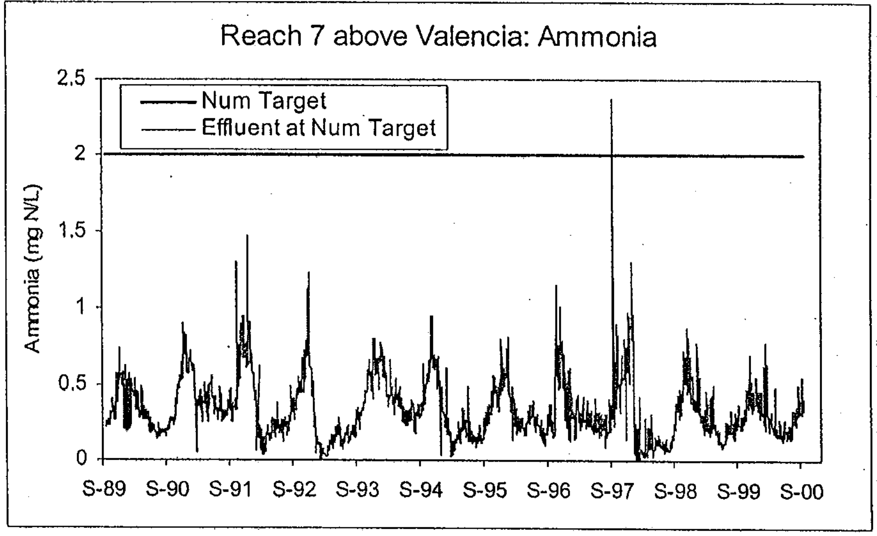


Figure 6. Simulated nitrate + nitrite concentrations in Reach 7 above Valencia considering Saugus effluent at numerical targets

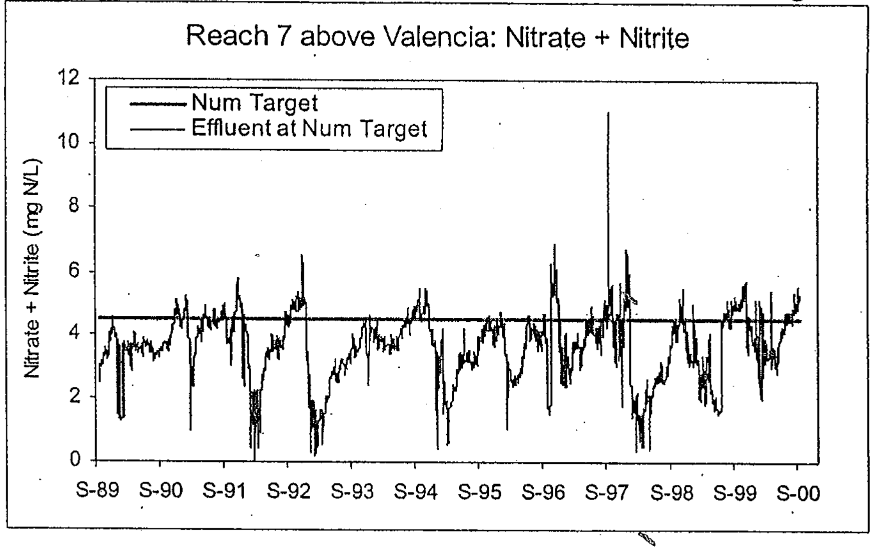


Figure 7. Simulated ammonia in Reach 7 below Valencia considering Saugus and Valencia effluent at Numerical Targets

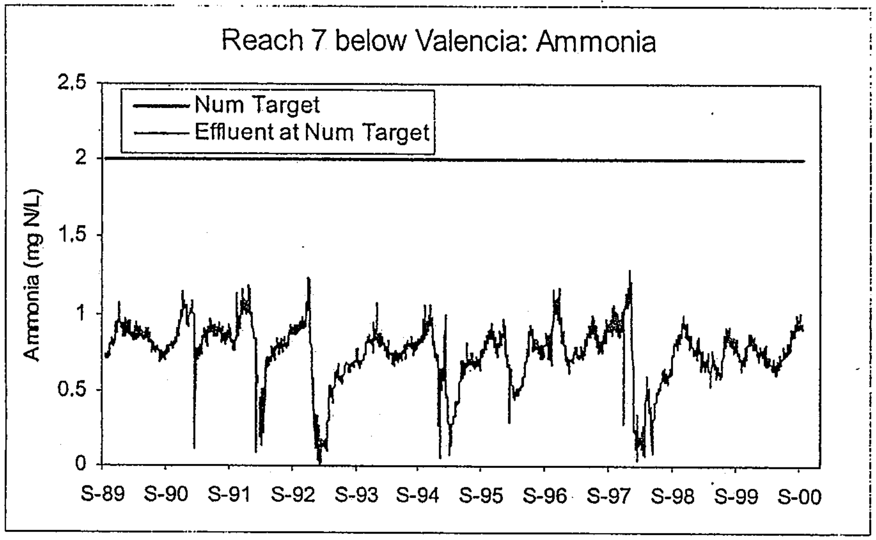

Reach 7 below Valencia: Ammonia

Figure 8. Simulated nitrate + nitrite in Reach 7 below Valencia considering Saugus and Valencia effluent at Numerical Targets

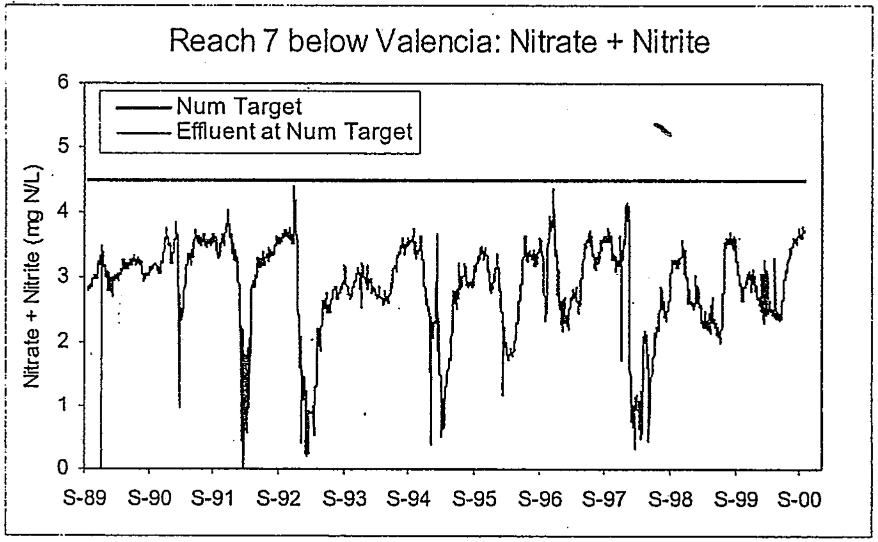

Reach 7 below Valencia: Nitrate + Nitrite

Figure 9. Simulated ammonia in Reach 7 at County Line considering Saugus and Valencia effluent at Numerical Targets

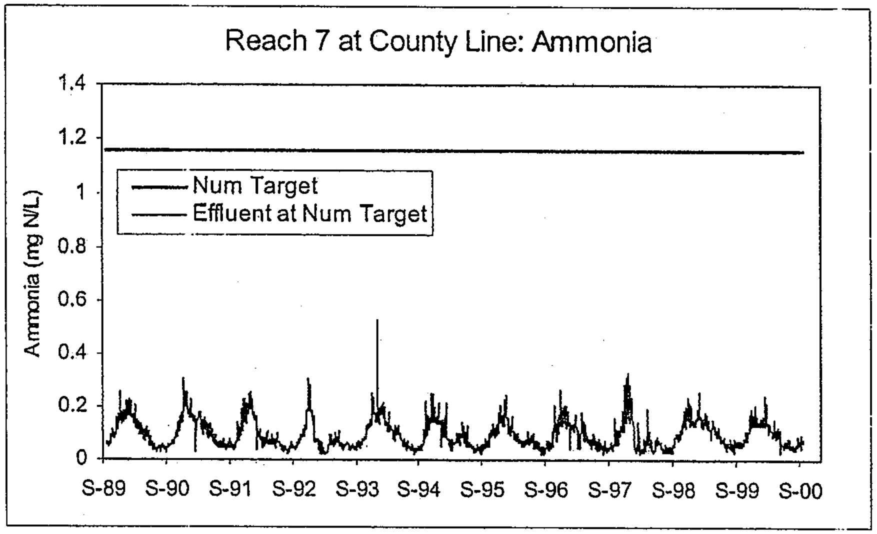

Reach 7 at County Line: Ammonia

Figure 10. Simulated nitrate + nitrite in Reach 7 at County Line considering Saugus and Valencia effluent at Numerical Targets

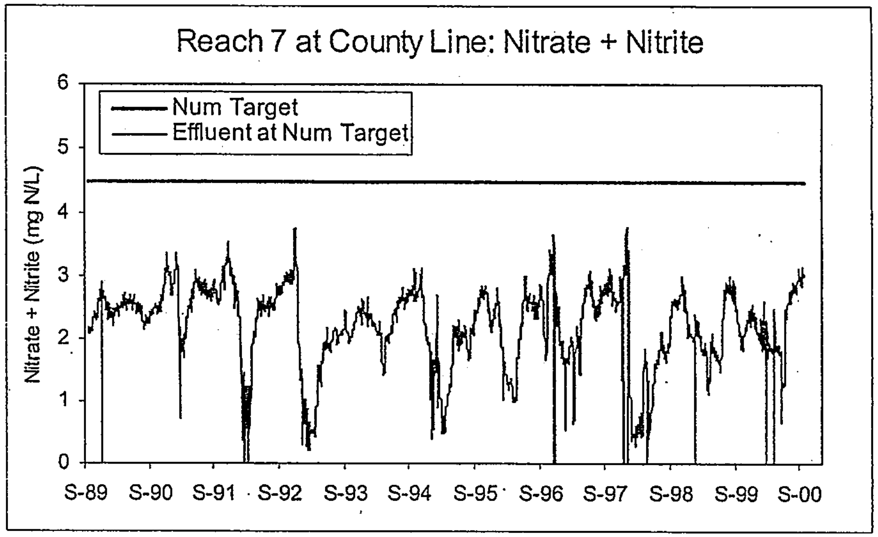

Reach 7 at County Line: Nitrate + Nitrite

Figure 11. Simulated ammonia in Reach 3 above Santa Paula considering Saugus and Valencia effluent at Numerical Targets

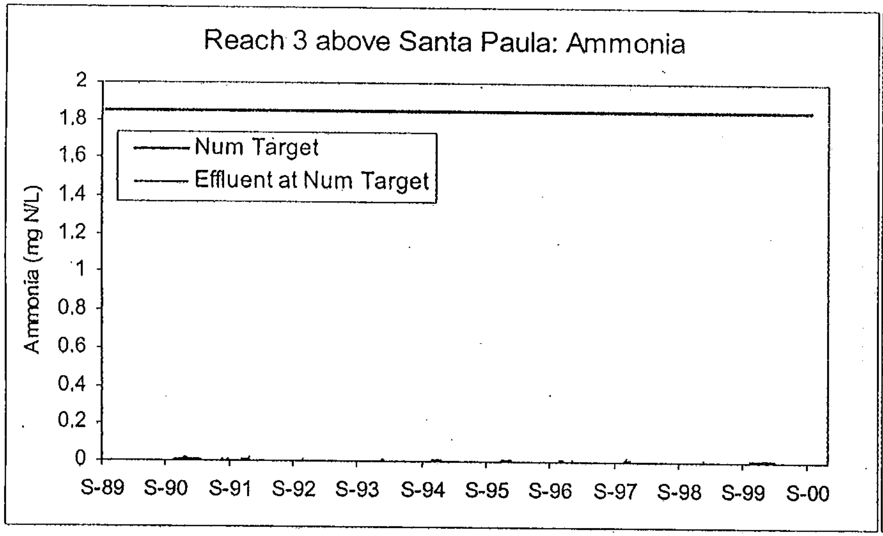


Figure 12. Simulated nitrate + nitrite in Reach 3 above Santa Paula considering Saugus & Valencia effluent at Numerical Targets

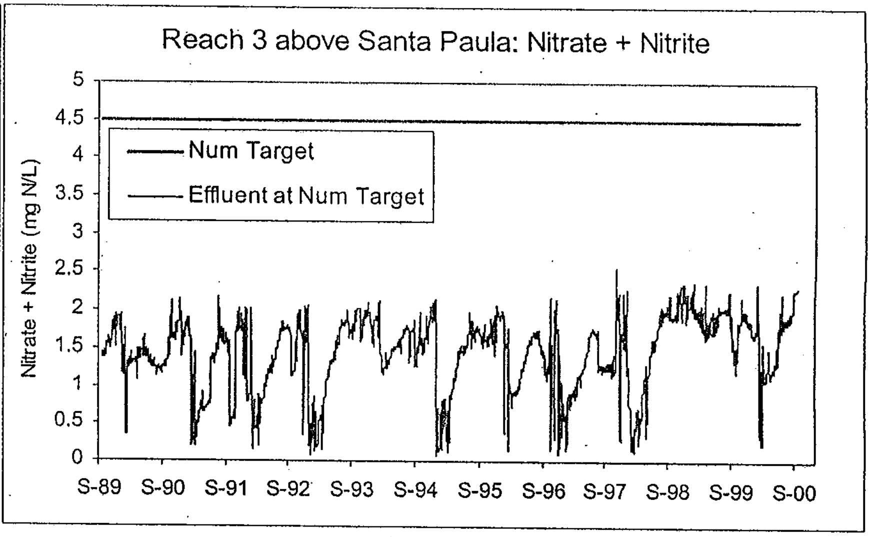


Figure 13. Simulated ammonia in Reach 3 at Santa Paula with Saugus, Valencia and Santa Paula effluent at Numerical Targets

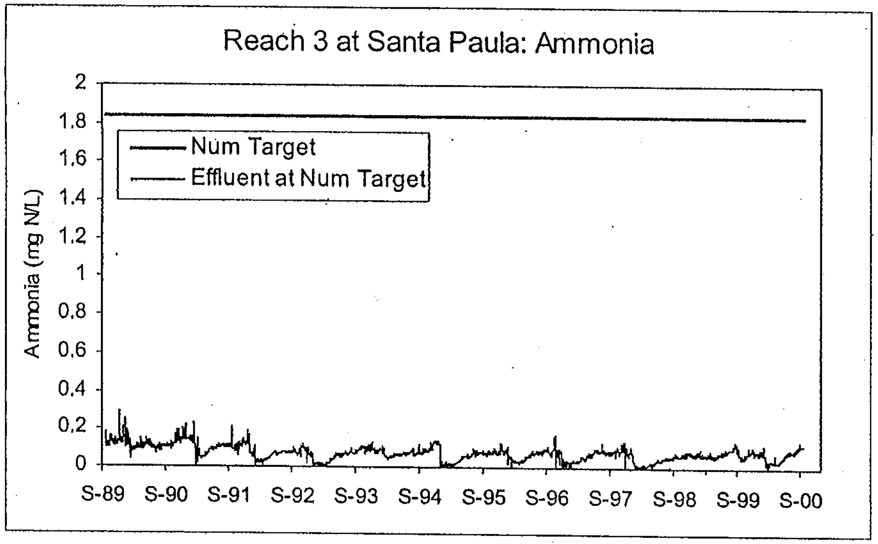


Figure 14. Simulated nitrate + nitrite in Reach 3 at Santa Paula with Saugus, Valencia and Santa Paula effluent at Numerical Targets

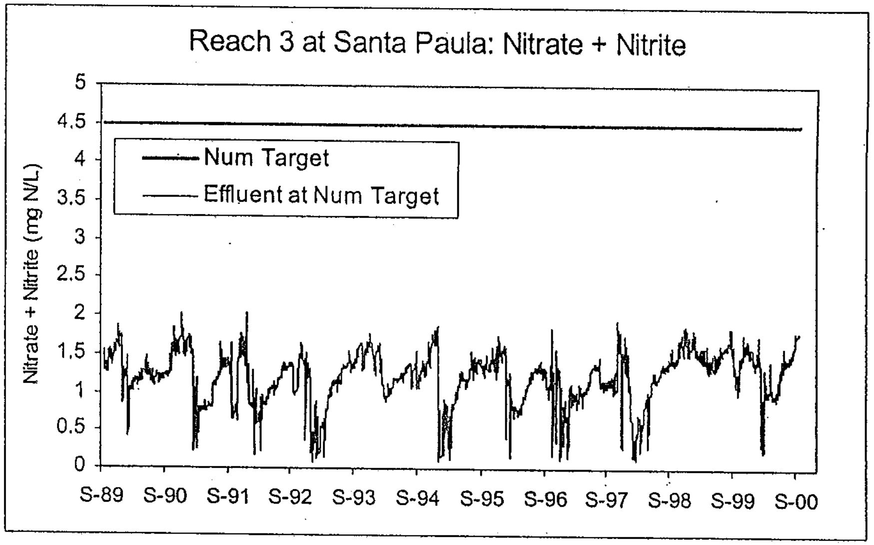


Figure 15. Simulated ammonia in Reach 3 below Santa Paula with Saugus, Valencia & Santa Paula effluent at Numerical Targets

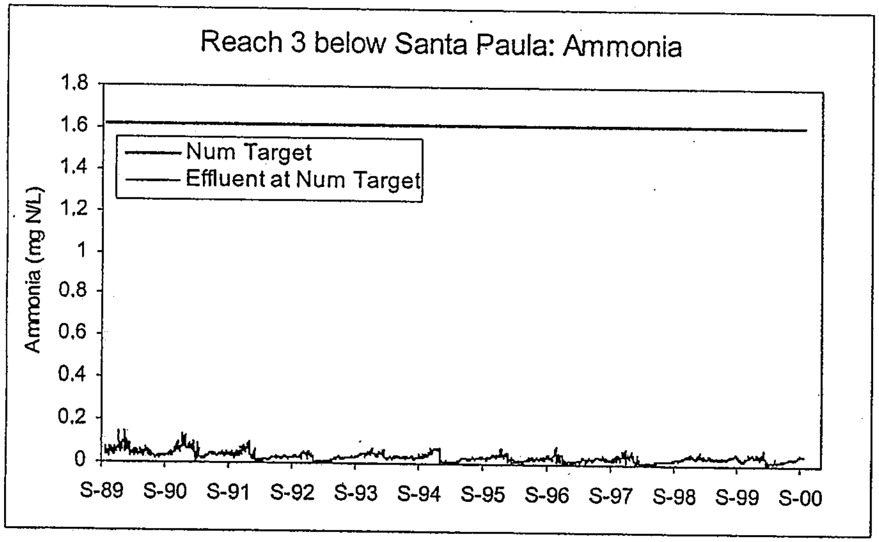


Figure 16. Simulated nitrate + nitrite in Reach 3 below Santa Paula with Saugus, Valencia & Santa Paula effluent at Numerical Targets

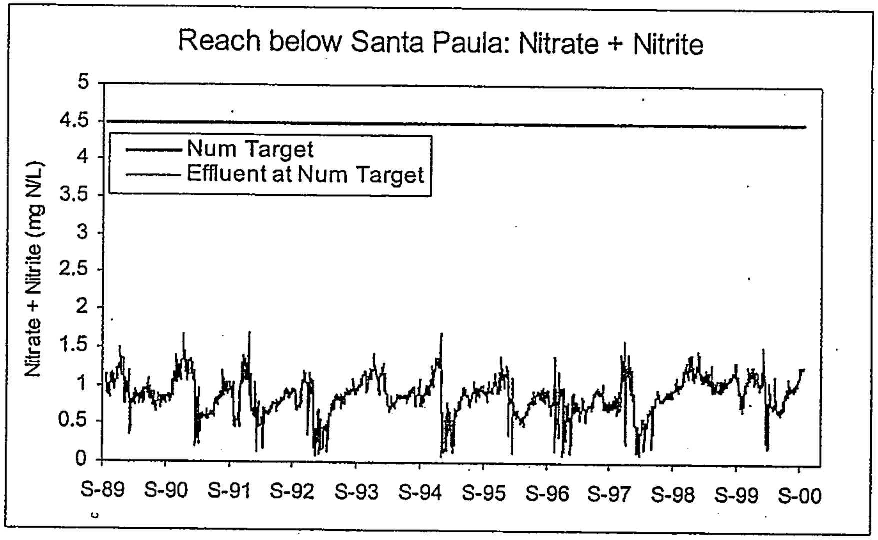


Figure 17. Simulated ammonia in Reach 8 considering Saugus effluent at Numerical Targets except ammonia at 2 mg/L

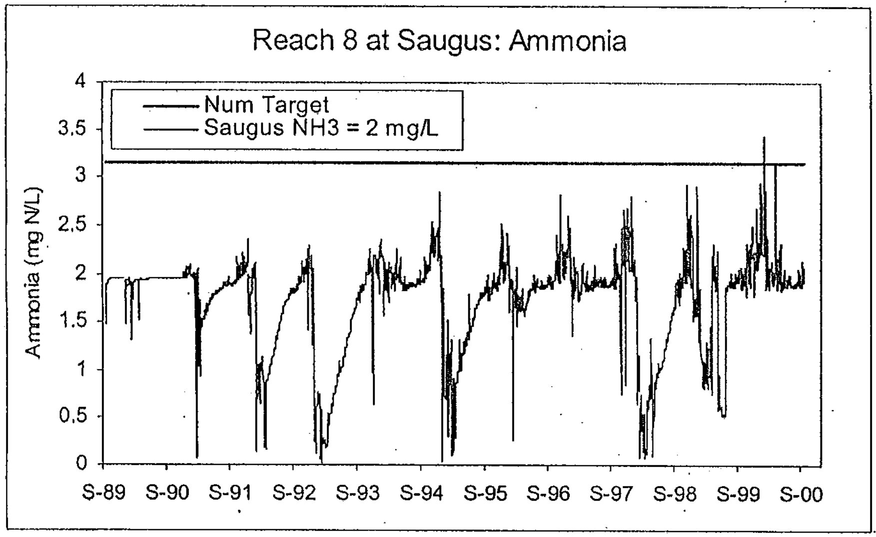


Figure 18. Simulated nitrate + nitrite in Reach 8 considering Saugus effluent at Numerical Targets except ammonia at 2 mg/L

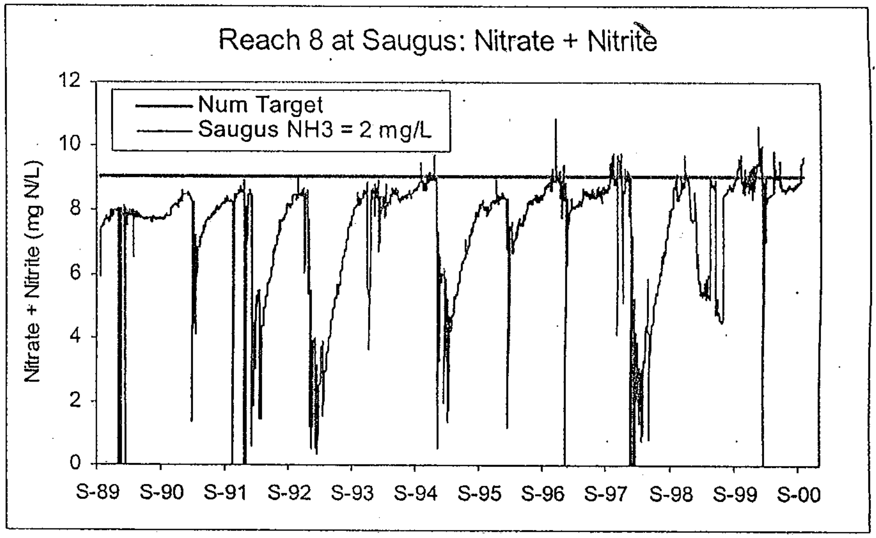


Figure 19. Simulated ammonia in Reach 7 above Valencia with Saugus effluent at Numerical Targets except ammonia at 2 mg/L

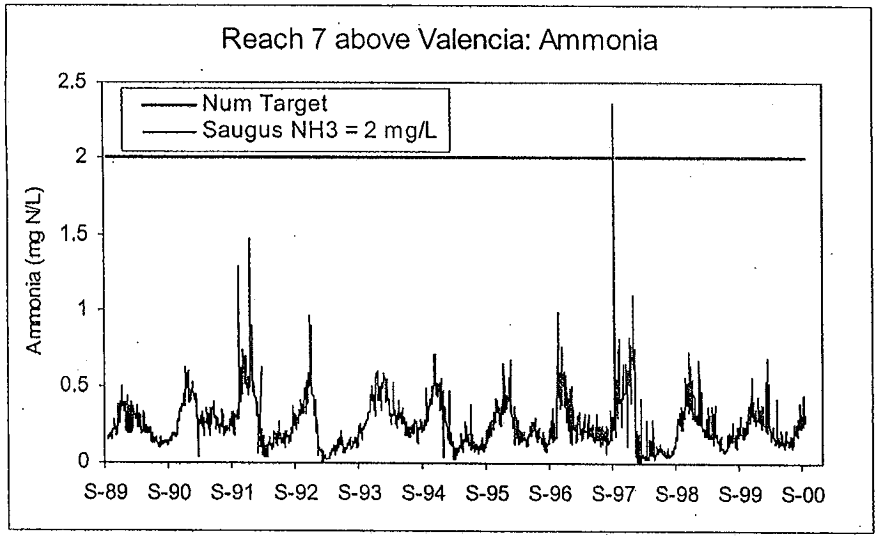


Figure 20. Simulated nitrate + nitrite in Reach 7 above Valencia with Saugus effluent at Numerical Targets except ammonia at 2 mg/L

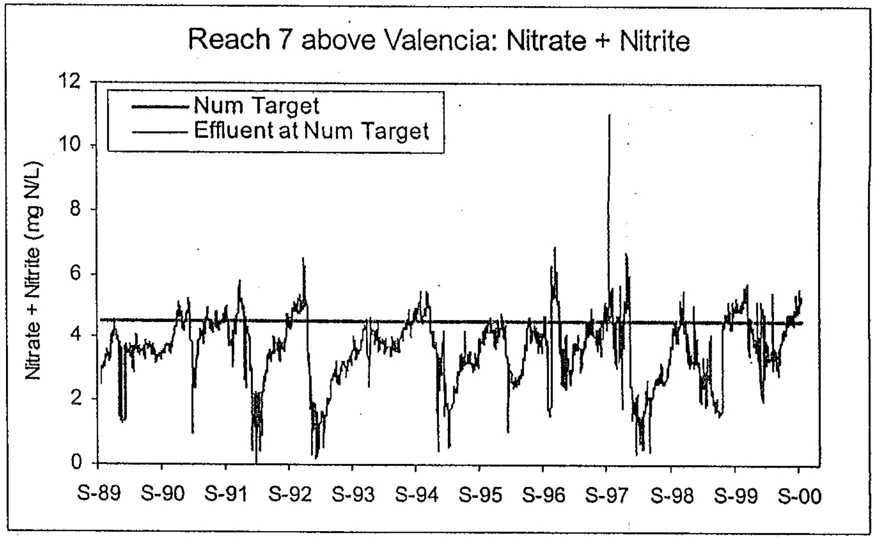


Figure 21. Simulated nitrate + nitrite in Reach 8 considering Saugus effluent at 3.15 mg/L as NH_3-N, 0.1 mg/L as NO_2-N, 8 mg/L as NO_3-N

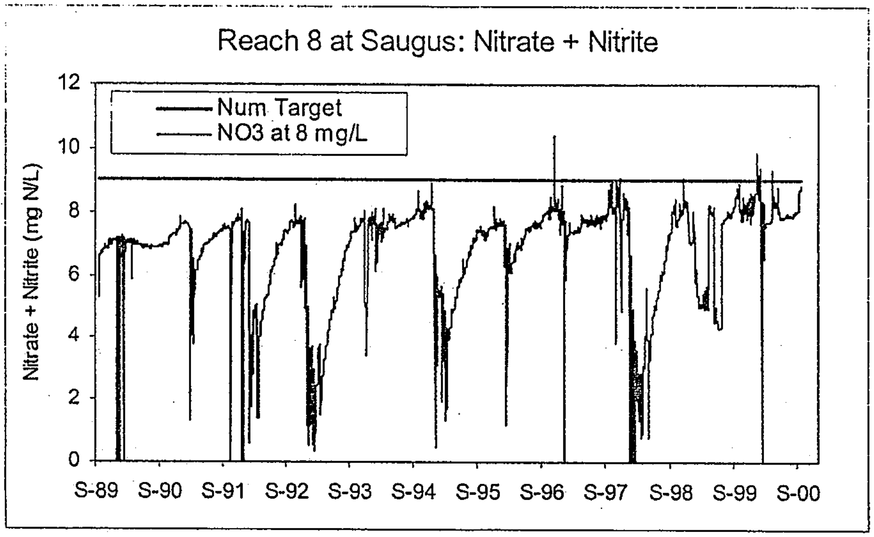


Figure 22. Simulated nitrate + nitrite in in Reach 7 above Valencia with Saugus effluent at 3.15 mg/L as NH_3-N, 0.1 mg/L as NO_2-N, 8 mg/L as NO_3-N

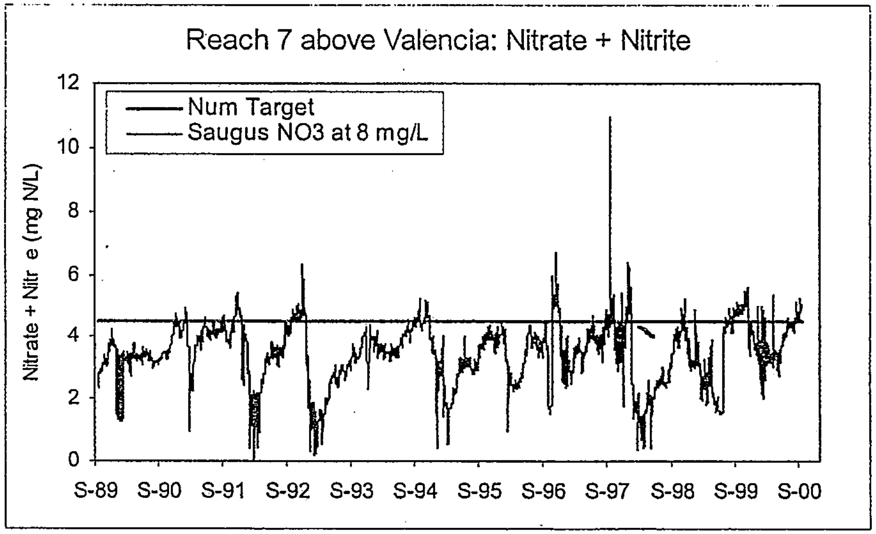


Figure 23. Simulated ammonia in Reach 7 below Valencia with Saugus effluent at 3.15 mg/L as NH_3-N, 0.1 mg/L as NO_2-N, 8 mg/L as NO_3-N

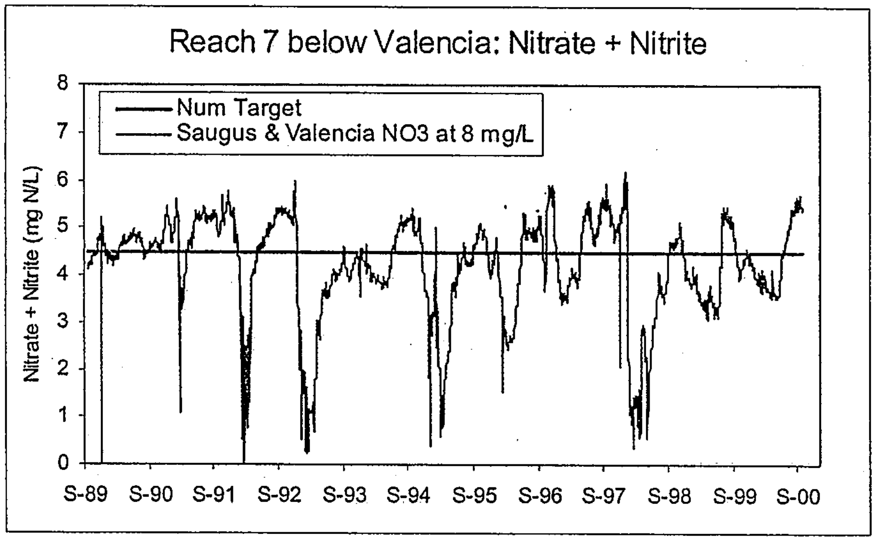


Figure 24. Simulated nitrate + nitrite in Reach 7 at County Line with Saugus effluent at 3.15 mg/L as NH_3-N, 0.1 mg/L as NO_2-N, 8 mg/L as NO_3-N

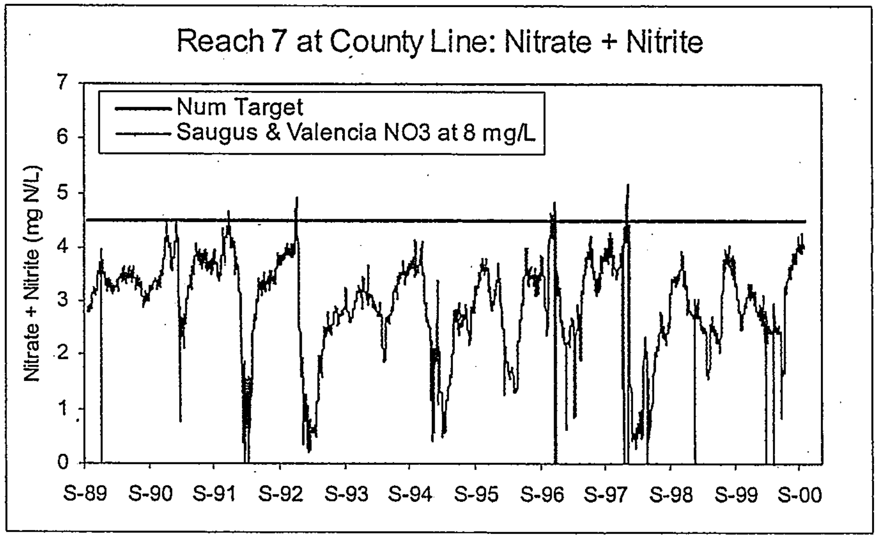


Figure 25. Simulated nitrate + nitrite concentrations in Reach 3 at Santa Paula with Saugus, Valencia and Santa Paula effluent at 8 mg/L as NO_3-N

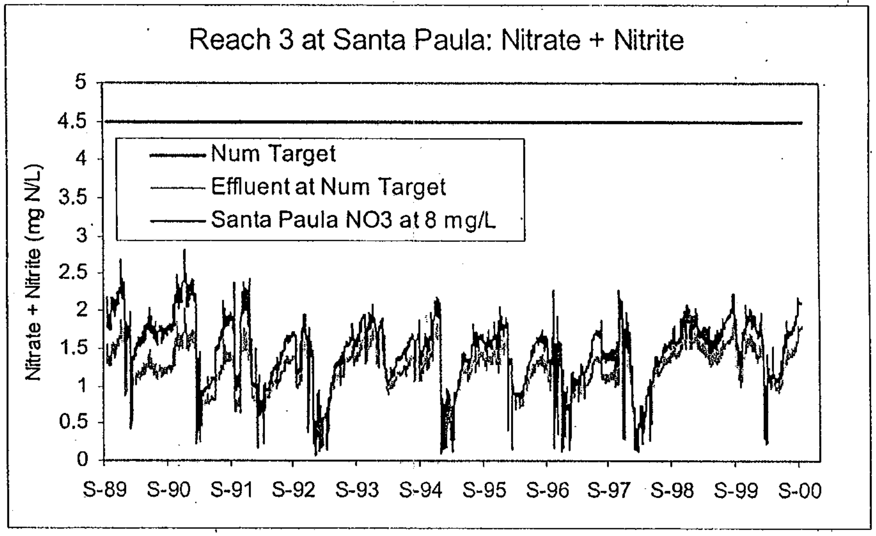


Figure 26. Simulated ammonia concentrations in Reach 8 considering Intermediate scenario

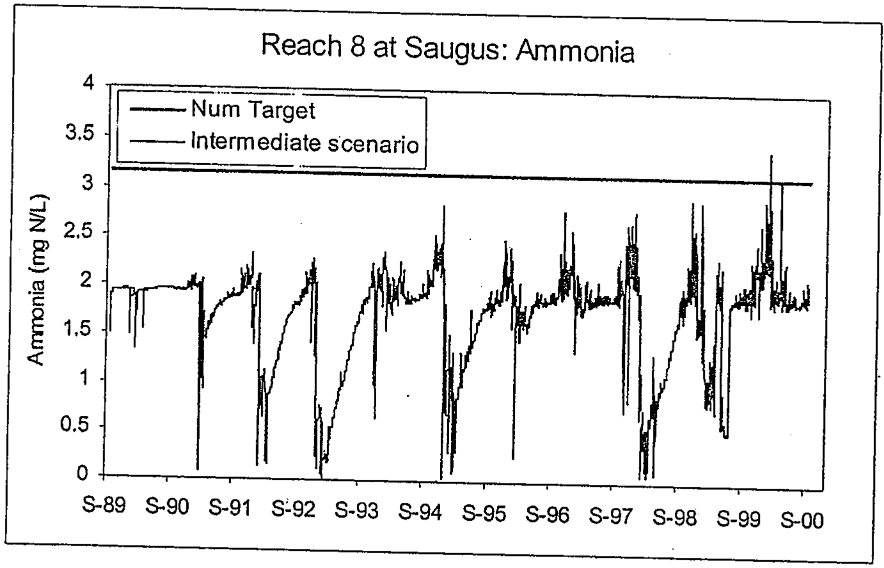


Figure 27. Simulated nitrate + nitrite concentrations in Reach 8 considering Intermediate scenario

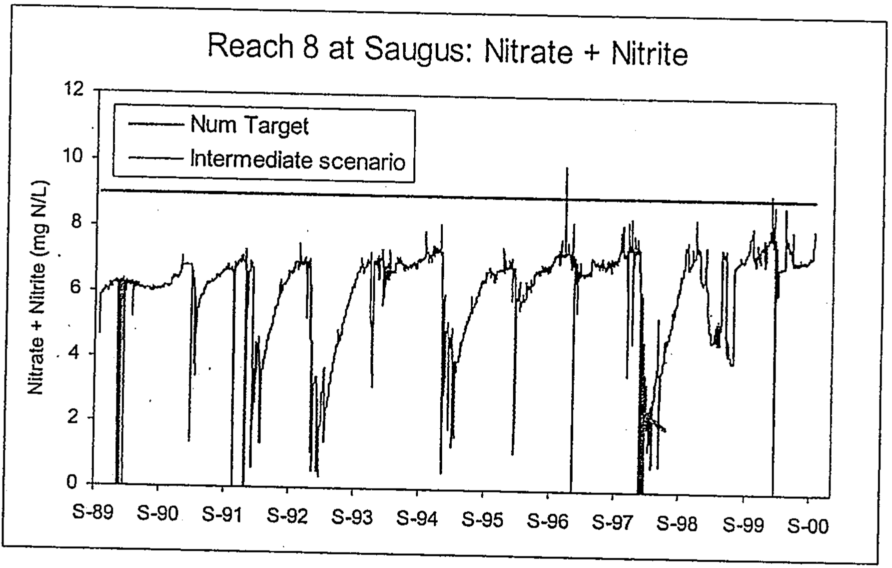


Figure 28. Simulated ammonia concentrations in Reach 7 above Valencia considering Intermediate scenario

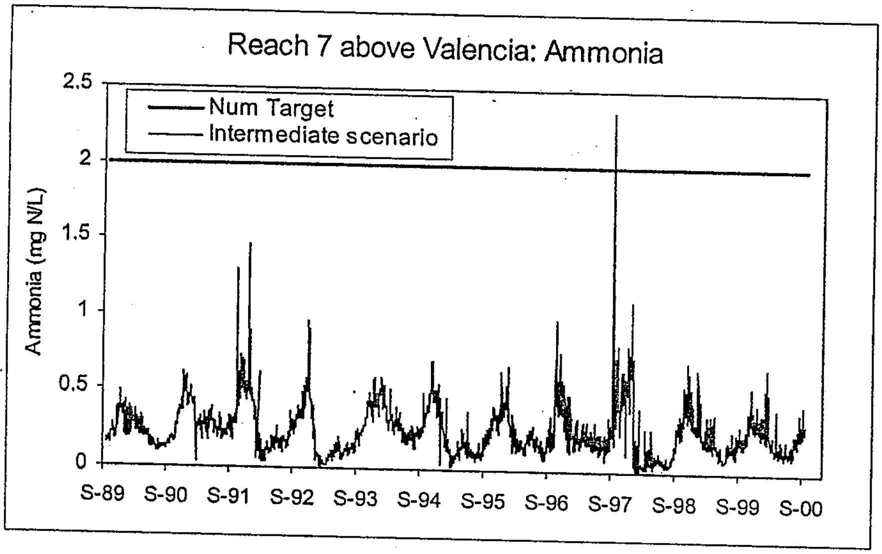


Figure 29. Simulated nitrate + nitrite concentrations in Reach 7 above Valencia considering Intermediate scenario

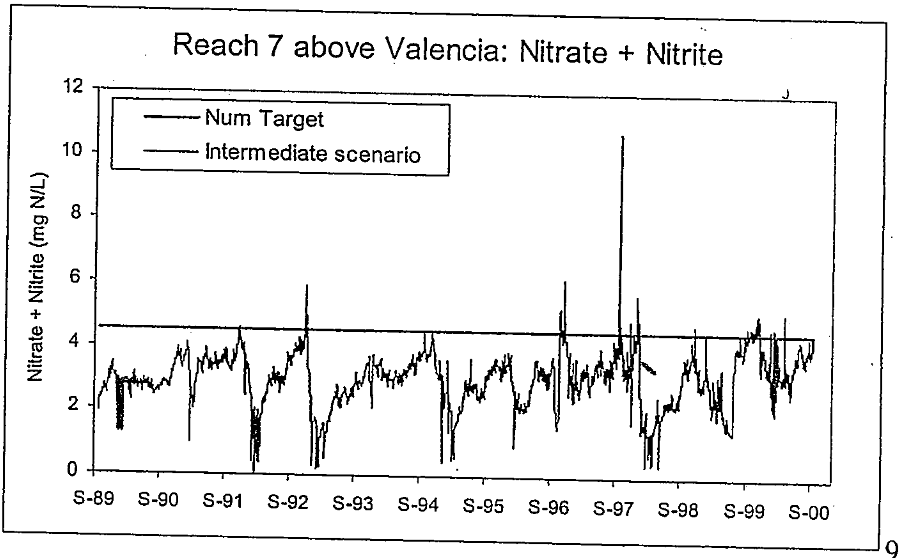


Figure 30. Simulated ammonia in Reach 7 below Valencia considering Intermediate scenario

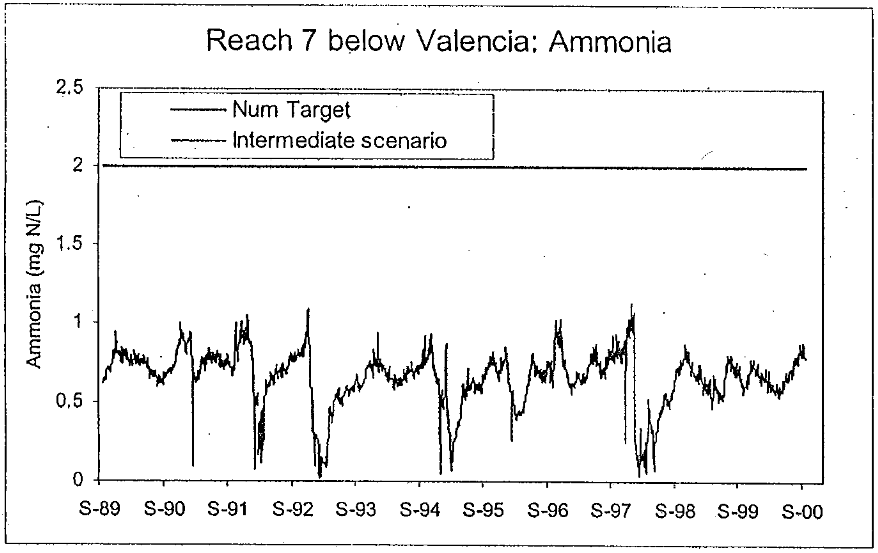


Figure 31. Simulated nitrate + nitrite in Reach 7 below Valencia considering Intermediate scenario

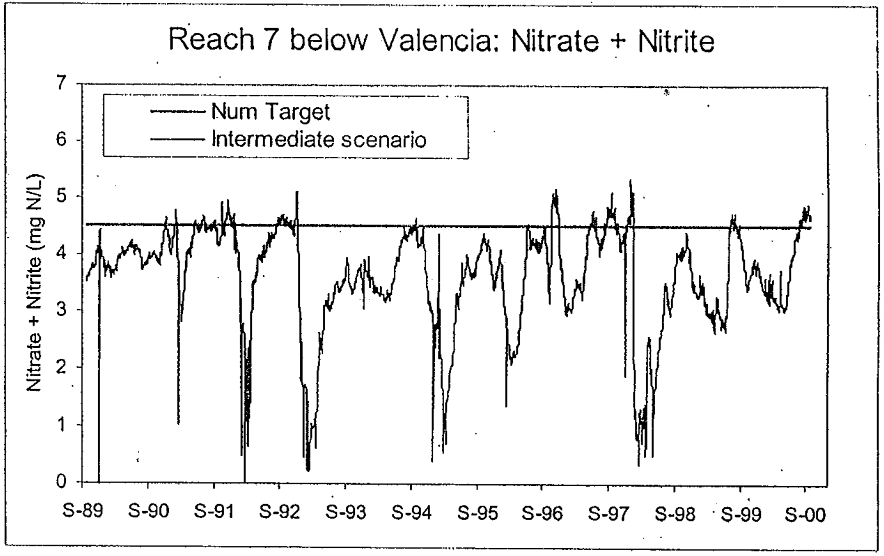


Figure 32. Simulated ammonia in Reach 7 at County Line considering Intermediate scenario

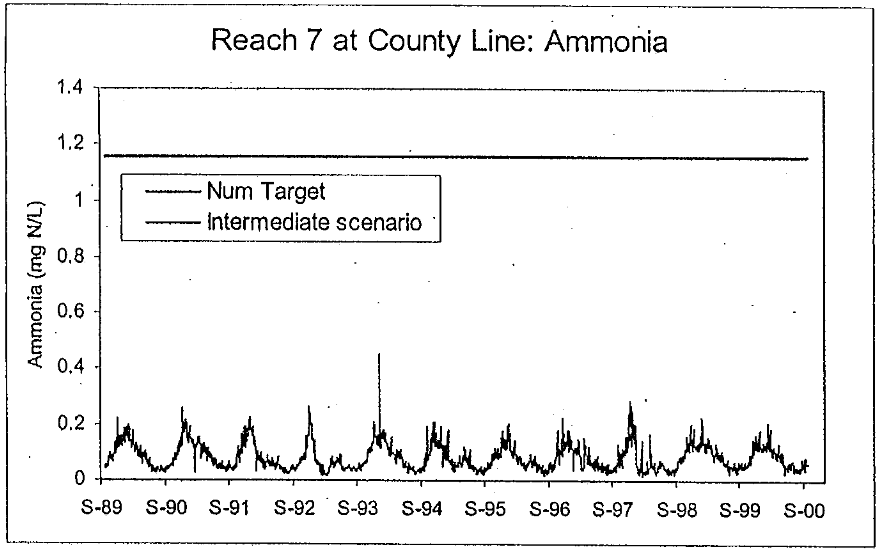


Figure 33. Simulated nitrate + nitrite in Reach 7 at County Line considering Intermediate scenario

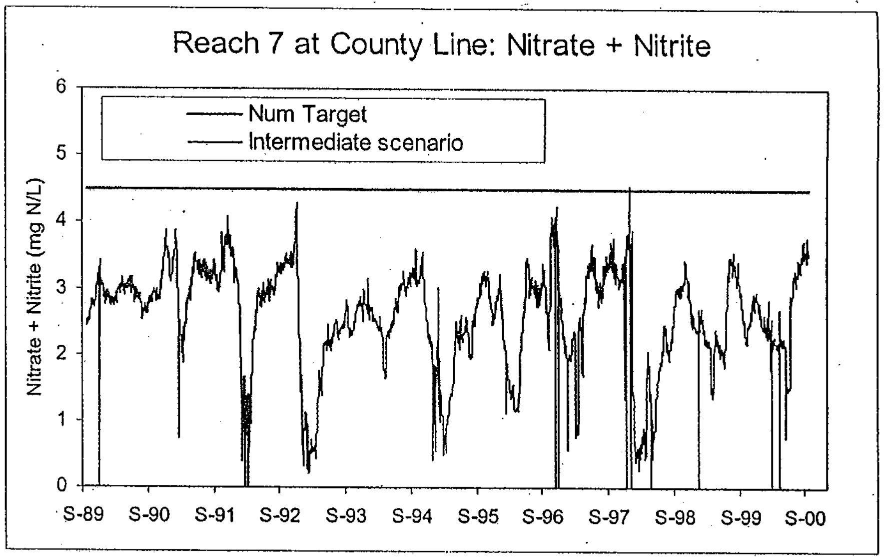


Figure 34. Simulated ammonia concentrations in Reach 3 at Santa Paula considering Intermediate scenario

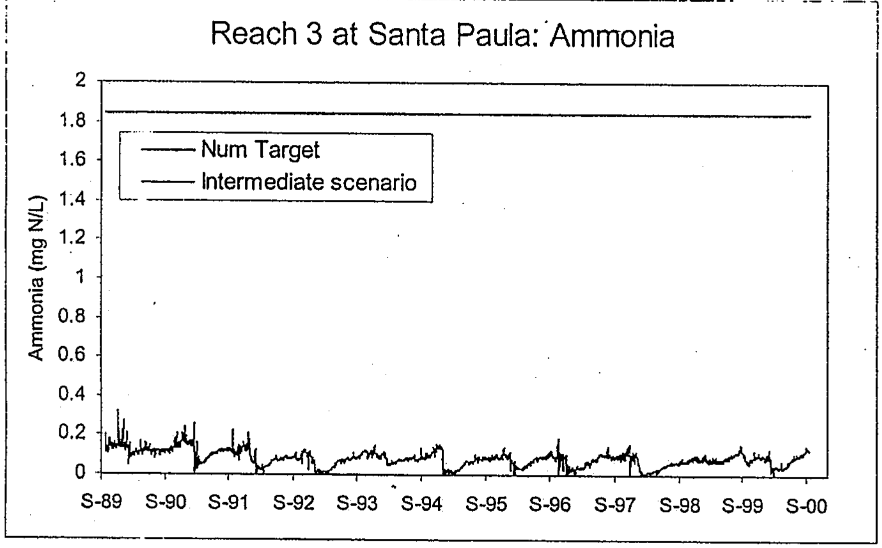


Figure 35. Simulated nitrate + nitrite concentrations in Reach 3 at Santa Paula considering Intermediate scenario

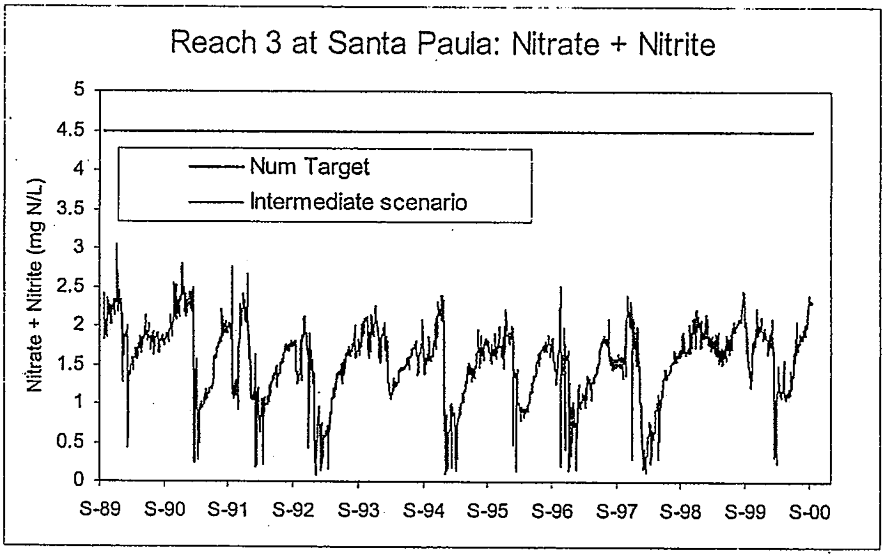


Figure 36. Simulated ammonia concentrations in Reach 3 below Santa Paula considering Intermediate scenario

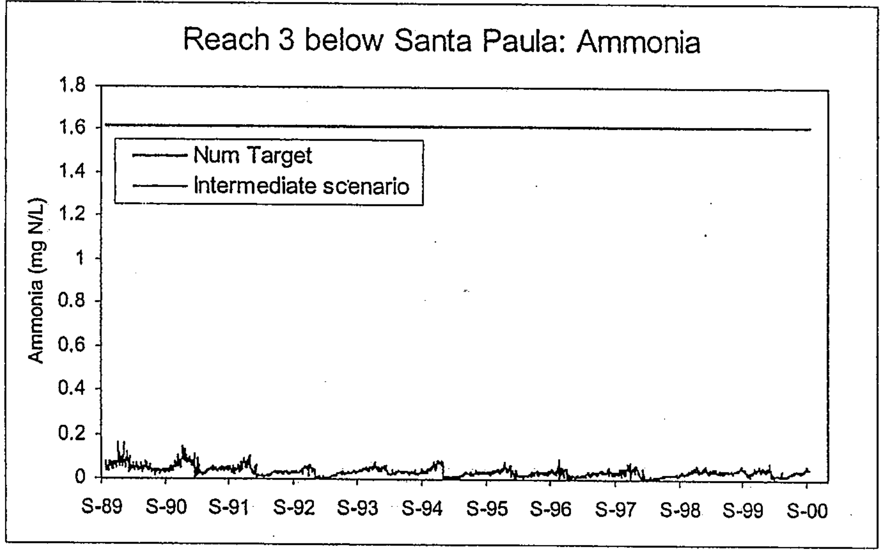


Figure 37. Simulated nitrate + nitrite concentrations in Reach 3 below Santa Paula considering Intermediate scenario

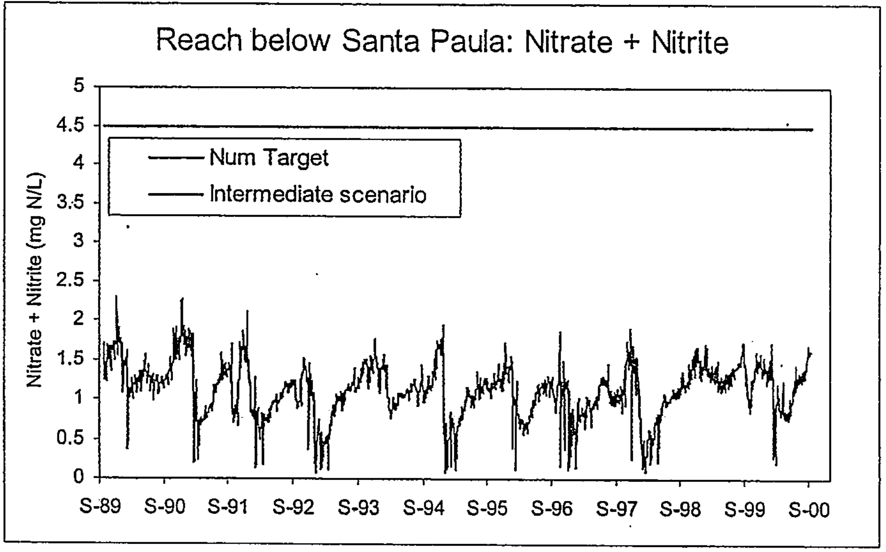


Figure 38. Simulated ammonia concentrations in Reach 8 due only to NPS load and minor PS loading

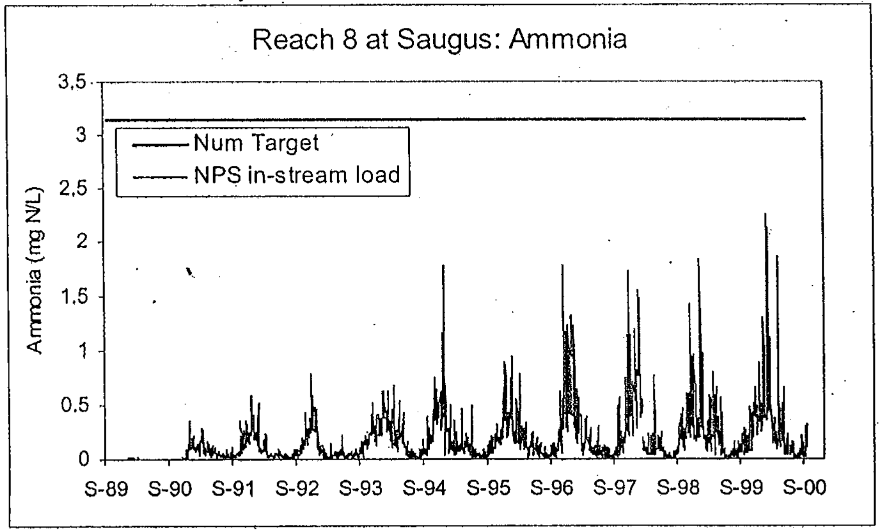


Figure 39. Simulated nitrate + nitrite concentrations in Reach 8 due only to NPS load and minor PS loading

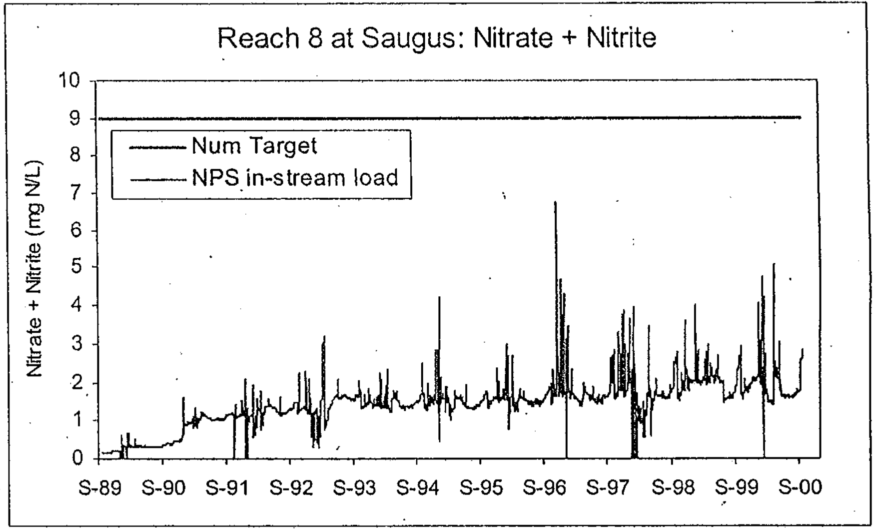


Figure 40. Simulated ammonia concentrations in Reach 7 above Valencia due only to NPS load and minor PS loading

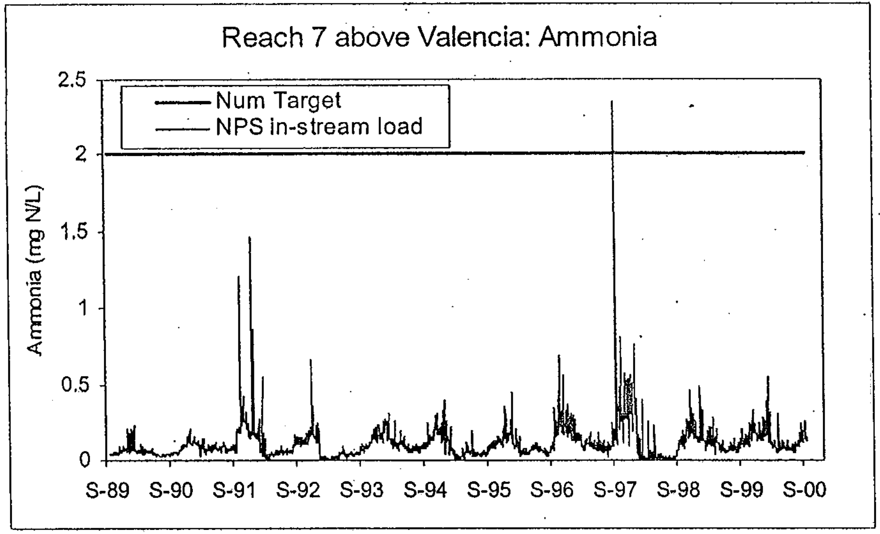


Figure 41. Simulated nitrate + nitrite concentrations in Reach 7 above Valencia due only to NPS load and minor PS loading

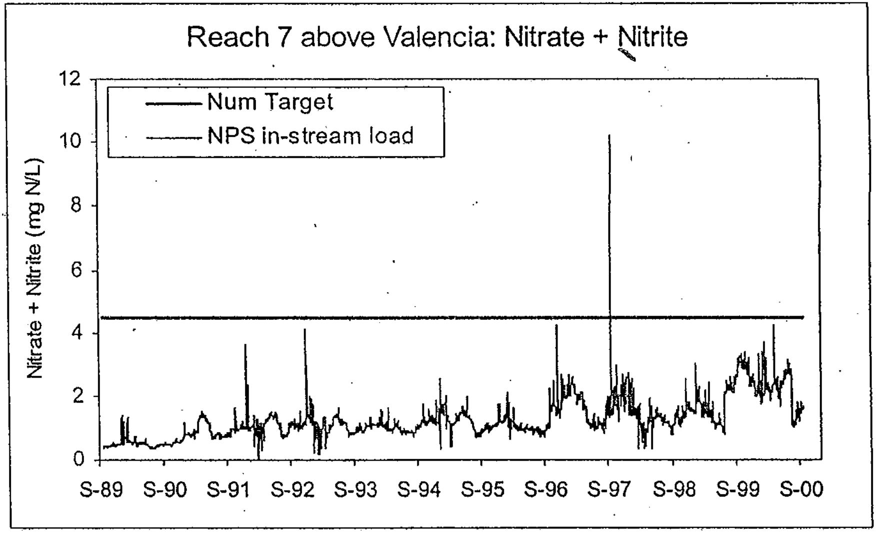


Figure 42. Simulated ammonia in Reach 7 below Valencia due only to NPS load and minor PS loading

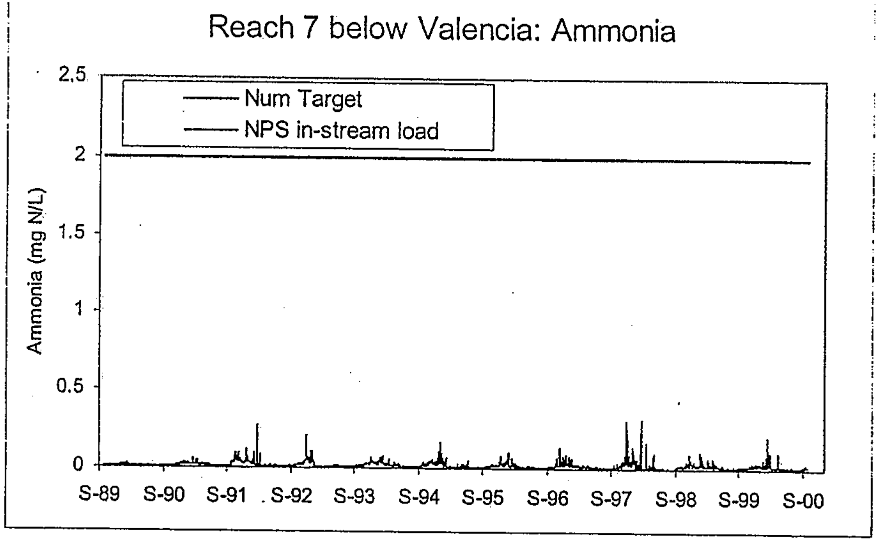


Figure 43. Simulated nitrate + nitrite in Reach 7 below Valencia due only to NPS load and minor PS loading

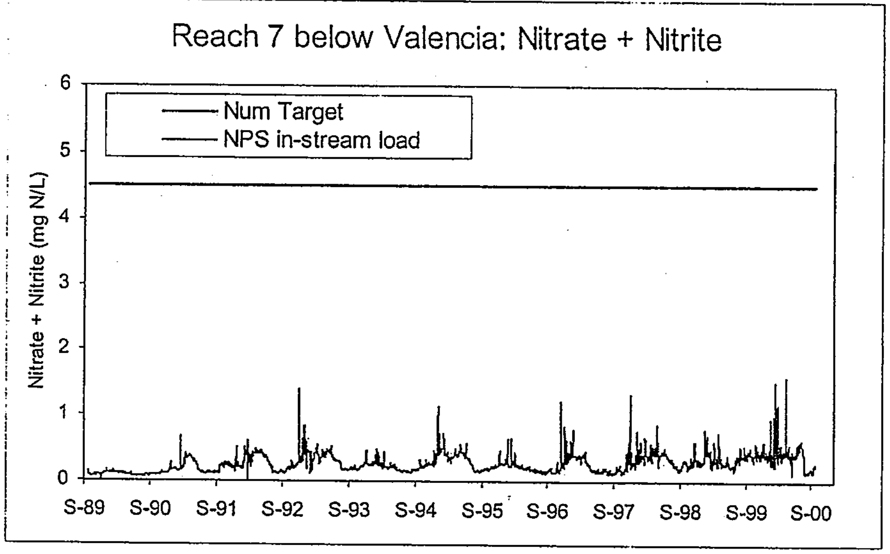


Figure 44. Simulated ammonia in Reach 7 at County Line due only to NPS load and minor PS loading

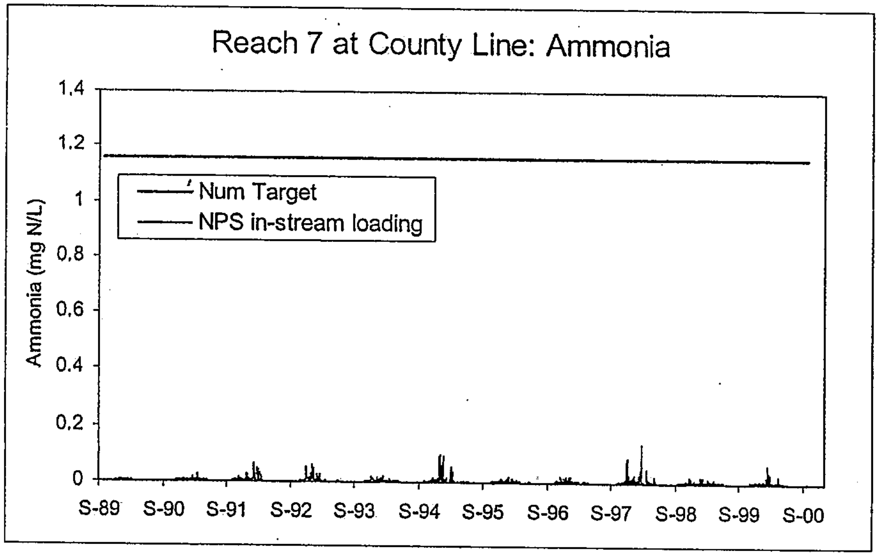


Figure 45. Simulated nitrate + nitrite in Reach 7 at County Line due only to NPS load and minor PS loading

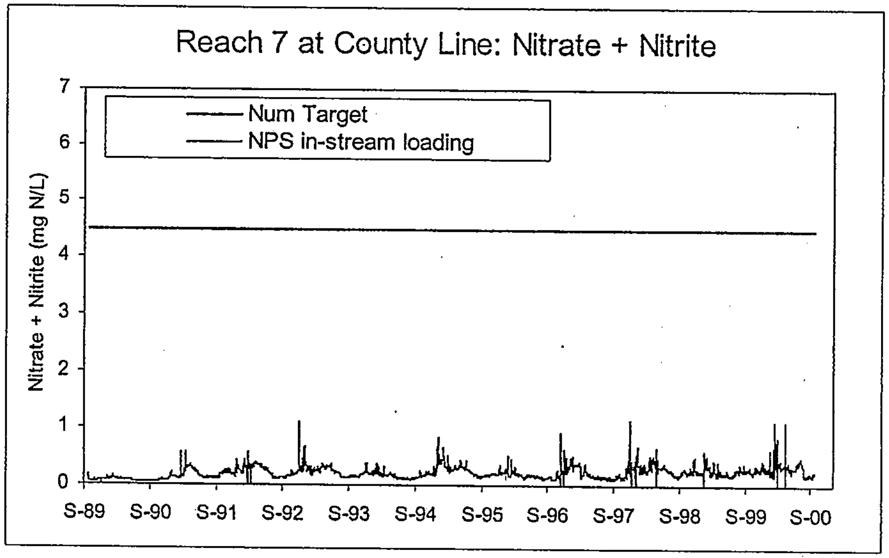


Figure 46. Simulated ammonia in Reach 3 above Santa Paula due only to NPS load and minor PS loading

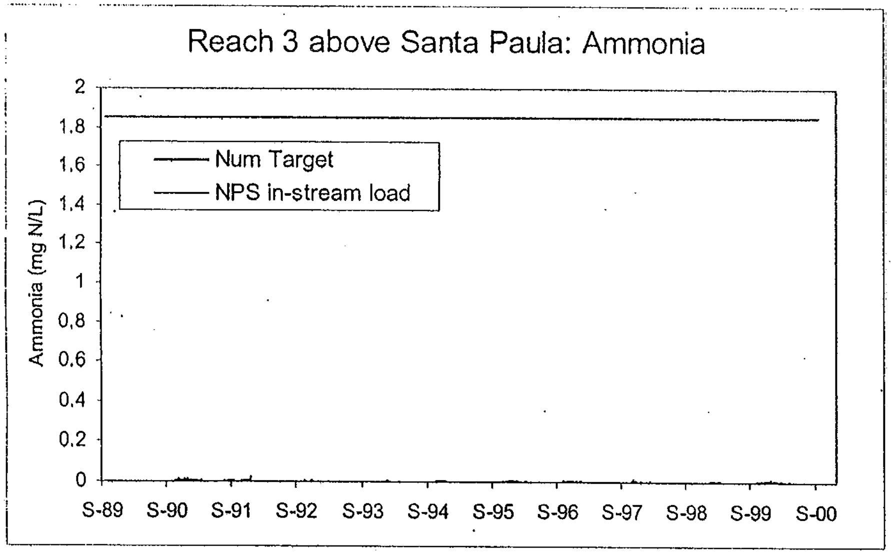


Figure 47. Simulated nitrate + nitrite in Reach 3 above Santa Paula due only to NPS load and minor PS loading

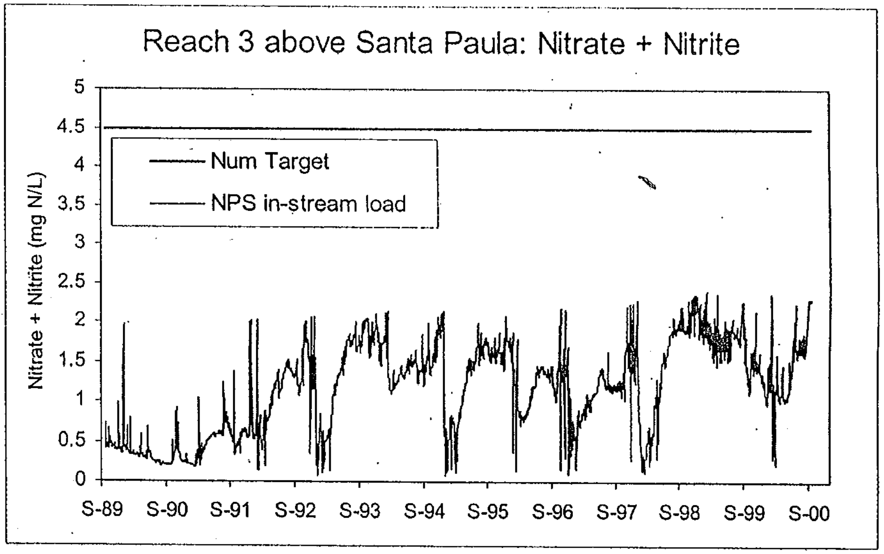


Figure 48. Simulated ammonia concentrations in Reach 3 at Santa Paula due only to NPS load and minor PS loading

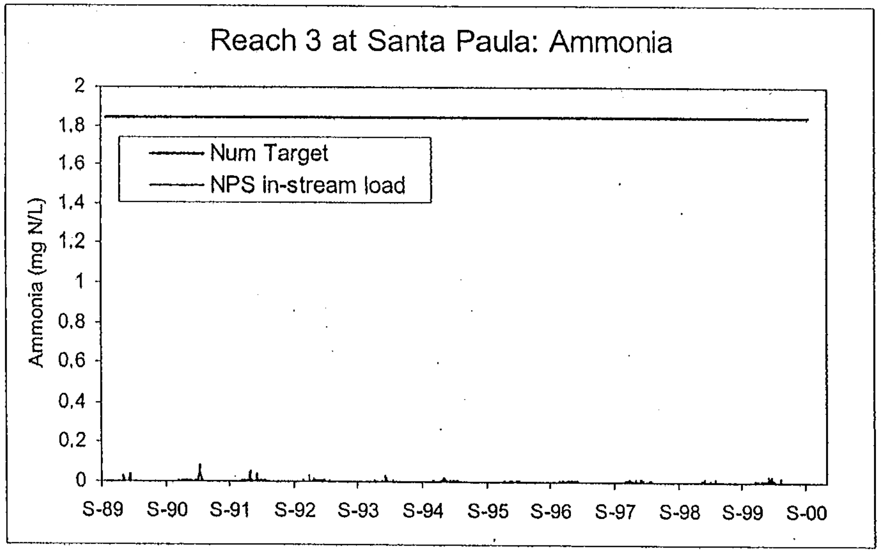


Figure 49. Simulated nitrate + nitrite concentrations in Reach 3 at Santa Paula due only to NPS load and minor PS loading

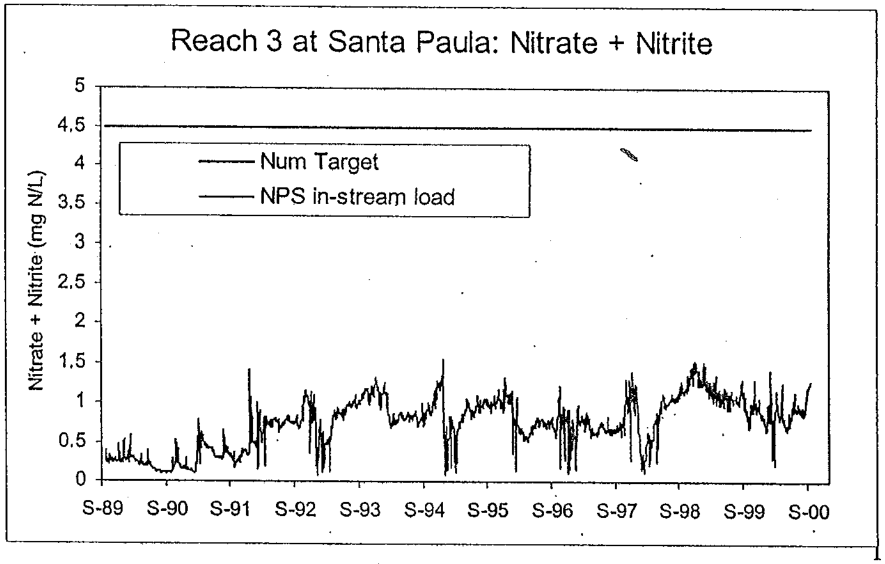


Figure 50. Simulated ammonia concentrations in Reach 3 below Santa Paula due only to NPS load and minor PS loading

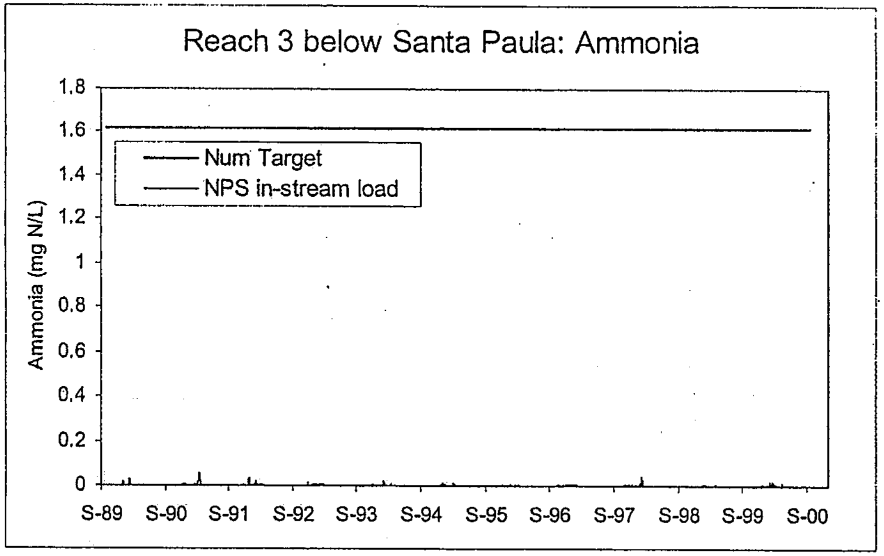
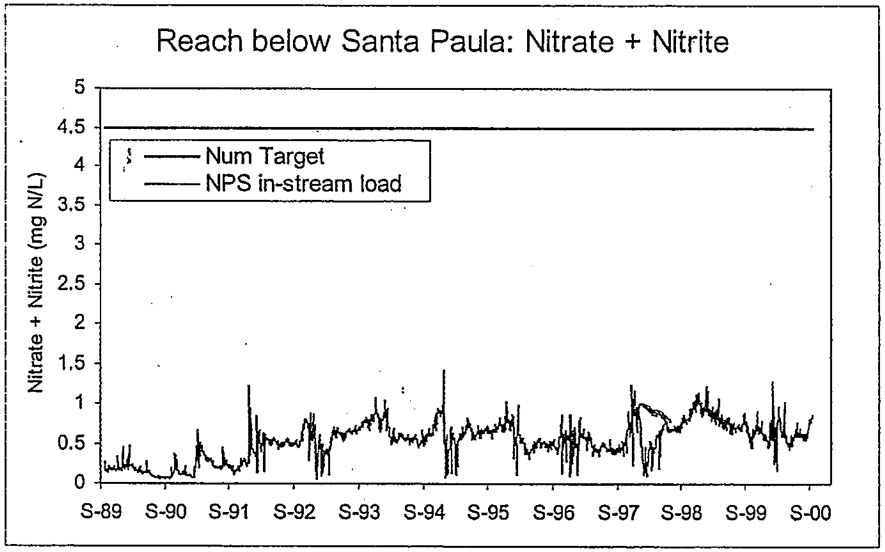


Figure 51. Simulated nitrate + nitrite concentrations in Reach 3 below Santa Paula due only to NPS load and minor PS loading



Report on Point and Non-Point Source Analysis for Segment 56 in Reach 7, below Valencia WRP

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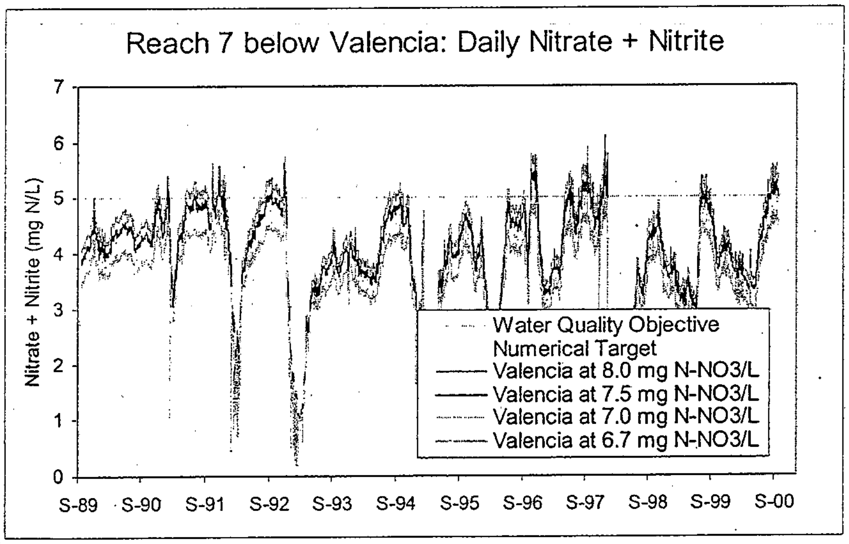
Based on the desired goal of reducing NPS loading from agricultural operations by 20%, we considered a 20% decrease in fertilizer application in all the catchments at or above Segment 56 (area immediately below Valencia), including the upper Reach 7, and all the areas in Reaches 8 and 9. The simulated daily nitrate + nitrite in-stream concentrations, at different levels of Valencia nitrate concentration in the effluent (from 6.7 to 8 mg N-NO3/L) are presented in Figure 1.

Figure 1. Simulated daily nitrate + nitrite in-stream concentrations



The Water Quality Objective (WQO, 5 mg NO2 + NO3 as N/L) and the Numerical Target (NT, 4.5 mg NO2 + NO3 as N/L) are exceeded during short periods typically near the end of the dry season and the first storm events. The statistics are presented in Table 1.

If the WQO and NT are evaluated on a daily basis, NT is exceeded around 5% of the time in all cases if the Valencia effluent nitrate concentration is above 6.7 mg/L. It should be noted that the WQO can be met on a daily basis around 95% of the time even when the Valencia effluent nitrate concentration is 7.5 mg /L, and that the exceedance of the historical nitrite + nitrate concentration is relatively small in magnitude and duration, even at the higher Valencia loading rate (8 mg/L).

Table 1. Statistics of simulated daily nitrate + nitrite concentrations below Valencia

	Valencia effluent nitrate concentration			
	6.7 mg/L	**7.0 mg/L**	**7.5 mg/L**	**8.0 mg/L**
95 Percentile	4.5	4.8	5.1	5.3
99 Percentile	4.8	5.1	5.3	5.6
99.9 Percentile	5.0	5.3	5.6	5.9

From these simulations, a 20% decrease in agricultural fertilizer application has very little effect on the simulated concentrations in this reach, since the percentage of land use that is occupied by farms is less than 10% for all the catchments in this area, thus the total land application is small. Nitrogen fertilizer applied to the land is mostly being assimilated by the crops and surrounding vegetation, or is relatively slowly leaching down into the subsurface and then migrating towards the river. It is possible that this migration is slow and will not be evident in the river for a number of years. Groundwater concentration data would help to determine the magnitude of this process.

In addition, a significant amount of NPS loading is via atmospheric deposition, which is currently under analysis to evaluate the potential for reducing nitrate concentrations if stormwater BMPs such as bioswales are installed to reduce this loading during storm events. Failing septic systems might also be contributing significantly to loading in some specific areas.

Since it is uncertain whether a very small short term exceedance of the historical nitrate + nitrite concentration would have any significant effect on aquatic organisms, 30-day and 365-day rolling averages were calculated based on these simulation results. These are presented in Figures 2 and 3.

Figure 2. 30-day rolling average nitrate + nitrite in-stream concentrations

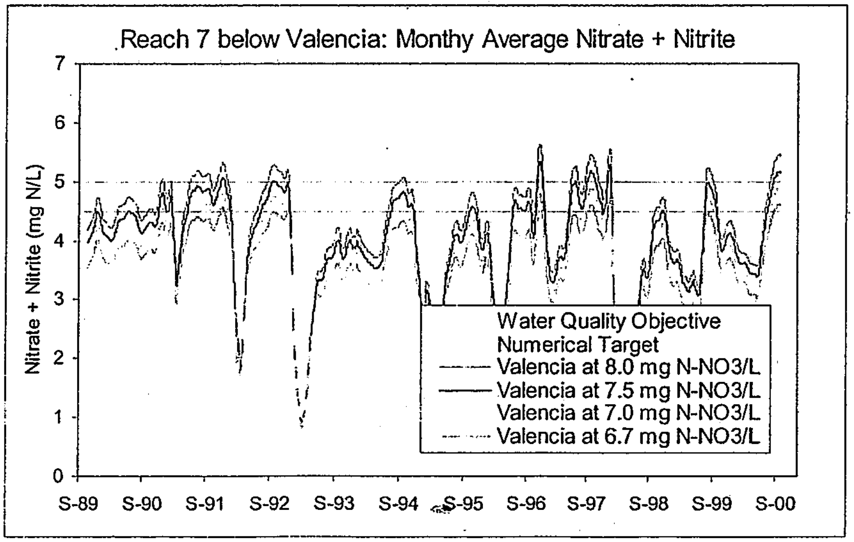


Table 2. Statistics of 30-day rolling average NO_2+ NO_3 concentrations below Valencia

	Valencia effluent nitrate concentration			
	6.7 mg/L	**7.0 mg/L**	**7.5 mg/L**	**8.0 mg/L**
95 Percentile	4.4	4.7	5.0	5.2
99 Percentile	4.6	4.9	5.2	5.5
99.9 Percentile	4.8	5.1	5.3	5.6

Figure 3. 365-day rolling average nitrate + nitrite in-stream concentrations

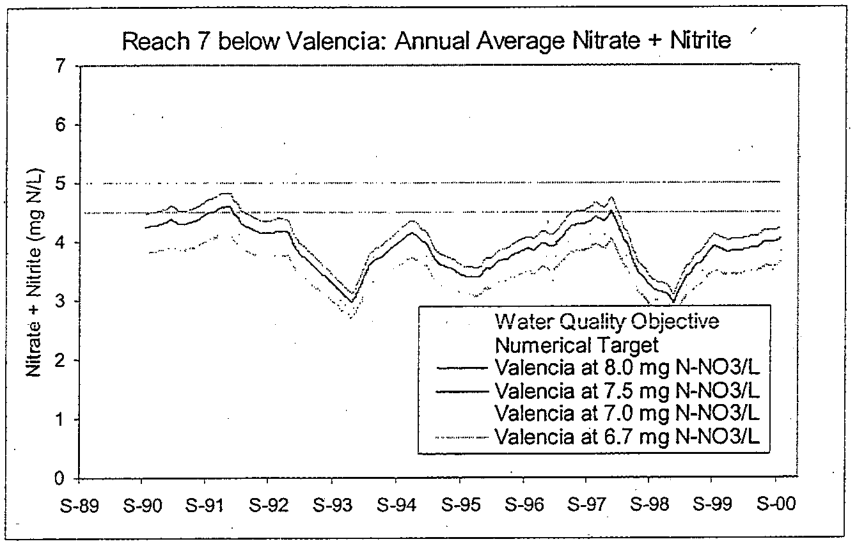


Table 3. Statistics of 365-day rolling average NO_2+ NO_3 conc. below Valencia

	Valencia effluent nitrate concentration			
	6.7 mg/L	**7.0 mg/L**	**7.5 mg/L**	**8.0 mg/L**
95 Percentile	4.0	4.2	4.5	4.7
99 Percentile	4.1	4.4	4.6	4.8
99.9 Percentile	4.1	4.4	4.6	4.8

As expected, with a longer averaging time there is a higher likelihood of compliance with the WQO for all Valencia WWTP loading scenarios.

Part 1

Final Task 1 Report For

Santa Clara River Nutrient TMDL Analysis:

Source Identification and Characterization

Prepared for

Santa Clara Nutrient TMDL Steering Committee

On behalf of the
Los Angeles Regional Water Quality Control Board and
Watershed Stakeholder Groups

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July 15, 2002

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I. Introduction

Background

The Los Angeles Regional Water Quality Control Board (LA RWCB) has determined that several segments and tributaries of the Santa Clara River do not meet the water quality criteria for their beneficial uses. As a result, these segments are listed on the 1998 303(d) list of impaired waters. The impairment is caused by excessive ammonia, nitrite/nitrate, organic enrichment, and low dissolved oxygen. Based on consent decree, Total Maximum Daily Loads (TMDLs) must be calculated which will protect the beneficial uses including recreation, wildlife habitat, and municipal, industrial, and agricultural supply. (LA RWCB 2002)

Objective

The Santa Clara River watershed drains an area of 1,618 square miles, with a wide variety of land uses including mountain forest, urbanized areas, and agricultural land. The watershed lies almost entirely in Los Angeles and Ventura Counties, California. The flow is highly seasonal and dominated by winter storm events. Several stream segments within the watershed have been determined to be impaired and need TMDLs calculated for their primary pollutants. This process involves five steps:

1. Assess the sources of pollution loads in the watershed,
2. Link pollution loads to numerical water quality targets for the impaired segments;
3. Determine the TMDLs for the impaired stream segments;
4. Provide technical assistance to the stakeholders group to fulfill their tasks.
5. Prepare a final report

This report summarizes the findings of the first task.

II. Loading Sources

In identifying impaired river segments and loading sources, the Santa Clara River has been divided into reaches. There are two separate designations of reaches: one from the United States Environmental Protection Agency (US EPA) and the other from LA RWQCB, as shown in Tables 1 and 2 (LA RWQCB 2002). ***This report uses the US EPA reach designations.***

Table 1: US EPA Reach designations for the Santa Clara River

Reach	Description
1	Santa Clara Estuary to Highway 101
2	Highway 101 to Freeman diversion dam
3	Freeman diversion dam to above Santa Paula Creek and below Timber Canyon
4	Above Timber Canyon to above Grimes Canyon
5	Above Grimes Canyon to Propane Road
6	Propane Road to Blue Cut gaging station
7	Blue Cut gaging station to west pier Highway 99
8	West pier Highway 99 to Bouquet Canyon Road
9	Bouquet Canyon Road to Lang gaging station
10	Above Lang gaging station

Table 2: LA RWQCB Reach designations for the Santa Clara River

Reach	Description
1	Santa Clara Estuary to Highway 101
2	Highway 101 to Freeman diversion dam
3	Freeman diversion dam to Fillmore "A" Street
4	Fillmore "A" Street to Blue Cut gaging station
5	Blue Cut gaging station to west pier Highway 99
6	West pier Highway 99 to Bouquet Canyon Road
7	Bouquet Canyon Road to Lang gaging station
8	Above Lang gaging station

Figure 1 shows the impaired reaches and tributaries of the Santa Clara River: Mint Canyon Creek (1), Santa Clara River Reach 8 (2), Santa Clara River Reach 7 (3), Santa Clara River Reach 3 (4), Wheeler Canyon / Todd Barranca (5), and Brown Barranca / Long Canyon (6).

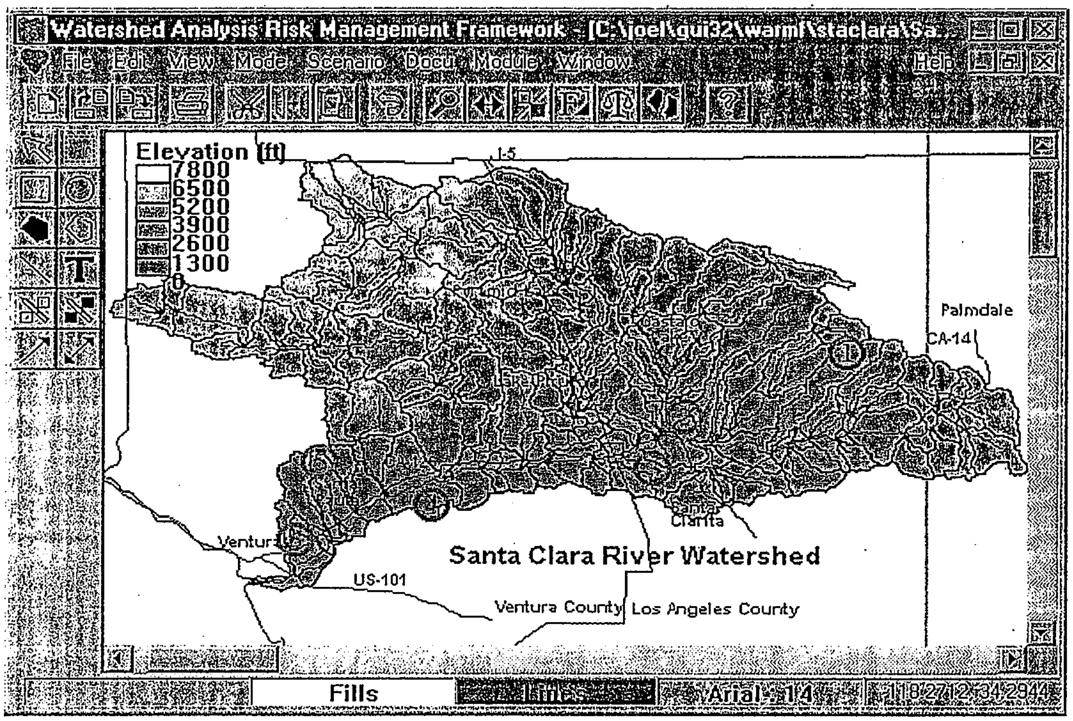

Figure 1: Impaired segments of the Santa Clara River watershed

For purposes of this analysis, the watershed has been broken into the land area which drains to each impaired reach of the Santa Clara River, as shown in Figure 2.

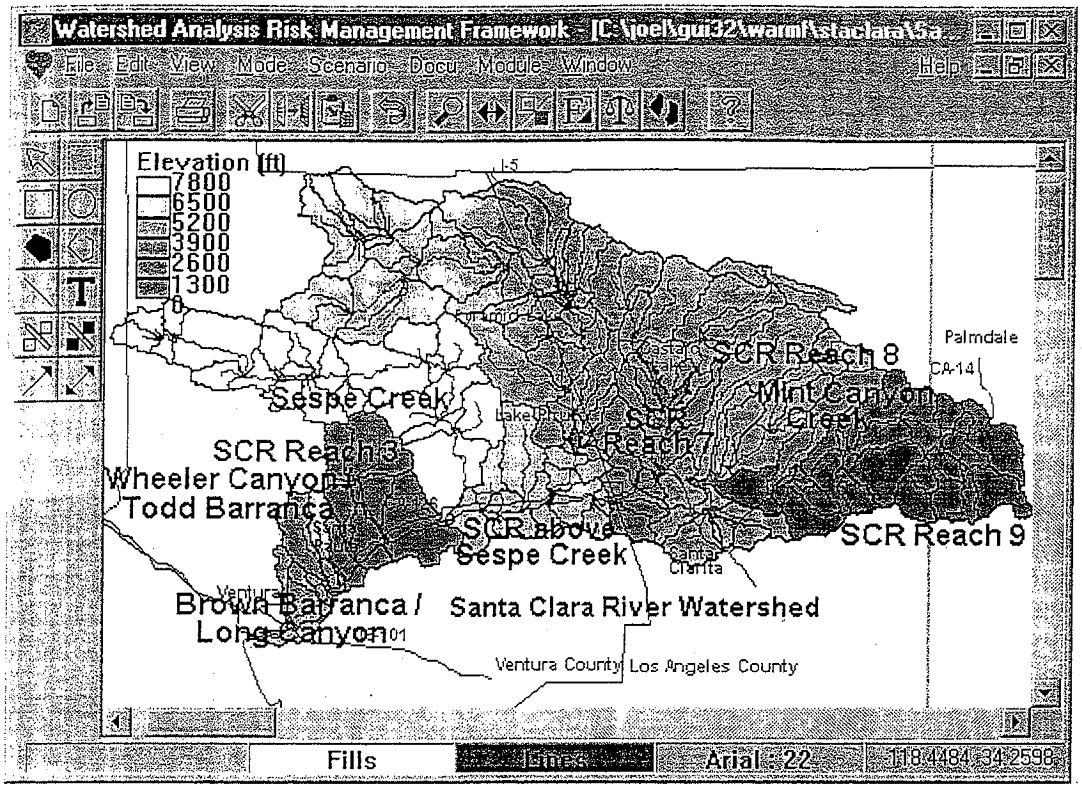

Figure 2 Analysis subregions of the Santa Clara River watershed

The Santa Clara River flows generally from east to west. The Mint Canyon Creek subregion in orange only consists of the land area draining to Mint Canyon Creek. The area draining to impaired Reach 8 has been split into two pieces. The brown area drains to Reach 9, including Reach 10. The turquoise color indicates the area which drains directly to the Santa Clara River, Reach 8. The turquoise area includes Santa Clarita. The magenta subregion drains to Santa Clara River Reach 7. The area draining to the impaired Reach 3 of the Santa Clara River is a large area which has been split into three pieces for this analysis. The yellow area is the Santa Clara River above Sespe Creek, which includes all of Reaches 5 and 6 of the Santa Clara River. In white is Sespe Creek, which drains eastward and then south to its confluence with the Santa Clara River. There is very little human impact within the Sespe Creek drainage. The red area drains to Santa Clara River Reach 3, also including Reach 4. The small yellow area near Santa Paula is Wheeler Canyon, whose drainage is called Todd Barranca near the Santa Clara River. The small green area is Long Canyon, whose drainage is called Brown Barranca.

The gray regions in Figure 2 are not included in this analysis. The watersheds tributary to Lake Piru and Castaic Lake provide flow and loading input to the Santa Clara River through the release from their dams. The gray region near Ventura does not drain to any impaired segment of the Santa Clara River watershed.

The lowlands near the lower Santa Clara River (yellow, white, and red areas) is an agricultural area, producing citrus fruit, avocadoes, and vegetables. Under this region is an unconfined aquifer. (UWCD 2002) This aquifer and stream diversions provide irrigation water for these crops.

Each catchment (black outlined object in Figure 1) is divided into land uses. The percentage of each land use in each catchment is calculated by overlaying an ArcView shapefile with the catchment boundaries. Three different databases were used for land use / land cover: 1980 data from BASINS (US EPA 2001), 1993 data from Southern California Association of Governments (SCAG) (SCAG 1993), and draft 2000 data from Ventura County (Ventura County 2002). The BASINS database covers the entire watershed and includes separate designations for each type of natural land cover. The SCAG database covers Ventura County and much of Los Angeles County (including the immediate Santa Clarita area) and has separate designations for different agricultural and urban land uses. The Ventura County database has detailed designations of agricultural land uses but is not detailed with regard to residential and commercial land uses. Table 3 shows the total land area of each subregion. Table 4 shows which database was used for each land use type in Ventura and Los Angeles Counties. Where SCAG and BASINS are listed as sources for Los Angeles County, SCAG was used in the area to which it applied and BASINS was used for the remaining (primarily rural) area. Table 5 shows the aggregate land use percentages within each region.

Table 3: Santa Clara River Watershed Subregion Areas

Subregion	Area (km^2)
Mint Canyon Creek	75
Santa Clara River Reach 9	534
Santa Clara River Reach 8	438
Santa Clara River Reach 7	218
Santa Clara River above Sespe Creek	268
Sespe Creek	685
Santa Clara River Reach 3	284
Wheeler Canyon / Todd Barranca	24
Brown Barranca / Long Canyon	7
TOTAL	2534

Table 4: Land Use Data Sources

Land Use	Ventura County	Los Angeles County
Deciduous	BASINS	BASINS
Mixed Forest	BASINS	BASINS
Orchard	Ventura County	SCAG/BASINS
Coniferous	BASINS	BASINS
Shrub / Scrub	BASINS	BASINS
Grassland	BASINS	BASINS
Park	Ventura County	SCAG
Golf Course	Ventura County	SCAG
Pasture	Ventura County	SCAG
Cropland	Ventura County	SCAG/BASINS
Marsh	Ventura County	BASINS
Barren	Ventura County	SCAG/BASINS
Water	Ventura County	SCAG/BASINS
Residential	SCAG	SCAG/BASINS
High Density Residential	SCAG	SCAG
Comm./Industrial	SCAG	SCAG/BASINS

Table 5: Land use in each watershed subregion, %

Land Use	Mint Canyon	SCR Reach 9	SCR Reach 8	SCR Reach 7	SCR abv Sespe	Sespe	SCR Reach 3	Wheeler / Todd	Long / Brown	Total
Deciduous	0.00	0.00	0.08	0.84	0.49	0.00	3.31	0.00	0.00	0.51
Mixed Forest	0.00	0.47	1.66	0.00	0.00	1.53	1.05	0.00	0.00	0.92
Orchard	0.00	0.11	0.18	0.33	11.85	2.04	16.62	10.53	24.21	3.92
Coniferous	0.00	5.99	1.24	1.23	8.33	28.71	33.67	44.30	0.00	14.41
Shrub / Scrub	87.75	74.95	62.60	80.72	70.37	66.85	36.33	38.83	56.31	66.30
Grassland	3.46	4.09	0.54	1.26	4.01	0.37	2.38	1.75	2.55	1.98
Park	0.00	0.05	0.24	0.00	0.19	0.01	0.20	0.00	0.82	0.10
Golf Course	0.00	0.05	1.09	0.64	0.16	0.00	0.09	0.00	0.00	0.28
Pasture	0.30	0.43	0.37	0.75	0.05	0.00	0.02	0.00	0.00	0.23
Cropland	0.74	0.21	0.46	1.80	1.13	0.09	1.17	0.89	4.95	0.60
Marsh	0.00	0.00	0.02	1.45	0.05	0.00	0.00	0.00	0.00	0.13
Barren	0.05	0.32	1.03	0.51	0.04	0.01	0.02	0.26	0.00	0.30
Water	0.00	0.00	0.67	0.08	0.01	0.00	0.00	0.00	0.00	0.12
Residential	2.80	6.77	1.52	1.13	0.40	0.19	0.99	2.32	0.00	2.10
High Density Residential	2.03	2.97	20.69	2.63	0.99	0.06	2.07	0.19	0.00	4.84
Comm./Industrial	2.87	3.59	7.61	6.63	1.94	0.12	2.07	0.94	11.16	3.24

This source identification and characterization analysis is focused on those pollutants of primary concern in the Santa Clara River watershed: nitrogen (ammonia, nitrite, nitrate) and phosphorus. Both nitrogen and phosphorus are also present in organic matter. Some data is available for organic nitrogen, but since measurement of ammonia is more common than measurement of organic or kjeldahl nitrogen, loading sources will be presented here in terms of ammonia. Since the natural reaction to convert nitrite to nitrate is faster than the reaction producing nitrite from ammonia, very little nitrite is normally present in nature. Therefore, the sources of nitrite are exclusively surface and subsurface point source discharges.

The time period used for this source characterization analysis is water years 1990-2000 (10/1/1989 – 9/30/2000). The loading is described seasonally by averaging the loading for each month in the 11 year time frame. Although three significant figures are provided in most cases in this report, that does not mean that any numbers presented are truly that precise. Rather, the significant figures are meant to ensure that the relationships between different loading sources are clear.

This report is intended to be a detailed summary of the current understanding of nutrient pollutant sources in the Santa Clara River watershed. Although every effort has been made to make this report as comprehensive as possible, there are probably other sources of pollutant loading in addition to those presented here. Any apparent omissions or corrections should be brought to the attention of the Santa Clara River Nutrient TMDL Steering Committee and Systech Engineering immediately.

The pollutant sources described in this report are divided into categories which describe how those sources affect water quality. This report does not attempt to link pollutant sources with water quality, however, as the transport and assimilation of pollutants varies according to location, time of year, water management, and the presence of other pollutants.

Direct Sources

Direct sources are those which discharge directly to the surface waters in the affected watershed subregions. Loading from these sources is only attenuated through in-stream processes including sediment adsorption and uptake by periphyton. Loading from these sources, as well as accompanying assimilative capacity, may also be removed by diversion.

Reservoir Releases

The releases from Castaic Lake and Lake Piru are treated in a manner similar to point sources, and no attempt is made to ascertain the ultimate source of pollutants. Flow for these sources is known from USGS gaging stations downstream of the dams (11109800 and 11108134), water quality is estimated from measured values from 1992-2000 from Piru Creek (USGS 11109800 and United Water Conservation District (UWCD) 4N18W03SW2) and extrapolated as necessary. Very little water quality data is available for Castaic Creek (UWCD 04N17W14SW1) and that data shows a similar quality to Piru Creek, so it is assumed that the water quality of Castaic Creek is the same as Piru Creek. Tables 6-8 show the average monthly loading for both these sources. Nitrite loading is assumed to be always zero for both sources.

Table 6: Monthly Reservoir Release Loading of Ammonia Nitrogen, kg/d

Region	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Castaic Lake	0.22	3.94	3.71	1.68	1.54	0.68	0.42	0.28	0.19	0.03	0.07	0.17	1.06
Lake Piru	1.53	2.63	3.34	1.89	3.26	2.39	1.68	4.31	15.21	14.25	7.35	2.4	5.02

Table 7: Monthly Reservoir Release Loading of Nitrate Nitrogen, kg/d

Region	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Castaic Lake	0.38	9.55	11.49	9.51	17.36	4.33	0.63	1.28	0	0.22	0.43	0.89	4.65
Lake Piru	2.68	6.37	10.33	10.68	36.76	15.31	2.52	19.46	0	96.54	43.57	12.2	21.53

Table 8: Monthly Reservoir Release Loading of Phosphorus, kg/d

Region	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Castaic Lake	0.2	3.61	3.41	3.37	1.41	0.62	0.38	0.26	0.07	0.03	0.07	0.16	1.11
Lake Piru	1.4	2.41	3.06	3.78	2.98	2.19	1.54	3.95	5.7	13.06	6.74	2.2	4.09

Direct Point Sources

Direct point sources are those which discharge directly to surface waters such as Santa Clara River and its tributaries. Each of these has a permit from the National Pollution Discharge Elimination System (NPDES). Table 9 shows a list of all the NPDES surface water dischargers, broken down into regions of the watershed, from the US EPA Permit Compliance System. The Fillmore WWTP includes both surface and groundwater discharges. Only the surface discharges are included here.

Table 9: Permitted Surface Water Discharges

NPDES Permit	Name	Average Flow, m^3/s
Total Mint Canyon Creek		0
CA0061638	City of Santa Clarita	0.0011
Total Santa Clara River Reach 9		0.0011
CA0003271	H R Textron Inc Valencia Facility	0.0003
CA0003352	Six Flags Magic Mountain Inc	0.0044
CA0054313	Saugus WWRP	0.2498
CA0057126	Keysor Century Corp	0.0042
CA0064017	H R Textron Inc Valencia Facility	0
Total Santa Clara River Reach 8		0.2587
CA0054216	Valencia WWRP	0.4036
CA0062561	Val Verde County Park Swimming Pool	0.000004
Total Santa Clara River Reach 7		0.4036
CA0059021	Fillmore WWTP	0.0078
CA0063240	Texaco Trading and Transportation Inc	0.0020
Total Santa Clara River above Sespe Creek		0.0098
Total Sespe Creek		0
CA0054224	Santa Paula WWRP	0.0858
Total Santa Clara River Reach 3		0.0858
Total Wheeler Canyon / Todd Barranca		0
Total Brown Barranca / Long Canyon		0
TOTAL WATERSHED		0.759

The flow and loading data for each was compiled from Discharge Monitoring Reports and information from the Los Angeles County Sanitation District. Tables 10-14 show the frequency of data used to evaluate point source loading and what assumptions were made to fill in data gaps. The data came from discharge monitoring reports (DMRs), United Water Conservation District water quality monitoring data (UWCD), and Los Angeles County Santitation District data (LACSD),

Table 10: Flow Data Frequency and Availability for Direct Point Source Discharges

NPDES Permit	Data Frequency and Availability
CA0061638	1989-2000: average of 2001 2001: two DMR data points
CA0003271	1989-9/2000: average of 10/2000-2001 10/2000-2001: monthly DMR data
CA0003352	1989-2000: average of 2001 2001: quarterly DMR data
CA0054313	1989-2001: daily LACSD data
CA0057126	1989-2001: one DMR flow value
CA0064017	DMR has zero discharge after 1/2000; assumed zero discharge always
CA0054216	1989-2001: daily LACSD data
CA0062561	1989-2000: copy of 2001 season 2001: two DMR measurements; operates seasonally May-September
CA0059021	1989-9/1998,11/1998,1/1999-4/1999,6/1999-12/1999,5/2001-10/2001: daily DMR data 10/1998,12/1998,5/1999,1/2001-4/2001: monthly or sporadic DMR data 1/2000-12/2000: no data: apparently no flow
CA0063240	1989-11/1993: average of 12/1993-2001 12/1993-2001: monthly DMR data
CA0054224	1989-6/1998: daily data 7/1998-2000: monthly DMR data 2001: daily/monthly DMR data

Table 11: Ammonia Nitrogen Data Frequency and Availability for Direct Point Source Discharges

NPDES Permit	Data Frequency and Availability
CA0061638	No data: zero discharge assumed
CA0003271	No data: zero discharge assumed
CA0003352	No data: assumed 20 mg/l discharge
CA0054313	1989-5/1992: average concentration of 6/1992-2001 6/1992-2001: monthly LACSD data
CA0057126	No data: zero discharge assumed
CA0064017	No data: zero discharge assumed
CA0054216	1989-1992: annual DMR data 1993-2001: monthly or more frequent LACSD data
CA0062561	No data: zero discharge assumed
CA0059021	1989-1/1993: average of 2/1993-8/2001 2/1993-8/2001: monthly DMR data when there was flow
CA0063240	No data: zero discharge assumed
CA0054224	1989-1997: monthly data 1998-2001: monthly DMR data

Table 12: Nitrite Nitrogen Data Frequency and Availability for Direct Point Source Discharges

NPDES Permit	Data Frequency and Availability
CA0061638	No specific data: zero discharge assumed
CA0003271	No specific data: zero discharge assumed
CA0003352	1989-2000: average of 2001 2001: quarterly DMR data
CA0054313	1989-5/1992: average concentration of 6/1992-2001 6/1992-2001: monthly LACSD data
CA0057126	1989-9/2000: average of 10/2000-2001 10/2000-2001: two DMR data points
CA0064017	No data: zero discharge assumed
CA0054216	1989-1992: annual DMR data 1993-2001: monthly LACSD data
CA0062561	1989-2000: copy of 2001 season 2001: two DMR measurements; operates seasonally May-September
CA0059021	1989-1/1993: average of 2/1993-8/2001 2/1993-8/2001: monthly DMR data when there was flow
CA0063240	No specific data: zero discharge assumed
CA0054224	1989-9/1997: monthly data 10/1997-12/1997: UWCD data 1998-2001: monthly DMR data

Table 13: Nitrate Nitrogen Data Frequency and Availability for Direct Point Source Discharges

NPDES Permit	Data Frequency and Availability
CA0061638	1989-2001: one 2001 data point for NO_2+NO_3 used for all years
CA0003271	1989-2000: average of 2001 NO2+NO3 data 2001: quarterly NO2+NO3 DMR data, zero discharge of NO2 assumed
CA0003352	1989-2000: average of 2001 2001: quarterly DMR data
CA0054313	1989-5/1992: average concentration of 6/1992-2001 6/1992-2001: monthly LACSD data
CA0057126	1989-9/2000: average of 10/2000-2001 10/2000-2001: two DMR data points
CA0064017	No data: zero discharge assumed
CA0054216	1989-1992: annual DMR data 1993-2001: monthly LACSD data
CA0062561	1989-2000: copy of 2001 season 2001: two DMR measurements; operates seasonally May-September
CA0059021	1989-1/1993: average of 2/1993-8/2001 2/1993-8/2001: monthly DMR data when there was flow
CA0063240	1989-7/1994,12/1997-1/1999,3/2000-2001: average of periods with data 8/1994-11/1997,2/1999-2/2000: quarterly NO_2+NO_3 DMR data
CA0054224	1989-9/1997: monthly data 10/1997-12/1997: UWCD data 1998-2001: monthly DMR data

Table 14: Phosphorus Data Frequency and Availability for Direct Point Source Discharges

NPDES Permit	Data Frequency and Availability
CA0061638	No data: zero discharge assumed
CA0003271	No data: zero discharge assumed
CA0003352	No data: assumed 6 mg/l discharge
CA0054313	1989: average concentration of 1990-2001 1990-2001: monthly/quarterly LACSD data
CA0057126	No data: zero discharge assumed
CA0064017	No data: zero discharge assumed
CA0054216	1989-2001: approximately monthly LACSD data
CA0062561	No data: zero discharge assumed
CA0059021	No data: assumed 3 mg/l discharge
CA0063240	No data: zero discharge assumed
CA0054224	1989-9/1997: average of 1997-2001 data 10/1997-12/1997: UWCD data 1998-2001: monthly DMR data

When available data is compiled and data gaps filled, there is a complete record of flow and loading for each pollutant over the entire time period for the source characterization analysis. Using that complete record, the average loading for each month was calculated and averaged for the same month in all years used in the analysis. The result is the monthly distribution of loading shown in Tables 15-18.

Table 15: Average Monthly Surface Discharge of Point Source Ammonia, kg/d as N

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Total Mint Canyon Creek	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
CA0061638	0	0	0	0	0	0	0	0	0	0	0	0	0
Total SCR Reach 9	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
CA0003271	0	0	0	0	0	0	0	0	0	0	0	0	0
CA0003352	7.55	7.55	7.55	7.55	7.55	7.55	7.55	7.55	7.55	7.81	7.41	7.41	7.55
CA0054313	250	230	229	209	243	239	225	237	246	259	260	278	243
CA0057126	0	0	0	0	0	0	0	0	0	0	0	0	0
CA0064017	0	0	0	0	0	0	0	0	0	0	0	0	0
Total SCR Reach 8	**258**	**238**	**237**	**217**	**251**	**247**	**233**	**245**	**254**	**267**	**267**	**285**	**251**
CA0054216	561	520	547	594	579	585	585	540	537	505	551	570	556
CA0062561	0	0	0	0	0	0	0	0	0	0	0	0	0
Total SCR Reach 7	**561**	**520**	**547**	**594**	**579**	**585**	**585**	**540**	**537**	**505**	**551**	**570**	**556**
CA0059021	4.9	1.6	9.8	16.4	7.2	15.8	29.2	12.1	3.7	2.3	2.9	5	9.3
CA0063240	0	0	0	0	0	0	0	0	0	0	0	0	0
Total SCR above Sespe Creek	**4.9**	**1.6**	**9.8**	**16.4**	**7.2**	**15.8**	**29.2**	**12.1**	**3.7**	**2.3**	**2.9**	**5**	**9.3**
Total Sespe Creek	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
CA0054224	146	139	154	134	144	157	139	136	123	120	136	155	140
Total SCR Reach 3	**146**	**139**	**154**	**134**	**144**	**157**	**139**	**136**	**123**	**120**	**136**	**155**	**140**
Total Wheeler Cyn / Todd Barr.	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Total Brown Barr. / Long Cyn	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
TOTAL WATERSHED	**970**	**899**	**948**	**961**	**981**	**1005**	**986**	**933**	**918**	**894**	**957**	**1015**	**956**

Table 16: Average Monthly Surface Discharge of Point Source Nitrite, kg/d as N

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Total Mint Canyon Creek	0	0	0	0	0	0	0	0	0	0	0	0	0
CA0061638	0	0	0	0	0	0	0	0	0	0	0	0	0
Total SCR Reach 9	0	0	0	0	0	0	0	0	0	0	0	0	0
CA0003271	0	0	0	0	0	0	0	0	0	0	0	0	0
CA0003352	0	0	0	0	0	0	0	0	0	0	0	0	0
CA0054313	52.3	42.7	39.9	38.9	41.8	38.3	41.1	40.9	41.6	39.9	43	51	42.7
CA0057126	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52
CA0064017	0	0	0	0	0	0	0	0	0	0	0	0	0
Total SCR Reach 8	52.8	43.2	40.4	39.4	42.3	38.8	41.6	41.4	42.1	40.4	43.5	51.5	43.2
CA0054216	46.2	48.6	51.7	46.7	51.2	50.1	52.6	45.3	52.9	47.1	44.2	46.3	48.5
CA0062561	0	0	0	0	0	0	0	0	0	0	0	0	0
Total SCR Reach 7	46.2	48.6	51.7	46.7	51.2	50.1	52.6	45.3	52.9	47.1	44.2	46.3	48.5
CA0059021	0.08	0.02	0.22	0.11	0.03	0.25	0.23	0.13	0.11	0.04	0.05	0.08	0.11
CA0063240	0	0	0	0	0	0	0	0	0	0	0	0	0
Total SCR above Sespe Creek	0.08	0.02	0.22	0.11	0.03	0.25	0.23	0.13	0.11	0.04	0.05	0.08	0.11
Total Sespe Creek	0	0	0	0	0	0	0	0	0	0	0	0	0
CA0054224	4.03	4.12	4.06	5.09	4.58	4.41	5.69	6.5	8.6	9.19	5.98	3.54	5.5
Total SCR Reach 3	4.03	4.12	4.06	5.09	4.58	4.41	5.69	6.5	8.6	9.19	5.98	3.54	5.5
Total Wheeler Cyn / Todd Barr.	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Brown Barr. / Long Cyn	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL WATERSHED	103	96	96	91	98	94	100	93	104	97	94	101	97

Table 17: Average Monthly Surface Discharge of Point Source Nitrate, kg/d as N

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Total Mint Canyon Creek	0	0	0	0	0	0	0	0	0	0	0	0	0
CA0061638	0.89	0.89	0.89	0.89	0.89	0.90	0.90	0.90	0.90	0.89	0.89	0.89	0.89
Total SCR Reach 9	0.89	0.89	0.89	0.89	0.89	0.90	0.90	0.90	0.90	0.89	0.89	0.89	0.89
CA0003271	0.18	0.19	0.19	0.19	0.2	0.2	0.21	0.21	0.2	0.19	0.18	0.19	0.19
CA0003352	1.71	1.71	1.71	1.64	1.64	1.64	1.68	1.68	1.68	1.77	1.68	1.68	1.68
CA0054313	28.1	33.8	30.7	35.7	45.6	57.5	43	30.4	37.2	40.5	33.3	29.3	37
CA0057126	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64
CA0064017	0	0	0	0	0	0	0	0	0	0	0	0	0
Total SCR Reach 8	30.6	36.3	33.2	38.2	48.1	60.0	45.5	32.9	39.7	43.1	35.8	31.8	39.5
CA0054216	188	189	203	201	175	189	206	194	185	220	228	202	199
CA0062561	0	0	0	0	0	0.006	0.021	0.024	0.004	0	0	0	0.005
Total SCR Reach 7	188	189	203	201	175	189	206	194	185	220	228	202	199
CA0059021	0.18	0.27	1.53	2.3	0.71	2.16	2.97	2.97	1.95	2.55	1.49	0.91	1.67
CA0063240	0.004	0.02	0.023	0.017	0.012	0.004	0.004	0.004	0.004	0.005	0.005	0.005	0.009
Total SCR above Sespe Creek	0.18	0.29	1.55	2.32	0.72	2.16	2.97	2.97	1.95	2.56	1.50	0.92	1.68

Total Sespe Creek	0	0	0	0	0	0	0	0	0	0	0	0	0
CA0054224	42.5	35	36.5	37.4	34.2	34.5	37.1	38.2	37.5	33.4	36.4	39.9	36.9
Total SCR Reach 3	42.5	35	36.5	37.4	34.2	34.5	37.1	38.2	37.5	33.4	36.4	39.9	36.9
Total Wheeler Cyn / Todd Barr.	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Brown Barr. / Long Cyn	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL WATERSHED	262	261	275	280	259	287	292	269	265	300	303	276	278

Table 18: Average Monthly Surface Discharge of Point Source Phosphorus, kg/d

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Total Mint Canyon Creek	0	0	0	0	0	0	0	0	0	0	0	0	0
CA0061638	0	0	0	0	0	0	0	0	0	0	0	0	0
Total SCR Reach 9	0	0	0	0	0	0	0	0	0	0	0	0	0
CA0003271	0	0	0	0	0	0	0	0	0	0	0	0	0
CA0003352	2.26	2.26	2.26	2.26	2.26	2.26	2.26	2.26	2.26	2.34	2.22	2.22	2.26
CA0054313	159	164	175	162	168	152	146	144	150	144	141	145	154
CA0057126	0	0	0	0	0	0	0	0	0	0	0	0	0
CA0064017	0	0	0	0	0	0	0	0	0	0	0	0	0
Total SCR Reach 8	161	166	177	164	170	154	148	146	152	146	143	147	156
CA0054216	339	337	348	343	287	266	274	266	220	228	251	284	286
CA0062561	0	0	0	0	0	0	0	0	0	0	0	0	0
Total SCR Reach 7	339	337	348	343	287	266	274	266	220	228	251	284	286
CA0059021	0.9	0.4	2.28	3.18	1.72	2.95	4.97	3.25	1.01	1.34	0.95	1.1	2.02
CA0063240	0	0	0	0	0	0	0	0	0	0	0	0	0
Total SCR above Sespe Creek	0.9	0.4	2.28	3.18	1.72	2.95	4.97	3.25	1.01	1.34	0.95	1.1	2.02
Total Sespe Creek	0	0	0	0	0	0	0	0	0	0	0	0	0
CA0054224	23.1	22.2	33	26.4	24	27.8	27.2	25.7	25.1	21	27.8	30.8	26.2
Total SCR Reach 3	23.1	22.2	33	26.4	24	27.8	27.2	25.7	25.1	21	27.8	30.8	26.2
Total Wheeler Cyn / Todd Barr.	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Brown Barr. / Long Cyn	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL WATERSHED	524	526	560	537	483	451	454	441	398	396	423	463	470

Subsurface Discharges

There are many groundwater waste discharges in the Santa Clara River watershed. In each case, there is a mechanism which allows the waste to percolate into the soil. Once into the soil, the water and its associated pollutants disperse, although they may be assimilated through soil adsorption or uptake by vegetation. These sources are not associated with any particular land use, but are assumed to be dispersed proportionately over all land uses.

Groundwater Discharges

The State of California issues permits for groundwater discharges. Table 19 shows all such dischargers in each subregion of the watershed.

Table 19: Permitted Groundwater Discharges

Name	Average Flow, m^3/s
Truck & RV Sales	0.000009
Veterans of Foreign Wars	0.000009
Total Mint Canyon Creek	**0.000018**
Acton Plaza	0.000088
Acton Rehabilitation Center	0.000964
Building A, Santiago Square, Acton	0.000464
Westar Properties, Acton	0.000088
Crown Valley Building Supply	0.000031
Crown Valley Community Church	0.000074
E Z Take Out, Acton	0.000057
Fire Camp #11, Acton	0.000394
Jack-in-the-Box #3304, Acton	0.000066
McDonald's Resaurant, Acton	0.000526
Mobil SS #11	0.000263
Mobil SS #18	0.000005
Rio Café	0.000066
Shell Oil, Acton	0.000066
Sierra Ranch WWTP	0.002848
Tract 21566, Acton	0.000066
Tract 22190, Acton	0.000066
Tract 22284 Acton	0.000004
Tract 45695, Acton	0.000053
Tract 46404, Acton	0.000832
Tract 46647 Acton	0.000158
Tract 47788, Acton	0.000250
Tract 48391, Acton	0.000044
Tract 48818, Acton	0.000066
Tract 49240, Acton	0.001038
Tract 49240, Acton	0.000355
Tract 49240, Acton	0.000197
Tract 49601, Acton	0.000482
Tract 49601, Acton	0.000066
Tract 49601, Acton	0.000407
Tract 49684, Acton	0.000066
Tract 50385, Acton	0.000066
Tract 52637, Acton	0.000066
Tract 52882, Acton	0.000920
Tract 52883, Acton	0.000066
Trans Technology Corp.	0.009201
Warm Springs Rehabilitation Center	0.000801
Total Santa Clara River Reach 9	**0.021270**
College of the Canyons	0.000040
H.R. Textron Valencia Facility	0.000197
Mobil Oil Newhall Station	0.006572
Total Santa Clara River Reach 8	**0.006809**
Total Santa Clara River Reach 7	**0**
Piru WWTP	0.004596
Fillmore WWTP	0.032716
Total Santa Clara River abv Sespe Ck	**0.037312**
Total Sespe Creek	**0**
Pan American Seed	0.000014
Thomas Aquinas College	0.000498
Total Santa Clara River Reach 3	**0.000512**
Limoneira & Olivelands Sewer Farm	0.000719
Saticoy Food Corp.	0.009201
Todd Road Jail Facility	0.003724
Total Wheeler Canyon / Todd Barranca	**0.013644**
Total Brown Barranca / Long Canyon	**0**
TOTAL WATERSHED	**0.079565**

In most cases, there is no monitoring data available for groundwater discharges. The State of California groundwater discharger database has a baseline flow. This was combined with assumed package sewage treatment plant effluent pollutant concentrations (25 mg/l NH_4-N, 5 mg/l NO_3-N, 6 mg/l P) to estimate load (Lindeburg 1999).

The flow and loading for each discharger with data was compiled from Discharge Monitoring Reports. Tables 20-24 show the frequency of data used to evaluate point source loading for those stations with data and what assumptions were made to fill in data gaps.

Table 20: Flow Data Frequency and Availability for Groundwater Point Source Discharges

Name	Data Frequency and Availability
Mobil SS #18	10/1989-10/2000: average of 10/2000-10/2001 10/2000-10/2001: weekly data
Warm Springs Rehabilitation Center	1989-1999: average of 2000-2001 2000-2001: monthly data
Fillmore WWTP	1989-9/1998,2/1999-12/1999: daily data 10/1998-1/1999,2000-2001: monthly data
Piru WWTP	1989-1992: average of 1993-2001 1993-2001: daily data
Pan American Seed	1989-1999: average of 2000-2001 2000-2001: quarterly data
Thomas Aquinas College	1989: monthly data 1990: daily and monthly data 1991-9/1998: daily data 10/1998-2001: average of 1989-1998
Limoneira & Olivelands Sewer Farm	1989-1992: average of 1993-2001 1993-2001: monthly data

Table 21: Ammonia Nitrogen Data Frequency and Availability for Groundwater Discharges

Name	Data Frequency and Availability
Mobil SS #18	No data: assumed zero discharge
Warm Springs Rehabilitation Center	1989-1999: average of 2000-2001 2000-2001: quarterly data
Fillmore WWTP	1989-7/1998: average of 8/1998-2001 8/1998-2001: monthly/quarterly data
Piru WWTP	1989-1999: average of 2000-2001 2000: monthly data 2001: quarterly data
Pan American Seed	No data: assumed 2 mg/l
Thomas Aquinas College	1989-4/1994: average of 5/1994-9/1998 5/1994–9/1998: quarterly data 10/1998-2001: average of 5/1994-9/1998
Limoneira & Olivelands Sewer Farm	No data: assumed no discharge

Table 22: Nitrite Nitrogen Data Frequency and Availability for Groundwater Discharges

Name	Data Frequency and Availability
Mobil SS #18	No data: assumed zero discharge
Warm Springs Rehabilitation Center	1989-1999: average of 2000-2001 2000-2001: quarterly data
Fillmore WWTP	1989-7/1998: average of 8/1998-2001 8/1998-2001: monthly/quarterly data
Piru WWTP	1989-1999: average of 2000-2001 2000: monthly data 2001: quarterly data
Pan American Seed	No data: assumed zero discharge
Thomas Aquinas College	1989-4/1994: average of 5/1994-9/1998 5/1994–9/1998: quarterly data 10/1998-2001: average of 5/1994-9/1998
Limoneira & Olivelands Sewer Farm	No data: assumed no discharge

Table 23: Nitrate Nitrogen Data Frequency and Availability for Groundwater Discharges

Name	Data Frequency and Availability
Mobil SS #18	No data: assumed zero discharge
Warm Springs Rehabilitation Center	1989-1999: average of 2000-2001 2000-2001: quarterly data
Fillmore WWTP	1989-7/1998: average of 8/1998-2001 8/1998-2001: monthly/quarterly data
Piru WWTP	1989-1999: average of 2000-2001 2000: monthly data 2001: quarterly data
Pan American Seed	No data: assumed 10 mg/l
Thomas Aquinas College	1989-4/1994: average of 5/1994-9/1998 5/1994–9/1998: quarterly data 10/1998-2001: average of 5/1994-9/1998
Limoneira & Olivelands Sewer Farm	1989-1992: average of 1993-2001 1993-2001: quarterly data

Table 24: Phosphorus Data Frequency and Availability for Groundwater Discharges

Name	Data Frequency and Availability
Mobil SS #18	No data: assumed zero discharge
Warm Springs Rehabilitation Center	No data: 3 mg/l assumed
Fillmore WWTP	No data: assumed 3 mg/l
Piru WWTP	1989-1999: average of 2000-2001 2000-2001: quarterly data
Pan American Seed	No data: assumed 2 mg/l
Thomas Aquinas College	No data: assumed 3 mg/l
Limoneira & Olivelands Sewer Farm	No data: assumed no discharge

When available data is compiled and data gaps filled, there is a complete record of flow and loading for each pollutant over the entire time period for the source characterization analysis. Using that complete record, the average loading for each month was calculated and averaged for the same month in all years used in the analysis. For discharges without data, constant flow and loading was assumed. The result is the monthly distribution of loading shown in Tables 25-28.

Table 25: Average Monthly Groundwater Discharge Loading of Ammonia Nitrogen, kg/d as N

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Truck & RV Sales	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019
Veterans of Foreign Wars	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019
Total Mint Canyon Creek	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038
Acton Plaza	0.189	0.189	0.189	0.189	0.189	0.189	0.189	0.189	0.189	0.189	0.189	0.189	0.189
Acton Rehabilitation Center	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
Building A, Santiago Sq, Acton	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Westar Properties, Acton	0.189	0.189	0.189	0.189	0.189	0.189	0.189	0.189	0.189	0.189	0.189	0.189	0.189
Crown Valley Building Supply	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066
Crown Valley Comm. Church	0.161	0.161	0.161	0.161	0.161	0.161	0.161	0.161	0.161	0.161	0.161	0.161	0.161
E Z Take Out, Acton	0.123	0.123	0.123	0.123	0.123	0.123	0.123	0.123	0.123	0.123	0.123	0.123	0.123

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Fire Camp #11, Acton	0.852	0.852	0.852	0.852	0.852	0.852	0.852	0.852	0.852	0.852	0.852	0.852	0.852
Jack-in-the-Box #3304, Acton	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142
McDonald's Resaurant, Acton	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14
Mobil SS #11	0.568	0.568	0.568	0.568	0.568	0.568	0.568	0.568	0.568	0.568	0.568	0.568	0.568
Mobil SS #18	0	0	0	0	0	0	0	0	0	0	0	0	0
Rio Café	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142
Shell Oil, Acton	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142
Sierra Ranch WWTP	6.15	6.15	6.15	6.15	6.15	6.15	6.15	6.15	6.15	6.15	6.15	6.15	6.15
Tract 21566, Acton	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142
Tract 22190, Acton	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142
Tract 22284 Acton	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009
Tract 45695, Acton	0.114	0.114	0.114	0.114	0.114	0.114	0.114	0.114	0.114	0.114	0.114	0.114	0.114
Tract 46404, Acton	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80
Tract 46647 Acton	0.341	0.341	0.341	0.341	0.341	0.341	0.341	0.341	0.341	0.341	0.341	0.341	0.341
Tract 47788, Acton	0.539	0.539	0.539	0.539	0.539	0.539	0.539	0.539	0.539	0.539	0.539	0.539	0.539
Tract 48391, Acton	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095
Tract 48818, Acton	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142
Tract 49240, Acton	2.24	2.24	2.24	2.24	2.24	2.24	2.24	2.24	2.24	2.24	2.24	2.24	2.24
Tract 49240, Acton	0.767	0.767	0.767	0.767	0.767	0.767	0.767	0.767	0.767	0.767	0.767	0.767	0.767

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Tract 49240, Acton	0.426	0.426	0.426	0.426	0.426	0.426	0.426	0.426	0.426	0.426	0.426	0.426	0.426
Tract 49601, Acton	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04
Tract 49601, Acton	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142
Tract 49601, Acton	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88
Tract 49684, Acton	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142
Tract 50385, Acton	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142
Tract 52637, Acton	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142
Tract 52882, Acton	1.99	1.99	1.99	1.99	1.99	1.99	1.99	1.99	1.99	1.99	1.99	1.99	1.99
Tract 52883, Acton	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142
Trans Technology Corp.	19.9	19.9	19.9	19.9	19.9	19.9	19.9	19.9	19.9	19.9	19.9	19.9	19.9
Warm Springs Rehab. Center	0.048	0.048	0.052	0.049	0.049	0.052	0.052	0.051	0.051	0.051	0.051	0.05	0.051
Total SCR Reach 9	44.3	44.3	44.3	44.3	44.3	44.3	44.3	44.3	44.3	44.3	44.3	44.3	44.3
College of the Canyons	0.087	0.087	0.087	0.087	0.087	0.087	0.087	0.087	0.087	0.08	0.08	0.08	0.085
H.R. Textron Valencia Facility	0.426	0.426	0.426	0.426	0.426	0.426	0.426	0.426	0.426	0.426	0.426	0.426	0.426
Mobil Oil Newhall Station	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2
Total SCR Reach 8	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7
Total SCR Reach 7	0	0	0	0	0	0	0	0	0	0	0	0	0
Fillmore WWTP	43.2	50.8	45.4	39.7	43.4	35.8	32	33.7	39.1	36.2	39.1	40	39.8
Piru WWTP	6.44	6.75	7.8	6.57	6.69	6.83	7.84	7.19	7.76	7.24	7.15	6.61	7.07
Total SCR above Sespe Creek	49.6	57.6	53.2	46.3	50.1	42.6	39.8	40.9	46.9	43.4	46.3	46.6	46.9
Total Sespe Creek	0	0	0	0	0	0	0	0	0	0	0	0	0
Pan American Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Thomas Aquinas College	0.589	0.814	0.546	0.41	0.41	0.401	0.386	0.383	0.278	0.277	0.49	0.387	0.444

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Total SCR Reach 3	0.589	0.814	0.546	0.41	0.41	0.401	0.386	0.383	0.278	0.277	0.49	0.387	0.444
Limoneira & Olivelands Sewer Farm	0	0	0	0	0	0	0	0	0	0	0	0	0
Saticoy Food Corp.	19.9	19.9	19.9	19.9	19.9	19.9	19.9	19.9	19.9	19.9	19.9	19.9	19.9
Todd Road Jail Facility	8.05	8.05	8.05	8.05	8.05	8.05	8.05	8.05	8.05	8.05	8.05	8.05	8.05
Total Wheeler Cyn/Todd Barr	27.9	27.9	27.9	27.9	27.9	27.9	27.9	27.9	27.9	27.9	27.9	27.9	27.9
Total Brown Barr. / Long Cyn	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL WATERSHED	137	145	141	134	137	130	127	128	134	131	134	134	134

Table 26: Average Monthly Groundwater Loading of Nitrite Nitrogen, kg/d as N

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Truck & RV Sales	0	0	0	0	0	0	0	0	0	0	0	0	0
Veterans of Foreign Wars	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Mint Canyon Creek	0	0	0	0	0	0	0	0	0	0	0	0	0
Acton Plaza	0	0	0	0	0	0	0	0	0	0	0	0	0
Acton Rehabilitation Center	0	0	0	0	0	0	0	0	0	0	0	0	0
Building A, Santiago Sq, Acton	0	0	0	0	0	0	0	0	0	0	0	0	0
Westar Properties, Acton	0	0	0	0	0	0	0	0	0	0	0	0	0
Crown Valley Building Supply	0	0	0	0	0	0	0	0	0	0	0	0	0
Crown Valley Comm. Church	0	0	0	0	0	0	0	0	0	0	0	0	0
E Z Take Out, Acton	0	0	0	0	0	0	0	0	0	0	0	0	0
Fire Camp #11, Acton	0	0	0	0	0	0	0	0	0	0	0	0	0
Jack-in-the-Box #3304, Acton	0	0	0	0	0	0	0	0	0	0	0	0	0
McDonald's Resaurant, Acton	0	0	0	0	0	0	0	0	0	0	0	0	0
Mobil SS #11	0	0	0	0	0	0	0	0	0	0	0	0	0
Mobil SS #18	0	0	0	0	0	0	0	0	0	0	0	0	0
Rio Café	0	0	0	0	0	0	0	0	0	0	0	0	0
Shell Oil, Acton	0	0	0	0	0	0	0	0	0	0	0	0	0
Sierra Ranch WWTP	0	0	0	0	0	0	0	0	0	0	0	0	0
Tract 21566, Acton	0	0	0	0	0	0	0	0	0	0	0	0	0
Tract 22190, Acton	0	0	0	0	0	0	0	0	0	0	0	0	0
Tract 22284 Acton	0	0	0	0	0	0	0	0	0	0	0	0	0
Tract 45695, Acton	0	0	0	0	0	0	0	0	0	0	0	0	0
Tract 46404, Acton	0	0	0	0	0	0	0	0	0	0	0	0	0
Tract 46647 Acton	0	0	0	0	0	0	0	0	0	0	0	0	0
Tract 47788, Acton	0	0	0	0	0	0	0	0	0	0	0	0	0
Tract 48391, Acton	0	0	0	0	0	0	0	0	0	0	0	0	0
Tract 48818, Acton	0	0	0	0	0	0	0	0	0	0	0	0	0
Tract 49240, Acton	0	0	0	0	0	0	0	0	0	0	0	0	0
Tract 49240, Acton	0	0	0	0	0	0	0	0	0	0	0	0	0

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Tract 49240, Acton	0	0	0	0	0	0	0	0	0	0	0	0	0
Tract 49601, Acton	0	0	0	0	0	0	0	0	0	0	0	0	0
Tract 49601, Acton	0	0	0	0	0	0	0	0	0	0	0	0	0
Tract 49601, Acton	0	0	0	0	0	0	0	0	0	0	0	0	0
Tract 49684, Acton	0	0	0	0	0	0	0	0	0	0	0	0	0
Tract 50385, Acton	0	0	0	0	0	0	0	0	0	0	0	0	0
Tract 52637, Acton	0	0	0	0	0	0	0	0	0	0	0	0	0
Tract 52882, Acton	0	0	0	0	0	0	0	0	0	0	0	0	0
Tract 52883, Acton	0	0	0	0	0	0	0	0	0	0	0	0	0
Trans Technology Corp.	0	0	0	0	0	0	0	0	0	0	0	0	0
Warm Springs Rehab. Center	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
Total SCR Reach 9	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
College of the Canyons	0	0	0	0	0	0	0	0	0	0	0	0	0
H.R. Textron Valencia Facility	0	0	0	0	0	0	0	0	0	0	0	0	0
Mobil Oil Newhall Station	0	0	0	0	0	0	0	0	0	0	0	0	0
Total SCR Reach 8	0	0	0	0	0	0	0	0	0	0	0	0	0
Total SCR Reach 7	0	0	0	0	0	0	0	0	0	0	0	0	0
Fillmore WWTP	0.646	0.989	0.943	0.853	0.794	0.427	0.408	0.521	0.593	0.579	0.601	0.606	0.661
Piru WWTP	0.144	0.153	0.179	0.147	0.149	0.155	0.18	0.154	0.162	0.152	0.154	0.14	0.156
Total SCR above Sespe Creek	0.79	1.142	1.122	[illegible]1	0.943	0.582	0.588	0.675	0.755	0.731	0.755	0.746	0.817
Total Sespe Creek	0	0	0	0	0	0	0	0	0	0	0	0	0
Pan American Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Thomas Aquinas College	0	0	0	0	0	0	0	0	0	0	0	0	0
Total SCR Reach 3	0	0	0	0	0	0	0	0	0	0	0	0	0
Limoneira & Olivelands Sewer Farm	0	0	0	0	0	0	0	0	0	0	0	0	0
Saticoy Food Corp.	0	0	0	0	0	0	0	0	0	0	0	0	0
Todd Road Jail Facility	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Wheeler Cyn/Todd Barr	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Brown Barr / Long Cyn	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL WATERSHED	0.794	1.146	1.126	1.004	0.947	0.586	0.592	0.679	0.759	0.735	0.759	0.75	0.821

Table 27: Average Monthly Groundwater Loading of Nitrate Nitrogen, kg/d as N

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Truck & RV Sales	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
Veterans of Foreign Wars	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
Total Mint Canyon Creek	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008
Acton Plaza	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038
Acton Rehabilitation Center	0.416	0.416	0.416	0.416	0.416	0.416	0.416	0.416	0.416	0.416	0.416	0.416	0.416
Building A, Santiago Sq, Acton	0.201	0.201	0.201	0.201	0.201	0.201	0.201	0.201	0.201	0.201	0.201	0.201	0.201
Westar Properties, Acton	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038
Crown Valley Building Supply	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013
Crown Valley Comm. Church	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032
E Z Take Out, Acton	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Fire Camp #11, Acton	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Jack-in-the-Box #3304, Acton	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028
McDonald's Resaurant, Acton	0.227	0.227	0.227	0.227	0.227	0.227	0.227	0.227	0.227	0.227	0.227	0.227	0.227
Mobil SS #11	0.114	0.114	0.114	0.114	0.114	0.114	0.114	0.114	0.114	0.114	0.114	0.114	0.114
Mobil SS #18	0	0	0	0	0	0	0	0	0	0	0	0	0
Rio Café	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028
Shell Oil, Acton	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028
Sierra Ranch WWTP	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23
Tract 21566, Acton	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Tract 22190, Acton	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028
Tract 22284 Acton	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Tract 45695, Acton	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023
Tract 46404, Acton	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36
Tract 46647 Acton	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068
Tract 47788, Acton	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108
Tract 48391, Acton	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019
Tract 48818, Acton	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028
Tract 49240, Acton	0.449	0.449	0.449	0.449	0.449	0.449	0.449	0.449	0.449	0.449	0.449	0.449	0.449
Tract 49240, Acton	0.153	0.153	0.153	0.153	0.153	0.153	0.153	0.153	0.153	0.153	0.153	0.153	0.153
Tract 49240, Acton	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085
Tract 49601, Acton	0.208	0.208	0.208	0.208	0.208	0.208	0.208	0.208	0.208	0.208	0.208	0.208	0.208
Tract 49601, Acton	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028
Tract 49601, Acton	0.176	0.176	0.176	0.176	0.176	0.176	0.176	0.176	0.176	0.176	0.176	0.176	0.176
Tract 49684, Acton	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028
Tract 50385, Acton	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028
Tract 52637, Acton	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028
Tract 52882, Acton	0.398	0.398	0.398	0.398	0.398	0.398	0.398	0.398	0.398	0.398	0.398	0.398	0.398

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Tract 52883, Acton	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028
Trans Technology Corp.	3.98	3.98	3.98	3.98	3.98	3.98	3.98	3.98	3.98	3.98	3.98	3.98	3.98
Warm Springs Rehab. Center	0.431	0.433	0.435	0.443	0.443	0.426	0.426	0.422	0.42	0.498	0.509	0.414	0.442
Total SCR Reach 8	**9.27**	**9.27**	**9.28**	**9.28**	**9.28**	**9.27**	**9.27**	**9.26**	**9.26**	**9.34**	**9.35**	**9.26**	**9.28**
College of the Canyons	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.016	0.016	0.016	0.017
H.R. Textron Valencia Facility	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085
Mobil Oil Newhall Station	2.84	2.84	2.84	2.84	2.84	2.84	2.84	2.84	2.84	2.84	2.84	2.84	2.84
Total SCR Reach 8	**2.94**	**2.94**	**2.94**	**2.94**	**2.94**	**2.94**	**2.94**	**2.94**	**2.94**	**2.94**	**2.94**	**2.94**	**2.94**
Total SCR Reach 7	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Fillmore WWTP	6.3	6.66	6.5	6.66	7.25	7.37	6.58	5.42	6.28	6.63	6.12	6.06	6.48
Piru WWTP	0.295	0.311	0.358	0.293	0.297	0.317	0.367	0.347	0.401	0.374	0.315	0.286	0.33
Total SCR above Sespe Creek	**6.6**	**6.97**	**6.86**	**6.95**	**7.55**	**7.69**	**6.95**	**5.77**	**6.68**	**7**	**6.44**	**6.35**	**6.81**
Total Sespe Creek	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Pan American Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Thomas Aquinas College	0.121	0.384	0.376	0.274	0.172	0.083	0.073	0.102	0.128	0.145	0.148	0.122	0.175
Total SCR Reach 3	**0.121**	**0.384**	**0.376**	**0.274**	**0.172**	**0.083**	**0.073**	**0.102**	**0.128**	**0.145**	**0.148**	**0.122**	**0.175**
Limoneira & Olivelands Sewer Farm	0.008	0.011	0.014	0.014	0.013	0.009	0.006	0.003	0.004	0.005	0.006	0.013	0.009
Saticoy Food Corp.	3.98	3.98	3.98	3.98	3.98	3.98	3.98	3.98	3.98	3.98	3.98	3.98	3.98
Todd Road Jail Facility	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61
Total Wheeler Cyn/Todd Barr	**5.60**	**5.60**	**5.60**	**5.60**	**5.60**	**5.60**	**5.60**	**5.60**	**5.60**	**5.60**	**5.60**	**5.60**	**5.60**
Total Brown Barr. / Long Cyn	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
TOTAL WATERSHED	**24.5**	**25.2**	**25.1**	**25.1**	**25.6**	**25.6**	**24.8**	**23.7**	**24.6**	**25**	**24.5**	**24.3**	**24.8**

Table 28: Average Monthly Groundwater Loading of Phosphorus, kg/d

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Truck & RV Sales	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Veterans of Foreign Wars	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Total Mint Canyon Creek	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Acton Plaza	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045
Acton Rehabilitation Center	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Building A, Santiago Sq, Acton	0.241	0.241	0.241	0.241	0.241	0.241	0.241	0.241	0.241	0.241	0.241	0.241	0.241
Westar Properties, Acton	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045
Crown Valley Building Supply	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016
Crown Valley Comm. Church	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039
E Z Take Out, Acton	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Fire Camp #11, Acton	0.204	0.204	0.204	0.204	0.204	0.204	0.204	0.204	0.204	0.204	0.204	0.204	0.204
Jack-in-the-Box #3304, Acton	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034
McDonald's Resaurant, Acton	0.273	0.273	0.273	0.273	0.273	0.273	0.273	0.273	0.273	0.273	0.273	0.273	0.273
Mobil SS #11	0.136	0.136	0.136	0.136	0.136	0.136	0.136	0.136	0.136	0.136	0.136	0.136	0.136
Mobil SS #18	0	0	0	0	0	0	0	0	0	0	0	0	0
Rio Café	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034
Shell Oil, Acton	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034
Sierra Ranch WWTP	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Tract 21566, Acton	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034
Tract 22190, Acton	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034
Tract 22284 Acton	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Tract 45695, Acton	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027
Tract 46404, Acton	0.432	0.432	0.432	0.432	0.432	0.432	0.432	0.432	0.432	0.432	0.432	0.432	0.432
Tract 46647 Acton	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082
Tract 47788, Acton	0.129	0.129	0.129	0.129	0.129	0.129	0.129	0.129	0.129	0.129	0.129	0.129	0.129
Tract 48391, Acton	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023
Tract 48818, Acton	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034
Tract 49240, Acton	0.538	0.538	0.538	0.538	0.538	0.538	0.538	0.538	0.538	0.538	0.538	0.538	0.538
Tract 49240, Acton	0.184	0.184	0.184	0.184	0.184	0.184	0.184	0.184	0.184	0.184	0.184	0.184	0.184
Tract 49240, Acton	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102
Tract 49601, Acton	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Tract 49601, Acton	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034
Tract 49601, Acton	0.211	0.211	0.211	0.211	0.211	0.211	0.211	0.211	0.211	0.211	0.211	0.211	0.211
Tract 49684, Acton	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034
Tract 50385, Acton	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034
Tract 52637, Acton	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Tract 52882, Acton	0.477	0.477	0.477	0.477	0.477	0.477	0.477	0.477	0.477	0.477	0.477	0.477	0.477
Tract 52883, Acton	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034
Trans Technology Corp.	4.77	4.77	4.77	4.77	4.77	4.77	4.77	4.77	4.77	4.77	4.77	4.77	4.77
Warm Springs Rehab. Center	0.205	0.205	0.203	0.204	0.204	0.209	0.21	0.211	0.21	0.211	0.212	0.207	0.208
Total SCR Reach 9	10.8	10.8	10.8	10.8	10.8	10.8	10.8	10.8	10.8	10.8	10.8	10.8	10.8
College of the Canyons	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.019	0.019	0.019	0.02
H.R. Textron Valencia Facility	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102
Mobil Oil Newhall Station	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41
Total SCR Reach 8	3.53	3.53	3.53	3.53	3.53	3.53	3.53	3.53	3.53	3.53	3.53	3.53	3.53
Total SCR Reach 7	0	0	0	0	0	0	0	0	0	0	0	0	0
Fillmore WWTP	9.08	10.31	8.87	8.07	8.61	7.76	7.33	7.06	8.94	8.67	8.63	8.59	8.48
Piru WWTP	0.462	0.469	0.503	0.419	0.431	0.458	0.525	0.477	0.511	0.477	0.432	0.395	0.463
Total SCR above Sespe Creek	9.5	10.8	9.4	8.5	9	8.2	7.9	7.5	9.5	9.1	9.1	9	8.9
Total Sespe Creek	0	0	0	0	0	0	0	0	0	0	0	0	0
Pan American Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
Thomas Aquinas College	0.157	0.225	0.17	0.126	0.14	0.11	0.102	0.105	0.086	0.092	0.135	0.113	0.129
Total SCR Reach 3	0.157	0.225	0.17	0.126	0.14	0.11	0.102	0.105	0.086	0.092	0.135	0.113	0.129
Limoneira & Olivelands Sewer Farm	0	0	0	0	0	0	0	0	0	0	0	0	0
Saticoy Food Corp.	4.77	4.77	4.77	4.77	4.77	4.77	4.77	4.77	4.77	4.77	4.77	4.77	4.77
Todd Road Jail Facility	1.93	1.93	1.93	1.93	1.93	1.93	1.93	1.93	1.93	1.93	1.93	1.93	1.93
Total Wheeler Cyn/Todd Barr	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7
Total Brown Barr. / Long Cyn	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL WATERSHED	30.7	32.1	30.6	29.7	30.2	29.4	29	28.6	30.6	30.2	30.3	30.2	30.1

Septic Systems

Septic system loading is estimated by multiplying the number of septic systems, the number of people served by each septic system (assumed to be 2.3), and flow and loading per capita. It is assumed that there is no loading of nitrite or nitrate from septic systems, although nitrification of ammonia will indirectly produce these species. It is assumed that the loading is uniform every month of the year and throughout the analysis time period. The per capita loading is assumed to be 75 gallons/capita/day (Wagener 2002) at a concentration of 32 mg/l of ammonia as nitrogen and 6 mg/l of phosphate as P (Maizel et al 1997). Table 29 shows the number of people served by septic systems and average flow from those systems for each subregion in Ventura County. There are an estimated 10,000 people served by septic systems in the Los Angeles County portion of the watershed, and it is assumed that they are distributed in proportion to land area outside the Santa Clarita area (Wagener 2002).

Table 29: Septic Systems, Flow, and Loading

Subregion	People	Flow, m^3/d	NH_4-N, kg/d	PO4-P, kg/d
Mint Canyon Creek	463	131	4.21	0.79
Santa Clara River Reach 9	3062	870	27.83	5.22
Santa Clara River Reach 8	1346	382	12.23	2.29
Santa Clara River Reach 7	1071	304	9.73	1.82
Santa Clara River abv Sespe Ck	526	149	4.78	0.90
Sespe Creek	215	61	1.95	0.37
Santa Clara River Reach 3	873	248	7.93	1.49
Wheeler Canyon / Todd Barr.	67	19	0.61	0.11
Brown Barranca / Long Canyon	2	0.6	0.02	0.003
TOTAL WATERSHED	7484	2166	69.30	12.99

Land Application Sources

These sources represent pollutants loaded to the land surface. Some portion is assimilated by soil and vegetation. The remainder may be transported through the soil to surface waters based on natural and irrigation hydrology. These sources are associated with specific land uses.

Diversions for Groundwater Recharge / Irrigation

There are seven locations within the watershed where water is diverted from streams and applied to the land. Table 30 lists each with average flow rate.

Table 30: Diversion Flows, m^3/s

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Total Mint Canyon Creek	0	0	0	0	0	0	0	0	0	0	0	0	0
Total SCR Reach 9	0	0	0	0	0	0	0	0	0	0	0	0	0
Total SCR Reach 8	0	0	0	0	0	0	0	0	0	0	0	0	0
Rancho Camulos	0.000	0.000	0.227	0.227	0.227	0.227	0.227	0.227	0.227	0.227	0.227	0.000	0.170
Isola (Newhall Land)	0.000	0.000	0.015	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.023
Total SCR Reach 7	0.000	0.000	0.242	0.256	0.256	0.256	0.256	0.256	0.256	0.256	0.256	0.029	0.193
Piru Mutual	0.023	0.023	0.023	0.066	0.066	0.066	0.066	0.066	0.066	0.042	0.042	0.042	0.049
Piru Creek Diversion	0.086	0.152	0.308	0.578	0.949	0.4	0.198	0.258	0.465	0.253	0.28	0.193	0.343
Total SCR aby Sespe Ck	0.109	0.175	0.331	0.644	1.015	0.466	0.264	0.324	0.531	0.295	0.322	0.235	0.392
Fillmore Irrigation Canal	0.004	0.007	0	0.041	0.073	0.071	0.094	0.086	0.084	0.073	0.06	0.054	0.054
Total Sespe Creek	0.004	0.007	0	0.041	0.073	0.071	0.094	0.086	0.084	0.073	0.06	0.054	0.054
Farmers Irrigation	0.014	0.014	0.014	0.064	0.064	0.064	0.09	0.09	0.09	0.056	0.056	0.056	0.056
Richardson Diversion	0.001	0.001	0.001	0.003	0.003	0.003	0.019	0.019	0.019	0.017	0.017	0.017	0.01
Total SCR Reach 3	0.015	0.015	0.015	0.067	0.067	0.067	0.109	0.109	0.109	0.073	0.073	0.073	0.066
Total Wheeler Cyn/Todd Barr	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Brown Barr / Long Cyn	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL WATERSHED	0.128	0.197	0.588	1.008	1.411	0.860	0.723	0.775	0.980	0.697	0.711	0.391	0.705

Of these locations, the Piru Creek Diversion recharges groundwater, while the others are used for irrigation. Tables 31-33 show the estimated loading of ammonia, nitrate, and phosphorus to the land surface from these diversions. The loading was calculated from the flow and average monthly concentrations from water quality monitoring near each diversion (LACSD station RE for Rancho Camulos and Isola; UWCD station 4N18W03SW2 for Piru Creek diversions; UWCD station 4N20W26SW1 for Fillmore

Irrigation Canal; UWCD station 3N21W11SW1 for Farmers Irrigation; UWCD station 3N21W22SW1 for Richardson Diversion). The loading was then averaged for each month over the 11 year analysis period. Nitrite loading is assumed to be zero. Note that the amount of loading applied to the land surface is also directly removed from the river.

Table 31: Ammonia loading from diversions, kg/d N

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Total Mint Canyon Creek	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Total SCR Reach 9	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Total SCR Reach 8	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Rancho Camulos	0	0	23.6	81.1	78.2	90.6	103	102.8	46.5	103	76.9	0	58.8
Isola (Newhall Land)	0	0	1.6	10.5	10.1	11.8	13.4	13.4	6.0	13.4	10.0	17.3	9
Total SCR Reach 7	**0.0**	**0.0**	**25.2**	**91.6**	**88.3**	**102.4**	**116.4**	**116.2**	**52.5**	**116.4**	**86.9**	**17.3**	**67.8**
Piru Mutual	0.059	0.059	0.059	0.114	0.171	0.171	0.172	0.172	0.229	0.108	0.108	0.108	0.128
Piru Creek Diversion	0.223	0.395	0.799	0.999	2.46	1.037	0.512	0.669	1.607	0.655	0.727	0.501	0.882
Total SCR abv Sespe Ck	**0.28**	**0.45**	**0.86**	**1.11**	**2.63**	**1.21**	**0.68**	**0.84**	**1.84**	**0.76**	**0.84**	**0.61**	**1.01**
Fillmore Irrigation Canal	0.021	0.038	0.001	0.036	0.236	0.226	0.292	0.255	0.405	0.223	0.18	0.159	0.173
Total Sespe Creek	**0.021**	**0.038**	**0.001**	**0.036**	**0.236**	**0.226**	**0.292**	**0.255**	**0.405**	**0.223**	**0.18**	**0.159**	**0.173**
Farmers Irrigation	0.049	0.049	0.049	0.167	0.222	0.222	0.31	0.31	0.387	0.195	0.195	0.195	0.196
Richardson Diversion	0.003	0.003	0.003	0.007	0.007	0.007	0.049	0.049	0.049	0.045	0.045	0.045	0.026
Total SCR Reach 3	**0.052**	**0.052**	**0.052**	**0.174**	**0.229**	**0.229**	**0.359**	**0.359**	**0.436**	**0.24**	**0.24**	**0.24**	**0.222**
Total Wheeler Cyn/Todd Barr	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Total Brown Barr. / Long Cyn	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
TOTAL WATERSHED	**0**	**1**	**26**	**93**	**91**	**104**	**118**	**118**	**55**	**118**	**88**	**18**	**69**

Table 32: Nitrate loading from diversions, kg/d N

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Total Mint Canyon Creek	0	0	0	0	0	0	0	0	0	0	0	0	0
Total SCR Reach 9	0	0	0	0	0	0	0	0	0	0	0	0	0
Total SCR Reach 8	0	0	0	0	0	0	0	0	0	0	0	0	0
Rancho Camulos	0	0	88	85	81	84	87	89	150	96	122	0	74
Isola (Newhall Land)	0	0	5.9	11	10.5	10.9	11.2	11.6	19.5	12.5	15.8	13.8	10.2
Total SCR Reach 7	0	0	94	96	92	95	98	101	170	109	138	14	84
Piru Mutual	0.103	0.143	0.182	0.645	1.934	1.096	0.258	0.775	0	0.732	0.641	0.549	0.588
Piru Creek Diversion	0.59	1.32	3.2	7.64	30.03	7.59	1.24	3.63	0.60	5.04	4.98	3.00	5.74
Total SCR aby Sespe Ck	0.69	1.46	3.38	8.29	32.0	8.69	1.5	4.41	0.6	5.77	5.62	3.55	6.33
Fillmore Irrigation Canal	0	0	0	0	0.178	0.51	1.1	0.481	0	0.67	0.136	0.06	0.261
Total Sespe Creek	0	0	0	0	0.178	0.51	1.1	0.481	0	0.67	0.136	0.06	0.261
Farmers Irrigation	1.26	0.95	0.64	1.51	1.95	2.1	3.15	54.7	23.42	2.31	1.1	0.27	7.78
Richardson Diversion	0.16	0.17	0.17	0.32	0.3	0.34	2.73	3	2.92	2.6	2.53	1.93	1.43
Total SCR Reach 3	1.42	1.12	0.81	1.83	2.25	2.44	5.88	57.7	26.34	4.91	3.63	2.2	9.21
Total Wheeler Cyn/Todd Barr	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Brown Barr. / Long Cyn	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL WATERSHED	2	3	98	106	126	107	107	163	196	120	147	20	100

Table 33: Phosphorus loading from diversions, kg/d P

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Total Mint Canyon Creek	0	0	0	0	0	0	0	0	0	0	0	0	0
Total SCR Reach 9	0	0	0	0	0	0	0	0	0	0	0	0	0
Total SCR Reach 8	0	0	0	0	0	0	0	0	0	0	0	0	0
Rancho Camulos	0	0	74	68	63	71	79	87	117	24	92	0	56
Isola (Newhall Land)	0	0	4.9	8.8	8.1	9.2	10.2	11.3	15.2	3.2	11.9	11.4	7.9
Total SCR Reach 7	0	0	79	77	71	80	89	98	132	27	104	11	64
Piru Mutual	0.054	0.054	0.054	0.228	0.157	0.157	0.157	0.157	0.086	0.099	0.099	0.099	0.117
Piru Creek Diversion	0.204	0.362	0.733	1.999	2.255	0.951	0.47	0.614	0.603	0.6	0.666	0.459	0.826
Total SCR abv Sespe Ck	0.258	0.416	0.787	2.227	2.412	1.108	0.627	0.771	0.689	0.699	0.765	0.558	0.943
Fillmore Irrigation Canal	0.014	0.025	0.001	0.071	0.157	0.151	0.195	0.17	0.162	0.148	0.12	0.106	0.11
Total Sespe Creek	0.014	0.025	0.001	0.071	0.157	0.151	0.195	0.17	0.162	0.148	0.12	0.106	0.11
Farmers Irrigation	0.024	0.024	0.024	0.111	0.111	0.111	0.155	0.155	0.155	0.097	0.097	0.097	0.097
Richardson Diversion	0.002	0	0.003	0.012	0.018	0.087	1.137	1.64	1.608	1.436	1.408	0.053	0.617
Total SCR Reach 3	0.026	0.024	0.027	0.123	0.129	0.198	1.292	1.795	1.763	1.533	1.505	0.15	0.714
Total Wheeler Cyn/Todd Barr	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Brown Barr./ Long Cyn	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL WATERSHED	0	0	80	79	74	82	91	101	135	30	106	12	66

Well Pumping Irrigation

Irrigation water pumped from the aquifer contains nitrogen and phosphorus. Agricultural pumping flow was compiled for each region of the watershed in Ventura County (UWCD 2002). Well water quality was also compiled for Ventura County (UWCD 2002). Water quality was averaged to estimate loading.

For the Los Angeles County portion of the watershed, pumping is assumed to provide the irrigation water for crops not otherwise provided for by diversions (Rancho Camulos and Isola). The two diversions provide all the water needed for SCR Region 7. For orchards and row crops, approximately 30 inches of irrigation water is applied each year (Daugovich 2002). The total irrigation water needed is calculated by multiplying 30 inches by the area of orchard and cropland land uses in each region within Los Angeles County. The timing of well pumping irrigation is estimated by using the proportion of irrigation diversion water in each month of the year (all sources except Piru Creek Diversion in Table 30). Well water quality varies greatly with location, but for this analysis, all Los Angeles County pumped irrigation water is assumed to contain 0.1 mg/l ammonia as N, 5 mg/l nitrate as N, and 0.05 mg/l phosphorus. Given these assumptions, Tables 34-37 show the flow and resulting load to each region of the watershed. Nitrite loading is assumed to be negligible.

Table 34: Pumped Irrigation Flow, m^3/s

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Total Mint Canyon Creek	0.002	0.002	0.010	0.015	0.017	0.017	0.020	0.019	0.019	0.016	0.016	0.007	0.013
Total SCR Reach 9	0.005	0.006	0.031	0.048	0.053	0.053	0.060	0.059	0.058	0.051	0.049	0.023	0.041
Total SCR Reach 8	0.008	0.010	0.051	0.078	0.087	0.087	0.099	0.096	0.095	0.083	0.080	0.037	0.068
Total SCR Reach 7	0	0	0	0	0	0	0	0	0	0	0	0	0
Total SCR aby Sespe Ck	1.072	1.072	1.072	1.072	1.072	1.072	1.372	1.372	1.372	1.390	1.390	1.390	1.226
Total Sespe Creek	0.165	0.165	0.165	0.165	0.165	0.165	0.247	0.247	0.247	0.247	0.247	0.247	0.206
Total SCR Reach 3	0.925	0.925	0.925	0.925	0.925	0.925	1.450	1.450	1.450	1.454	1.454	1.454	1.189
Total Wheeler Cyn/Todd Barr	0.020	0.020	0.020	0.020	0.020	0.020	0.017	0.017	0.017	0.019	0.019	0.019	0.019
Total Brown Barr. / Long Cyn	0.004	0.004	0.004	0.004	0.004	0.004	0.005	0.005	0.005	0.004	0.004	0.004	0.004
TOTAL WATERSHED	2.20	2.20	2.28	2.33	2.34	2.34	3.27	3.27	3.26	3.26	3.26	3.18	2.77

Table 35: Estimated well pumping irrigation loading of ammonia, kg/d as N

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Total Mint Canyon Creek	0.01	0.02	0.09	0.13	0.15	0.15	0.17	0.16	0.16	0.14	0.14	0.06	0.12
Total SCR Reach 9	0.04	0.05	0.27	0.41	0.46	0.46	0.52	0.51	0.50	0.44	0.42	0.20	0.36
Total SCR Reach 8	0.07	0.08	0.44	0.68	0.75	0.75	0.85	0.83	0.82	0.72	0.69	0.32	0.58
Total SCR Reach 7	0	0	0	0	0	0	0	0	0	0	0	0	0
Total SCR abv Sespe Ck	9.0	9.0	9.0	9.0	9.0	9.0	11.4	11.4	11.4	11.5	11.5	11.5	10.2
Total Sespe Creek	1.42	1.42	1.42	1.42	1.42	1.42	2.13	2.13	2.13	2.14	2.14	2.14	1.78
Total SCR Reach 3	8.0	8.0	8.0	8.0	8.0	8.0	12.5	12.5	12.5	12.6	12.6	12.6	10.3
Total Wheeler Cyn/Todd Barr	0.62	0.61	0.62	0.62	0.62	0.62	0.53	0.53	0.53	0.59	0.59	0.59	0.59
Total Brown Barr. / Long Cyn	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04
TOTAL WATERSHED	19.2	19.2	19.9	20.3	20.4	20.4	28.1	28.1	28.1	28.2	28.1	27.5	24.0

Table 36: Estimated well pumping irrigation loading of nitrate, kg/d as N

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Total Mint Canyon Creek	0.7	0.8	4.4	6.7	7.5	7.4	8.5	8.2	8.2	7.1	6.8	3.2	5.8
Total SCR Reach 9	2.2	2.5	13.4	20.6	23.0	22.8	26.1	25.4	25.1	21.9	21.1	9.8	17.8
Total SCR Reach 8	3.6	4.2	22.0	33.8	37.7	37.4	42.7	41.6	41.2	35.9	34.6	16.1	29.2
Total SCR Reach 7	0	0	0	0	0	0	0	0	0	0	0	0	0
Total SCR abv Sespe Ck	317	317	317	317	317	317	425	425	425	429	429	429	372
Total Sespe Creek	76	76	76	76	76	76	113	113	113	114	114	114	94
Total SCR Reach 3	385	385	385	385	385	385	615	615	615	619	619	619	501
Total Wheeler Cyn/Todd Barr	1.3	1.3	1.3	1.3	1.3	1.3	1.2	1.2	1.2	1.3	1.3	1.3	1.3
Total Brown Barr. / Long Cyn	1.2	1.2	1.2	1.2	1.2	1.2	1.6	1.6	1.6	1.4	1.4	1.4	1.4
TOTAL WATERSHED	787	788	820	842	849	848	1233	1231	1230	1230	1227	1194	1023

Table 37: Estimated well pumping irrigation loading of phosphorus, kg/d

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Total Mint Canyon Creek	0.01	0.01	0.04	0.07	0.07	0.07	0.08	0.08	0.08	0.07	0.07	0.03	0.06
Total SCR Reach 9	0.02	0.03	0.13	0.21	0.23	0.23	0.26	0.25	0.25	0.22	0.21	0.10	0.18
Total SCR Reach 8	0.04	0.04	0.22	0.34	0.38	0.37	0.43	0.42	0.41	0.36	0.35	0.16	0.29
Total SCR Reach 7	0	0	0	0	0	0	0	0	0	0	0	0	0
Total SCR abv Sespe Ck	4.96	4.96	4.96	4.96	4.96	4.96	6.45	6.45	6.45	6.53	6.53	6.53	5.73
Total Sespe Creek	0.71	0.71	0.71	0.71	0.71	0.71	1.07	1.07	1.07	1.07	1.07	1.07	0.89
Total SCR Reach 3	3.67	3.67	3.67	3.67	3.67	3.67	5.69	5.69	5.69	5.70	5.70	5.70	4.68
Total Wheeler Cyn/Todd Barr	0.09	0.09	0.09	0.09	0.09	0.09	0.07	0.07	0.07	0.08	0.08	0.08	0.08
Total Brown Barr. / Long Cyn	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
TOTAL WATERSHED	9.5	9.5	9.8	10.1	10.1	10.1	14.1	14.1	14.0	14.1	14.0	13.7	11.9

Atmospheric Deposition

There are two forms of atmospheric deposition: wet and dry. Wet deposition is from pollutants present in rain. Dry deposition is from gradual accumulation on the ground and leaf surfaces during dry weather. Dry deposition includes particulate matter and uptake of gases including NO_x. NO_x is converted to nitrate upon uptake by vegetation. Atmospheric deposition may be assimilated in the soil and in vegetative uptake, with some portion reaching surface waters through the natural hydrologic cycle. The following equations govern the collection of pollutants through atmospheric deposition (Chen 2001).

Wet deposition to land use j D_{jw} (kg/d) is a function of the amount of precipitation, the concentration of the precipitation, and the land area, as shown in equation 1.

$$D_{jw} = \frac{PC_pA_j}{10^9} \qquad \text{(eq. 1)}$$

where P is the precipitation rate (cm/d), C_p is the precipitation concentration (mg/l), and A_j is the area of land use j (cm^2). The dry deposition to land use j D_{jd} (kg/d) is the sum of the particulate deposition to leaf surfaces D_{jdl}, the particulate deposition to the ground D_{jdg}, and the gaseous uptake by leaves U_{jdl} as shown in equations 2-5.

$$D_{jd} = D_{jdl} + D_{jdg} + U_{jdl} \qquad \text{(eq. 2)}$$

$$D_{jdl} = \frac{e_d V_d C_a L_j A_j}{10^{15}} \qquad \text{(eq. 3)}$$

$$D_{jdg} = \frac{V_d C_a A_j}{10^{15}} \qquad \text{(eq. 4)}$$

$$U_{jdl} = \frac{e_d U_d C_a L_j A_j}{10^{15}} \qquad \text{(eq. 5)}$$

where e_d is the dry collection efficiency (assumed 0.6 from Chen 1983), V_d is the particulate deposition velocity (cm/d), U_d is the gaseous uptake velocity (cm/d) and C_a is the atmospheric concentration ($\mu g/m^3$). Since gaseous uptake means the nitrogen is absorbed to meet the nutrient demand of vegetation, this is not available for watershed loading, and it is omitted from the atmospheric loading in this analysis ($U_d = 0$). Linkage analysis will take this effect into account in determining the uptake needed by vegetation beyond NO_x uptake.

Table 38 shows the monthly particulate deposition rate from Joshua Tree National Park (CASTNET 2001). The Joshua Tree site is the nearest of a national network of monitoring stations. Data for a Santa Monica Bay study has deposition velocities approximately triple that of Joshua Tree with relatively large particle size (UCLA 1994). A study prepared for the California Air Resources Board indicates that particulate deposition velocity of nitrate is approximately 0.182 times the gaseous deposition velocity of HNO_3 (Russell 1990). Russell cites two other studies (Finlayson-Pitts and Pitts 1986; McRae and Russell 1984) which give land use adjusted summer HNO_3 deposition rates ranging from 1.0 to 4.7. WARMF performs its own land use adjustments from a neutral deposition velocity. Adjusting the cited HNO3 deposition rates so that WARMF would approximate the same deposition flux gives a land use neutral HNO_3 deposition rate of approximately 1.2. Using the 0.182 relationship between particulate nitrate and gaseous HNO_3 from Russell, the estimated summer particulate deposition velocity of 0.22 cm/s is within 5% of that from Joshua Tree. Table 39 shows the estimated monthly leaf area index for each land use (Nikolov 1999).

Table 38: Monthly Particulate Deposition Rate, cm/s

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Particulate Deposition	0.11	0.14	0.17	0.21	0.24	0.24	0.22	0.22	0.19	0.15	0.12	0.11

Table 39: Monthly Leaf Area Index for each Land Use

Land Use	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Deciduous	0	0	0	0.5	1	2.5	4	4.5	4.5	1	0	0
Mixed Forest	1	1	1	2	2	3	4	4	3	2	1	1
Orchard	4	4	4	4	4	4	4	4	4	4	4	4
Coniferous	2	2	2	3	3	4	4	4	3	3	2	2
Shrub / Scrub	0.5	0.5	0.5	1	1	1	1	1	1	1	0.5	0.5
Grassland	0.5	0.5	0.5	1	1	1	1	1	1	1	0.5	0.5
Park	1	1	1	1	1	1	1	1	1	1	1	1
Golf Course	1	1	1	1	1	1	1	1	1	1	1	1
Pasture	0.5	0.5	0.5	1	1	1	1	1	1	1	0.5	0.5
Cropland	1	1	1	1	1	1	1	1	1	1	1	1
Marsh	1	1	1	1	1	1	1	1	1	1	1	1
Barren	0	0	0	0	0	0	0	0	0	0	0	0
Water	0	0	0	0	0	0	0	0	0	0	0	0
Residential	0	0	0	0.2	0.4	1	1.6	1.8	1.8	0.4	0	0
High Density Residential	0	0	0	0.2	0.4	1	1.6	1.8	1.8	0.4	0	0
Comm./Industrial	0	0	0	0	0	0	0	0	0	0	0	0

Air quality monitoring data is available from several monitoring stations as shown in Figure 3. Tables 40 and 41 list the average monthly particulate concentrations of ammonia and nitrate (CARB 2002). With precipitation data from various meteorological stations (NCDC 2002), rain chemistry from a single station at Tanbark Flat, Los Angeles County (NADP 2002), and land uses within each subregion, one can calculate the total atmospheric deposition, as shown in Tables 42 and 43. Only ammonia and nitrate are deposited from the atmosphere. Loading of phosphorus is assumed to be insignificant.

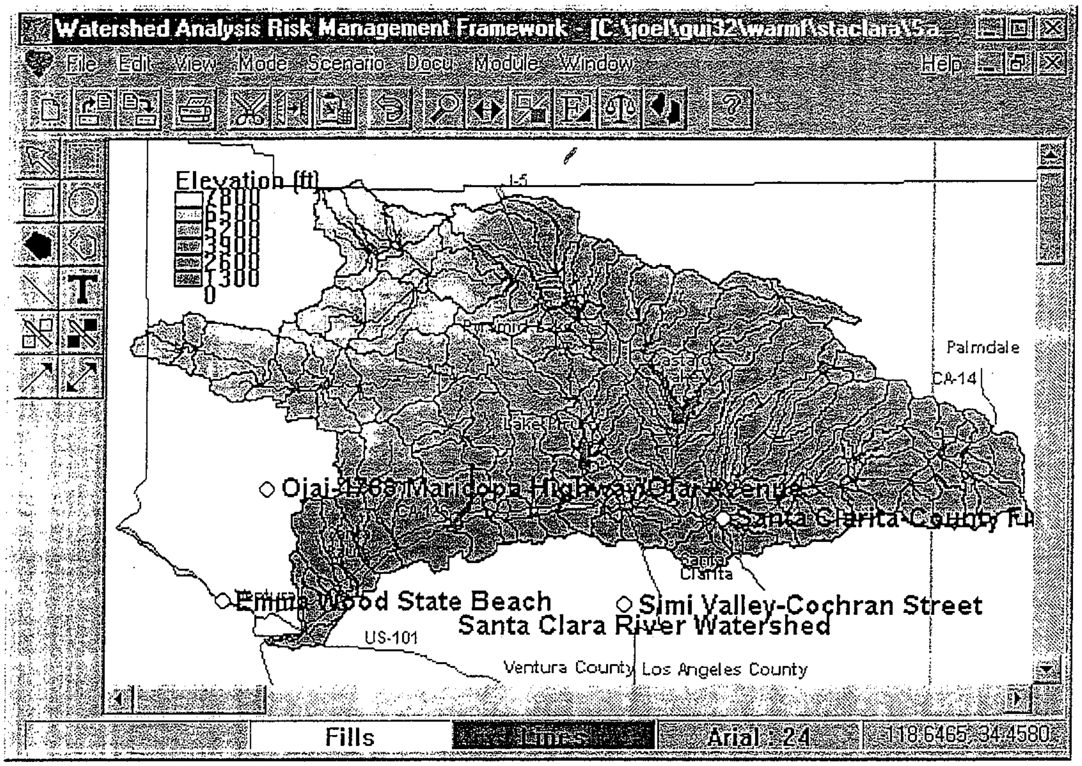

Figure 3: Air quality monitoring stations in the Santa Clara River watershed

Table 40: Average Monthly Atmospheric Concentration of Particulate Ammonia, $\mu g/m^3$ as N

Region	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Emma Wood State Beach	0.69	0.98	1.07	0.67	1.02	0.84	0.78	0.67	0.65	0.85	0.84	0.71	0.81
Ojai – 1768 Maricopa Highway	0.87	1.04	0.77	0.90	1.01	0.87	0.82	0.99	0.82	0.58	0.60	0.58	0.82
Santa Clarita – County Fire Stn	0.49	0.46	0.81	0.72	0.93	0.75	0.89	0.97	0.94	1.16	0.96	0.82	0.83
Simi Valley – Cochran Street	0.48	0.60	1.05	0.80	0.84	0.83	1.03	0.83	0.80	1.31	0.93	0.56	0.84

Table 41: Average Monthly Atmospheric Concentration of Particulate Nitrate, μg/m^3 as N

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Emma Wood State Beach	0.74	0.79	0.71	0.63	0.71	0.75	0.73	0.70	0.70	1.02	0.84	0.67	0.75
Ojai – 1768 Maricopa Highway	0.96	0.98	0.82	0.88	0.65	0.55	0.62	0.70	0.85	0.77	0.70	0.72	0.77
Santa Clarita – County Fire Stn	0.48	0.49	0.69	0.62	0.72	0.64	0.55	0.52	0.48	0.75	0.73	0.61	0.61
Simi Valley – Cochran Street	0.63	0.69	1.05	0.92	0.87	0.83	0.65	0.58	0.64	0.89	0.94	0.69	0.78

Table 42: Atmospheric Deposition of Ammonia Nitrogen, kg/d

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Mint Canyon Ck	[illegible]35	65.2	61.7	53.4	29.3	24.1	24.9	22.6	[illegible]21	26.7	19.8	27.7	34.3
Santa Clara River Reach 9	18.7	38.4	37.4	29.3	20.7	18.6	20.1	17.0	16.6	20.2	13.0	19.9	22.5
Santa Clara River Reach 8	17.9	33.4	31.1	23.1	14.5	12.3	13.7	12.1	11.0	13.4	[illegible]98	14.2	17.2
Santa Clara River Reach 7	11.0	20.1	18.8	14.1	[illegible]91	[illegible]70	[illegible]76	[illegible]63	[illegible]59	[illegible]79	[illegible]58	[illegible]87	10.2
Santa Clara River aby Sespe Ck	14.1	23.4	24.6	20.1	12.8	10.1	11.5	[illegible]86	[illegible]91	11.2	[illegible]78	13.1	13.9
Sespe Creek	48.7	94.5	79.6	68.9	45.9	33.9	33.4	27.2	25.7	33.8	22.6	38.6	46.1
Santa Clara River Reach 3	14.5	25.2	28.1	23.8	16.6	13.5	15.6	12.3	12.1	13.5	[illegible]93	14.6	16.6
Wheeler Canyon / Todd Barr.	12.4	20.6	23.6	11.7	12.3	10.8	12.2	9.6	7.9	11.1	8.8	10.2	12.6
Brown Barranca / Long Canyon	3.87	6.46	7.01	3.19	3.02	2.6	2.95	2.3	2.16	3.05	2.7	3.19	3.54
TOTAL WATERSHED	1300	2440	2290	1860	1240	990	1060	870	840	1040	710	1130	1310

Table 43: Monthly Atmospheric Deposition of Nitrate Nitrogen, kg/d

Region	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Mint Canyon Ck	36	61.5	64.8	66	27.3	21.1	14.2	17.3	17.8	22.8	20.5	35.6	33.7
Santa Clara River Reach 9	19.9	35.6	38.7	34.0	18.4	15.7	10.6	10.7	13.8	16.5	14.3	27.5	21.3
Santa Clara River Reach 8	18.1	31.1	32.4	27.4	13.1	10.5	76	84	87	11.8	10.0	18.1	16.4
Santa Clara River Reach 7	11.0	18.9	19.3	16.7	82	60	43	40	48	68	61	11.3	98
Santa Clara River abv Sespe Ck	14.9	24.2	26.4	26.8	13.7	10.7	79	61	86	96	93	18.5	14.7
Sespe Creek	49.0	91.1	85.7	95.2	50.0	39.4	22.3	20.5	24.4	31.1	26.4	51.7	48.9
Santa Clara River Reach 3	15.6	26.1	30.1	31.9	17.4	13.6	10.0	86	11.4	10.6	11.9	20.0	17.3
Wheeler Canyon / Todd Barr.	13.5	20.8	25.1	12.9	13	10.9	7.8	6.8	7	8.8	12.9	14.8	12.9
Brown Barranca / Long Canyon	4.2	6.52	7.47	3.45	3.36	2.64	1.89	1.59	1.92	2.47	3.99	4.62	3.68
TOTAL WATERSHED	1340	2360	2420	2400	1250	990	650	610	740	900	820	1530	1330

Fertilization

Fertilization is applied to the land surface for the purpose of being taken up by orchards and row crops. What is not taken up may be assimilated in the soil or may be transported to surface waters. Since fertilization occurs on land which is irrigated, it has a greater opportunity for transport than atmospheric deposition. Tables 44-46 show fertilization rates per unit area for agricultural land uses (Daugovich 2002) and estimated unit rates for other land uses from animal waste, debris, and other sources. Nitrogen in fertilizer is assumed to be 50% ammonia and 50% nitrate.

Table 44: Monthly Unit Land Application Rate of Ammonia Nitrogen, kg/ha/d

Land Use	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Deciduous	0	0	0	0	0	0	0	0	0	0	0	0	0
Mixed Forest	0	0	0	0	0	0	0	0	0	0	0	0	0
Orchard	0.000	0.000	0.000	0.123	0.245	0.245	0.245	0.245	0.245	0.123	0.000	0.000	0.123
Coniferous	0	0	0	0	0	0	0	0	0	0	0	0	0
Shrub / Scrub	0	0	0	0	0	0	0	0	0	0	0	0	0
Grassland	0	0	0	0	0	0	0	0	0	0	0	0	0
Park	0	0	0	0	0	0	0	0	0	0	0	0	0
Golf Course	0.000	0.000	0.000	0.960	0.960	0.960	0.960	0.960	0.960	0.000	0.000	0.000	0.480
Pasture	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068
Farm[1]	0.000	0.000	0.000	0.577	0.577	0.577	0.577	0.577	0.577	0.000	0.000	0.000	0.288
Farm[2]	0.288	0.288	0.288	0.577	0.577	0.577	0.577	0.577	0.577	0.288	0.288	0.288	0.433
Farm[3]	0.412	0.412	0.824	0.824	0.824	0.824	0.824	0.824	0.824	0.824	0.824	0.412	0.721
Marsh	0	0	0	0	0	0	0	0	0	0	0	0	0
Barren	0	0	0	0	0	0	0	0	0	0	0	0	0
Water	0	0	0	0	0	0	0	0	0	0	0	0	0
Residential	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
High Density Residential	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Comm./Industrial	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001

1. SCR above Sespe Creek, SCR Reaches 7, 8, and 9, Mint Canyon Creek
2. Sespe Creek, SCR Reach 3
3. Wheeler Canyon / Todd Barranca, Long Canyon / Brown Barranca

Table 45: Monthly Unit Land Application Rate of Nitrate Nitrogen, kg/ha/d

Land Use	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Deciduous	0	0	0	0	0	0	0	0	0	0	0	0	0
Mixed Forest	0	0	0	0	0	0	0	0	0	0	0	0	0
Orchard	0.000	0.000	0.000	0.123	0.245	0.245	0.245	0.245	0.245	0.123	0.000	0.000	0.123
Coniferous	0	0	0	0	0	0	0	0	0	0	0	0	0
Shrub / Scrub	0	0	0	0	0	0	0	0	0	0	0	0	0
Grassland	0	0	0	0	0	0	0	0	0	0	0	0	0
Park	0	0	0	0	0	0	0	0	0	0	0	0	0
Golf Course	0.000	0.000	0.000	0.960	0.960	0.960	0.960	0.960	0.960	0.000	0.000	0.000	0.480
Pasture	0	0	0	0	0	0	0	0	0	0	0	0	0
Farm[1]	0.000	0.000	0.000	0.577	0.577	0.577	0.577	0.577	0.577	0.000	0.000	0.000	0.288
Farm[2]	0.288	0.288	0.288	0.577	0.577	0.577	0.577	0.577	0.577	0.288	0.288	0.288	0.433
Farm[3]	0.412	0.412	0.824	0.824	0.824	0.824	0.824	0.824	0.824	0.824	0.824	0.412	0.721
Marsh	0	0	0	0	0	0	0	0	0	0	0	0	0
Barren	0	0	0	0	0	0	0	0	0	0	0	0	0
Water	0	0	0	0	0	0	0	0	0	0	0	0	0
Residential	0	0	0	0	0	0	0	0	0	0	0	0	0
High Density Residential	0	0	0	0	0	0	0	0	0	0	0	0	0
Comm./Industrial	0	0	0	0	0	0	0	0	0	0	0	0	0

1. SCR above Sespe Creek, SCR Reaches 7, 8, and 9, Mint Canyon Creek
2. Sespe Creek, SCR Reach 3
3. Wheeler Canyon / Todd Barranca, Long Canyon / Brown Barranca

Table 46: Monthly Unit Land Application Rate of Phosphorus, kg/ha/d

Land Use	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Deciduous	0	0	0	0	0	0	0	0	0	0	0	0	0
Mixed Forest	0	0	0	0	0	0	0	0	0	0	0	0	0
Orchard	0.000	0.000	0.000	0.061	0.123	0.123	0.123	0.123	0.123	0.061	0.000	0.000	0.061
Coniferous	0	0	0	0	0	0	0	0	0	0	0	0	0
Shrub / Scrub	0	0	0	0	0	0	0	0	0	0	0	0	0
Grassland	0	0	0	0	0	0	0	0	0	0	0	0	0
Park	0	0	0	0	0	0	0	0	0	0	0	0	0
Golf Course	0	0	0	0	0	0	0	0	0	0	0	0	0
Pasture	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033
Farm[1]	0.000	0.000	0.000	0.399	0.399	0.399	0.399	0.399	0.399	0.000	0.000	0.000	0.200
Farm[2]	0.200	0.200	0.200	0.399	0.399	0.399	0.399	0.399	0.399	0.200	0.200	0.200	0.299
Farm[3]	0.254	0.254	0.509	0.509	0.509	0.509	0.509	0.509	0.509	0.509	0.509	0.254	0.445
Marsh	0	0	0	0	0	0	0	0	0	0	0	0	0
Barren	0	0	0	0	0	0	0	0	0	0	0	0	0
Water	0	0	0	0	0	0	0	0	0	0	0	0	0
Residential	0	0	0	0	0	0	0	0	0	0	0	0	0
High Density Residential	0	0	0	0	0	0	0	0	0	0	0	0	0
Comm./Industrial	0	0	0	0	0	0	0	0	0	0	0	0	0

1. SCR above Sespe Creek, SCR Reaches 7, 8, and 9, Mint Canyon Creek
2. Sespe Creek, SCR Reach 3
3. Wheeler Canyon / Todd Barranca, Long Canyon / Brown Barranca

When these application rates are applied based on the land use area in each subregion, the result is the net loading rate to each subregion as shown in Tables 47-49.

Table 47: Monthly Land Application of Ammonia, kg/d as N

Region	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Mint Canyon Ck	2.1	2.1	2.1	34.1	34.1	34.1	34.1	34.1	34.1	2.1	2.1	2.1	18.1
Santa Clara River Reach 9	23	23	23	120	127	127	127	127	127	30	23	23	75
Santa Clara River Reach 8	24	24	24	608	618	618	618	618	618	34	24	24	321
Santa Clara River Reach 7	13	13	13	383	391	391	391	391	391	22	13	13	202
Santa Clara River aby Sespe Ck	2	2	2	607	997	997	997	997	997	391	2	2	499
Sespe Creek	18	18	18	207	379	379	379	379	379	189	18	18	198
Santa Clara River Reach 3	98	98	98	796	1376	1376	1376	1376	1376	676	98	98	737
Wheeler Canyon / Todd Barr.	8.9	8.9	17.7	48.7	79.7	79.7	79.7	79.7	79.7	48.7	17.7	8.9	46.5
Brown Barranca / Long Canyon	14.4	14.4	28.6	49.4	70.2	70.2	70.2	70.2	70.2	49.4	28.6	14.4	45.9
TOTAL WATERSHED	200	200	230	2850	4070	4070	4070	4070	4070	1440	230	200	2140

Table 48: Monthly Land Application of Nitrate, kg/d as N

Region	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Mint Canyon Ck	0	0	0	32	32	32	32	32	32	0	0	0	16
Santa Clara River Reach 9	0	0	0	98	105	105	105	105	105	7	0	0	52
Santa Clara River Reach 8	0	0	0	584	594	594	594	594	594	10	0	0	297
Santa Clara River Reach 7	0	0	0	369	378	378	378	378	378	9	0	0	189
Santa Clara River aby Sespe Ck	0	0	0	605	995	995	995	995	995	389	0	0	498
Sespe Creek	18	18	18	207	379	379	379	379	379	189	18	18	201
Santa Clara River Reach 3	96	96	96	795	1375	1375	1375	1375	1375	674	96	96	735
Wheeler Canyon / Todd Barr.	8.8	8.8	17.6	48.6	79.6	79.6	79.6	79.6	79.6	48.6	17.6	8.8	46.4
Brown Barranca / Long Canyon	14.3	14.3	28.6	49.3	70.1	70.1	70.1	70.1	70.1	49.3	28.6	14.3	45.8
TOTAL WATERSHED	140	140	160	2790	4010	4010	4010	4010	4010	1380	160	140	2080

Table 49: Monthly Land Application of Phosphorus, kg/d

Region	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Mint Canyon Ck	0.7	0.7	0.7	22.9	22.9	22.9	22.9	22.9	22.9	0.7	0.7	0.7	11.8
Santa Clara River Reach 9	7.6	7.6	7.6	55.9	59.5	59.5	59.5	59.5	59.5	11.2	7.6	7.6	33.6
Santa Clara River Reach 8	5.3	5.3	5.3	90.5	95.4	95.4	95.4	95.4	95.4	10.2	5.3	5.3	50.4
Santa Clara River Reach 7	5	5	5	16.6	17.1	17.1	17.1	17.1	17.1	10	5	5	88
Santa Clara River aby Sespe Ck	0	0	0	31.5	51.2	51.2	51.2	51.2	51.2	19.4	0	0	25.6
Sespe Creek	12	12	12	110	196	196	196	196	196	98	12	12	104
Santa Clara River Reach 3	67	67	67	421	713	713	713	713	713	355	67	67	390
Wheeler Canyon / Todd Barr.	5.4	5.4	10.9	26.3	42	42	42	42	42	26.3	10.9	5.4	25
Brown Barranca / Long Canyon	8.8	8.8	17.6	28	38.5	38.5	38.5	38.5	38.5	28	17.6	8.8	25.8
TOTAL WATERSHED	110	110	130	1240	1850	1850	1850	1850	1850	730	130	110	980

III. Loading Balance

The loading to the land and surface waters in the watershed is linked to the water quality within the impaired reaches of the Santa Clara River. Although modeling is required to reliably link loading with water quality, a rough accounting of pollutants can be approximated through a balance of direct loading, and land application loading with in-stream loading. In-stream loading is the product of flow and concentration within the river itself.

Most of the loading to the land surface may be assimilated in the soil and vegetation before it ever reaches the river but direct loading is not assimilated at all before reaching the river. The magnitude of the land surface loading is likely to be disproportionate to its impact upon water quality in the river. Note that in the following tables, the "Subsurface Discharges" and "Land Application Sources" categories have been combined together into "Total Land Surface Loading" to facilitate the analysis of assimilation of nonpoint source loading. Loading in the river may be assimilated by in-stream processes or lost with water that seeps into the river bed. Estimates of in-stream loading include error from incomplete flow measurement and sporadic water quality measurement. In spite of the error in estimating in-stream loading, it provides a check that loading *in* the river is accounted for by loading *to* the river. It can indicate if loading sources are not completely accounted for.

The assimilation of land surface loading can be estimated through an analysis of the loading balance. If the direct loading is subtracted from in-stream loading, the result is that portion of loading which came from the land surface. That amount can be compared with the tabulated land surface loading to determine the approximate fraction assimilated. Care should be taken in analyzing assimilation of ammonia and nitrate, since nitrification makes ammonia appear to be assimilated but the resulting nitrate may appear as in-stream loading of nitrate.

Mint Canyon Creek

For Mint Canyon Creek, there is currently no water quality monitoring data. Using the most upstream monitoring station on the Santa Clara River, just upstream of the Saugus Wastewater Reclamation Plant, to estimate concentration in Mint Canyon Creek, Tables 50-53 show the loading balance for ammonia, nitrite, nitrate, and phosphorus.

Table 50: Loading balance of ammonia for Mint Canyon Creek, kg/d N

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Upstream Regions	0	0	0	0	0	0	0	0	0	0	0	0	0
Reservoir Releases	0	0	0	0	0	0	0	0	0	0	0	0	0
Direct Point Sources	0	0	0	0	0	0	0	0	0	0	0	0	0
Diversions	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Direct Loading	0	0	0	0	0	0	0	0	0	0	0	0	0
Groundwater Discharges	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038
Septic Systems	4.21	4.21	4.21	4.21	4.21	4.21	4.21	4.21	4.21	4.21	4.21	4.21	4.21
Diversion Recharge/Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	0
Well Pumping Irrigation	0.01	0.02	0.09	0.13	0.15	0.15	0.17	0.16	0.16	0.14	0.14	0.06	0.12
Atmospheric Deposition	35	65.2	61.7	53.4	29.3	24.1	24.9	22.6	21	26.7	19.8	27.7	34.3
Fertilization	2.1	2.1	2.1	34.1	34.1	34.1	34.1	34.1	34.1	2.1	2.1	2.1	18.1
Total Land Surface Loading	41.4	71.6	68.1	91.9	67.8	62.6	63.4	61.1	59.5	33.2	26.3	34.1	56.8
Total Instream Loading	0.134	0.202	0.394	0.009	0	0.012	0.005	0.006	0.004	0.006	0.011	0.008	0.066

Table 51: Loading balance of nitrite for Mint Canyon Creek, kg/d N

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Upstream Regions	0	0	0	0	0	0	0	0	0	0	0	0	0
Reservoir Releases	0	0	0	0	0	0	0	0	0	0	0	0	0
Direct Point Sources	0	0	0	0	0	0	0	0	0	0	0	0	0
Diversions	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Direct Loading	0	0	0	0	0	0	0	0	0	0	0	0	0
Groundwater Discharges	0	0	0	0	0	0	0	0	0	0	0	0	0
Septic Systems	0	0	0	0	0	0	0	0	0	0	0	0	0
Diversion Recharge/Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	0
Well Pumping Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	0
Atmospheric Deposition	0	0	0	0	0	0	0	0	0	0	0	0	0
Fertilization	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Land Surface Loading	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Instream Loading	0.016	0.024	0	0.001	0.007	0.001	0.001	0.001	0	0.001	0.001	0.001	0.005

Table 52: Loading balance of nitrate for Mint Canyon Creek, kg/d N

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Upstream Regions	0	0	0	0	0	0	0	0	0	0	0	0	0
Reservoir Releases	0	0	0	0	0	0	0	0	0	0	0	0	0
Direct Point Sources	0	0	0	0	0	0	0	0	0	0	0	0	0
Diversions	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Direct Loading	0	0	0	0	0	0	0	0	0	0	0	0	0
Groundwater Discharges	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008
Septic Systems	0	0	0	0	0	0	0	0	0	0	0	0	0
Diversion Recharge/Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	0
Well Pumping Irrigation	0.7	0.8	4.4	6.7	7.5	7.4	8.5	8.2	8.2	7.1	6.8	3.2	5.8
Atmospheric Deposition	36	61.5	64.8	66	27.3	21.1	14.2	17.3	17.8	22.8	20.5	35.6	33.7
Fertilization	0	0	0	32	32	32	32	32	32	0	0	0	16
Total Land Surface Loading	37	62	69	105	67	61	55	58	58	30	27	39	56
Total Instream Loading	16	24	21.2	1.1	3.7	1.5	0.6	0.8	0.4	0.7	1.3	1	6

Table 53: Loading balance of phosphorus for Mint Canyon Creek, kg/d P

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Upstream Regions	0	0	0	0	0	0	0	0	0	0	0	0	0
Reservoir Releases	0	0	0	0	0	0	0	0	0	0	0	0	0
Direct Point Sources	0	0	0	0	0	0	0	0	0	0	0	0	0
Diversions	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Direct Loading	0	0	0	0	0	0	0	0	0	0	0	0	0
Groundwater Discharges	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Septic Systems	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79
Diversion Recharge/Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	0
Well Pumping Irrigation	0.01	0.01	0.04	0.07	0.07	0.07	0.08	0.08	0.08	0.07	0.07	0.03	0.06
Atmospheric Deposition	0	0	0	0	0	0	0	0	0	0	0	0	0
Fertilization	0.7	0.7	0.7	22.9	22.9	22.9	22.9	22.9	22.9	0.7	0.7	0.7	11.8
Total Land Surface Loading	1.5	1.5	1.5	23.8	23.8	23.8	23.8	23.8	23.8	1.6	1.6	1.5	12.7
Total Instream Loading	16.5	24.8	17.7	1.2	4.4	1.5	0.7	0.8	0.5	0.8	1.3	1	5.9

Santa Clara River Reach 9

To calculate the in-stream loading for Santa Clara River Reach 9, the flow was estimated by starting with the gaging station at Old Road Bridge, then subtracting the flow from Saugus WWRF and twice the flow of the Bouquet Canyon Creek gage. Doubling the Bouquet Canyon gaged flow accounts for neighboring San Francisquito Canyon, which has similar characteristics and watershed size. The water quality monitoring was from Los Angeles County Sanitation District (LA CSD) station RA. Data only exists for February, March and May, so the February data was extrapolated to cover the wet season (December-March) and May was extrapolated to all of the dry season (May-November). April was the average of March and May.

Since Mint Canyon Creek is upstream of the Santa Clara River Reach 9 region, its outflow is considered as a direct loading input to Reach 9. Note that most of the in-stream loading occurs in spring with high winter flows.

Table 54: Loading balance of ammonia for Santa Clara River Reach 9, kg/d N

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Mint Canyon Creek	0.134	0.202	0.394	0.009	0	0.012	0.005	0.006	0.004	0.006	0.011	0.008	0.066
Reservoir Releases	0	0	0	0	0	0	0	0	0	0	0	0	0
Direct Point Sources	0	0	0	0	0	0	0	0	0	0	0	0	0
Diversions	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Direct Loading	0.134	0.202	0.394	0.009	0	0.012	0.005	0.006	0.004	0.006	0.011	0.008	0.066
Groundwater Discharges	44.3	44.3	44.3	44.3	44.3	44.3	44.3	44.3	44.3	44.3	44.3	44.3	44.3
Septic Systems	27.83	27.83	27.83	27.83	27.83	27.83	27.83	27.83	27.83	27.83	27.83	27.83	27.83
Diversion Recharge/Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	0
Well Pumping Irrigation	0.04	0.05	0.27	0.41	0.46	0.46	0.52	0.51	0.5	0.44	0.42	0.2	0.36
Atmospheric Deposition	18.7	38.4	37.4	29.3	20.7	18.6	20.1	17.0	16.6	20.2	13.0	19.9	22.5
Fertilization	23	23	23	12.0	12.7	12.7	12.7	12.7	12.7	30	23	23	75
Total Land Surface Loading	28.2	47.9	46.9	48.6	40.7	38.6	40.1	37.0	36.6	30.5	22.6	29.4	37.2
Total Instream Loading	2	23	9	53	103	30	11	18	19	16	26	2	26

Table 55: Loading balance of nitrite for Santa Clara River Reach 9, kg/d N

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Mint Canyon Creek	0.016	0.024	0	0.001	0.007	0.001	0.001	0.001	0	0.001	0.001	0.001	0.005
Reservoir Releases	0	0	0	0	0	0	0	0	0	0	0	0	0
Direct Point Sources	0	0	0	0	0	0	0	0	0	0	0	0	0
Diversions	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Direct Loading	0	0	0	0	0	0	0	0	0	0	0	0	0
Groundwater Discharges	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
Septic Systems	0	0	0	0	0	0	0	0	0	0	0	0	0
Diversion Recharge/Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	0
Well Pumping Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	0
Atmospheric Deposition	0	0	0	0	0	0	0	0	0	0	0	0	0
Fertilization	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Land Surface Loading	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
Total Instream Loading	0	0	0	1.56	3.17	0.92	0.34	0.54	0.58	0.51	0.8	0	0.7

Table 56: Loading balance of nitrate for Santa Clara River Reach 9, kg/d N

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Mint Canyon Creek	16	24	21.2	1.1	3.7	1.5	0.6	0.8	0.4	0.7	1.3	1	6
Reservoir Releases	0	0	0	0	0	0	0	0	0	0	0	0	0
Direct Point Sources	0.89	0.89	0.89	0.89	0.89	0.9	0.9	0.9	0.9	0.89	0.89	0.89	0.89
Diversions	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Direct Loading	16.89	24.89	22.09	1.99	4.59	2.4	1.5	1.7	1.3	1.59	2.19	1.89	6.89
Groundwater Discharges	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.3	12.3	12.2	12.2
Septic Systems	0	0	0	0	0	0	0	0	0	0	0	0	0
Diversion Recharge/Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	0
Well Pumping Irrigation	2.2	2.5	13.4	20.6	23	22.8	26.1	25.4	25.1	21.9	21.1	9.8	17.8
Atmospheric Deposition	19.9	35.6	38.7	34.0	18.4	15.7	10.6	10.7	13.8	16.5	14.3	27.5	21.3
Fertilization	0	0	0	98	10.5	10.5	10.5	10.5	10.5	7	0	0	52
Total Land Surface Loading	21.3	37.1	41.3	47.1	32.4	29.7	24.9	25.0	28.0	20.6	17.6	29.7	29.5
Total Instream Loading	54	68.1	39.5	16.4	10.4	30	11	18	19	17	26	60	13.2

Table 57: Loading balance of phosphorus for Santa Clara River Reach 9, kg/d P

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Mint Canyon Creek	16.5	24.8	17.7	1.2	4.4	1.5	0.7	0.8	0.5	0.8	1.3	1	5.9
Reservoir Releases	0	0	0	0	0	0	0	0	0	0	0	0	0
Direct Point Sources	0	0	0	0	0	0	0	0	0	0	0	0	0
Diversions	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Direct Loading	17	25	18	1	4	2	1	1	1	1	1	1	6
Groundwater Discharges	14.3	14.3	14.3	14.3	14.3	14.4	14.4	14.4	14.4	14.4	14.4	14.3	14.4
Septic Systems	5.22	5.22	5.22	5.22	5.22	5.22	5.22	5.22	5.22	5.22	5.22	5.22	5.22
Diversion Recharge/Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	0
Well Pumping Irrigation	0.02	0.03	0.13	0.21	0.23	0.23	0.26	0.25	0.25	0.22	0.21	0.1	0.18
Atmospheric Deposition	0	0	0	0	0	0	0	0	0	0	0	0	0
Fertilization	7.6	7.6	7.6	55.9	59.5	59.5	59.5	59.5	59.5	11.2	7.6	7.6	33.6
Total Land Surface Loading	27	27	27	76	79	79	79	79	79	31	27	27	53
Total Instream Loading	4	49	118	93	120	35	13	21	22	19	30	4	44

Santa Clara River Reach 8

To calculate in-stream loading for Santa Clara River Reach 8, the gaging station at Old Road Bridge was used as the flow estimate. The water quality monitoring was from Los Angeles County Sanitation District (LA CSD) stations RB and RB01. Since Santa Clara River Reach 9 is upstream of the Santa Clara River Reach 8 region, its outflow is considered as a direct loading input to Reach 8. Note that during the winter rainy season most of the loading is from non-point sources, but during the dry season there is little nonpoint source loading reaching the Santa Clara River and some attenuation of pollutants loaded directly to the river. Sometimes, the flow from the Saugus WWRF is greater than the flow at the Old Road bridge gage, indicating that some flow and its associated in-stream loading is being lost as water seeps into the river bed.

Table 58: Loading balance of ammonia for Santa Clara River Reach 8, kg/d N

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Santa Clara River Reach 9	2	23	9	53	103	30	11	18	19	16	26	2	26
Reservoir Releases	0	0	0	0	0	0	0	0	0	0	0	0	0
Direct Point Sources	258	238	237	217	251	247	233	245	254	267	267	285	251
Diversions	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Direct Loading	260	261	246	270	354	277	244	263	273	283	293	287	276
Groundwater Discharges	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7
Septic Systems	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2
Diversion Recharge/Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	0
Well Pumping Irrigation	0.07	0.08	0.44	0.68	0.75	0.75	0.85	0.83	0.82	0.72	0.69	0.32	0.58
Atmospheric Deposition	179	334	311	231	145	123	137	121	110	134	98	142	172
Fertilization	24	24	24	608	618	618	618	618	618	34	24	24	321
Total Land Surface Loading	230	385	362	867	791	769	783	767	756	196	150	193	521
Total Instream Loading	434	2427	916	496	670	283	207	215	203	145	228	321	545

Table 59: Loading balance of nitrite for Santa Clara River Reach 8, kg/d N

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Santa Clara River Reach 9	0	0	0	1.56	3.17	0.92	0.34	0.54	0.58	0.51	0.8	0	0.70
Reservoir Releases	0	0	0	0	0	0	0	0	0	0	0	0	0
Direct Point Sources	52.8	43.2	40.4	39.4	42.3	38.8	41.6	41.4	42.1	40.4	43.5	51.5	43.2
Diversions	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Direct Loading	52.8	43.2	40.4	41	45.5	39.7	41.9	41.9	42.7	40.9	44.3	51.5	43.8
Groundwater Discharges	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
Septic Systems	0	0	0	0	0	0	0	0	0	0	0	0	0
Diversion Recharge/Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	0
Well Pumping Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	0
Atmospheric Deposition	0	0	0	0	0	0	0	0	0	0	0	0	0
Fertilization	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Land Surface Loading	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
Total Instream Loading	9.2	32.0	32.9	37.8	57.9	13.5	12.4	26.7	24	0.7	39.3	15.8	49.2

Table 60: Loading balance of nitrate for Santa Clara River Reach 8, kg/d N

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Santa Clara River Reach 9	54	681	395	164	104	30	11	18	19	17	26	60	132
Reservoir Releases	0	0	0	0	0	0	0	0	0	0	0	0	0
Direct Point Sources	30.6	36.3	33.2	38.2	48.1	60	45.5	32.9	39.7	43.1	35.8	31.8	39.5
Diversions	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Direct Loading	84.6	717.3	428.2	202.2	152.1	90	56.5	50.9	58.7	60.1	61.8	91.8	171
Groundwater Discharges	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.3	12.3	12.2	12.2
Septic Systems	0	0	0	0	0	0	0	0	0	0	0	0	0
Diversion Recharge/Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	0
Well Pumping Irrigation	3.6	4.2	22	33.8	37.7	37.4	42.7	41.6	41.2	35.9	34.6	16.1	29.2
Atmospheric Deposition	181	311	324	274	131	105	76	84	87	118	100	181	164
Fertilization	0	0	0	584	594	594	594	594	594	10	0	0	297
Total Land Surface Loading	197	327	358	904	775	749	725	732	734	176	147	209	503
Total Instream Loading	98	735	239	159	168	137	108	46	56	31	63	168	167

Table 61: Loading balance of phosphorus for Santa Clara River Reach 8, kg/d P

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Santa Clara River Reach 9	4	49	118	93	120	35	13	21	22	19	30	4	44
Reservoir Releases	0	0	0	0	0	0	0	0	0	0	0	0	0
Direct Point Sources	161	166	177	164	170	154	148	146	152	146	143	147	156
Diversions	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Direct Loading	165	215	295	257	290	189	161	167	174	165	173	151	200
Groundwater Discharges	14.3	14.3	14.3	14.3	14.3	14.4	14.4	14.4	14.4	14.4	14.4	14.3	14.4
Septic Systems	2.29	2.29	2.29	2.29	2.29	2.29	2.29	2.29	2.29	2.29	2.29	2.29	2.29
Diversion Recharge/Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	0
Well Pumping Irrigation	0.04	0.04	0.22	0.34	0.38	0.37	0.43	0.42	0.41	0.36	0.35	0.16	0.29
Atmospheric Deposition	0	0	0	0	0	0	0	0	0	0	0	0	0
Fertilization	5.3	5.3	5.3	90.5	95.4	95.4	95.4	95.4	95.4	10.2	5.3	5.3	50.4
Total Land Surface Loading	22	22	22	107	112	112	113	113	113	27	22	22	67.3
Total Instream Loading	276	1968	686	580	402	183	109	90	87	10	183	305	407

Santa Clara River Reach 7

For Santa Clara River Reach 7, flow is estimated from the USGS station at the Los Angeles / Ventura county line. Water quality is estimated from USGS and UWCD monitoring data at the same location and LA CSD station RF just downstream. This region includes direct loading from Reach 8 and from Castaic Lake releases. The imbalance between direct loading and in-stream loading of ammonia and an imbalance of nitrate in the opposite direction implies that nitrification is an important process in this reach. Assimilation of additional ammonia and phosphorus is also apparent. The cause could be periphyton growth and/or water seeping into the river bed.

Table 62: Loading balance of ammonia for Santa Clara River Reach 7, kg/d N

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Santa Clara River Reach 8	434	2427	916	496	670	283	207	215	203	145	228	321	545
Reservoir Releases (Castaic)	0.22	3.94	3.71	1.68	1.54	0.68	0.42	0.28	0.19	0.03	0.07	0.17	1.06
Direct Point Sources	561	520	547	594	579	585	585	540	537	505	551	570	556
Diversions	0	0	-25	-92	-88	-102	-116	-116	-53	-116	-87	-17	-68
Total Direct Loading	995	2951	1442	1000	1162	766	676	639	688	534	692	874	1034
Groundwater Discharges	0	0	0	0	0	0	0	0	0	0	0	0	0
Septic Systems	9.73	9.73	9.73	9.73	9.73	9.73	9.73	9.73	9.73	9.73	9.73	9.73	9.73
Diversion Recharge/Irrigation	0	0	25	92	88	102	116	116	53	116	87	17	68
Well Pumping Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	0
Atmospheric Deposition	110	201	188	141	91	70	76	63	59	79	58	87	102
Fertilization	13	13	13	383	391	391	391	391	391	22	13	13	202
Total Land Surface Loading	133	224	236	625	580	573	593	580	512	227	168	127	382
Total Instream Loading	1864	2462	624	92	168	98	37	46	79	679	24	382	546

Table 63: Loading balance of nitrite for Santa Clara River Reach 7, kg/d N

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Santa Clara River Reach 8	9.2	320	32.9	37.8	57.9	13.5	12.4	26.7	24	0.7	39.3	15.8	49.2
Reservoir Releases (Castaic)	0	0	0	0	0	0	0	0	0	0	0	0	0
Direct Point Sources	46.2	48.6	51.7	46.7	51.2	50.1	52.6	45.3	52.9	47.1	44.2	46.3	48.5
Diversions	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Direct Loading	55.4	368.6	84.6	84.5	109.1	63.6	65	72	76.9	47.8	83.5	62.1	97.7
Groundwater Discharges	0	0	0	0	0	0	0	0	0	0	0	0	0
Septic Systems	0	0	0	0	0	0	0	0	0	0	0	0	0
Diversion Recharge/Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	0
Well Pumping Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	0
Atmospheric Deposition	0	0	0	0	0	0	0	0	0	0	0	0	0
Fertilization	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Land Surface Loading	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Instream Loading	169	132	97	86	63	85	47	23	26	70	35	46	73

Table 64: Loading balance of nitrate for Santa Clara River Reach 7, kg/d N

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Santa Clara River Reach 8	98	735	239	159	168	137	108	46	56	31	63	168	167
Reservoir Releases (Castaic)	0.4	9.6	11.5	9.5	17.4	4.3	0.6	1.3	0	0.2	0.4	0.9	4.7
Direct Point Sources	188	189	203	201	175	189	206	194	185	220	228	202	199
Diversions	0	0	-94	-96	-92	-95	-98	-101	-170	-109	-138	-14	-84
Total Direct Loading	286	934	360	274	268	235	217	140	71	142	153	357	287
Groundwater Discharges	0	0	0	0	0	0	0	0	0	0	0	0	0
Septic Systems	0	0	0	0	0	0	0	0	0	0	0	0	0
Diversion Recharge/Irrigation	0	0	94	96	92	95	98	101	170	109	138	14	84
Well Pumping Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	0
Atmospheric Deposition	110	189	193	167	82	60	43	40	48	68	61	113	98
Fertilization	0	0	0	369	378	378	378	378	378	9	0	0	189
Total Land Surface Loading	110	189	287	632	552	533	519	519	596	186	199	127	371
Total Instream Loading	2433	2196	1935	791	533	432	304	407	365	336	392	704	902

Table 65: Loading balance of phosphorus for Santa Clara River Reach 7, kg/d P

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Santa Clara River Reach 8	276	1968	686	580	402	183	109	90	87	10	183	305	407
Reservoir Releases (Castaic)	0.2	3.61	3.41	3.37	1.41	0.62	0.38	0.26	0.07	0.03	0.07	0.16	1.11
Direct Point Sources	339	337	348	343	287	266	274	266	220	228	251	284	286
Diversions	0	0	-79	-77	-71	-80	-89	-98	-132	-27	-104	-11	-64
Total Direct Loading	615	2309	958	849	619	370	294	258	175	211	330	578	630
Groundwater Discharges	0	0	0	0	0	0	0	0	0	0	0	0	0
Septic Systems	1.82	1.82	1.82	1.82	1.82	1.82	1.82	1.82	1.82	1.82	1.82	1.82	1.82
Diversion Recharge/Irrigation	0	0	79	77	71	80	89	98	132	27	104	11	64
Well Pumping Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	0
Atmospheric Deposition	0	0	0	0	0	0	0	0	0	0	0	0	0
Fertilization	5	5	5	166	171	171	171	171	171	10	5	5	88
Total Land Surface Loading	6.8	6.8	85.8	244.8	243.8	252.8	261.8	270.8	304.8	38.8	110.8	17.8	153.8
Total Instream Loading	639	798	576	252	144	98	81	79	79	82	95	148	256

Santa Clara River upstream of Sespe Creek

For the Santa Clara River upstream of Sespe Creek, there is no gaging station which directly measures flow at Sespe Creek. The estimated flow is USGS gage at Saticoy plus the diverted Freeman flow, minus the undiverted flow of Santa Paula and Sespe Creeks, minus the flow from the Santa Paula WRP. Water quality is estimated from the UWCD site downstream of the Fillmore WRP discharge (04N19W33SW1). This region includes direct loading inputs from Reach 7 and from Lake Piru releases. This stretch of river includes the "dry gap", a stretch of river which usually has no flow because of water seeping into the river bed. This assimilation mechanism is clearly a key process in this section of the watershed.

Table 66: Loading balance of ammonia for Santa Clara River above Sespe Creek, kg/d N

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Santa Clara River Reach 7	1864	2462	624	92	168	98	37	46	79	679	24	382	546
Reservoir Releases (Piru)	1.5	2.6	3.3	1.9	3.3	2.4	1.7	4.3	15.2	14.3	7.4	2.4	5
Direct Point Sources	4.9	1.6	9.8	16.4	7.2	15.8	29.2	12.1	3.7	2.3	2.9	.5	9.3
Diversions	-0.28	-0.45	-0.86	-1.11	-2.63	-1.21	-0.68	-0.84	-1.84	-0.76	-0.84	-0.61	-1.01
Total Direct Loading	1870	2466	636	109	176	115	67	62	96	695	33	389	559
Groundwater Discharges	494.6	571.6	532	46.3	501	426	39.8	40.9	469	43.4	46.3	46.6	469
Septic Systems	4.78	4.78	4.78	4.78	4.78	4.78	4.78	4.78	4.78	4.78	4.78	4.78	4.78
Diversion Recharge/Irrigation	0.28	0.45	0.86	1.11	2.63	1.21	0.68	0.84	1.84	0.76	0.84	0.61	1.01
Well Pumping Irrigation	9	9	9	9	9	9	114	114	114	115	115	115	102
Atmospheric Deposition	141	234	246	201	128	101	115	86	91	112	78	131	139
Fertilization	2	2	2	607	997	997	997	997	997	391	2	2	499
Total Land Surface Loading	207	308	316	869	1192	1156	1169	1141	1153	563	143	196	701
Total Instream Loading	0	529	424	313	215	64	58	50	100	587	485	397	269

Table 67: Loading balance of nitrite for Santa Clara River above Sespe Creek, kg/d N

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Santa Clara River Reach 7	169	132	97	86	63	85	47	23	26	70	35	46	73
Reservoir Releases (Piru)	0	0	0	0	0	0	0	0	0	0	0	0	0
Direct Point Sources	0.08	0.02	0.22	0.11	0.03	0.25	0.23	0.13	0.11	0.04	0.05	0.08	0.11
Diversions	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Direct Loading	169	132	97	86	63	85	47	23	26	70	35	46	73
Groundwater Discharges	0.79	1.142	1.122	1	0.943	0.582	0.588	0.675	0.755	0.731	0.755	0.746	0.817
Septic Systems	0	0	0	0	0	0	0	0	0	0	0	0	0
Diversion Recharge/Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	0
Well Pumping Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	0
Atmospheric Deposition	0	0	0	0	0	0	0	0	0	0	0	0	0
Fertilization	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Land Surface Loading	0.79	1.142	1.122	1	0.943	0.582	0.588	0.675	0.755	0.731	0.755	0.746	0.817
Total Instream Loading	0	0	0	0	0	22.1	8.5	0	0	0	0	0	2.6

Table 68: Loading balance of nitrate for Santa Clara River above Sespe Creek, kg/d N

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Santa Clara River Reach 7	2433	2196	1935	791	533	432	304	407	365	336	392	704	902
Reservoir Releases (Piru)	3	6	10	11	37	15	3	19	0	97	44	12	22
Direct Point Sources	0.18	0.29	1.553	2.317	0.722	2.164	2.974	2.974	1.954	2.555	1.495	0.915	1.679
Diversions	-0.69	-1.46	-3.38	-8.29	-32	-8.69	-1.5	-4.41	-0.6	-5.77	-5.62	-3.55	-6.33
Total Direct Loading	2435	2201	1943	796	539	440	308	425	366	430	432	713	919
Groundwater Discharges	6.6	6.97	6.86	6.95	7.55	7.69	6.95	5.77	6.68	[illegible]7	6.44	6.35	6.81
Septic Systems	0	0	0	0	0	0	0	0	0	0	0	0	0
Diversion Recharge/Irrigation	0.69	1.46	3.38	8.29	32	8.69	1.5	4.41	0.6	5.77	5.62	3.55	6.33
Well Pumping Irrigation	317	317	317	317	317	317	425	425	425	429	429	429	372
Atmospheric Deposition	149	242	264	268	137	107	[illegible]79	[illegible]61	[illegible]86	[illegible]96	[illegible]93	185	147
Fertilization	0	0	0	605	995	995	995	995	995	389	0	0	498
Total Land Surface Loading	473	567	591	1205	1489	1435	1507	1491	1513	927	534	624	1030
Total Instream Loading	181	2117	1326	612	302	265	156	81	142	718	498	331	561

Table 69: Loading balance of phosphorus for Santa Clara River above Sespe Creek, kg/d P

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Santa Clara River Reach 7	639	798	576	252	144	98	81	79	79	82	95	148	256
Reservoir Releases (Piru)	1.4	2.4	3.1	3.8	3	2.2	1.5	4	5.7	13.1	6.7	2.2	4.1
Direct Point Sources	0.9	0.4	2.28	3.18	1.72	2.95	4.97	3.25	1.01	1.34	0.95	1.1	2.02
Diversions	-0.26	-0.42	-0.79	-2.23	-2.42	-1.11	-0.63	-0.77	-0.69	-0.7	-0.77	-0.56	-0.94
Total Direct Loading	641	800	581	257	146	102	87	85	85	96	102	151	261
Groundwater Discharges	9.5	10.8	9.4	8.5	9	8.2	7.9	7.5	9.5	9.1	9.1	9	8.9
Septic Systems	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Diversion Recharge/Irrigation	0.26	0.42	0.79	2.23	2.42	1.11	0.63	0.77	0.69	0.7	0.77	0.56	0.94
Well Pumping Irrigation	4.96	4.96	4.96	4.96	4.96	4.96	6.45	6.45	6.45	6.53	6.53	6.53	5.73
Atmospheric Deposition	0	0	0	0	0	0	0	0	0	0	0	0	0
Fertilization	0	0	0	315	512	512	512	512	512	194	0	0	256
Total Land Surface Loading	16	17	16	332	529	527	528	528	530	211	17	17	272
Total Instream Loading	0	112	90	64	43	31	12	0	2	27	34	37	38

Sespe Creek

The Sespe Creek in-stream loading was estimated based on the undiverted flow of Sespe Creek (USGS gage flow minus Fillmore Irrigation Canal flow) and water quality monitoring by the USGS (station 11113000) and UWCD (4N20W26SW1). Most of this region is natural landscape, but the area near the mouth of Sespe Creek has some anthropogenic pollutant sources. Note that approximately 99% of nitrogen and 90% of phosphorus loaded to the land surface is assimilated.

Table 70: Loading balance of ammonia for Sespe Creek, kg/d N

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Upstream Regions	0	0	0	0	0	0	0	0	0	0	0	0	0
Reservoir Releases	0	0	0	0	0	0	0	0	0	0	0	0	0
Direct Point Sources	0	0	0	0	0	0	0	0	0	0	0	0	0
Diversions	0.02	0.04	0	0.04	0.24	0.23	0.29	0.26	0.41	0.22	0.18	0.16	0.17
Total Direct Loading	0.02	0.04	0	0.04	0.24	0.23	0.29	0.26	0.41	0.22	0.18	0.16	0.17
Groundwater Discharges	0	0	0	0	0	0	0	0	0	0	0	0	0
Septic Systems	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95
Diversion Recharge/Irrigation	0.02	0.04	0	0.04	0.24	0.23	0.29	0.26	0.41	0.22	0.18	0.16	0.17
Well Pumping Irrigation	1.42	1.42	1.42	1.42	1.42	1.42	2.13	2.13	2.13	2.14	2.14	2.14	1.78
Atmospheric Deposition	48.7	94.5	79.6	68.9	45.9	33.9	33.4	27.2	25.7	33.8	22.6	38.6	46.1
Fertilization	18	18	18	20.7	37.9	37.9	37.9	37.9	37.9	18.9	18	18	19.8
Total Land Surface Loading	50.8	96.6	81.7	89.9	84.2	72.2	71.7	65.5	64.0	53.1	24.8	40.8	66.3
Total Instream Loading	39.3	64.9	32	4.6	7.1	3.1	1.2	0.5	0.6	0.6	1.1	7.2	13.5

Table 71: Loading balance of nitrite for Sespe Creek, kg/d N

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Upstream Regions	0	0	0	0	0	0	0	0	0	0	0	0	0
Reservoir Releases	0	0	0	0	0	0	0	0	0	0	0	0	0
Direct Point Sources	0	0	0	0	0	0	0	0	0	0	0	0	0
Diversions	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Direct Loading	0	0	0	0	0	0	0	0	0	0	0	0	0
Groundwater Discharges	0	0	0	0	0	0	0	0	0	0	0	0	0
Septic Systems	0	0	0	0	0	0	0	0	0	0	0	0	0
Diversion Recharge/Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	0
Well Pumping Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	0
Atmospheric Deposition	0	0	0	0	0	0	0	0	0	0	0	0	0
Fertilization	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Land Surface Loading	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Instream Loading	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 72: Loading balance of nitrate for Sespe Creek, kg/d N

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Upstream Regions	0	0	0	0	0	0	0	0	0	0	0	0	0
Reservoir Releases	0	0	0	0	0	0	0	0	0	0	0	0	0
Direct Point Sources	0	0	0	0	0	0	0	0	0	0	0	0	0
Diversions	0	0	0	0	-0.18	-0.51	-1.1	-0.48	0	-0.67	-0.14	-0.06	-0.26
Total Direct Loading	0	0	0	0	-0.18	-0.51	-1.1	-0.48	0	-0.67	-0.14	-0.06	-0.26
Groundwater Discharges	0	0	0	0	0	0	0	0	0	0	0	0	0
Septic Systems	0	0	0	0	0	0	0	0	0	0	0	0	0
Diversion Recharge/Irrigation	0	0	0	0	0.18	0.51	1.1	0.48	0	0.67	0.14	0.06	0.26
Well Pumping Irrigation	76	76	76	76	76	76	113	113	113	114	114	114	94
Atmospheric Deposition	490	911	857	952	500	394	223	205	244	311	264	517	489
Fertilization	18	18	18	207	379	379	379	379	379	189	18	18	201
Total Land Surface Loading	584	1005	951	1235	955	850	716	697	736	615	396	649	784
Total Instream Loading	0	0	0	0	5.33	6.97	4.63	1.01	0	1.95	0.84	2.72	1.95

Table 73: Loading balance of phosphorus for Sespe Creek, kg/d P

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Upstream Regions	0	0	0	0	0	0	0	0	0	0	0	0	0
Reservoir Releases	0	0	0	0	0	0	0	0	0	0	0	0	0
Direct Point Sources	0	0	0	0	0	0	0	0	0	0	0	0	0
Diversions	-0.01	-0.03	0	-0.07	-0.16	-0.15	-0.2	-0.17	-0.16	-0.15	-0.12	-0.11	-0.11
Total Direct Loading	-0.01	-0.03	0	-0.07	-0.16	-0.15	-0.2	-0.17	-0.16	-0.15	-0.12	-0.11	-0.11
Groundwater Discharges	0	0	0	0	0	0	0	0	0	0	0	0	0
Septic Systems	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
Diversion Recharge/Irrigation	0.01	0.03	0	0.07	0.16	0.15	0.2	0.17	0.16	0.15	0.12	0.11	0.11
Well Pumping Irrigation	0.71	0.71	0.71	0.71	0.71	0.71	1.07	1.07	1.07	1.07	1.07	1.07	0.89
Atmospheric Deposition	0	0	0	0	0	0	0	0	0	0	0	0	0
Fertilization	12	12	12	110	196	196	196	196	196	98	12	12	104
Total Land Surface Loading	13.1	13.1	13.1	111.2	197.2	197.2	197.6	197.6	197.6	99.6	13.6	13.6	105.4
Total Instream Loading	26.2	43.3	21.3	9.2	4.7	2.1	0.8	0.4	0.3	0.4	0.7	4.8	9.5

Santa Clara River Reach 3

Flow at the Freeman diversion, calculated as the sum of the gaged flow at Saticoy plus the Freeman diversion flow, was used with water quality data collected by UWCD (3N21W32SW1) at the same location to estimate in-stream loading. The difference between in-stream loading and direct loading indicates that much non-point source load of nitrogen reaches the river in this region.

Table 74: Loading balance of ammonia for Santa Clara River Reach 3, kg/d N

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Sespe Ck & SCR above Sespe	39	594	456	318	222	67	59	51	101	588	486	404	283
Reservoir Releases	0	0	0	0	0	0	0	0	0	0	0	0	0
Direct Point Sources	146	139	154	134	144	157	139	136	123	120	136	155	140
Diversions	-0.05	-0.05	-0.05	-0.17	-0.23	-0.23	-0.36	-0.36	-0.44	-0.24	-0.24	-0.24	-0.22
Total Direct Loading	185	733	610	452	366	224	198	187	224	708	622	559	423
Groundwater Discharges	0.589	0.814	0.546	0.41	0.41	0.401	0.386	0.383	0.278	0.277	0.49	0.387	0.444
Septic Systems	7.93	7.93	7.93	7.93	7.93	7.93	7.93	7.93	7.93	7.93	7.93	7.93	7.93
Diversion Recharge/Irrigation	0.05	0.05	0.05	0.17	0.23	0.23	0.36	0.36	0.44	0.24	0.24	0.24	0.22
Well Pumping Irrigation	8	8	8	8	8	8	12.5	12.5	12.5	12.6	12.6	12.6	10.3
Atmospheric Deposition	145	252	281	238	166	135	156	123	121	135	93	146	166
Fertilization	98	98	98	796	1376	1376	1376	1376	1376	676	98	98	737
Total Land Surface Loading	260	367	396	1051	1559	1528	1553	1520	1518	832	212	265	922
Total Instream Loading	275	1878	1062	581	323	256	225	214	594	4537	4901	248	1258

Table 75: Loading balance of nitrite for Santa Clara River Reach 3, kg/d N

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Sespe Ck & SCR above Sespe	0	0	0	0	0	22.1	8.5	0	0	0	0	0	2.6
Reservoir Releases	0	0	0	0	0	0	0	0	0	0	0	0	0
Direct Point Sources	4.03	4.12	4.06	5.09	4.58	4.41	5.69	6.5	8.6	9.19	5.98	3.54	5.5
Diversions	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Direct Loading	4	4	4	5	5	27	14	7	9	9	6	4	8
Groundwater Discharges	0	0	0	0	0	0	0	0	0	0	0	0	0
Septic Systems	0	0	0	0	0	0	0	0	0	0	0	0	0
Diversion Recharge/Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	0
Well Pumping Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	0
Atmospheric Deposition	0	0	0	0	0	0	0	0	0	0	0	0	0
Fertilization	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Land Surface Loading	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Instream Loading	0	0	0	0	0	0	0	0	0	0	68.7	0	5.7

Table 76: Loading balance of nitrate for Santa Clara River Reach 3, kg/d N

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Sespe Ck & SCR above Sespe	181	2117	1326	612	307	272	161	82	142	720	499	334	563
Reservoir Releases	0	0	0	0	0	0	0	0	0	0	0	0	0
Direct Point Sources	42.5	35	36.5	37.4	34.2	34.5	37.1	38.2	37.5	33.4	36.4	39.9	36.9
Diversions	1.42	1.12	0.81	1.83	2.25	2.44	5.88	57.7	26.3	4.91	3.63	2.2	9.21
Total Direct Loading	222	2151	1362	648	339	304	192	63	153	748	532	372	591
Groundwater Discharges	0.121	0.384	0.376	0.274	0.172	0.083	0.073	0.102	0.128	0.145	0.148	0.122	0.175
Septic Systems	0	0	0	0	0	0	0	0	0	0	0	0	0
Diversion Recharge/Irrigation	1.42	1.12	0.81	1.83	2.25	2.44	5.88	57.7	26.3	4.91	3.63	2.2	9.21
Well Pumping Irrigation	385	385	385	385	385	385	615	615	615	619	619	619	501
Atmospheric Deposition	156	261	301	319	174	136	100	86	114	106	119	200	173
Fertilization	96	96	96	795	1375	1375	1375	1375	1375	674	96	96	735
Total Land Surface Loading	639	744	783	1501	1936	1899	2096	2134	2130	1404	838	917	1418
Total Instream Loading	519	3198	1319	556	247	150	111	93	167	927	779	537	717

Table 77: Loading balance of phosphorus for Santa Clara River Reach 3, kg/d P

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Sespe Ck & SCR above Sespe	26	15 5	11 1.1	73	48	33	13	0	2	27	35	42	48
Reservoir Releases	0	0	0	0	0	0	0	0	0	0	0	0	0
Direct Point Sources	23.1	22.2	33	26.4	24	27.8	27.2	25.7	25.1	21	27.8	30.8	26.2
Diversions	0.03	0.02	0.03	0.12	0.13	0.2	1.29	1.8	1.76	1.53	1.51	0.15	0.71
Total Direct Loading	49	17 7	14 4	99	72	61	39	24	25	46	61	73	73
Groundwater Discharges	0.157	0.225	0.17	0.126	0.14	0.11	0.102	0.105	0.086	0.092	0.135	0.113	0.129
Septic Systems	1.49	1.49	1.49	1.49	1.49	1.49	1.49	1.49	1.49	1.49	1.49	1.49	1.49
Diversion Recharge/Irrigation	0.03	0.02	0.03	0.12	0.13	0.2	1.29	1.8	1.76	1.53	1.51	0.15	0.71
Well Pumping Irrigation	3.67	3.67	3.67	3.67	3.67	3.67	5.69	5.69	5.69	5.7	5.7	5.7	4.68
Atmospheric Deposition	0	0	0	0	0	0	0	0	0	0	0	0	0
Fertilization	67	67	67	42 1	71 3	71 3	71 3	71 3	71 3	35 5	67	67	39 0
Total Land Surface Loading	72	72	72	42 6	71 8	71 8	72 2	72 2	72 2	36 4	76	74	39 7
Total Instream Loading	6	0	24	21	15	39	46	51	92	51 3	43 3	15	10 5

Wheeler Canyon / Todd Barranca

For Wheeler Canyon / Todd Barranca there is insufficient flow data available to estimate in-stream loading. There are no direct loading sources, so all loading in the river results from land surface loading.

Table 78: Loading balance of ammonia for Wheeler Canyon / Todd Barranca, kg/d N

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Upstream Regions	0	0	0	0	0	0	0	0	0	0	0	0	0
Reservoir Releases	0	0	0	0	0	0	0	0	0	0	0	0	0
Direct Point Sources	0	0	0	0	0	0	0	0	0	0	0	0	0
Diversions	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Direct Loading	0	0	0	0	0	0	0	0	0	0	0	0	0
Groundwater Discharges	27.9	27.9	27.9	27.9	27.9	27.9	27.9	27.9	27.9	27.9	27.9	27.9	27.9
Septic Systems	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
Diversion Recharge/Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	0
Well Pumping Irrigation	0.62	0.61	0.62	0.62	0.62	0.62	0.53	0.53	0.53	0.59	0.59	0.59	0.59
Atmospheric Deposition	12.4	20.6	23.6	11.7	12.3	10.8	12.2	9.6	7.9	11.1	8.8	10.2	12.6
Fertilization	8.9	8.9	17.7	48.7	79.7	79.7	79.7	79.7	79.7	48.7	17.7	8.9	46.5
Total Land Surface Loading	50	59	70	90	121	120	121	118	117	89	56	48	88
Total Instream Loading													

Table 79: Loading balance of nitrite for Wheeler Canyon / Todd Barranca, kg/d N

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Upstream Regions	0	0	0	0	0	0	0	0	0	0	0	0	0
Reservoir Releases	0	0	0	0	0	0	0	0	0	0	0	0	0
Direct Point Sources	0	0	0	0	0	0	0	0	0	0	0	0	0
Diversions	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Direct Loading	0	0	0	0	0	0	0	0	0	0	0	0	0
Groundwater Discharges	0	0	0	0	0	0	0	0	0	0	0	0	0
Septic Systems	0	0	0	0	0	0	0	0	0	0	0	0	0
Diversion Recharge/Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	0
Well Pumping Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	0
Atmospheric Deposition	0	0	0	0	0	0	0	0	0	0	0	0	0
Fertilization	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Land Surface Loading	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Instream Loading													

Table 80: Loading balance of nitrate for Wheeler Canyon / Todd Barranca, kg/d N

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Upstream Regions	0	0	0	0	0	0	0	0	0	0	0	0	0
Reservoir Releases	0	0	0	0	0	0	0	0	0	0	0	0	0
Direct Point Sources	0	0	0	0	0	0	0	0	0	0	0	0	0
Diversions	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Direct Loading	0	0	0	0	0	0	0	0	0	0	0	0	0
Groundwater Discharges	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6
Septic Systems	0	0	0	0	0	0	0	0	0	0	0	0	0
Diversion Recharge/Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	0
Well Pumping Irrigation	1.3	1.3	1.3	1.3	1.3	1.3	1.2	1.2	1.2	1.3	1.3	1.3	1.3
Atmospheric Deposition	13.5	20.8	25.1	12.9	13	10.9	7.8	6.8	17	8.8	12.9	14.8	12.9
Fertilization	8.8	8.8	17.6	48.6	79.6	79.6	79.6	79.6	79.6	48.6	17.6	8.8	46.4
Total Land Surface Loading	29	37	50	68	100	97	94	93	93	64	37	31	66
Total Instream Loading													

Table 81: Loading balance of phosphorus for Wheeler Canyon / Todd Barranca, kg/d P

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Upstream Regions	0	0	0	0	0	0	0	0	0	0	0	0	0
Reservoir Releases	0	0	0	0	0	0	0	0	0	0	0	0	0
Direct Point Sources	0	0	0	0	0	0	0	0	0	0	0	0	0
Diversions	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Direct Loading	0	0	0	0	0	0	0	0	0	0	0	0	0
Groundwater Discharges	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7
Septic Systems	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
Diversion Recharge/Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	0
Well Pumping Irrigation	0.09	0.09	0.09	0.09	0.09	0.09	0.07	0.07	0.07	0.08	0.08	0.08	0.08
Atmospheric Deposition	0	0	0	0	0	0	0	0	0	0	0	0	0
Fertilization	5.4	5.4	10.9	26.3	42	42	42	42	42	26.3	10.9	5.4	25
Total Land Surface Loading	12.3	12.3	17.8	33.2	48.9	48.9	48.9	48.9	48.9	33.2	17.8	12.3	31.9
Total Instream Loading													

Brown Barranca / Long Canyon

For Brown Barranca / Long Canyon there is no flow or water quality data currently available to estimate in-stream loading. There are no direct loading sources, so all loading in the stream comes from land surface loading.

Table 82: Loading balance of ammonia for Brown Barranca / Long Canyon, kg/d N

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Upstream Regions	0	0	0	0	0	0	0	0	0	0	0	0	0
Reservoir Releases	0	0	0	0	0	0	0	0	0	0	0	0	0
Direct Point Sources	0	0	0	0	0	0	0	0	0	0	0	0	0
Diversions	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Direct Loading	0	0	0	0	0	0	0	0	0	0	0	0	0
Groundwater Discharges	0	0	0	0	0	0	0	0	0	0	0	0	0
Septic Systems	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Diversion Recharge/Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	0
Well Pumping Irrigation	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Atmospheric Deposition	3.87	6.46	7.01	3.19	3.02	2.6	2.95	2.3	2.16	3.05	2.7	3.19	3.54
Fertilization	14.4	14.4	28.6	49.4	70.2	70.2	70.2	70.2	70.2	49.4	28.6	14.4	45.9
Total Land Surface Loading	18.32	20.91	35.66	52.64	73.27	72.85	73.21	72.56	72.42	52.51	31.36	17.65	49.5
Total Instream Loading													

Table 83: Loading balance of nitrite for Brown Barranca / Long Canyon, kg/d N

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Upstream Regions	0	0	0	0	0	0	0	0	0	0	0	0	0
Reservoir Releases	0	0	0	0	0	0	0	0	0	0	0	0	0
Direct Point Sources	0	0	0	0	0	0	0	0	0	0	0	0	0
Diversions	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Direct Loading	0	0	0	0	0	0	0	0	0	0	0	0	0
Groundwater Discharges	0	0	0	0	0	0	0	0	0	0	0	0	0
Septic Systems	0	0	0	0	0	0	0	0	0	0	0	0	0
Diversion Recharge/Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	0
Well Pumping Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	0
Atmospheric Deposition	0	0	0	0	0	0	0	0	0	0	0	0	0
Fertilization	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Land Surface Loading	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Instream Loading													

Table 84: Loading balance of nitrate for Brown Barranca / Long Canyon, kg/d N

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Upstream Regions	0	0	0	0	0	0	0	0	0	0	0	0	0
Reservoir Releases	0	0	0	0	0	0	0	0	0	0	0	0	0
Direct Point Sources	0	0	0	0	0	0	0	0	0	0	0	0	0
Diversions	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Direct Loading	0	0	0	0	0	0	0	0	0	0	0	0	0
Groundwater Discharges	0	0	0	0	0	0	0	0	0	0	0	0	0
Septic Systems	0	0	0	0	0	0	0	0	0	0	0	0	0
Diversion Recharge/Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	0
Well Pumping Irrigation	1.2	1.2	1.2	1.2	1.2	1.2	1.6	1.6	1.6	1.4	1.4	1.4	1.4
Atmospheric Deposition	4.2	6.52	7.47	3.45	3.36	2.64	1.89	1.59	1.92	2.47	3.99	4.62	3.68
Fertilization	14.3	14.3	28.6	49.3	70.1	70.1	70.1	70.1	70.1	49.3	28.6	14.3	45.8
Total Land Surface Loading	19.7	22	37.3	54	74.7	73.9	73.6	73.3	73.6	53.2	34	20.3	50.9
Total Instream Loading													

Table 85: Loading balance of phosphorus for Brown Barranca / Long Canyon, kg/d P

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Upstream Regions	0	0	0	0	0	0	0	0	0	0	0	0	0
Reservoir Releases	0	0	0	0	0	0	0	0	0	0	0	0	0
Direct Point Sources	0	0	0	0	0	0	0	0	0	0	0	0	0
Diversions	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Direct Loading	0	0	0	0	0	0	0	0	0	0	0	0	0
Groundwater Discharges	0	0	0	0	0	0	0	0	0	0	0	0	0
Septic Systems	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Diversion Recharge/Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	0
Well Pumping Irrigation	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Atmospheric Deposition	0	0	0	0	0	0	0	0	0	0	0	0	0
Fertilization	14.3	14.3	28.6	49.3	70.1	70.1	70.1	70.1	70.1	49.3	28.6	14.3	45.8
Total Land Surface Loading	14.3	14.3	28.6	49.3	70.1	70.1	70.1	70.1	70.1	49.3	28.6	14.3	45.8
Total Instream Loading													

IV. Data Gaps

In any analysis of watershed loading and water quality, there is imperfect data. The data available is used, and gaps in the data are filled in with basic assumptions. A "data gap", for purposes of this report, are those cases where missing data does the most to increase uncertainty and decrease accuracy of a source characterization analysis or linkage analysis (modeling). Based on the information collected, following are the key data gaps.

- There is no water quality data available for Mint Canyon Creek to evaluate the water quality conditions in this impaired reach and to calibrate the water quality model.
- There is no flow or water quality data available for Brown Barranca / Long Canyon. This segment is impaired, but the accuracy of water quality modeling will be unknown without flow and water quality monitoring data. Wheeler Canyon / Todd Barranca, a nearby impaired stream, has data and will be used as a model for the linkage analysis.

V. Uncertainty

It is important to understand the sources of uncertainty and how that uncertainty can propagate through the linkage analysis and TMDL calculation steps of this project. In many ways the water quality is controlled through human interactions with the watershed, including point sources and diversions. These human impacts are well characterized and are not the prime source of uncertainty. The natural processes of the river pose the greatest challenge to understanding the transport and fate of pollutants. This includes loss of river water by seepage into the river bed and exfiltration of groundwater from the local aquifers. The uncertainty can be minimized through the compilation of information and knowledge from those most familiar with the watershed and through rigorous linkage analysis to learn where water is entering and leaving the river. Since different regions of the watershed have significantly different ambient water quality, the available monitoring data will help clarify the paths water takes through the watershed as the linkage analysis is conducted.

VI. Conclusion

The data currently available is in general clearly sufficient to conduct a thorough loading analysis and calibrate a water quality model to demonstrate the linkage between pollutant sources and in-stream water quality. The various modes of land application loading have different transport mechanisms to deliver pollutants to surface waters, but the relative importance of each can be discerned by comparing the loading of each pollutant to each region. The information in this document is an important element in determining how a TMDL should be calculated and what implementation strategies would be most promising.

VII. Acknowledgements

Systech Engineering would like to thank all those individuals who delivered a large amount data in a short time to make this report possible. In particular, we wish to thank Tim Robinson of UC Santa Barbara for preparing hardcopy documents and posting a variety of electronic data for download, Dan Detmer of the United Water Conservation District for providing diversion data and water quality data, Suk Chong of the Los Angeles Department of Public Works for providing precipitation and gaging data, Oleg Daugovich for providing agricultural information, and Arturo Keller for gathering, coordinating and transferring a wide variety of data.

VIII. References

California Air Resources Board (CARB). 2002. California Ambient Air Quality Data 1980-1999. CD No. PTSD-00-014-CD

Chen, C.W., S.A. Gherini, R.J.M. Hudson, J.D. Dean. 1983. "The Integrated Lake-Watershed Acidification Study Volume 1: Model Principles and Application Procedures". Publication No. EA-3221, Electric Power Research Institute, Palo Alto, CA.

Chen, C.W., J. Herr, and L. Weintraub. 2001. "Watershed Analysis Risk Management Framework (WARMF): Update One – A Decision Support System for Watershed Analysis and Total Maximum Daily Load Calculation, Allocation and Implementation" Publication No. 1005181, Electric Power Research Institute, Palo Alto, CA.

Daugovich, Oleg (University of California at Davis). 2002. personal e-mails to Arturo Keller.

Finlayson-Pitts, B.J. and J.N. Pitts Jr. 1986. "Atmospheric Chemistry: Fundamentals and Experimental Techniques". Wiley, New York, NY.

Lindeburg, Michael R. 1999. "Civil Engineering Reference Manual for the PE Exam", 7th ed. Professional Publications Inc, Belmont, CA.

Los Angeles Regional Water Quality Control Board (LA RWQCB) (Arturo Keller, Santa Clara River Nutrient TMDL Facilitator). 2002. Request for Proposals for Santa Clara River Nutrient TMDL Analysis.

Maizel, Margaret S. et al. 1997. "The Potential for Nutrient Loadings from Septic Systems to Ground and Surface Water Reserources and the Chesapeake Bay". Environmental Protection Agency Chesapeake Bay Program. EPA publication #903-R-97-006.

McRae, G.J. and A.G. Russell. 1984. "Dry Deposition of Nitrogen Containing Species". In "Atmospheric Deposition: Wet and Dry" (B.B. Hicks, editor). Acid Precipitation Series (J.I. Teasley, editor). Volume 4. Butterworths (Ann Arbor Science), Boston, MA.

National Atmospheric Deposition Program (NADP). 2002. NADP/NTN Monitoring Location CA42, Tanbark Flat. Web site: http://nadp.sws.uiuc.edu/nadpdata/

National Climatic Data Center (NCDC). 2002. Summary of the Day Database.

Nikolov, Ned T. 1999. "1-km Resolution Database of Monthly Vegetation Leaf Area Index and Canopy Clumping Factor for the Western USA" (CD). N & T Services, Oak Ridge, TN.

Russell, A.G. and D.A. Winner, K.F. McCue, G.R. Cass. March 1990. "Mathematical modeling and control of the dry deposition flux of nitrogen containing air pollutants". Prepared for Research Division, California Air Resources Board. Final Report No. A6-188-32.

United States Environmental Protection Agency (US EPA). 2001. BASINS software version 3.0

United Water Conservation District (UWCD). 2002. Database query for well pumping within each WARMF catchment with a six month time resolution.

United Water Conservation District (UWCD). 2002. Database query of well water quality data within each WARMF catchment.

United Water Conservation District (UWCD). 2002. Web site: www.unitedwater.org

Wagener, Richard (Los Angeles County Department of Health Services). July 2002. Personal telephone conversation with Elizabeth Erickson.

Linkage Analysis For

Santa Clara River Nutrient TMDL Analysis
Parts I and II: Hydrology and Water Quality

Prepared for

Santa Clara Nutrient TMDL Steering Committee

On behalf of the
Los Angeles Regional Water Quality Control Board and
Watershed Stakeholder Groups

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September 1, 2002

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I. Introduction

Background

The Los Angeles Regional Water Quality Control Board (LA RWCB) has determined that several segments and tributaries of the Santa Clara River do not meet the water quality criteria for their beneficial uses. As a result, these segments are listed on the 1998 303(d) list of impaired waters. The impairment is caused by excessive ammonia, nitrite/nitrate, organic enrichment, and low dissolved oxygen. Based on consent decree, Total Maximum Daily Loads (TMDLs) must be determined to protect the beneficial uses including recreation, wildlife habitat, and municipal, industrial, and agricultural supply. (LA RWCB 2002)

Objective

The Santa Clara River watershed drains an area of 1,618 square miles, with a wide variety of land uses including mountain forest, urbanized areas, and agricultural land. The watershed lies in Los Angeles and Ventura Counties, California. The flow is highly seasonal and dominated by winter storm events.

The process for TMDL determination involves five steps:

1. Assess the sources of pollution loads in the watershed,
2. Link pollution loads to numerical water quality targets for the impaired segments;
3. Determine the TMDLs for the impaired stream segments;
4. Provide technical assistance to the stakeholders group to fulfill their tasks in developing implementation plans.
5. Prepare a final report

The final report for task 1, referred to in this document as the "Source Analysis Report", was completed in August 2002 (Systech 2002). This is the linkage analysis report for task 2.

Linkage Analysis Report

The Source Analysis Report lists all sources of point and nonpoint source pollutant load within the Santa Clara River watershed. The purpose of the linkage analysis is to determine the relationships between the pollutant loads and the water quality of river segments in the watershed. This requires determining what portion of pollutants on the soil surface or in the soil are transported to river segments. The linkage analysis must also show how pollutants may be assimilated within river segments. The key to the linkage analysis is a watershed model capable of simulating the physical and chemical processes that affect river hydrology and water quality.

This report discusses the key processes and assumptions of the watershed model, the primary model parameters adjusted in calibration, and the performance of the model in comparison to observed data. This report evaluates the model for its use in calculating TMDLs for the impaired river segments of the watershed. This includes a sensitivity analysis and a discussion of uncertainty. Accompanying this report is the calibrated watershed model, complete with User's Manual (Herr et al. 2000) and Technical Documentation (Chen et al. 2001).

II. Watershed Summary

Area and Topography

The Santa Clara River watershed drains an area of 1,618 square miles in the Transverse mountain range of southern California as shown in Figure 1. Elevations within the watershed range from sea level at the river's outlet near the city of Ventura to 8,800 feet at the summit of Mount Pinos in the northwest corner of the watershed. There are four reservoirs in the watershed: Pyramid Lake and Lake Piru on Piru Creek, Castaic Lake on Castaic Creek, and Bouquet Canyon Reservoir (small unlabeled reservoir in the northeast part of the watershed).

The land areas upstream of the reservoirs are not believed to significantly contribute to the water quality problems of the Santa Clara River. No point or nonpoint management strategy will be implemented in those areas. Due to the budget limitation, it was decided to exclude the tributary watersheds of Pyramid Lake, Lake Piru, and Castaic Lake from modeling analysis. The releases from Lake Piru and Castaic Lake are treated as external inputs to the remaining 1,052 square mile watershed. Bouquet Canyon Reservoir is included in this analysis because its tributary area is small and flow release records are not available.

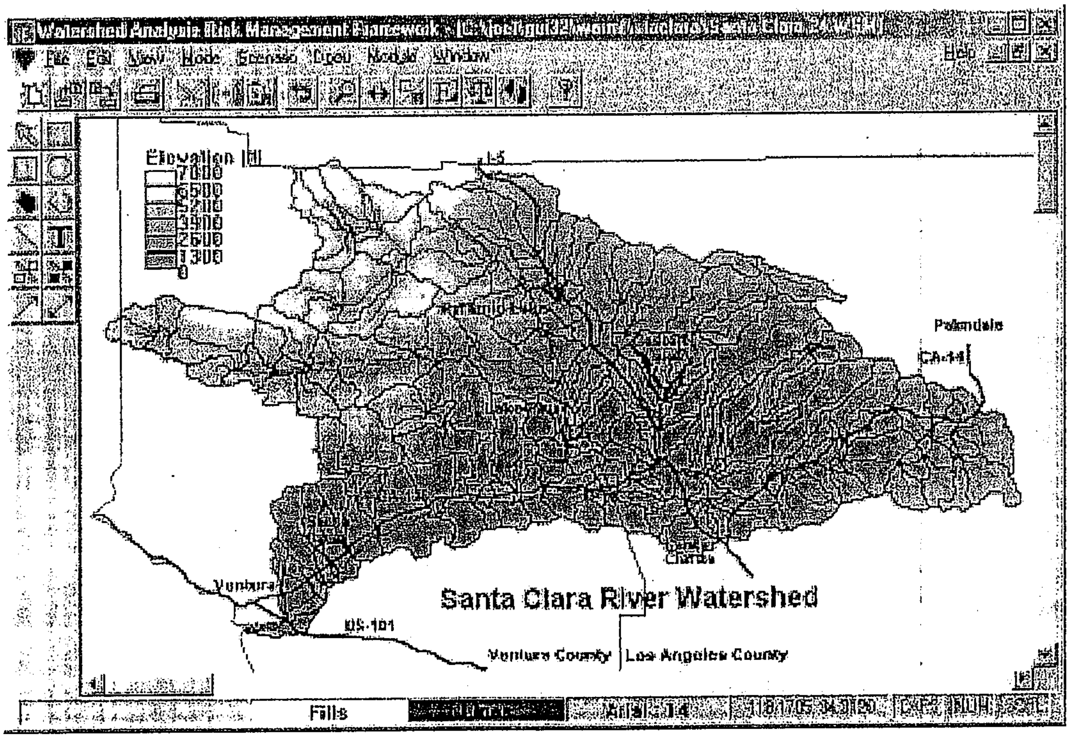


Figure 1: Santa Clara River watershed

Rivers

Rivers in the Santa Clara watershed are broadly defined by topography. Tributaries to the Santa Clara River are relatively narrow and steeply sloping in the canyons to the north of the Santa Clara River. The Santa Clara River itself is a broad sandy wash, only a small portion of which normally contains the shallow flowing water. The Santa Clara River flows generally from east to west from its headwaters south of Palmdale to the Pacific Ocean near Ventura. In identifying river segments, the Santa Clara River has been divided into reaches. There are two separate designations of reaches: one from the United States Environmental Protection Agency (US EPA) and the other from LA RWQCB, as shown in Table 1 and Table 2 (LA RWQCB 2002). ***This report uses the US EPA reach designations.***

Table 1: US EPA Reach designations for the Santa Clara River

Reach	Description
1	Santa Clara Estuary to Highway 101
2	Highway 101 to Freeman diversion dam
3	Freeman diversion dam to above Santa Paula Creek and below Timber Canyon
4	Above Timber Canyon to above Grimes Canyon
5	Above Grimes Canyon to Propane Road
6	Propane Road to Blue Cut gaging station
7	Blue Cut gaging station to west pier Highway 99
8	West pier Highway 99 to Bouquet Canyon Road
9	Bouquet Canyon Road to Lang gaging station
10	Above Lang gaging station

Table 2: LA RWQCB Reach designations for the Santa Clara River

Reach	Description
1	Santa Clara Estuary to Highway 101
2	Highway 101 to Freeman diversion dam
3	Freeman diversion dam to Fillmore "A" Street
4	Fillmore "A" Street to Blue Cut gaging station
5	Blue Cut gaging station to west pier Highway 99
6	West pier Highway 99 to Bouquet Canyon Road
7	Bouquet Canyon Road to Lang gaging station
8	Above Lang gaging station

For the purpose of discussion, the Santa Clara River is divided into eastern, central, and western sections. Figure 2 through Figure 4 show the river reaches of the Santa Clara River and its main tributaries. Reaches and tributaries shown in red are impaired reaches for which a TMDLs must be calculated.

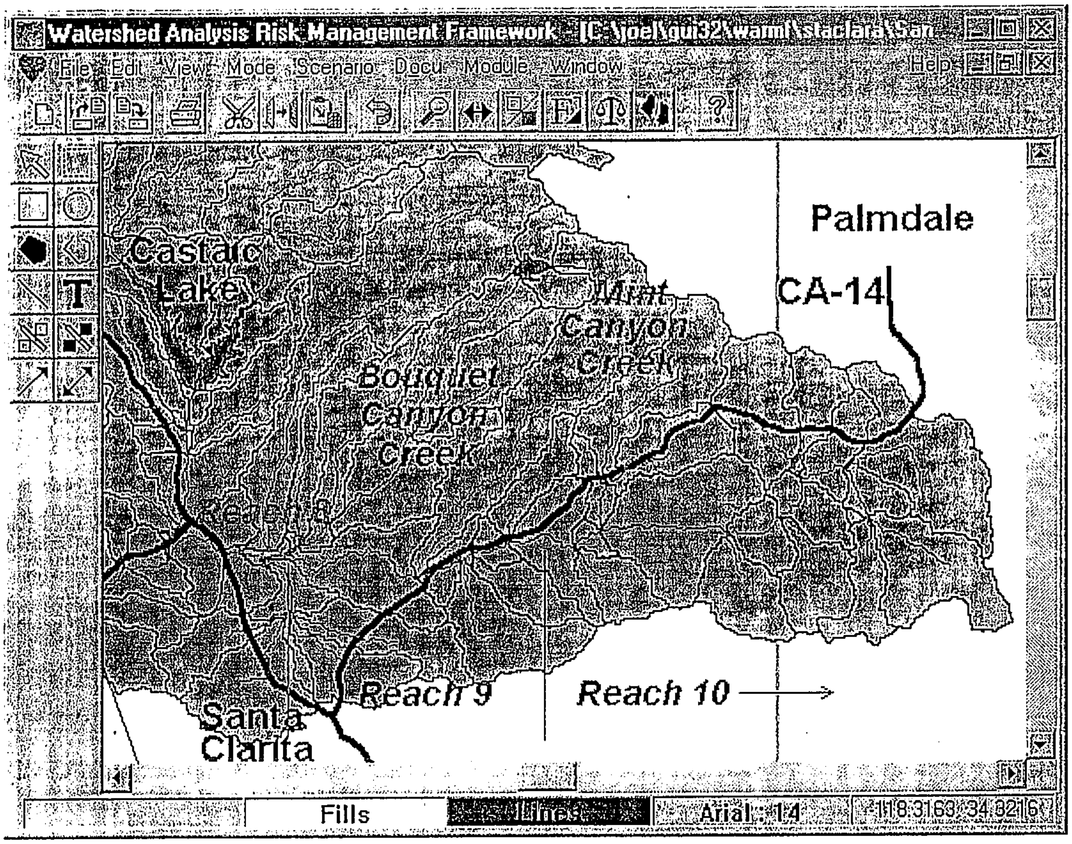


Figure 2: River segments of the eastern Santa Clara River watershed

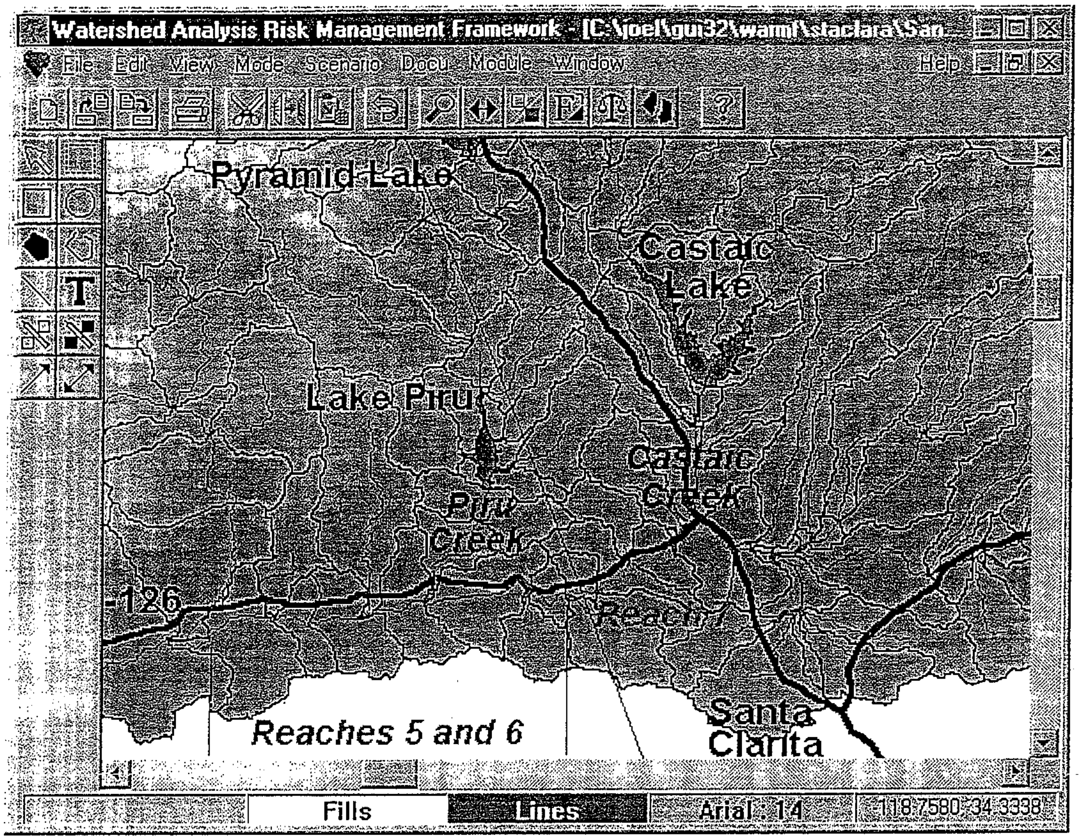


Figure 3: River segments of the central Santa Clara River watershed

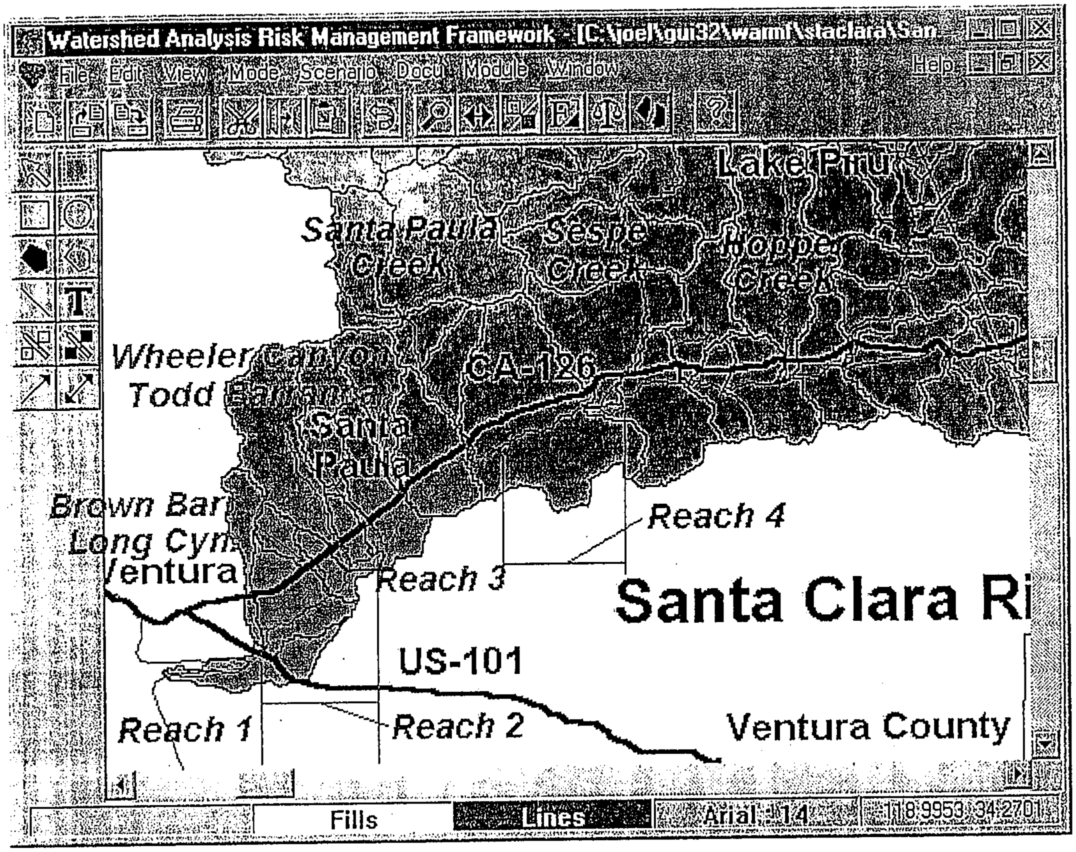


Figure 4: River segments of the western Santa Clara River watershed

Soils and Vegetation

Soils in the watershed can be divided into two basic classes: the upland soils of the mountains and the alluvial soils near the Santa Clara River. The upland soils are approximately one meter thick down to bedrock and the alluvial soils are 18-36 meters thick above an unconfined aquifer (USDA NRCS 1994, UWCD 2002). Native vegetation is approximately 78% scrubland and 17% coniferous forest, with small fractions of other forest, grassland, marsh, and water (US EPA 2001).

Land Use

Approximately 15% of the land in the Santa Clara River watershed has been developed for urban and agricultural use (DWR 2002, SCAG 1993, SCAG 2001). Urban land is primarily in the cities of Ventura, Santa Paula, Fillmore, and Santa Clarita. Agricultural land is primarily in the lowlands near Santa Clara River reaches 1-7. Table 3 shows the land use in each region of the watershed using 2000 data for Ventura County, 1993 data for Los Angeles County, and 2001 data for Santa Clarita.

Table 3: Land use in the Santa Clara River watershed, %

Land Use	Percent
Deciduous	0.51
Mixed Forest	0.92
Orchard	3.92
Coniferous	14.41
Shrub / Scrub	66.30
Grassland	1.98
Park	0.10
Golf Course	0.28
Pasture	0.23
Cropland	0.60
Marsh	0.13
Barren	0.30
Water	0.12
Residential	2.10
High Density Residential	4.84
Comm./Industrial	3.24

Meteorology

The meteorology of the watershed varies greatly by season and by location. Average Annual rainfall varies from 23 cm/year (9 in/year) at the easternmost station in the watershed to 80 cm/year (32 in/year) at a station in the Sespe Creek watershed. 84% of precipitation occurs from December-March (NCDC 2002, Ventura County 2002, LA DPW 2002). Snowfall occurs in the higher altitudes of the mountains in winter. Precipitation is greatest in the mountains and the western part of the watershed. The precipitation decreases eastward across the watershed as shown in Figure 5. Average temperature decreases with increasing elevation and is generally greater inland than along the coast, as shown in Figure 6.

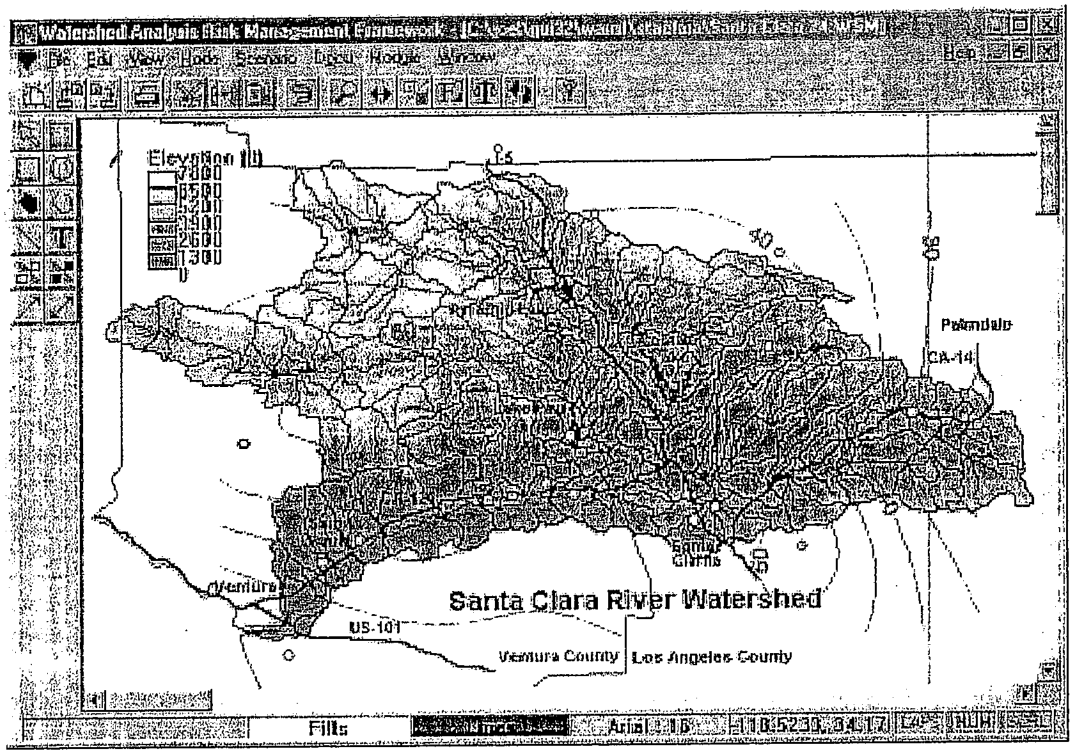


Figure 5: Meteorology stations and precipitation isohyets (cm/year) for the Santa Clara R. watershed

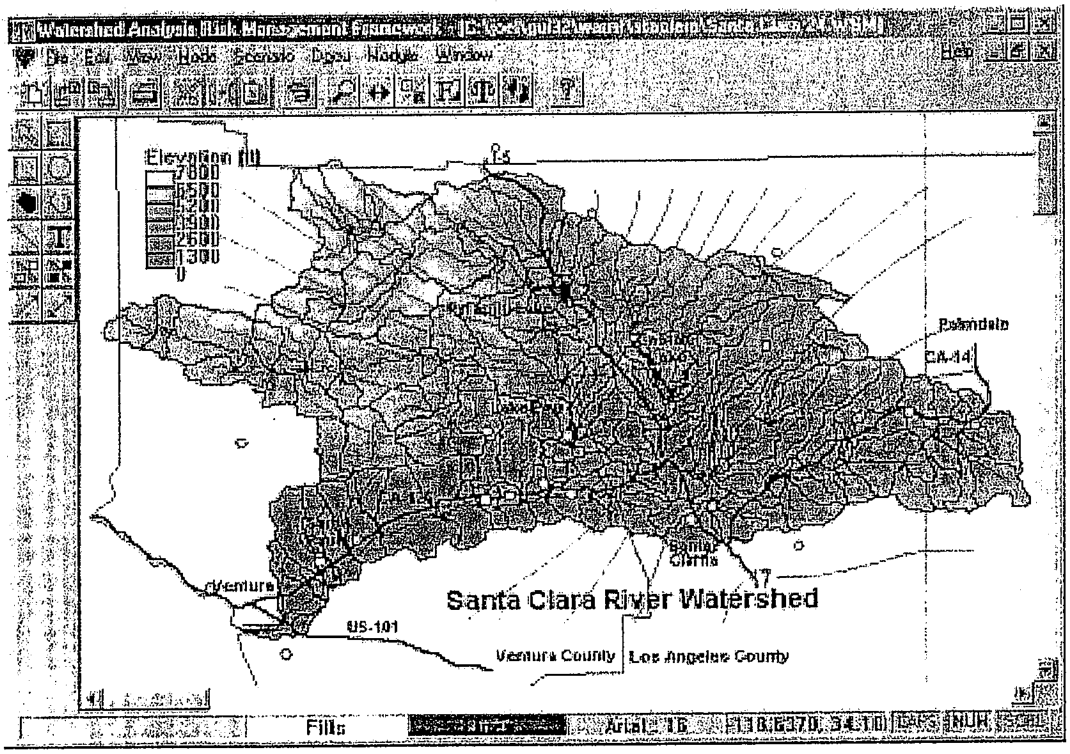


Figure 6: Meteorology stations and temperature isotherms (°C) for the Santa Clara River watershed

Hydrology

The hydrology of the Santa Clara River watershed varies greatly by location. Flow in the western tributaries (Figure 4)is perennial, but flow is intermittent in the eastern part of the watershed (Figure 2). Figure 7 shows the locations of flow gages in the watershed.

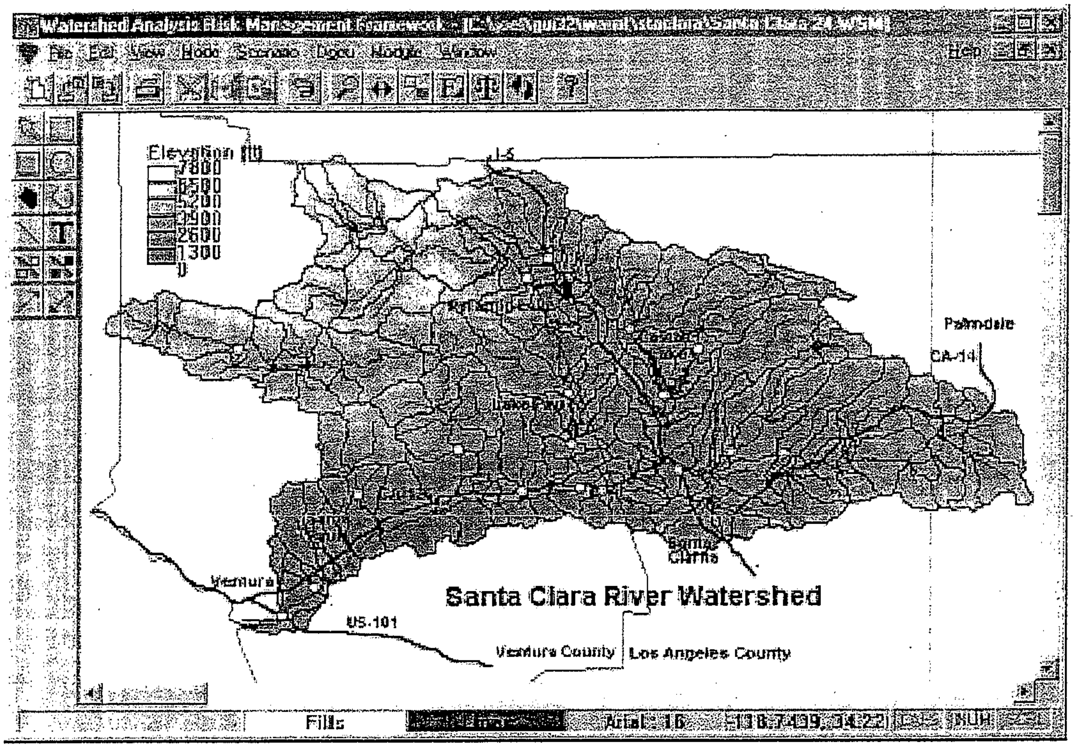


Figure 7: Locations of stream gages

The hydrology changes as the Santa Clara River flows westward from its source south of Palmdale. East of Santa Clarita, flow is intermittent. Reach 9 of the Santa Clara River (Figure 2) has water approximately 66% of the time at its confluence with Bouquet Canyon Creek. Downstream of the Saugus (Reach 8) and Valencia (Reach 7) wastewater reclamation facilities in the vicinity of Santa Clarita, the Santa Clara River has perennial flow. The perennial flow continues to at least the Los Angeles / Ventura county line (Reach 7). From the county line to the Santa Paula area (Reach 4, 5, and 6), there are complex interactions between the surface river water and groundwater. At various locations within this section, the Santa Clara River may be losing water to, or gaining water from, the groundwater. A section of river between the county line and Fillmore is known as the "dry gap" because it rarely contains water. Modeling the hydrology of this river section requires good estimates of where these surface water/groundwater interactions take place and how much water is lost or gained over time.

Hydrologic modeling is key to understanding the fate of pollutants in the watershed. Each source of flow for the Santa Clara River has its own pollutant concentrations. The model must approximate the amount of water coming from each source with as much accuracy as possible under different hydrologic regimes to accurately account for the transport and fate of pollutants.

Water Quality

The water quality of the Santa Clara River is highly dependent upon hydrology. The western tributaries (Figure 4) have naturally lower nutrient concentrations than the eastern tributaries (Figure 2) because the natural vegetation has higher productivity to remove nutrients from the soil and because they have much more flow per unit land area to flush out pollutants. The water quality of the Santa Clara River from Santa Clarita to its outlet is heavily influenced by point sources and groundwater interactions.

Table 4 shows the river segments not meeting their water quality objectives as identified by the Los Angeles Regional Water Quality Control Board in 1998 (LA RWQCB 2002). The locations of the impaired segments are shown in red in Figure 2 through Figure 4.

Table 4: Impaired river segments of the Santa Clara River watershed

River Segment	Cause of Impairment
Mint Canyon Creek	Nitrate, nitrite
Santa Clara River Reach 8	Ammonia, nitrate, nitrite, organic enrichment, low dissolved oxygen
Santa Clara River Reach 7	Ammonia, nitrate, nitrite
Santa Clara River Reach 3	Ammonia
Wheeler Canyon / Todd Barranca	Nitrate, nitrite
Brown Barranca / Long Canyon	Nitrate, nitrite

Figure 8 shows the locations of water quality monitoring stations, which are places where ambient surface water quality was measured at least once. At many stations, data was only collected a few times. Some stations did not collect nutrient data, which is of principal interest to this project.

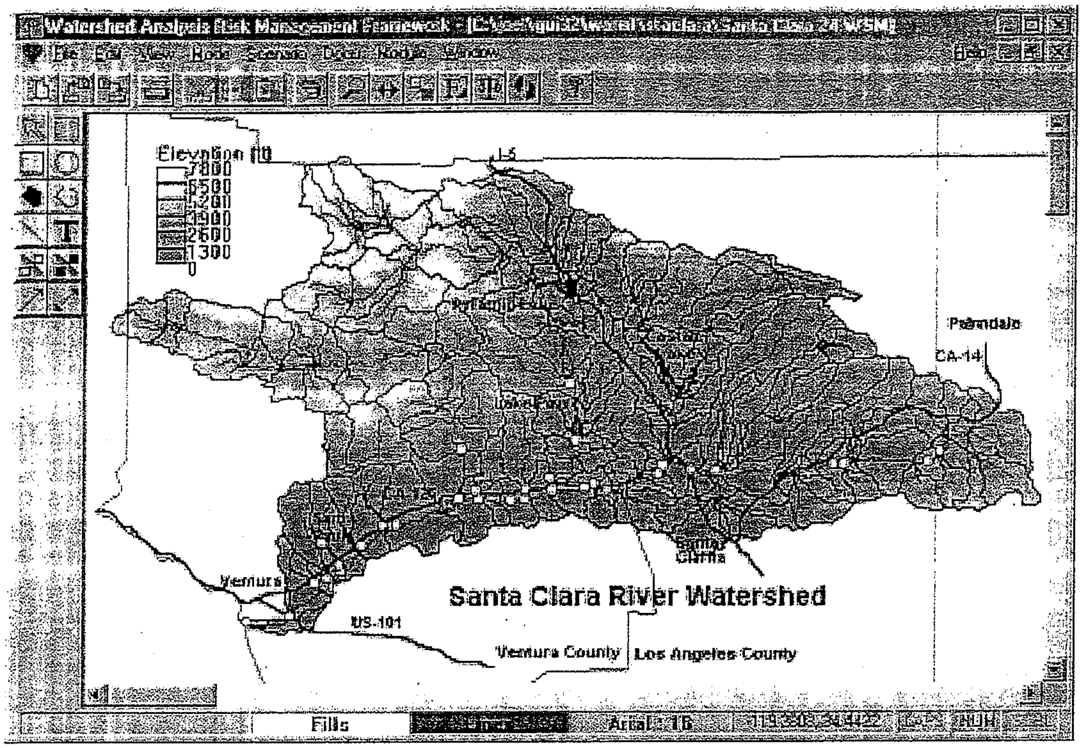


Figure 8: Locations of water quality monitoring stations

III. Watershed Modeling Methodology

Introduction

The watershed model chosen for the Santa Clara River is called the Watershed Analysis Risk Management Framework (WARMF). WARMF is a comprehensive modeling framework which links land catchments, river segments, and reservoir segments into a seamless watershed network. It has a graphical user interface with several modules. WARMF has an engineering module to perform watershed simulation for hydrology, nonpoint source loads, and water quality; a data module for storing and editing data in GIS format; a knowledge module to store reference information; a TMDL module to determine various combinations of point and nonpoint loads to meet the water quality criteria; and a consensus module to help stakeholders develop an implementation plan. A WARMF CD, complete with calibrated model, technical documentation, and user's guide is provided with this report for the stakeholders to use.

The time period selected for modeling was water years 1990-2000 (10/1/1989-9/30/2000). This time period has sufficient data to calibrate the model and includes a variety of hydrologic conditions. In particular, water years 1991 (10/1/1990-9/30/1991) and 1998 (10/1/1997-9/30/1998) represent a very dry year and a very wet year, respectively. These two years will be used to represent critical hydrologic conditions when using the model for watershed management and TMDL calculation.

Physical Representation

The watershed is divided up into land catchments, river segments, and reservoir segments. Each is linked together in a network so that output from catchments is automatically input to the adjacent river segment, and each river segment is connected to the one downstream, to reservoir segments, and back to river segments to form a complete network.

Each catchment is divided into the canopy, land surface, and several soil layers. Below the surface, it is assumed that each soil layer has uniform hydrology and water quality. The nonpoint source load from land catchments include pollutants associated with surface runoff and those associated with ground water accretion to the river segment. Each river segment is assumed to be completely mixed. Reservoir segments are divided into horizontal layers, each of which is assumed to be mixed.

WARMF can be run with any simulation time step. It is typically run with a daily time step because input data is most available at that temporal resolution. The Santa Clara River watershed has been set up to run on a daily time step.

Hydrologic Simulation

Hydrology simulation is based on mass balance of water, driven by precipitation. Water is routed from catchments to river segments, and reservoir segments. Provision is also made to allow for prescribed flows, including point sources, reservoir releases, diversions, and groundwater pumping. The accuracy of hydrologic simulation therefore depends on the accuracy of data for precipitation and prescribed flows.

Catchments

Each catchment is assigned to a meteorology station (shown in Figure 5 and Figure 6). To translate the precipitation amount occurring at a meteorology station to the precipitation occurring at a catchment, a precipitation multiplier is used to account for orographic effects. A temperature lapse rate is used to transpose the temperature at the meteorology station to the temperature at the catchment due to elevation differences between the catchment and the meteorology station.

Falling precipitation is divided into rainfall and snowfall based on temperature. Some rainfall is intercepted by the canopy. The remaining throughfall reaching the soil surface percolates into the soil. Snowfall accumulates and melts on the soil surface with the water volume tracked each day.

WARMF represents the soil by layers. Each layer has its thickness, field capacity, porosity, hydraulic conductivity, and slope. The moisture content of each soil layer is tracked every day. Water percolating into the soil first raises the moisture content to field capacity. Above field capacity, lateral flow occurs by Darcy's Law. If all soil layers reach saturation, overland flow occurs. The complete WARMF technical documentation describes the algorithms used (Chen 2001).

Septic system discharges occur in the Santa Clara River watershed. The number of people served by septics per catchment is specified and the per capita flow and loading is the same for all septic systems.

Subsurface discharges of treated effluent also occur in the watershed. Figure 9 shows the location of State of California permitted subsurface discharges in the Santa Clara River watershed. Each discharge has a schedule of flow and loading. The model assumes that the subsurface discharge spreads evenly over the entire catchment for percolation into the groundwater system.

Catchments can have pumping according to a flow schedule. The pumped water can be used for municipal/industrial purposes, in which case it is removed from the model, or it can be pumped to a river, or it can be applied to the land surface as irrigation. The volume of water is removed from the lowest soil layer of the catchment, and then applied at its destination.

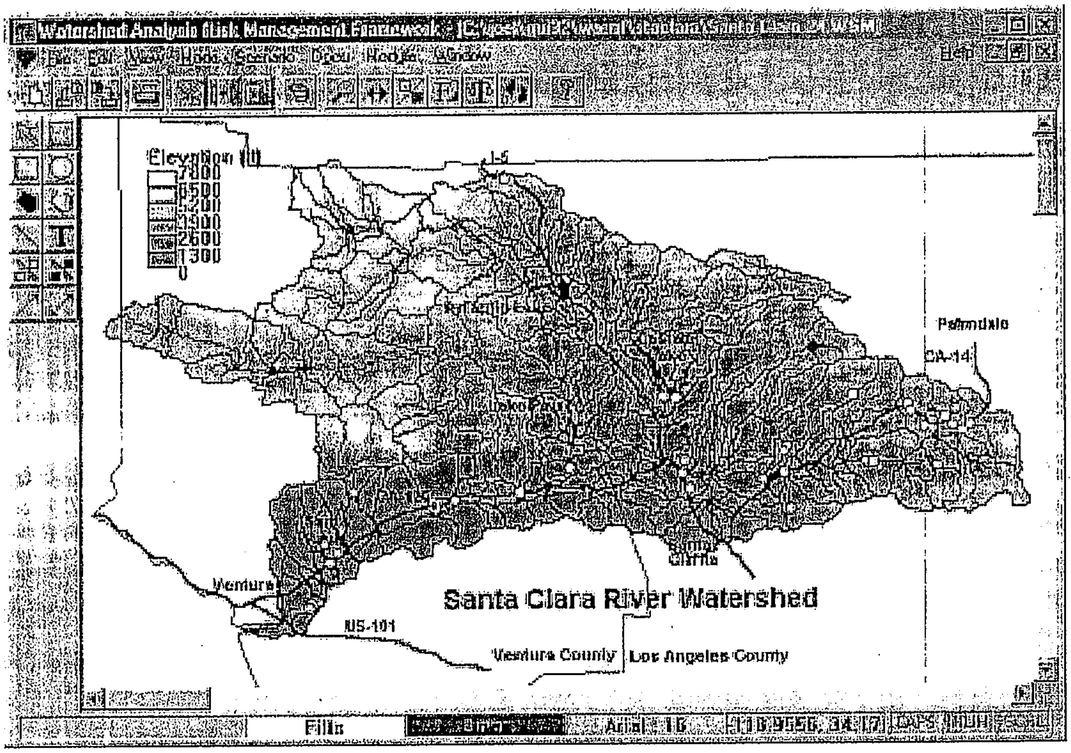


Figure 9: Locations of permitted subsurface discharges

WARMF divides the land surface into land uses. Within each land use, an impervious fraction of the surface may be specified. It is assumed that precipitation falling on impervious surfaces is routed through a storm drain system and discharged to local creeks and thus is not available for evaporation and infiltration into the soil. The travel time through the storm drain system is assumed to be short, so that drained water reaches the local creek in the same (daily) time step in which the precipitation falls. A test was conducted to determine if this assumption is valid for the Santa Clara River.

The test was performed using flow at the Old Road Bridge gage (the downstream end of Reach 8 as shown in Figure 2 near where Interstate 5 crosses the river). The gage is downstream of the Saugus wastewater reclamation facility. The city of Santa Clarita also drains storm water to the Santa Clara River upstream of the Old Road Bridge. Land use for the city is known (SCAG 2001), and impervious fractions were assumed to be 20% for residential, 40% for high density residential, and 60% for commercial/industrial. Impervious runoff can be calculated by multiplying precipitation by impervious area. Figure 10 shows Saugus WWRF flow, gaged flow, and calculated impervious runoff on a logarithmic scale.

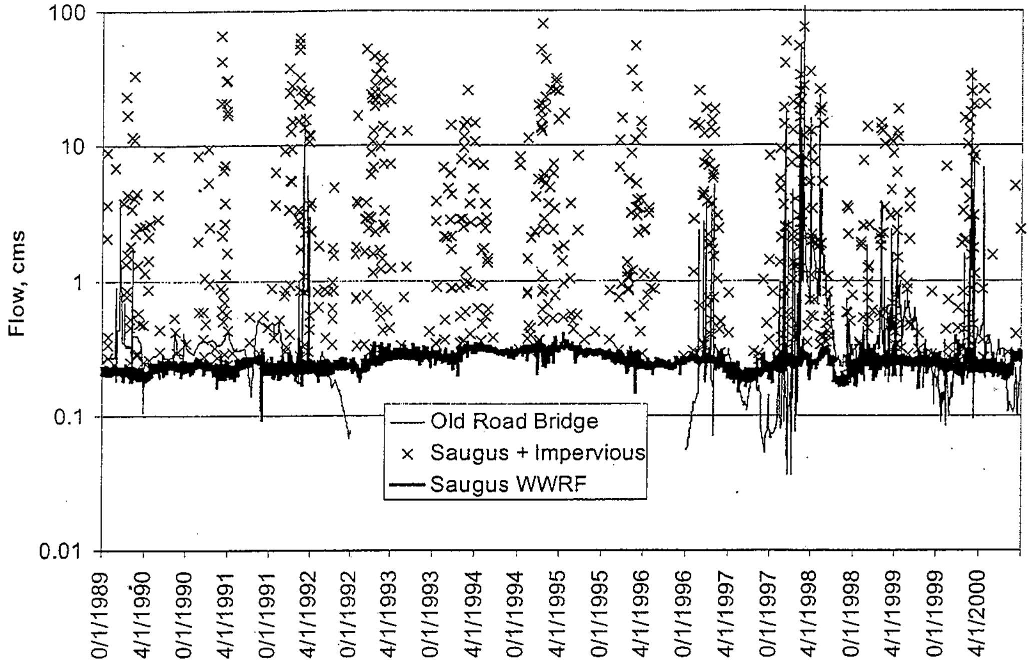


Figure 10: Saugus WWRF Flow, Gaged Old Road Bridge Flow, and Calculated Impervious Flow, m^3/s

For the relatively dry years of 1989-1992, the gaged flow at the Old Road Bridge was almost identical to the Saugus WWWRF flow. The calculated impervious runoff did not have any impact on the river flow. For the wet years of 1996 to 2000, the calculated runoff from impervious area appeared to have contributed flow to the river.

It was determined that all storm water, from pervious and impervious areas, passed through a wide pervious river bed of Santa Clara River. We therefore decided to deactivate the feature for the river to receive immediate runoff from impervious area. The catchment flow was simulated as if the land surface was pervious. Under such assumption, the simulated river flow would not have the peaks associated with storm water in dry years. In wet years, the model would simulate ground water table reaching the land surface, generating faster surface runoff to the river as indicated in the gaged flow data.

The model's treatment of impervious flows thus differs somewhat from what is believed to occur. The model allows percolation of precipitation on impervious surfaces in the catchment in which the precipitation fell. In the field, the storm drain system may transports that precipitation to another catchment, thus transferring the percolation to another location. This treatment by the model could result in travel times to surface water greater than those expected in the field. Since groundwater ammonia concentrations are very low and denitrification is assumed to not significantly occur, this increased travel time is not expected to cause significant error in the concentration of nutrients transported to the river. However, if the model were used at some later date to simulate the transport of other water quality constituents, such as fecal coliform, error could be introduced as a result of the model's formulation.

Rivers

WARMF assumes that all rivers are "gaining" rivers, which means they receive water from subsurface flow but do not lose water to percolation into the river bed. To simulate flow for the Santa Clara River, the flow lost to the river bed was estimated on a daily basis for each river segment. The estimated flow was then diverted from the river segments.

There were estimates of groundwater accretions for two river segments (UWCD (McEachron) 2002). The estimated flow was used in favor of the groundwater lateral flow simulated by WARMF. To accommodate such situation, the horizontal hydraulic conductivity of the soil in the applicable catchments was set to zero in WARMF to prevent the double accounting of groundwater accretion to the river. The estimated ground water accretion was simulated with a pump removing water from the groundwater of each catchment to each adjacent river segment.

Figure 11 shows the river sections that use prescribed gains and losses of water. The red sections have prescribed loss. The green sections have prescribed gain. The yellow sections have both prescribed gain and loss, sometimes gaining and sometimes losing over the course of the simulation. The blue sections only have gains, which are simulated by WARMF.

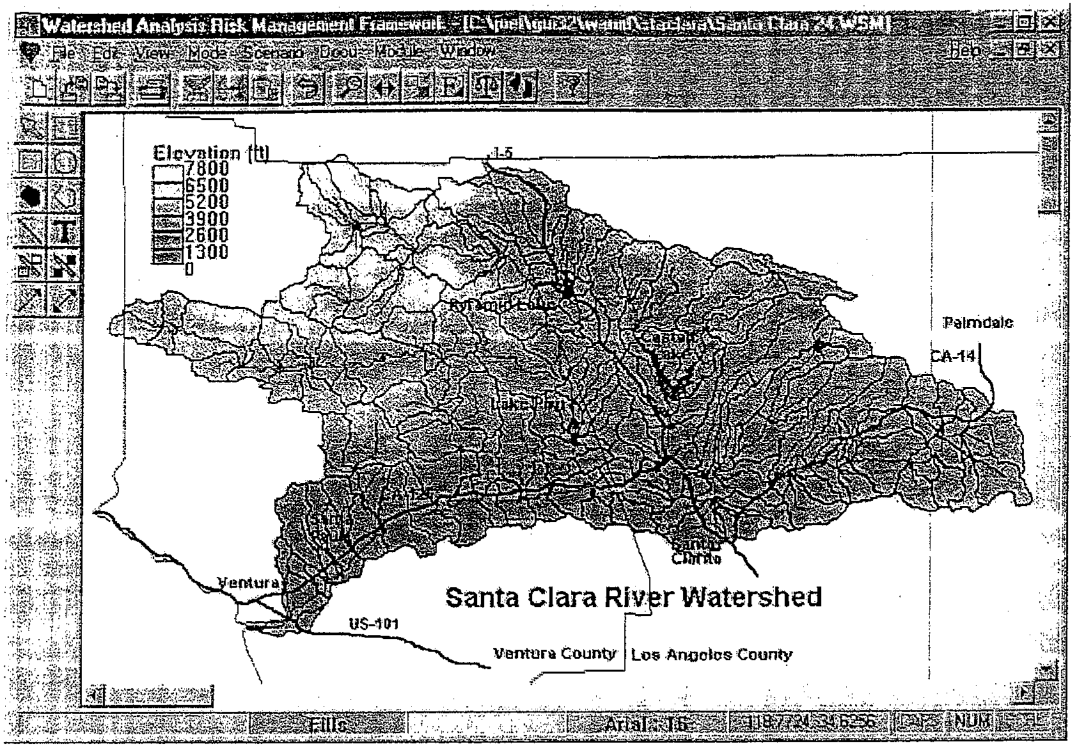


Figure 11: River segments with prescribed gains (green), losses (red), or both (yellow)

There are many point source discharges to the Santa Clara River. Their flow and loading is specified as a time series schedule in the WARMF Data Module. Each point source is linked to a river segment so that its flow and loading is added to the river segment accordingly.

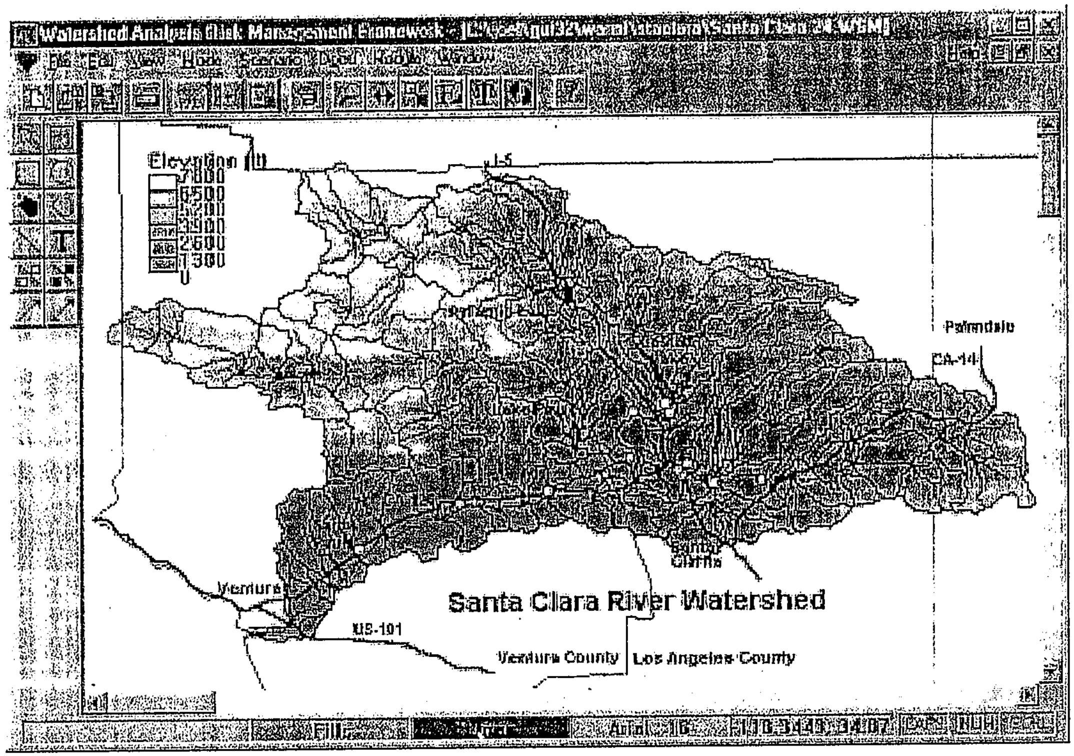


Figure 12: Locations of surface point source discharges

In the rapidly growing Santa Clarita area, groundwater pumping is often required to dewater construction sites. When this occurs, it can contribute significant flow to the Santa Clara River. Figure 13 shows dewatering sites with available flow records during the simulation period. The model extracts the prescribed pumping rates from the groundwater of the catchment and releases it to the adjacent river segment.

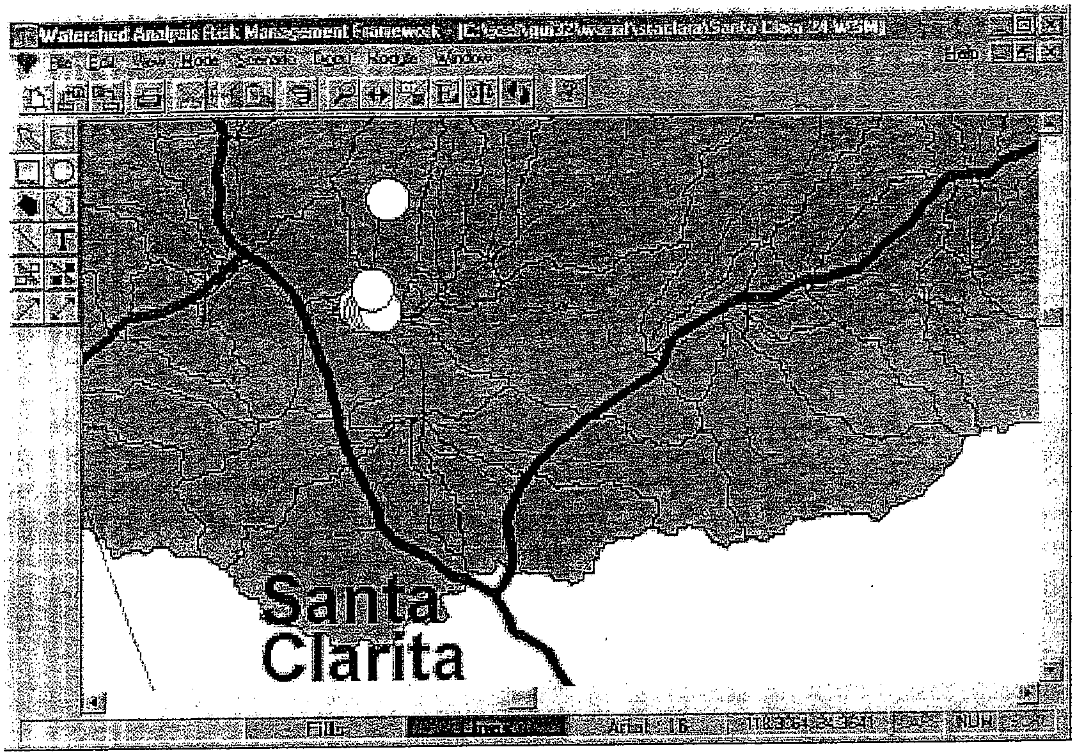


Figure 13: Santa Clarita area with dewatering sites with flow records

In the Santa Clara River, water is also diverted for direct agricultural use and groundwater recharge. Figure 14 shows the locations of these diversions. In WARMF, the specified water is removed from the applicable river segments and applied to the catchment surface as irrigation.

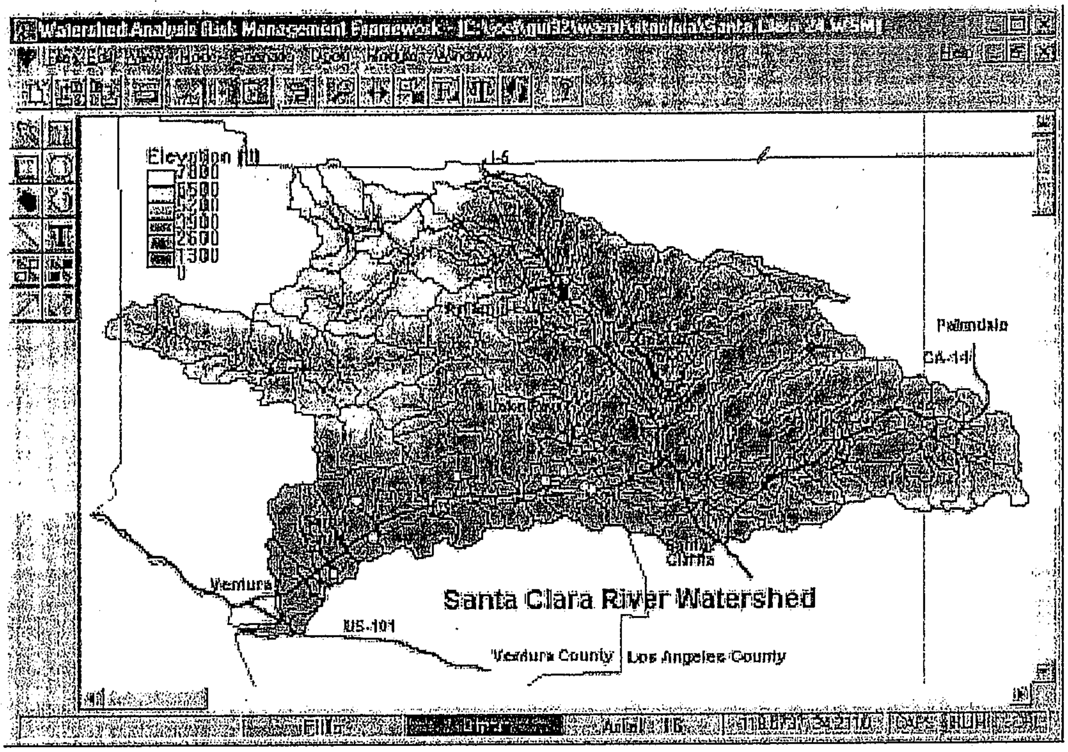


Figure 14: Santa Clara River watershed with diversions

Water Quality Simulation

Water quality simulation is based on mass balance of each chemical constituent. Temperature simulation is based heat transfer with ambient air. As water is routed through catchments, rivers, and reservoir segments, the associated chemical constituents are routed with the water. At each step of the simulation, chemical interactions are simulated to transform the chemicals to other forms. WARMF tracks each chemical with its sources, such as point source, septic system, and land uses. When two quantities of water are mixed, the chemical constituents are also mixed and the source of the new mixture is a mass weighted average of the sources for each chemical.

Catchments

Water quality simulation begins with atmospheric deposition to the land surface. Wet deposition is applied to the canopy and land surface based on the chemical concentrations in rain. Dry deposition is loaded to the canopy and land surface based on a monthly deposition rate and air quality concentrations.

To perform the calculations, WARMF requires monitoring stations with precipitation chemistry and air quality data. Figure 15 shows the locations of the four air quality monitoring stations in the Santa Clara River watershed (CARB 2002). Rainfall chemistry data came from a separate station at Tanbark Flat in the mountains east of the watershed in Los Angeles County (NADP 2002).

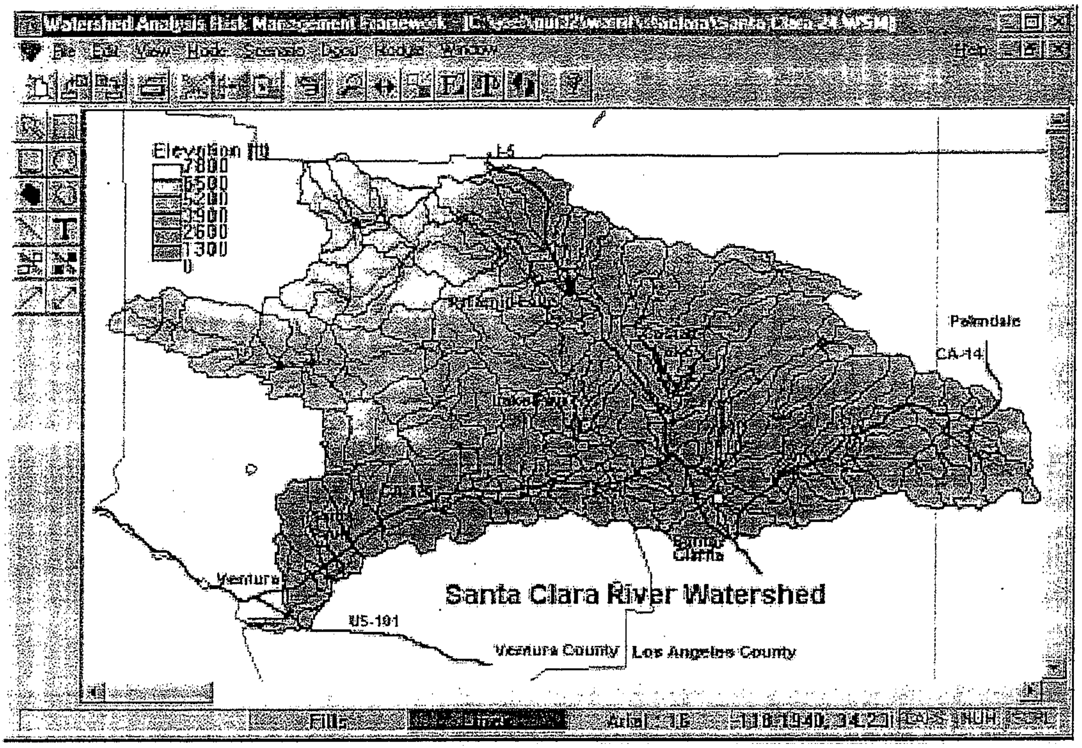


Figure 15: Santa Clara River watershed with air quality monitoring stations

Atmospheric deposition is joined by land application from fertilizers, urban debris, and wildlife. The canopy absorbs some of the total deposition to incorporate into its biomass, and the remainder is then carried by throughfall to the soil surface. As rainfall and snow melt percolate into the soil, they carry the chemical constituents washed down from the canopy. Once inside the soil, chemicals undergo many processes, including competitive cation exchange, anion adsorption, chemical reactions, and uptake by vegetation. pH is calculated from alkalinity and inorganic carbon by tracking the mass of each of the cations and anions. As lateral flow occurs, dissolved constituents are carried with it to river segments. When the soil is saturated, chemicals accumulated on the soil surface flow with overland flow to river segments.

Chemical constituents associated with septic systems and subsurface discharges (Figure 9) are mixed with the constituents already present in the soil layers. Water pumped out of the catchment carries with it the dissolved constituents in the soil solution.

Rivers

Each river segment acts as a mixed tank reactor. All inflows from local catchments, upstream river segments, upstream reservoirs, point sources, and dewatering operations are combined, reacted, and discharged to the downstream segment. Reaeration is simulated to balance dissolved oxygen and carbon dioxide concentrations. pH is calculated from alkalinity and inorganic carbon concentrations.

WARMF also simulates three species of floating algae and periphyton (attached algae) Their growth removes nutrients from the water. Periphyton simulation may be turned on or off for each river segment depending on the suitability of the substrate for periphyton growth.

Model Calibration Process

During model calibration, parameters which are not known are calibrated within reasonable ranges. Calibration is done in three stages: global, seasonal, and specific. Global calibration achieves an overall balance over the course of the simulation period. Seasonal calibration makes the model's predictions follow the seasonal variation in observed data. Specific calibration tunes model parameters so that simulated results match specific observed data points. Model calibration is often a never-ending iterative process.

Calibration proceeds in a certain order. Hydrologic calibration is first, since water quality is highly dependent upon hydrology. Temperature is calibrated with hydrology because of the importance of evapotranspiration and freezing in the hydrologic cycle. Water quality calibration proceeds after hydrologic calibration, but the hydrologic calibration can be revised to better simulate the water quality.

Hydrology

For calibration purposes, many model parameters are considered "known". These parameters, shown in Table 5 are not adjusted during calibration. Calibration parameters shown in Table 6 were adjusted within the range of values shown in the right column for the Santa Clara River watershed. Refer to the WARMF User's Guide (Herr 2000) and Technical Documentation (Chen 2001) for more information on the specific parameters.

Table 5: Key known hydrologic parameters

Type	Parameter	Source
Catchment	Area	Digital Elevation Models (DEMs) (USGS 2002)
Catchment	Slope	DEMs (USGS 2002)
Catchment	Width	DEMs (USGS 2002)
Catchment	Aspect	DEMs (USGS 2002)
Catchment	Land Use	GIS Databases (US EPA 2001, DWR 2002, SCAG 2001)
Catchment	No. Septic Systems	County database (Ventura County 2002) and estimated general numbers (Wagener 2002)
River	Length	DEMs (USGS 2002)
River	Slope	DEMs (USGS 2002)
System	Septic System Flow	Los Angeles County Department of Health Services (Wagener 2002)

Time series input data including meteorology (NCDC 2002, VC FCD 2002, LAC DPW 2002), pumping rates (UWCD (Detmer) 2002), point source flows (LACSD 2002), and diversion rates (Subbotin 2002, UWCD (Detmer) 2002) is not adjusted during calibration. Agricultural pumping rates were not provided for Los Angeles County, but were assumed to be enough for 30 inches per year from April 16 until October 15 on Orchard, Farm, and Golf Course land uses (Daugovich 2002). Errors in time series input data are propagated through WARMF, which sometimes can lead to discrepancies between model predictions and observed data.

Table 6: Calibration parameters for hydrologic simulation

Type	Parameter	Values used
Catchment Surface	Detention Storage	20 %
Catchment Surface	Manning's n	0.3
Catchment Surface	Meteorology Station	
Catchment Surface	Precipitation Weighting	0.8-1.25
Catchment Surface	Temperature Lapse	0–7 °C
Catchment Surface	Altitude Lapse	0.005–0.009 °C/m
Catchment Soil Layers	Thickness	23 - 10000 cm
Catchment Soil Layers	Initial Moisture	0.15-0.3
Catchment Soil Layers	Field Capacity	0.15-0.3
Catchment Soil Layers	Saturation	0.27-0.4
Catchment Soil Layers	Horizontal Hydraulic Conductivity	40 – 9000 cm/d
Catchment Soil Layers	Vertical Hydraulic Conductivity (Max. Infiltration Rate)	5 – 9000 cm/d
Catchment Soil Layers	Root Distribution	0-0.75
River	Initial Depth	0.01-0.1 m
River	Manning's n	0.04
River	Convective Heat Factor	1E-6 – 1E-4
System	Land Use Open in Winter	0-1
System	Snow Formation Temperature	3 °C
System	Open Area Melting Rate	0.08 cm/°C/d
System	Forested Area Melting Rate	0.05 cm/°C/d
System	Open Area Sublimation Rate	0.05 cm/d
System	Forested Area Sublimation Rate	0.05 cm/d
System	Evaporation Magnitude	1.2
System	Evaporation Skewness	1.015
System	Soil Thermal Convection Rate	0.003 cm/s

Calibration begins with system wide parameters affecting global and seasonal balance. The parameters for specific catchments or river segments are then adjusted to match local hydrographs. The hydrologic calibration may be tuned further as part of the water quality calibration.

Water Quality

Water quality calibration follows the same principles as hydrologic calibration. The water quality constituents least dependent upon others are calibrated first. The order of calibration is as follows: temperature, sediment, conservative constituents (major cations and anions), pH, nutrients and dissolved oxygen.

For the Santa Clara River project, many parameters are considered "known" and are not adjusted. The values of these parameters are enumerated in the Source Analysis Report (Systech 2002). Table 7 shows the key known water quality parameters. All time series input data, including air / rain chemistry and point source loading, is not adjusted. Table

8 shows the parameters which are adjusted in water quality calibration, with the values used in the Santa Clara River watershed shown in the right column.

Table 7: Key known water quality parameters

Type	Parameter	Source
Catchment	Land Application Rates	Refer to the Source Analysis Report (Systech 2002)
Catchment	Soil Erosivity	MUIR Database (USDA NRCS 2002)
Catchment	Soil Surface Particle Content	MUIR Database (USDA NRCS 2002)
System	Particle Deposition Velocity	Refer to the Source Analysis Report (Systech 2002)
System	Septic System Loading	Refer to the Source Analysis Report (Systech 2002)

Table 8: Calibration parameters for water quality simulation of nitrogen and phosphorus

Type	Parameter	Values used
Catchment Surface	Air Chemistry File	
Catchment Soil Layers	Organic Acid Decay Rate	0.06/yr
Catchment Soil Layers	Nitrification Rate	0.1/d
Catchment Soil Layers	Denitrification Rate	0/d
Catchment Soil Layers	Initial Concentrations	0.001-150 mg/l
Catchment Soil Layers	Cation Exchange Coefficient	12.22 mg/100 g
Catchment Soil Layers	Initial Base Saturation (major cations)	0.001-70%
Catchment Soil Layers	Adsorption Isotherms (minor cations, anions)	0-80 l/kg
River	Aeration Factor	1
River	SOD	$0.2 g/m^2/d$
River	Organic Carbon Decay Rate	0.1/d
River	Nitrification Rate	1/d
River	Denitrification Rate	0-0.5/d
River	Periphyton Switch	OFF
System / Land Use	Cropping Factor	0.01-0.5
System / Land Use	Productivity	$0\text{-}3 kg/m^2/yr$
System / Land Use	Leaf Area Index	0-1.8
System / Land Use	Monthly Update Distribution	0-0.3
System / Land Use	Litter Fall Rate	$0\text{-}0.16 kg/m^2/mo$
System / Periphyton	All Coefficients	Periphyton turned off for all rivers

IV. Model Calibration

Introduction

Hydrology and water quality calibration have been conducted for the Santa Clara River watershed. The calibration results are discussed in three sections: the perennial western tributaries (Figure 4), the intermittent flow eastern tributaries (Figure 2), and the main stem of the Santa Clara River.

Since nutrients are the primary interest, the Santa Clara River Nutrient TMDL Steering Committee has mandated that calibration priority should be given to those nutrients of immediate concern (all forms of nitrogen). Phosphorus and dissolved oxygen are also included because they affect algal growth, which removes nitrogen. Chemical constituents such as pH, the major cations and anions, and total dissolved solids, have received little or no calibration.

Some calibration priority has also been given to simulation of low flow conditions, since those are believed to be the most critical for calculation of TMDLs. However, it is also important to achieve a good overall water balance and representation of peak flows to simulate timing of flows and distribution between high flow and low flow periods.

Calibration is also focused on the impaired streams of the watershed (Table 4). WARMF calculates simulation results for flow and all chemical constituents for all river segments in the watershed. The results presented here are for those locations relevant to the impaired streams and for which there is observed data to compare against simulation results.

WARMF calculates various statistics to quantitatively describe how well model predictions match observed data. The statistics include correlation coefficient, frequency distribution, absolute error, and relative error. Where there are sufficient data points to warrant a statistical comparison, the results are discussed in this report. To interpret the results, one must recognize the advantages and drawbacks of quantitative statistics.

The correlation coefficient, r, is often used to compare two sets of randomly distributed data. In WARMF, the correlation coefficient is used to compare two time series of data. The pairs of observed and simulated data for the same time are used to calculate the correlation coefficient. The pairs of data may not be randomly distributed. Since the time element is removed from the pairs of data, the calculated correlation coefficient assumes that all errors are in magnitude and not in time. In actual time series, there can be errors in magnitude or in time. If the wrong value is predicted, it is a magnitude error. If the right value is predicted, but one or two days late or early, it is a timing error. Errors in magnitude are important for TMDL analysis. Errors in timing may be important for such issues as flood prediction, but are not important for TMDL analysis.

The relative error measures the deviations between the pairs taken from two time series of simulated and observed data. It is the cumulative error, which allows for negative deviation to cancel out the positive deviation. The relative error reveals the overall model bias when there is sufficient data points (e.g. daily observed values) to help cancel out the timing error.

The absolute error measures the precision of the model. The negative deviation does not cancel out the positive deviation in the calculation of absolute error. The absolute error does not take the timing error into account.

In this report, the match between simulated and observed hydrology data will be recorded with the number of observed data points n, correlation coefficient r, and relative error expressed as a percent. Because there are only scattered data points for water quality, the correlation coefficient is poorly suited as a measure of error. Instead, absolute error is reported with relative error as a judge of precision.

Western Perennial Tributaries

Santa Paula Creek, Sespe Creek, and Hopper Creek (Figure 4) are tributaries of the Santa Clara River which are normally perennial. Hopper Creek was dry for periods in 1989-1992 and in 2000 but had water 82% of the time overall (UWCD 2002). Santa Paula and Sespe Creeks had water 100% of the time (USGS 2002). Above the respective gages for these streams, the land is mostly undeveloped with no more than 2% agriculture and 1% urban land uses within those areas (DWR 2002, US EPA 2001).

Hydrology

Seasonal hydrology of the western perennial tributaries is typified by late winter/early spring (January-March) peak flows and gradually declining base flow the rest of the year. The Sespe Creek watershed includes significant snowfall.

Key Assumptions

There is no meteorology data available from the upper parts of the Sespe and Santa Paula watersheds. The nearest stations are Ojai in the southwest and Sespe-Westates in the east. Most of the watershed is at a higher altitude than the meteorology stations.

During the calibration, it was noted that high precipitation was recorded at both Ojai and Sespe-Westates stations. The reported precipitation produced too much water for the river. We used the precipitation weighting factor to adjust the precipitation downward by 10-15%. We also assumed that the temperature of the upper catchments was lower than at the meteorology stations, in rough proportion to altitude. We also assumed that snowfall occurred whenever the air temperature was below 3 ^{o}C. Snow melting would occur when the air temperature is above 0 ^{o}C. .

Simulation Results

There are three gaging stations in this section of the watershed. They are on Santa Paula, Sespe, and Hopper Creeks (Figure 16).

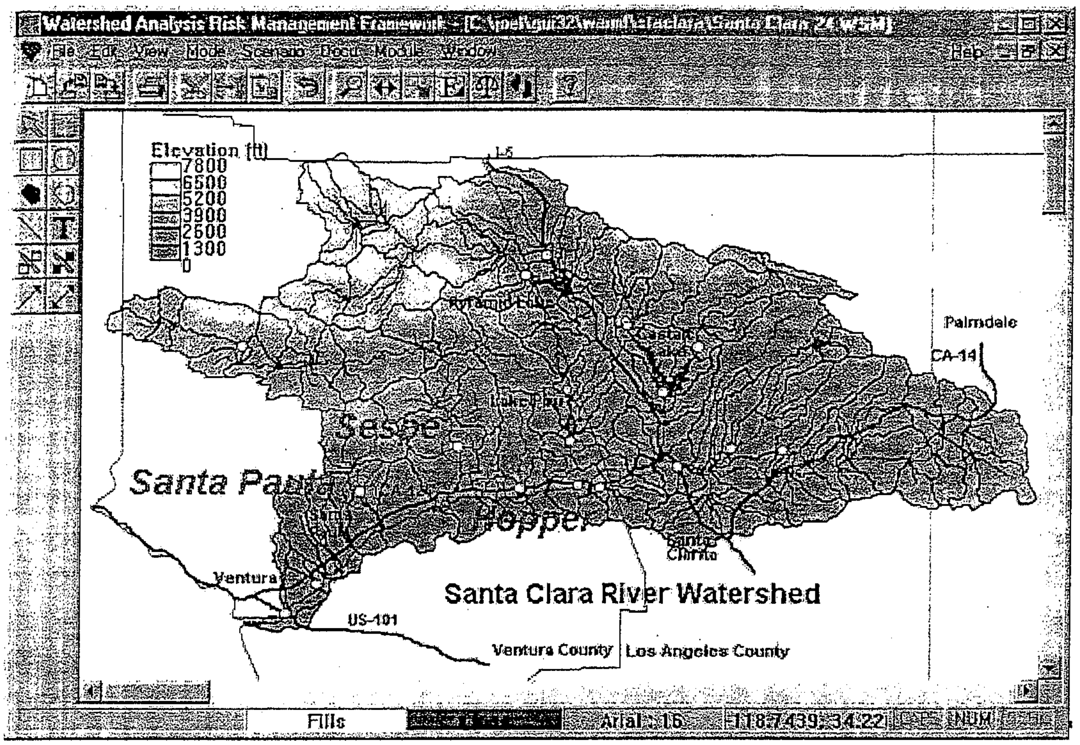


Figure 16: Stream gages in the western tributaries of the Santa Clara River

The simulated and observed flows at these stations are compared in Figure 17 through Figure 22. For each creek the first figure shows the full hydrograph and the second figure shows the same results but only in the 0-2 m^3/s range. The blue lines represent simulation results and the black circles represent observed data.

In general, the model has simulated the seasonal pattern of stream flow. Most of the time, each river has low flow. High flows occurred only during the winter and early spring storms. The model under predicted the peak flows at all three stations. The peak flow discrepancy is highest for Hopper Canyon Creek, intermediate for Sespe Creek, and lowest for Santa Paula Creek. The calibration for Sespe Creek in particular has been optimized for low and medium flow conditions, which is why the low flow error is greatest during 1998, a very wet year.

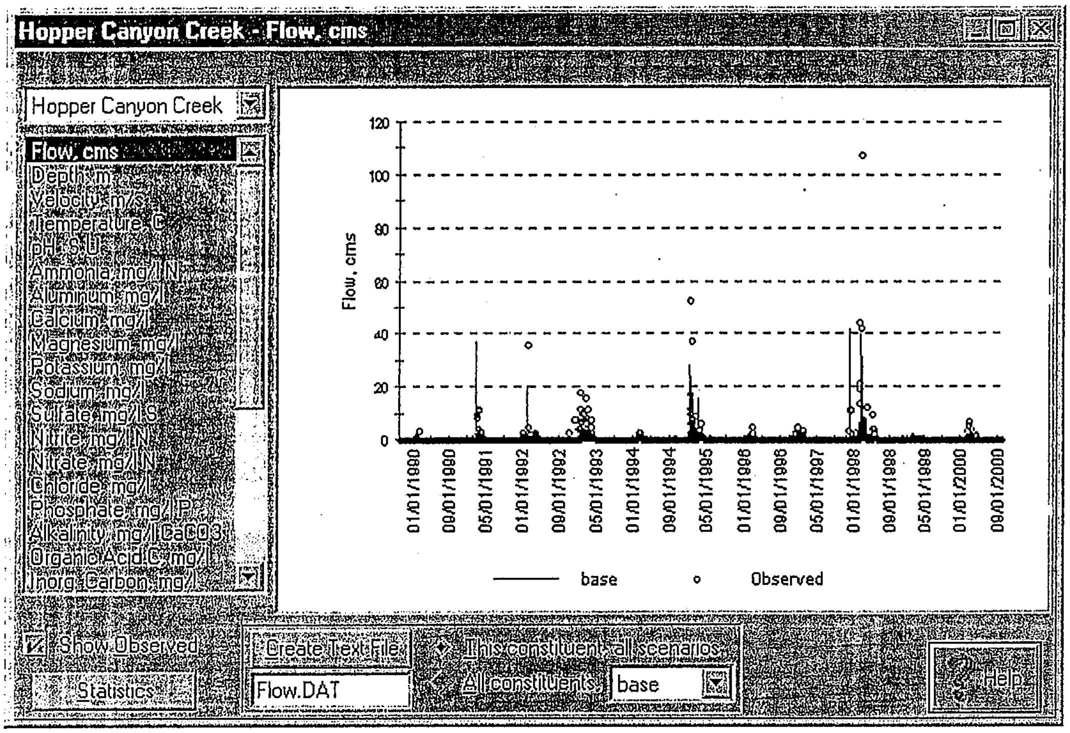


Figure 17: Simulated and Observed Flow for Hopper Creek at Highway 126 (n = 4018; r = 0.61; relative error = -3.6%)

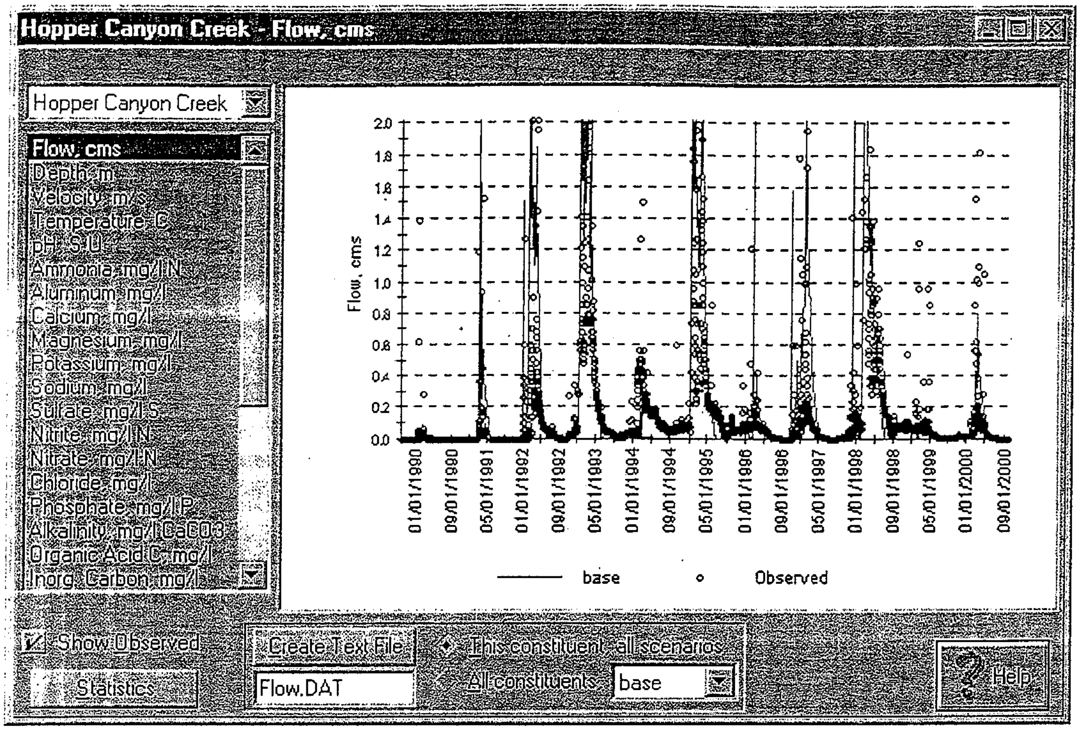


Figure 18: Simulated and Observed Flow: 0-2 m^3/s for Hopper Creek at Highway 126 (n = 3910; r = 0.69; relative error = +41.9%)

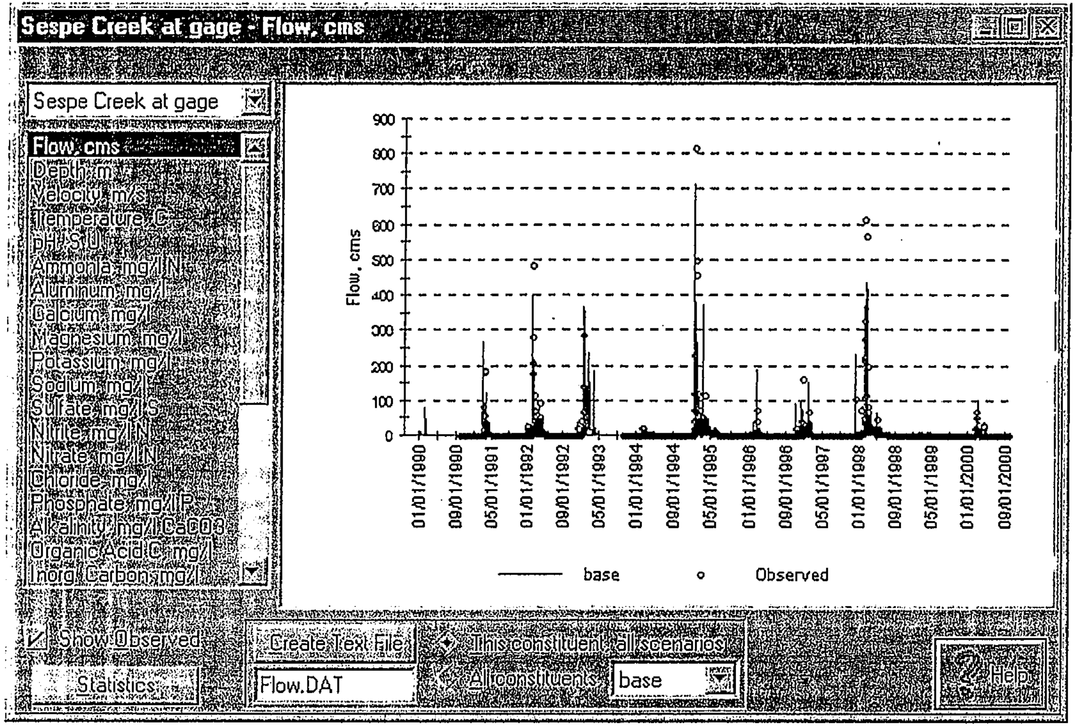


Figure 19: Simulated and Observed Flow for Sespe Creek near Fillmore
(n = 3394; r = 0.83; relative error = +12.7%)

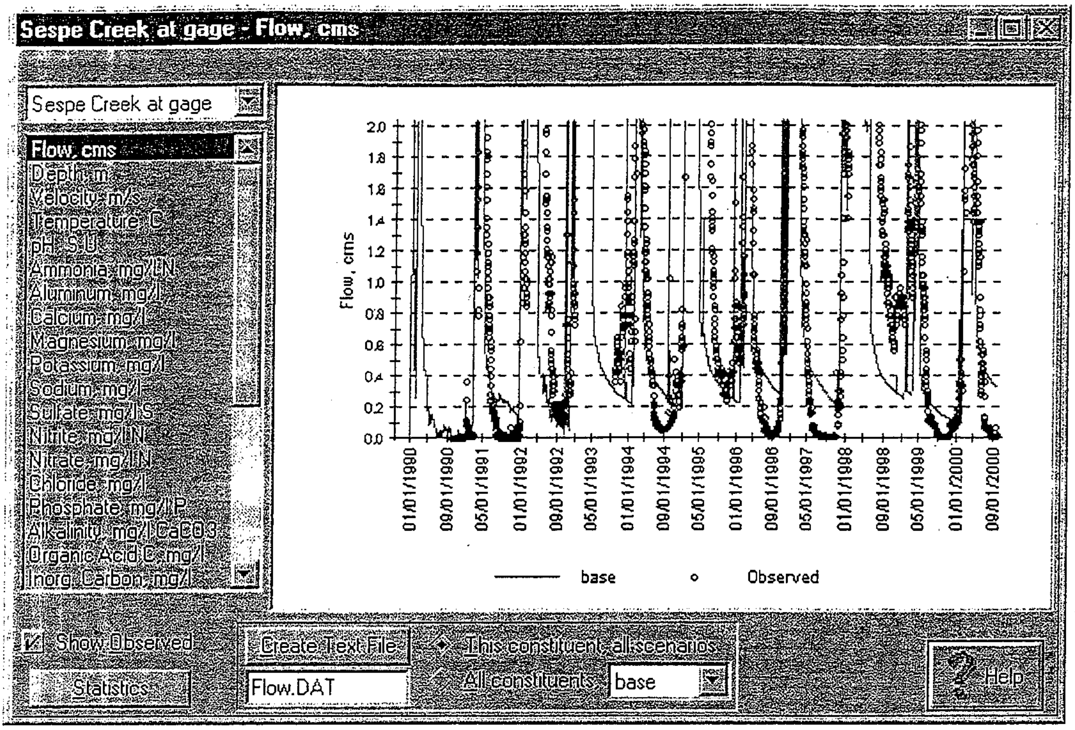
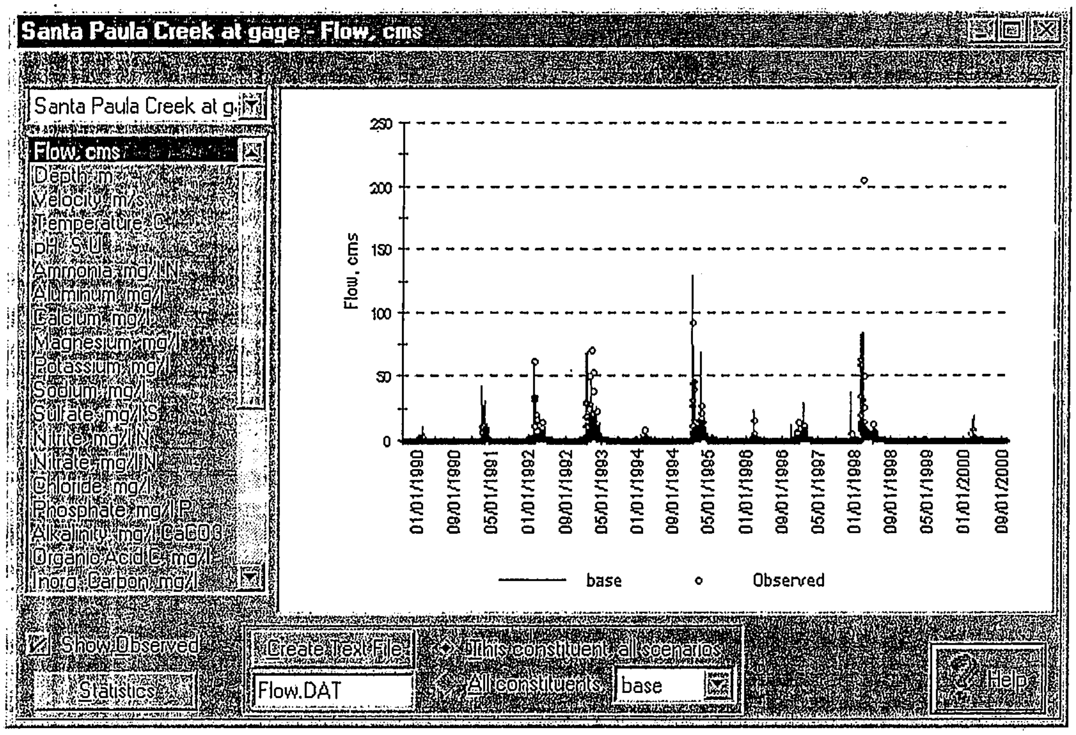


Figure 20: Simulated and Observed Flow: 0-2 m^3/s for Sespe Creek near Fillmore (n = 2678; r = 0.53; relative error = -46%)



☑ Show Observed

Flow.DAT

base

Figure 21: Simulated and Observed Flow for Santa Paula Creek near Santa Paula
(n = 4018; r = 0.77; relative error = -0.8%)

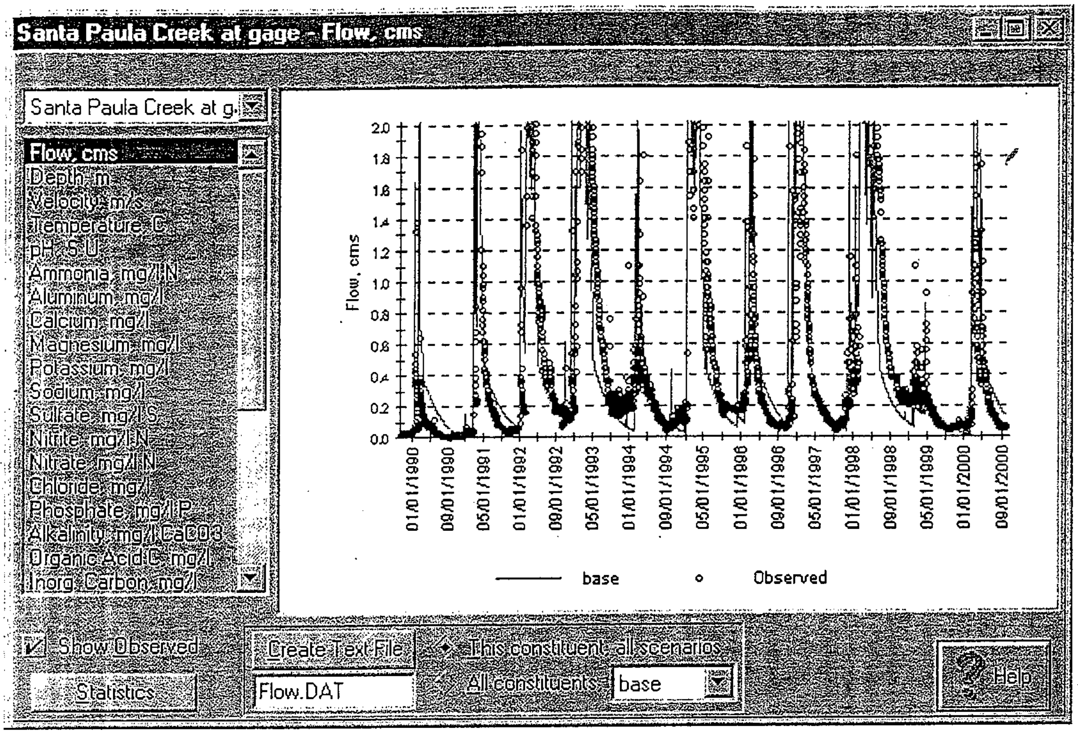


Figure 22: **Simulated and Observed Flow: 0-2 m^3/s for Santa Paula Creek near Santa Paula (n = 3607; r = 0.63; relative error = +11.4%)**

The simulation results for low flow range show that the model has simulated both rising limb and recession limb reasonably well for each tributary. The match is best for average years, but is not as good for very dry or very wet years. The correlation statistics reflect the difficulty in predicting the timing and magnitude of flows simultaneously.

Figure 23 through Figure 25 compare the frequency distribution of observed and simulated flows for the three gaging stations. The simulated (blue) and observed (black) flow curves fall on top of each other for Santa Paula Creek. The model over predicted the days of low flows (0.01 m^3/s) by less than 2% for Santa Paula Creek.

For Sespe Creek, the simulated frequency distribution curve matches the observed for flow above 1 cms. The model under predicted the days of low flows (0.1 cms) by as much as 25%. For Hopper Creek, the simulated frequency distribution curve matches the observed for flow above 0.2 cms. The model over predicted the days of low flow (0.01 cms) by as much as 40%.

Over all, WARMF has predicted correct frequency of high flows for all three creeks. This is expected, because larger storms measured at the meteorological station were more evenly distributed to all watersheds. The over and under predictions of extreme low flows are probably caused by the uneven distribution of small storms over the three watershed areas. This interpretation assumes that the stream gages have measured the extreme low flows accurately. The calibration of Sespe Creek shows an underrepresentation of flows in the 0.5-1.0 m^3/s range and an overrepresentation of flows between 0.01-0.1 m^3/s.

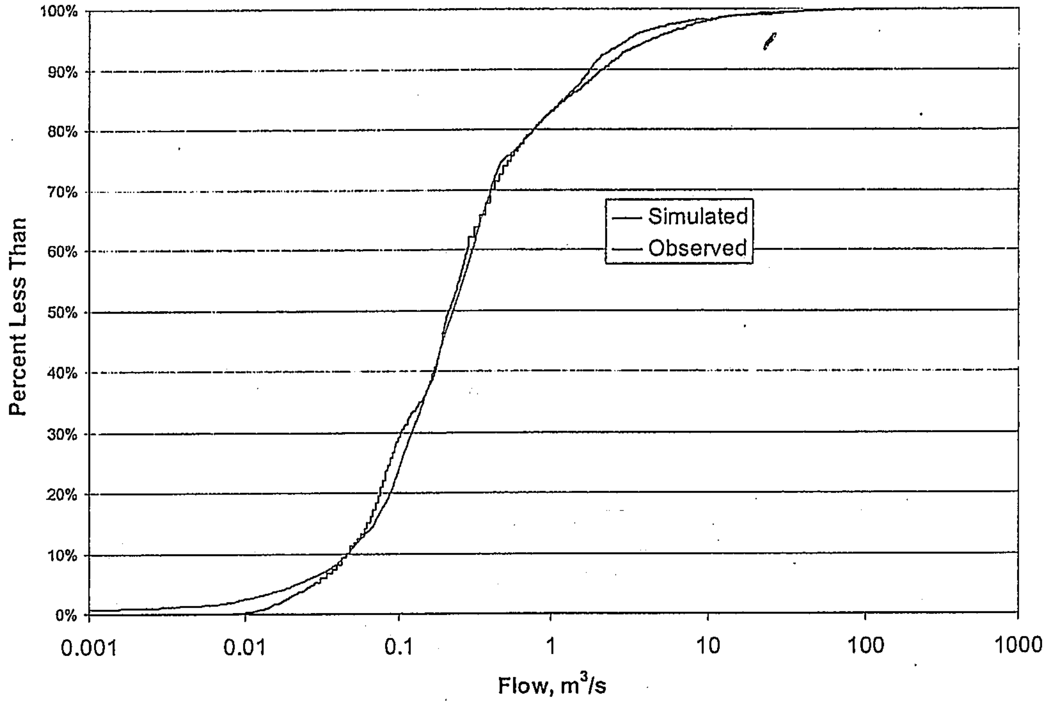


Figure 23: Frequency distribution of flow for Santa Paula Creek

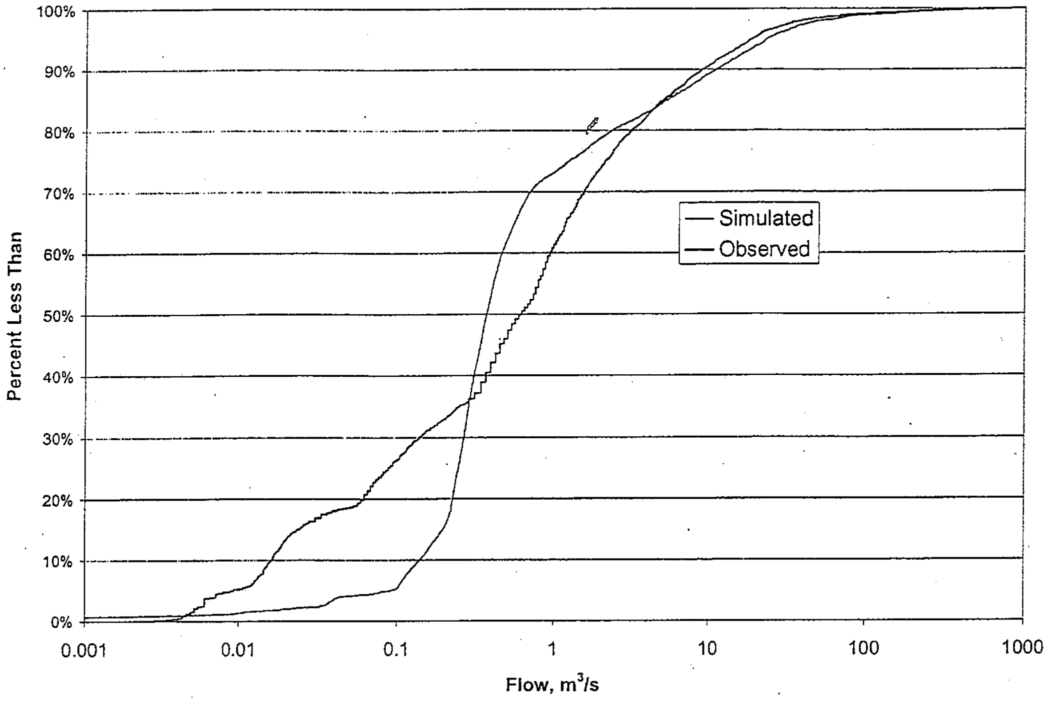


Figure 24: Frequency distribution of flow for Sespe Creek

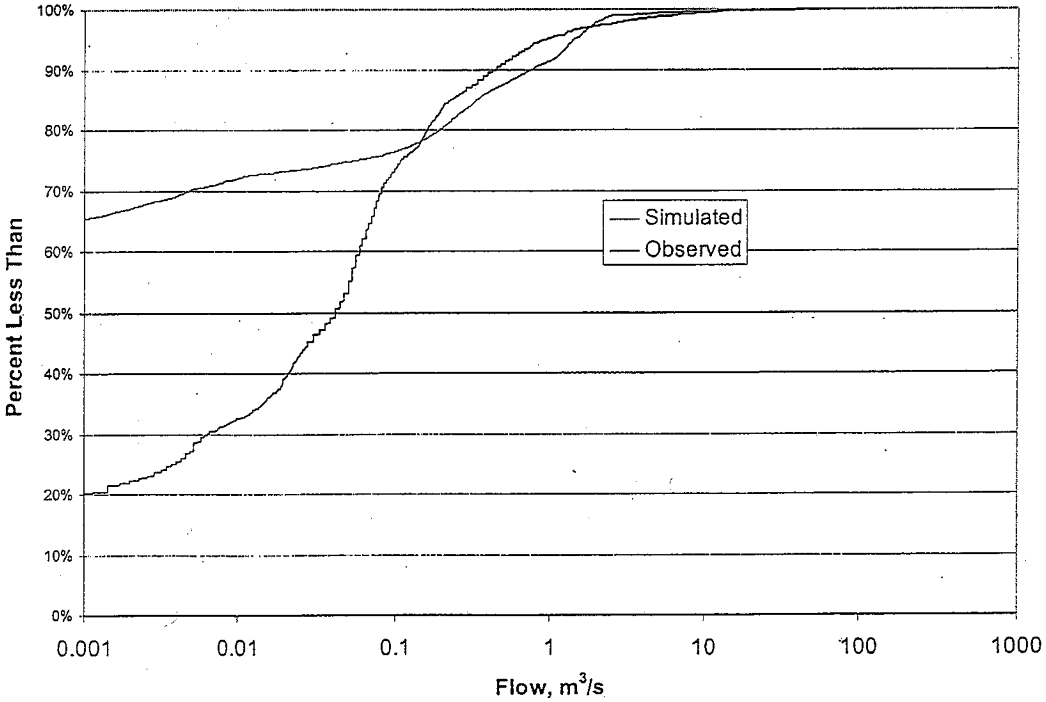


Figure 25: Frequency distribution of flow for Hopper Creek

Water Quality

The water quality of each of the western tributaries is relatively good. Typical ammonia concentrations are less than 0.1 mg/l as N, nitrate is less than 1 mg/l as N, and phosphate is around 0.02 mg/l as P. The water quality monitoring station for Santa Paula Creek is downstream of its gage, near the confluence with the Santa Clara River. Because of that, it includes influences from the intervening land, which is 26% agricultural and 3% urban.

Key Assumptions

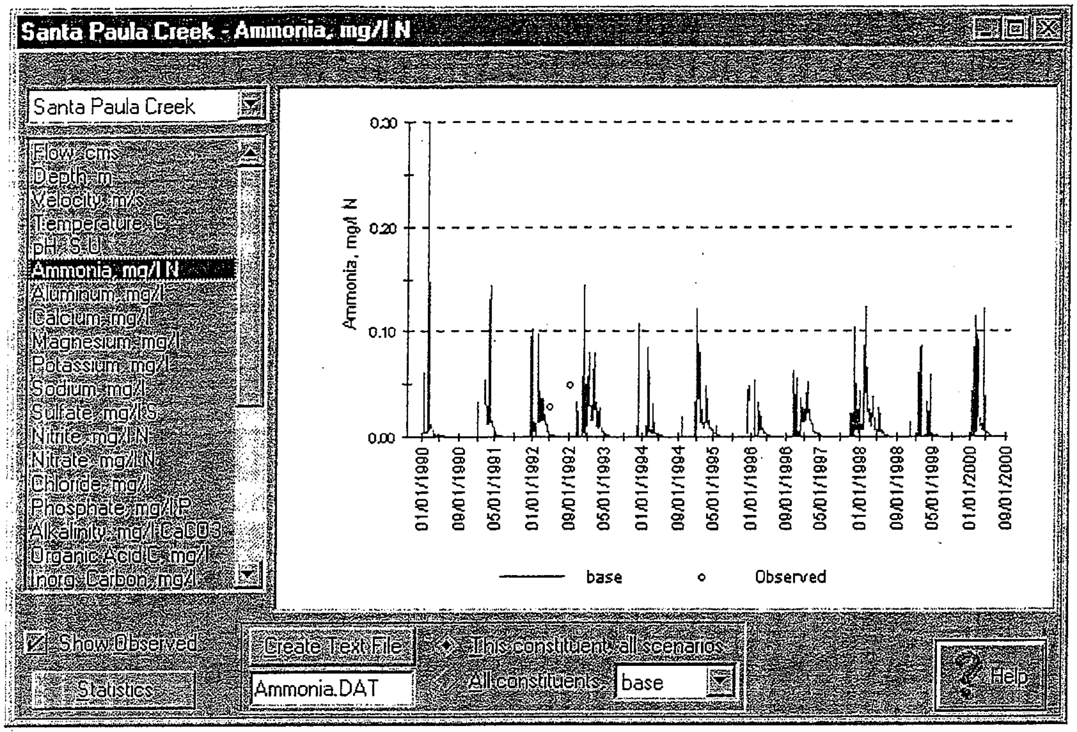
The background concentration of nitrate is dependent on the balance between nitrogen loading to the land surface through atmospheric deposition and uptake from the soil by vegetation. Excess is stored in the soil, where nitrification occurs. The flow is high enough in these creeks to flush out any excess nitrate.

Productivity of the vegetation, which affects how much nutrients are taken up, was assumed to be the average of literature values for each type of vegetation on the land. Initial soil concentrations of nutrients were assumed to be very low, in concert with the monitoring data from each creek.

Simulation Results

Simulated results (blue line) and observed data (black circles) are compared in Figure 26 through Figure 34. Ammonia is underpredicted by the model at Santa Paula and Sespe Creeks. However, both simulated and observed show low concentrations, below 0.1 mg/l. Similarly, for nitrate the model underpredicts (Santa Paula) and overpredicts (Sespe) nitrate concentration but is in the correct range of values. Phosphate concentrations are matched precisely for the limited amount of data available. Simulated nitrate for Hopper Creek is clearly too high. The casue of this discrepancy is not known, but the relatively small contribution of flow from Hopper Creek to the lower Santa Clara River means the net effect of this error is small at the Freeman Diversion.

Since the Sespe Creek watershed is in a mountainous area without development, the air quality was assumed to have half the concentration of each constituent as was measured at the Ojai air quality station. Refer to the Sensitivity Analysis section of this document for a discussion of the effect of air quality on water quality in this part of the watershed.



Santa Paula Creek

☑ Show Observed

Ammonia.DAT

● This constituent, all scenarios

○ All constituents

base

Figure 26: Simulated and Observed Ammonia for Santa Paula Creek at Santa Clara River (n = 2; relative error = -0.04 mg/l; absolute error = 0.04 mg/l)

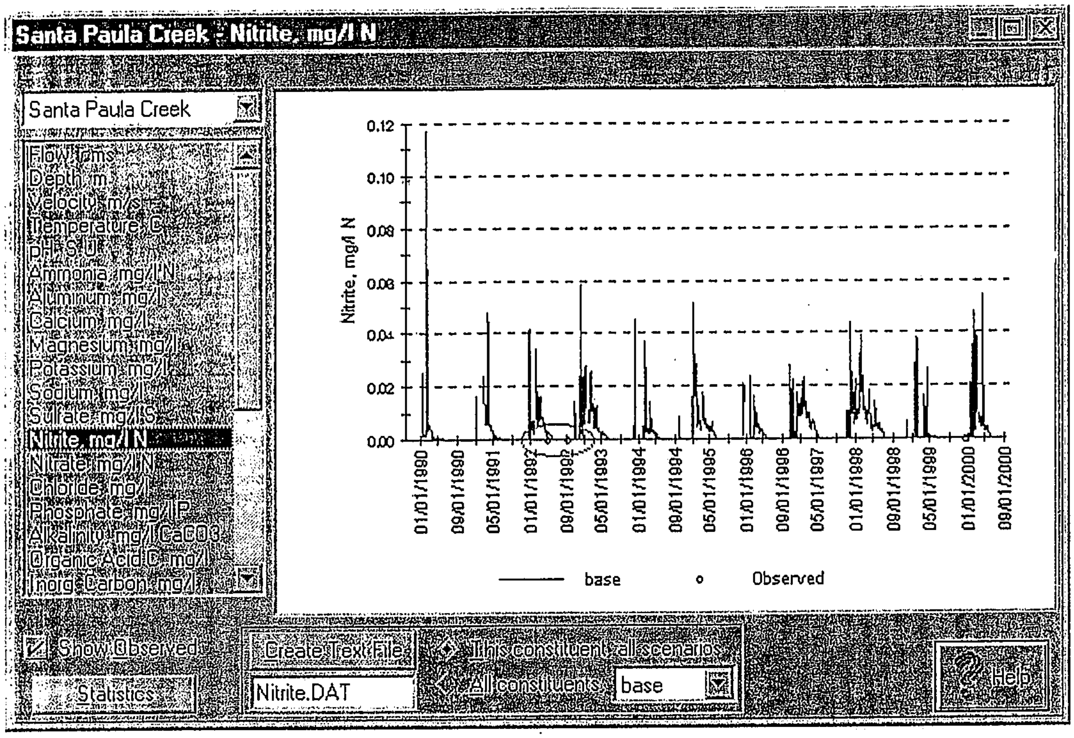
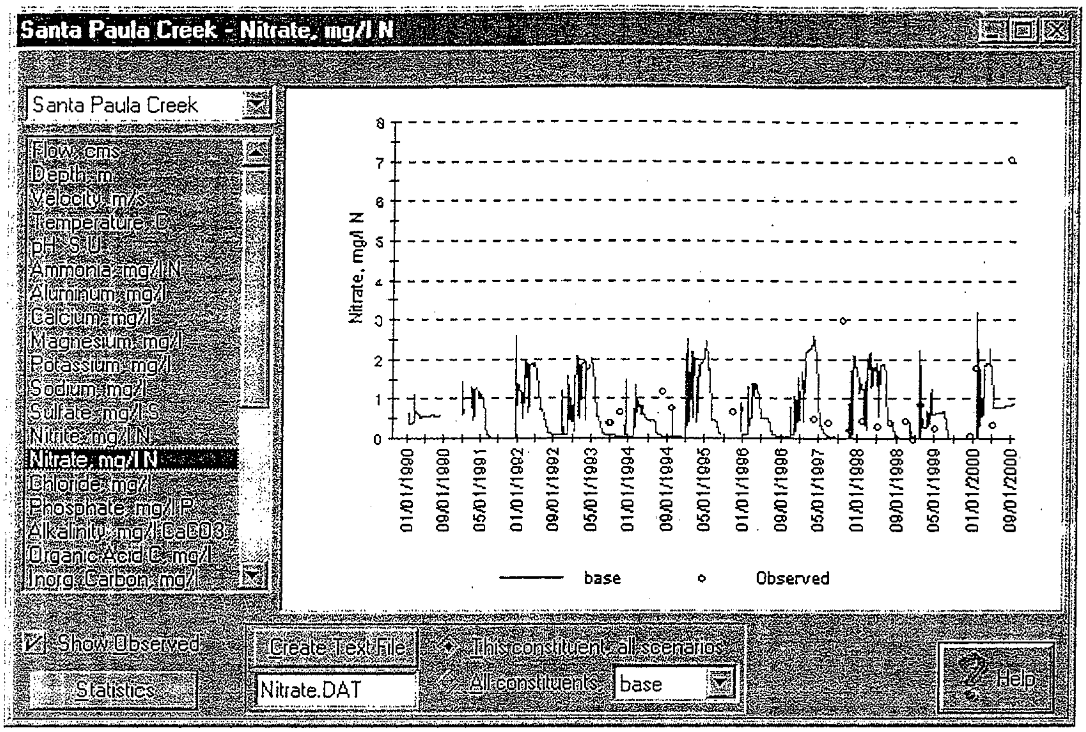


Figure 27: Simulated and Observed Nitrite for Santa Paula Creek at Santa Clara River (n = 2; relative error = 0.00 mg/l; absolute error = 0.00 mg/l)



Santa Paula Creek - Nitrate, mg/l N

Santa Paula Creek

Nitrate, mg/l N

☑ Show Observed

Nitrate.DAT

◆ This constituent, all scenarios

○ All constituents: base

Figure 28: Simulated and Observed Nitrate for Santa Paula Creek at Santa Clara River (n = 18; relative error = -0.43 mg/l; absolute error = 1.04 mg/l)

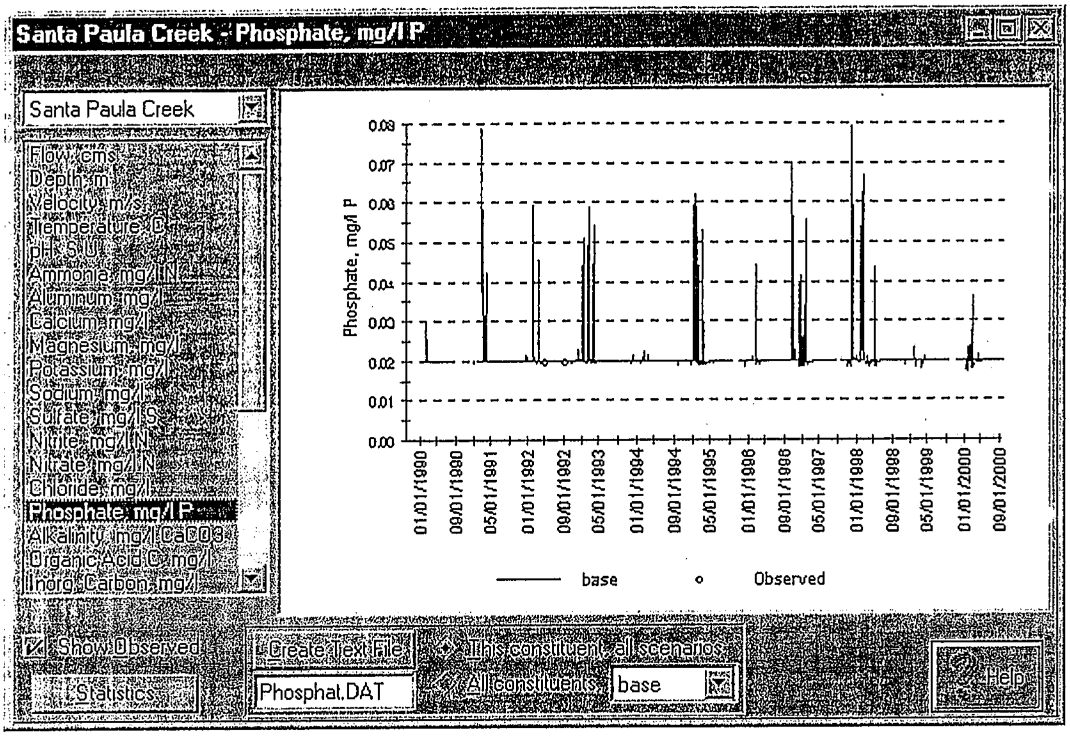
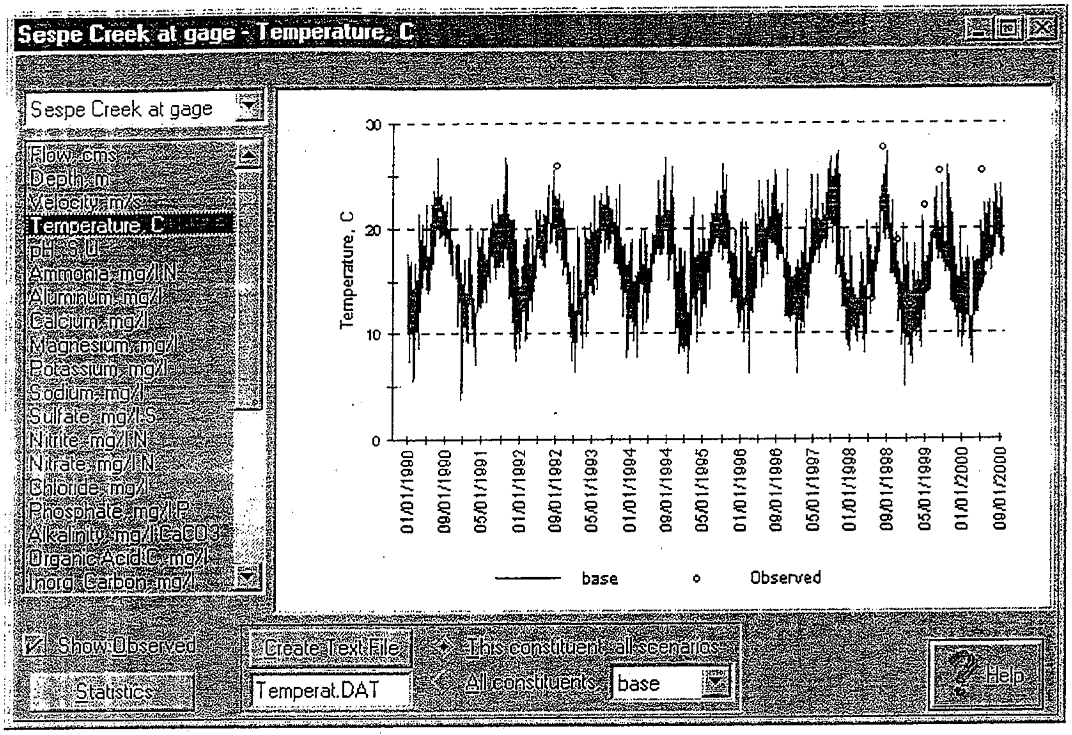


Figure 29: Simulated and Observed Phosphate for Santa Paula Creek at Santa Clara River (n = 2; relative error = 0.00 mg/l; absolute error = 0.00 mg/l)



Sespe Creek at gage

☑ Show Observed

Temperat.DAT

base

Figure 30: Simulated and Observed Temperature for Sespe Creek near Fillmore (n = 10; relative error = -3.5 °C; absolute error = 4.0 °C)

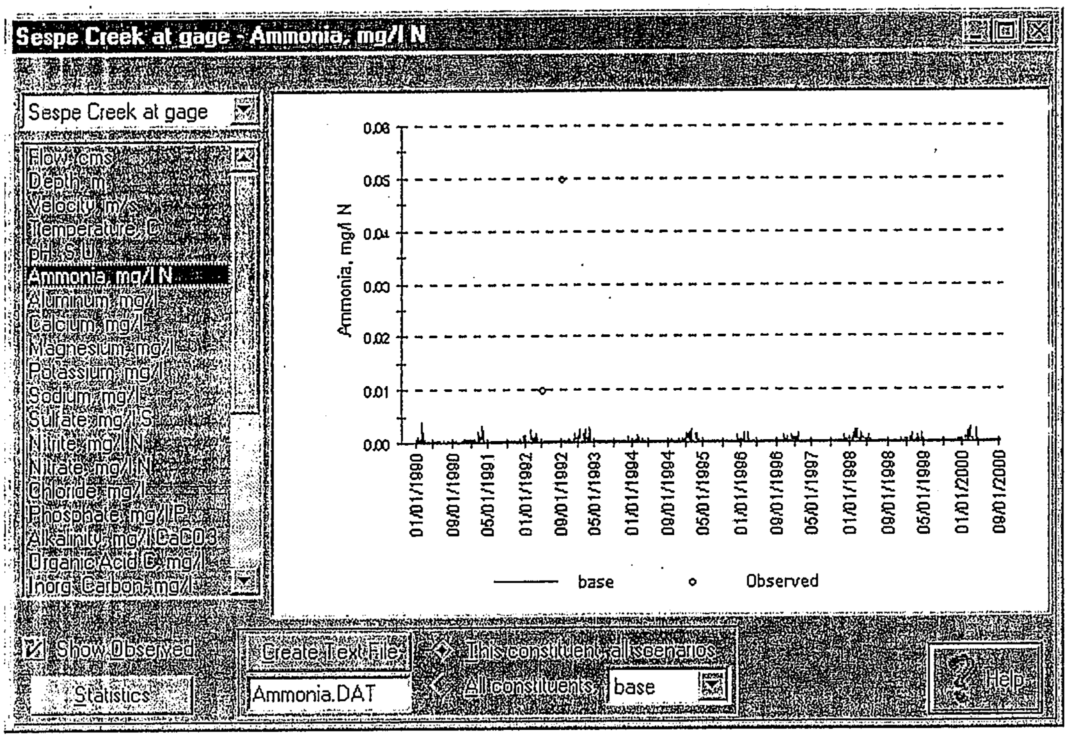
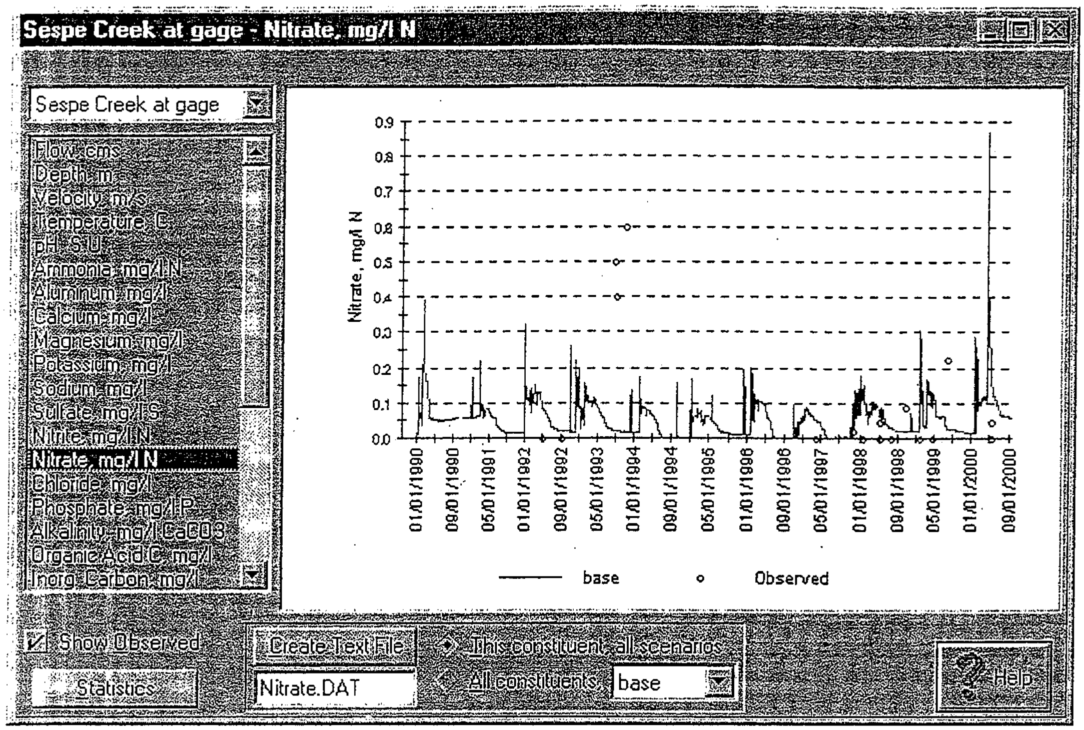


Figure 31: Simulated and Observed Ammonia for Sespe Creek near Fillmore
(n = 2; relative error = -0.03 mg/l; absolute error = 0.03 mg/l)



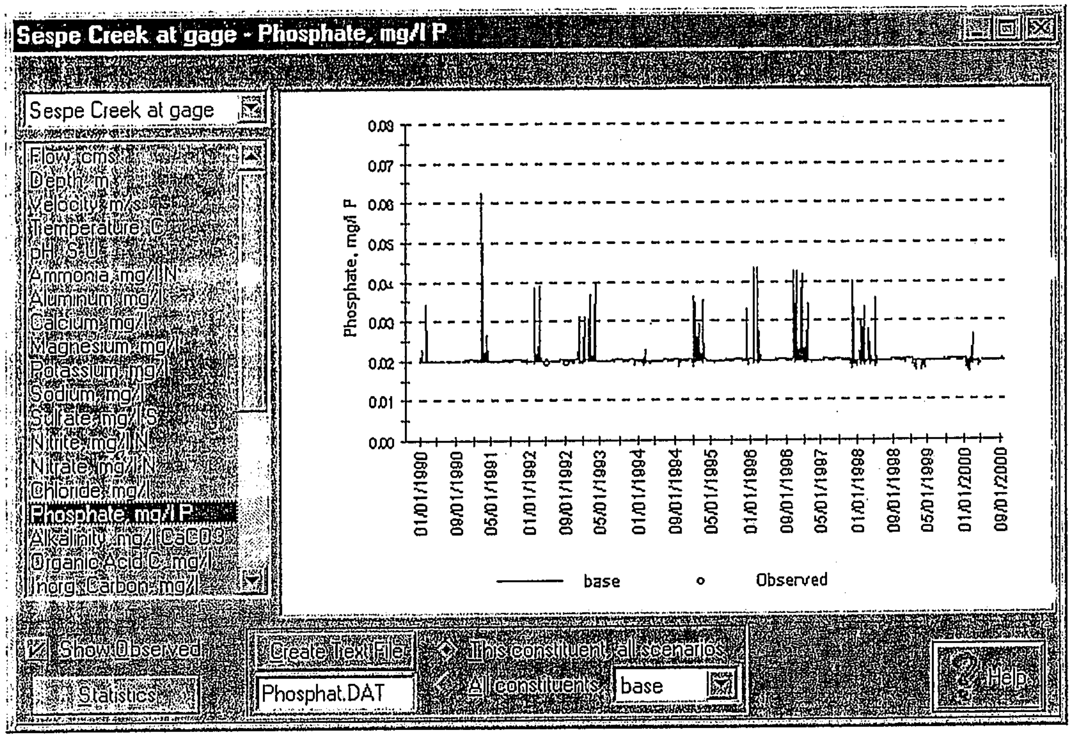
Sespe Creek at gage

☑ Show Observed

Nitrate.DAT

base

Figure 32: Simulated and Observed Nitrate for Sespe Creek near Fillmore
(n = 17; relative error = -0.05 mg/l; absolute error = 0.16 mg/l)



Sespe Creek at gage - Phosphate, mg/l P

Sespe Creek at gage

Phosphate, mg/l P

☑ Show Observed

Phosphat.DAT

base

Figure 33: Simulated and Observed Phosphate for Sespe Creek near Fillmore
(n = 2; relative error = 0.00 mg/l; absolute error = 0.00 mg/l)

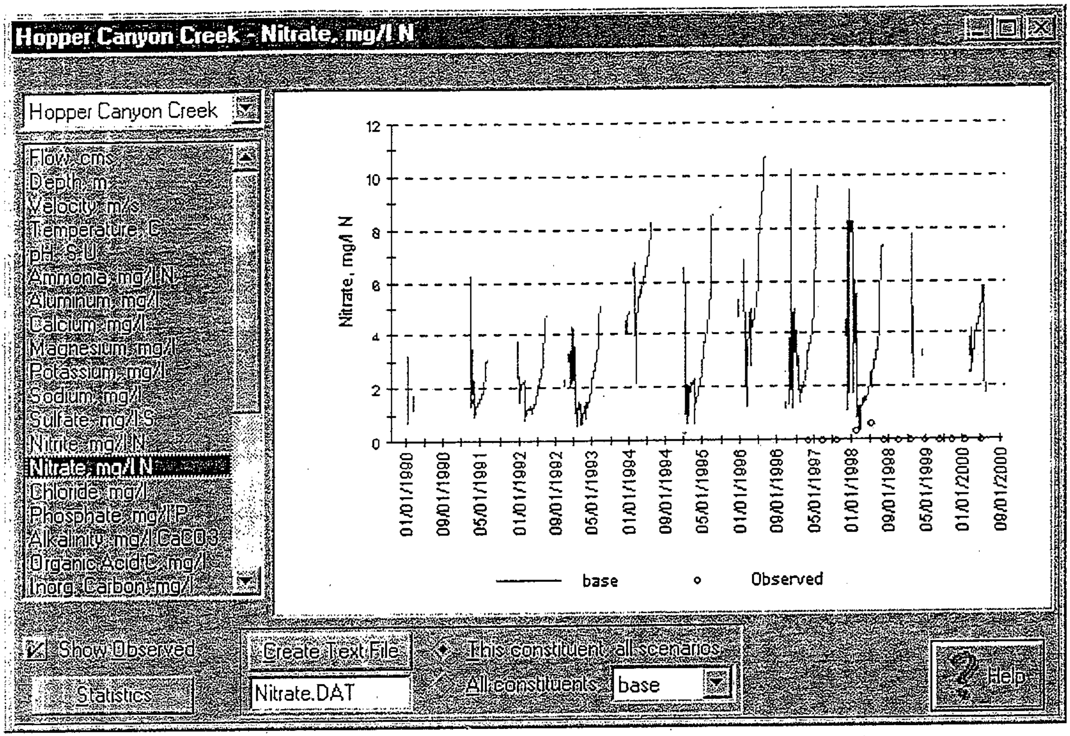


Figure 34: Simulated and Observed Nitrate for Hopper Creek
(n = 4; relative error = 3.93 mg/l; absolute error = 3.76 mg/l)

Eastern Intermittent Tributaries

Mint Canyon Creek and Bouquet Canyon Creek are intermittent tributaries of the Santa Clara River. Mint Canyon Creek and Bouquet Canyon Creek each have limited urban area: 2.2% of Mint Canyon is urbanized and 4.3% of Bouquet Canyon is urbanized. Both have less than 1% agriculture (SCAG 2002, US EPA 2001). Neither of these tributaries has any surface point source discharges or other known artificial sources of water.

The simulation results for Santa Clara River Reaches 9 and 10 (Figure 2), upstream of Bouquet Canyon Creek, are also discussed in this section. These reaches do not have flow data, but do have water quality data. The watershed for reaches 9 and 10 includes a part of Santa Clarita and the Highway 14 corridor. Most of this land is undeveloped. It includes 9.8% urban land, 0.3% agricultural land, and 0.2% golf courses.

Hydrology

The hydrology of this region of the watershed is characterized by brief sharp flow peaks for unusually large storm events, fast recession from those peaks, and no flow at all for part of the year. This hydrograph is due to the thin soil, desert-like climate, and steep canyons.

Key Assumptions

When comparing precipitation records to the gaging data for Mint Canyon Creek and Bouquet Canyon Creek to precipitation records, there are a few obvious mismatches like the one shown in Figure 35. There was one storm event on 2/23/1993. After that, there was no more precipitation, yet the flow gradually increased. The area is not subject to snow hydrology, so there is no logical explanation for the hydrograph.

There were five similar cases in the observed hydrograph of Bouquet Canyon Creek. Figure 36 through Figure 39 present the plots of precipitation events and flow in Bouquet Canyon Creek for 4/3/1990-4/9/1990, 12/4/1993-12/19/1993, 2/27/1995-3/3/1995, and 11/6/1997-11/10/1997. The other case, from 10/1/1995 to 5/31/1996, the recorded flow was a constant 0.02 m^3/s every day.

It was assumed that the unexplained flows were due to the dewatering operations of construction projects. The time and magnitude of the dewatering operations were estimated based on the observed hydrograph and entered into WARMF. It is possible that the unexplained flows in the Bouquet Canyon Creek are the reservoir releases from Bouquet Reservoir, but there are no records available.

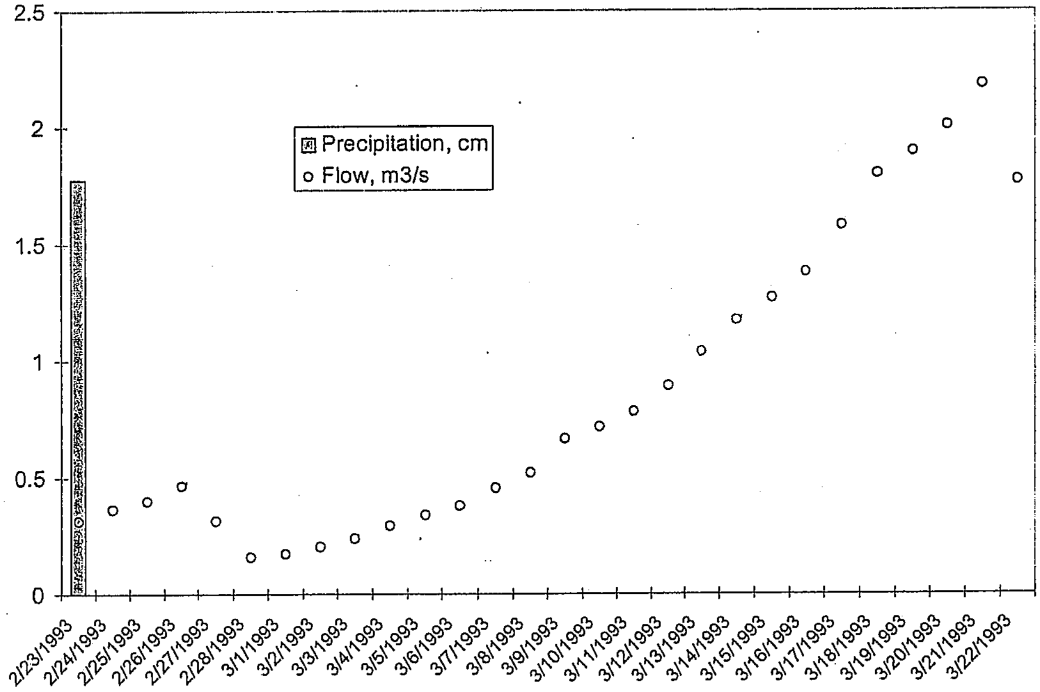


Figure 35: Precipitation and flow for Mint Canyon Creek, 2/23/1993-3/22/1993

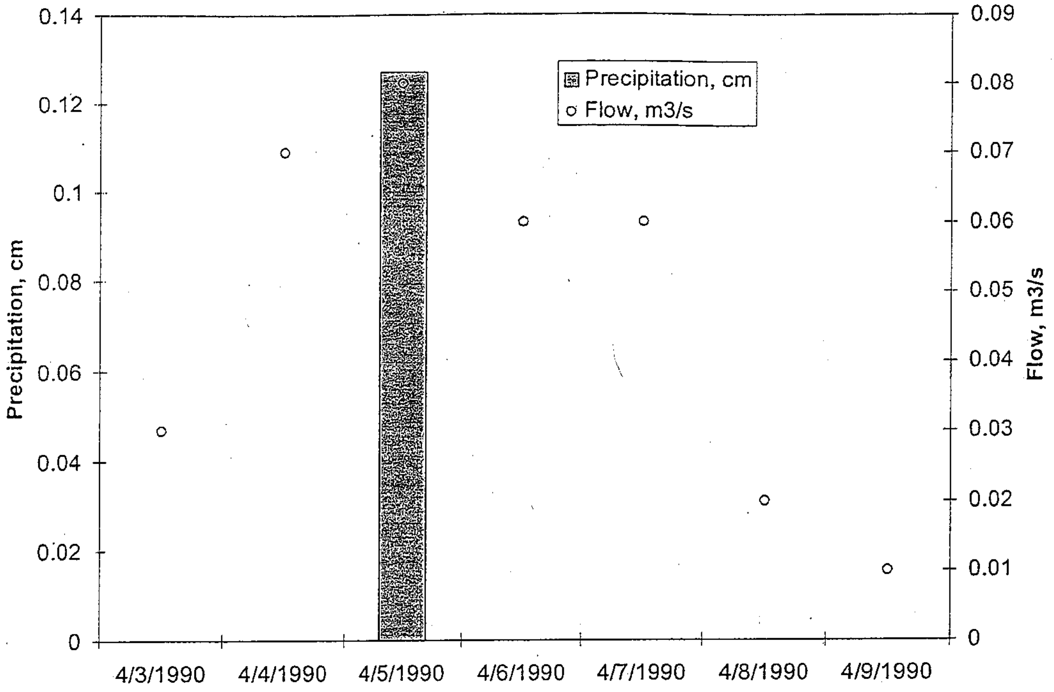


Figure 36: Precipitation and flow for Bouquet Canyon Creek, 4/3/1990-4/9/1990

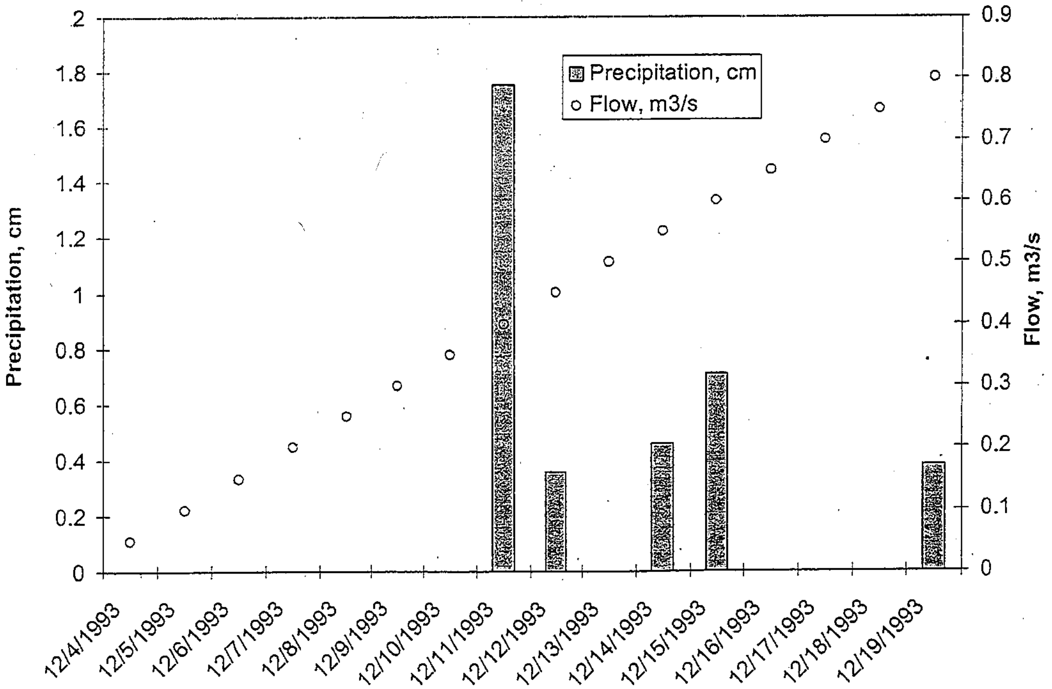


Figure 37: Precipitation and flow for Bouquet Canyon Creek, 12/4/1993-12/19/1993

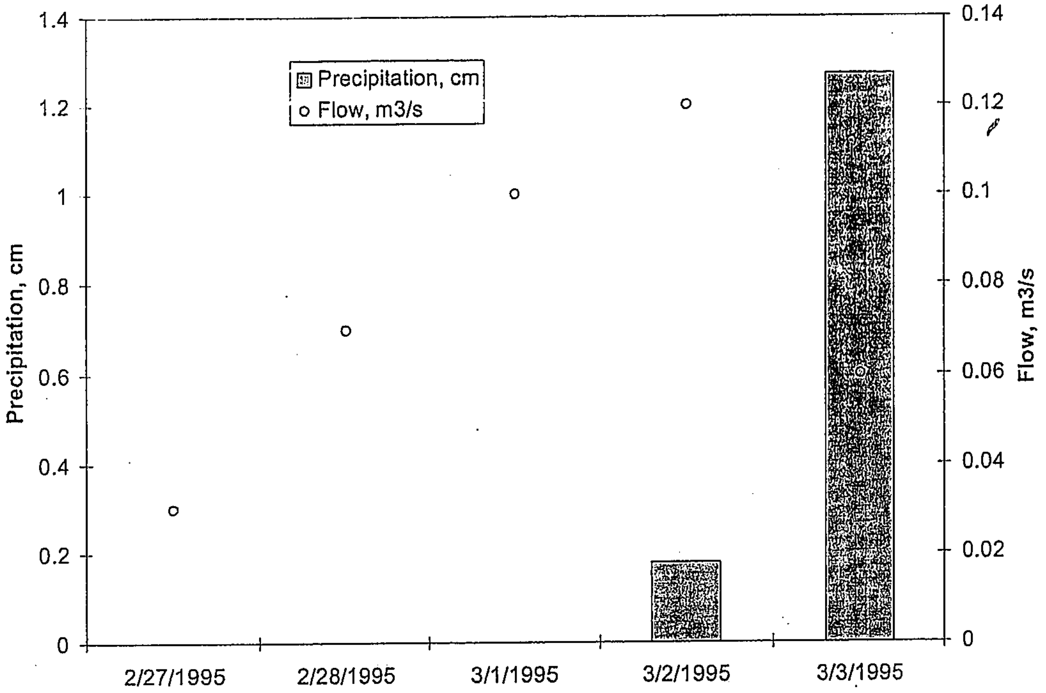


Figure 38: Precipitation and flow for Bouquet Canyon Creek, 2/27/1995-3/3/1995

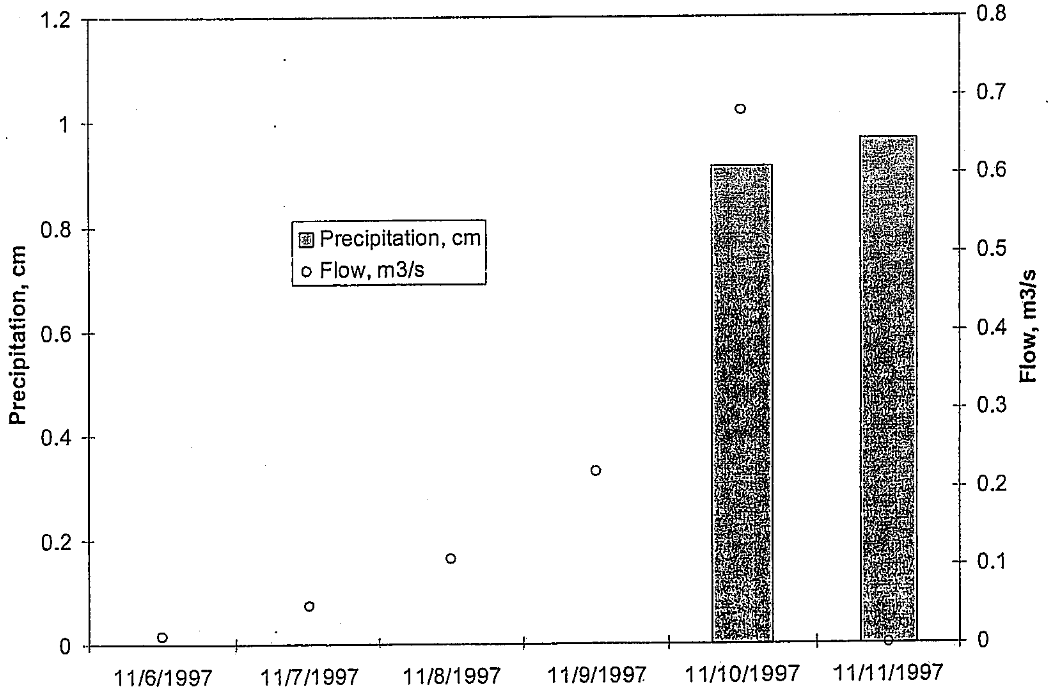


Figure 39: Precipitation and flow for Bouquet Canyon Creek, 11/6/1997-11/10/1997

Simulation Results

For the eastern tributaries, there are two gaging stations: Mint Canyon Creek at Fitch Avenue and Bouquet Canyon Creek at Urbandale (Figure 40).

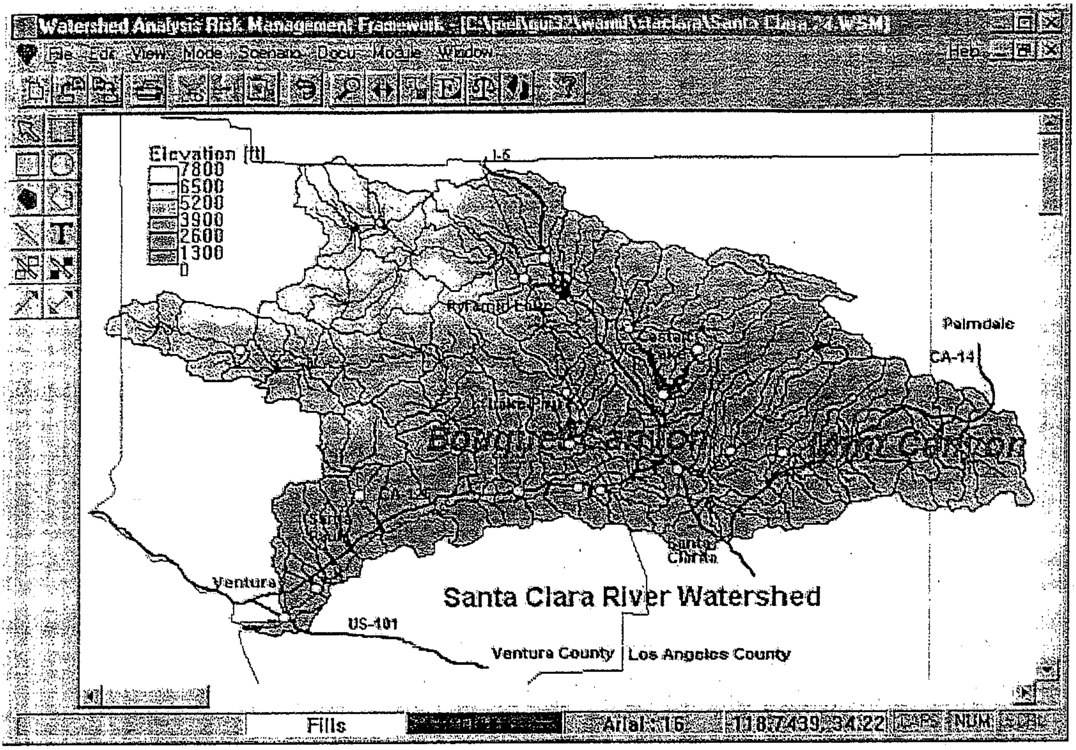


Figure 40: Stream gages in the eastern tributaries of the Santa Clara River

Simulation results (blue) and observed data (black circles) are compared in Figure 41 through Figure 44. For each creek, the first figure shows the full hydrograph and the second shows the same results but only the 0-2 m^3/s range.

WARMF has simulated typical patterns of storm peaks, rapid recessions, and low/zero flows commonly observed in those creeks. For Mint Canyon Creek, the gaging station was not in operation for the model predicted very high flow for January 1992. Simulated results do not match the observed storm peak in January of 1990.

For Bouquet Canyon Creek, the model missed the storm flow for January 1990 and spring of 2000. It predicted a high flow for February 1992, which was not recorded by the gaging station. The model matched well the two highest flow peaks of the simulation period.

The frequency distribution plots of simulated and observed flows are shown in Figure 45 and Figure 46 for Mint Canyon Creek and Bouquet Creek respectively. For Mint Canyon Creek, the curves match well for high flow above 0.03 cms. The model over predicted the number of days for low flow (0.001 cms) by 15%. For Bouquet Creek, the curves match well for high flow above 0.1 cms. The model under predicted the number of days for low flow (0.001 cms) by 12%. This is probably caused by the more even distribution of large storms and uneven distribution of small storms as explained earlier in this report.

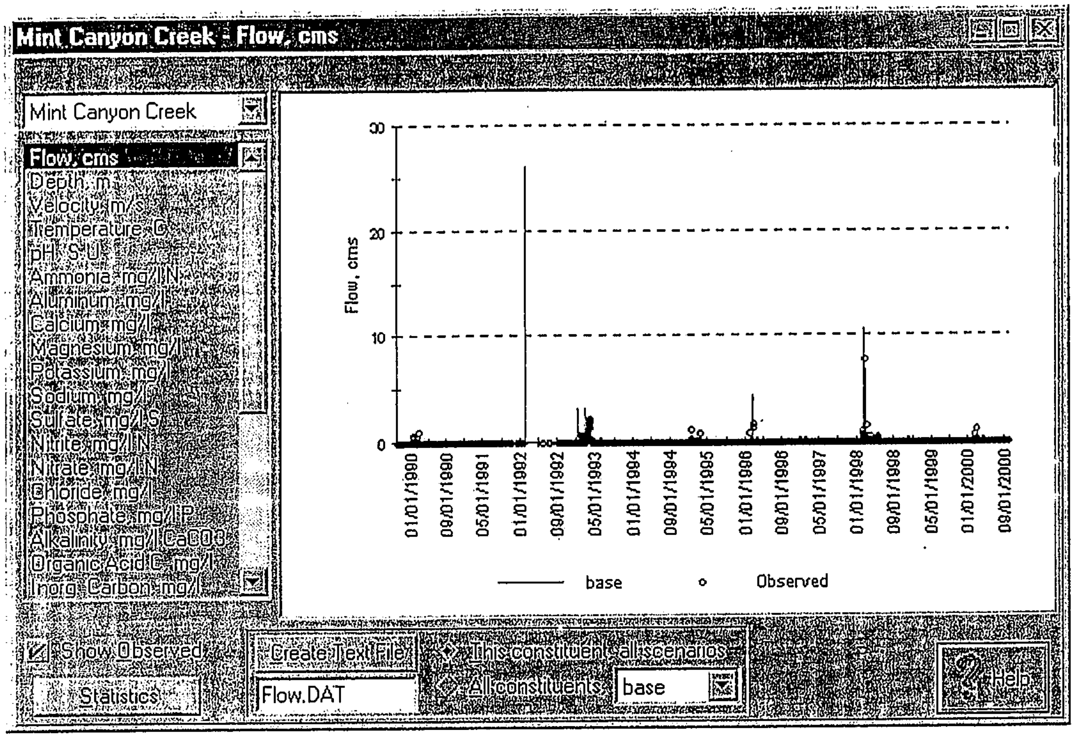
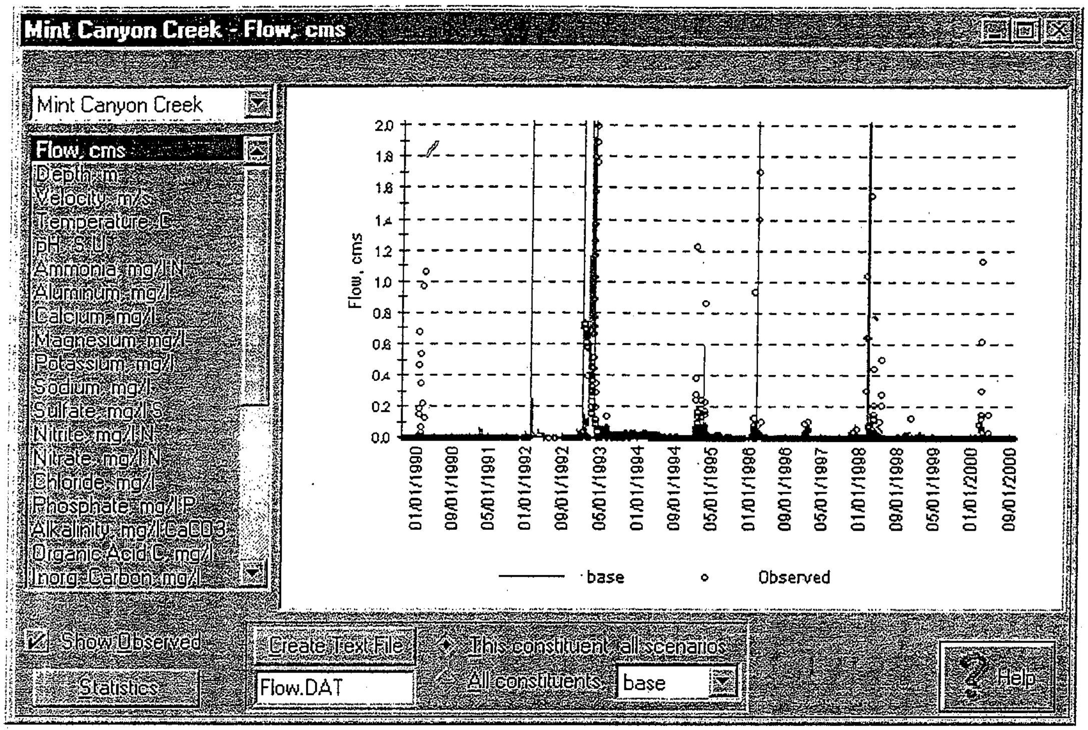


Figure 41: Simulated and Observed Flow for Mint Canyon Creek at Fitch Avenue (n = 3732; r = 0.84; relative error = -10.6%)



Mint Canyon Creek - Flow, cms

Mint Canyon Creek

Flow, cms

☑ Show Observed

Flow.DAT

● This constituent, all scenarios

○ All constituents base

Figure 42: Simulated and Observed Flow: 0-2 m^3/s for Mint Canyon Creek at Fitch Avenue (n = 3729; r = 0.61; relative error = -16.1%)

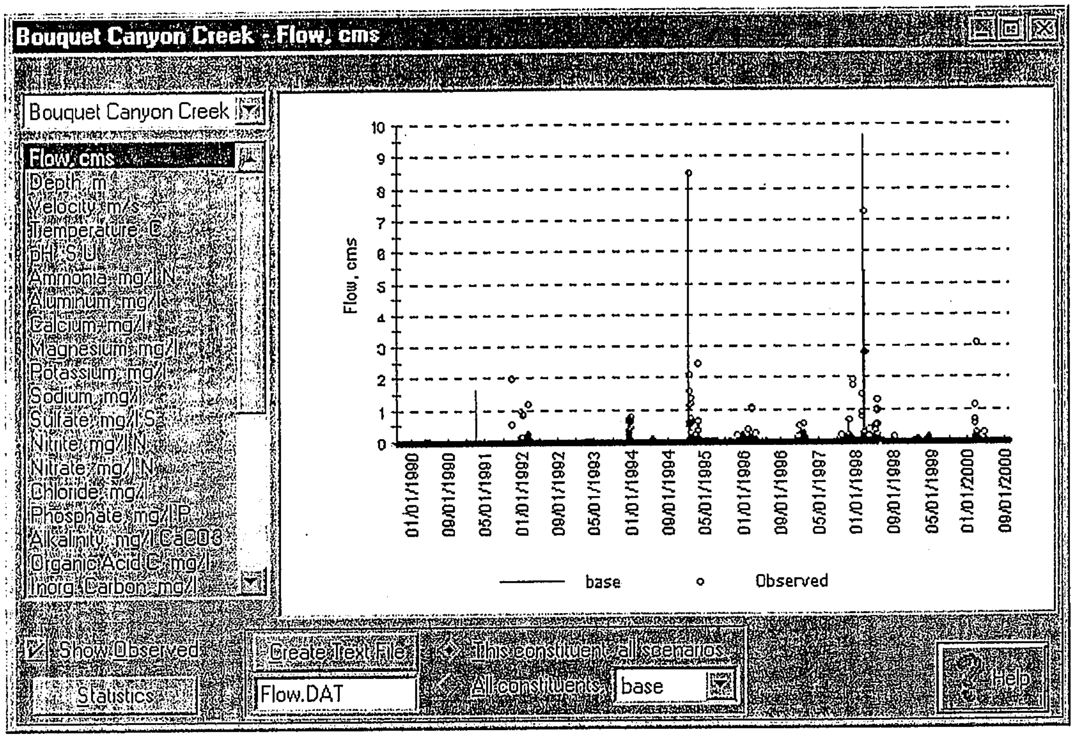


Figure 43: Simulated and Observed Flow for Bouquet Canyon Creek at Urbandale
(n = 4018; r = 0.80; relative error = -3.6%)

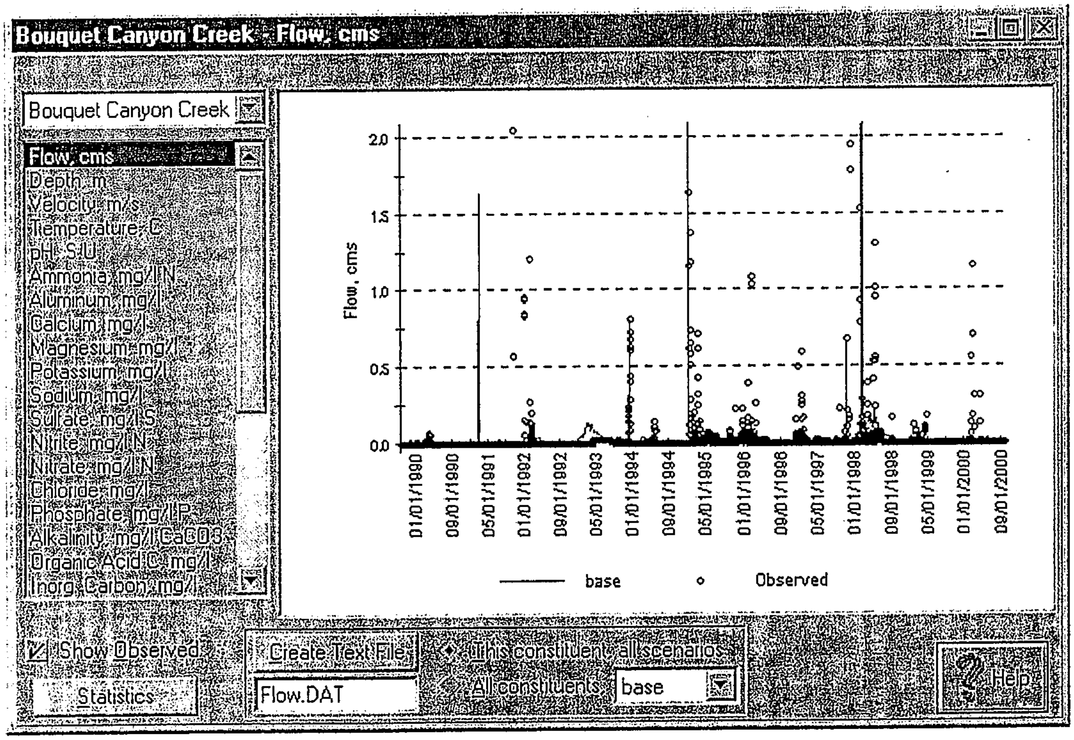


Figure 44: Simulated and Observed Flow: 0-2 m^3/s for Bouquet Canyon Creek at Urbandale
(n = 4010; r = 0.30; relative error = +9.3%)

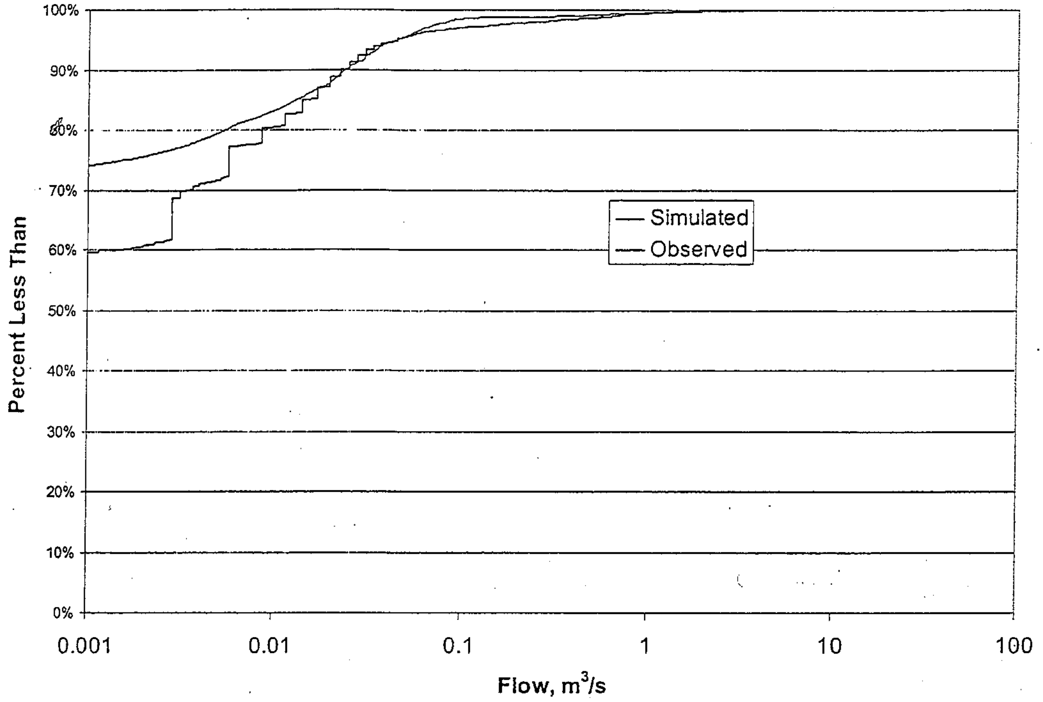


Figure 45: Frequency distribution of flow for Mint Canyon Creek at Fitch Avenue

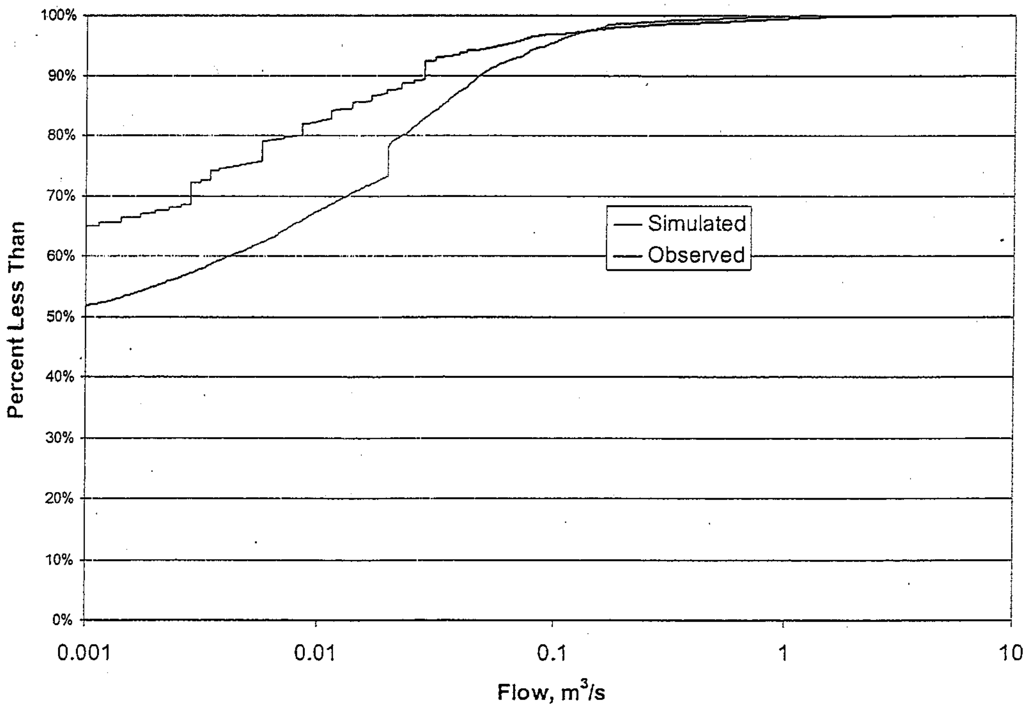


Figure 46: Frequency distribution of flow for Bouquet Canyon Creek at Urbandale

Water Quality

There is no available water quality monitoring data for Mint Canyon Creek. The only data available for Bouquet Canyon Creek is after the simulation period used in this project. Some water quality data has been collected from the Santa Clara River, mostly between February and June when there is flow. Any data collected at very low flow may be difficult for the model to match because the source of such flow could be very localized so that it is not simulated by WARMF.

Key Assumptions

Atmospheric deposition is a major source of nitrogen to the land surface in this part of the watershed. Nutrient uptake by scrubland vegetation is the major sink of nutrients. The difference is accumulated in the soil and concentrated by evaporation. High concentrations of nutrients can result due to the low volume of water to flush the nutrients out to the stream segments.

Simulation Results

During the simulation period, there is only monitoring data from the Santa Clara River at the locations highlighted in Figure 47.

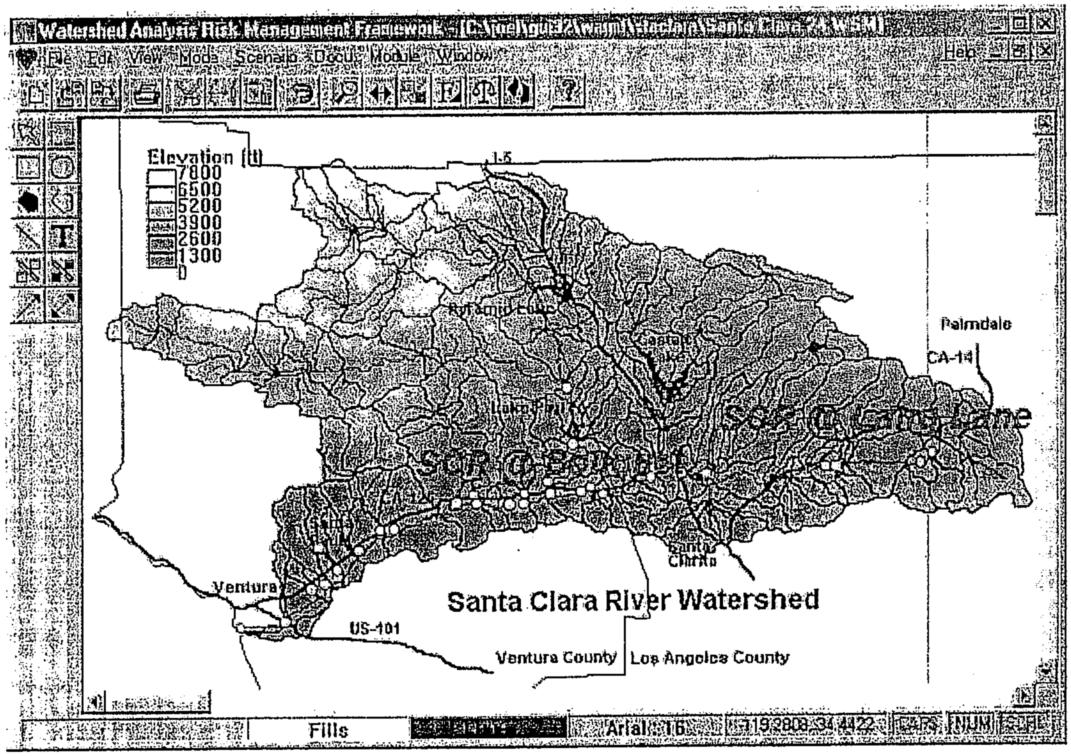


Figure 47: Water quality monitoring stations for the eastern tributaries of the Santa Clara River

Figure 50 compares the simulated and observed water temperature for the Santa Clara Creek at Bouquet Canyon Creek confluence. The model simulates a well behaved seasonal variation of water temperatures, from approximately 5 degrees Celsius in the winter to 30 degrees Celsius in the summer. The observed data indicates that the water was heated up quicker in the spring than predicted. This is a timing issue, because the ranges of simulated and observed temperatures are the same.

Ammonia results at Bouquet Canyon show that the model matches the low values of the observed data. The remaining measured value of 6.7 mg/l in May 1999 may be anomalous, or it may be part of a pattern which more monitoring would reveal. Model simulations and observed data both show low nitrate concentrations in early spring. The May 1999 data from the Santa Clara River at Lang Lane and at Bouquet Canyon show low nitrate, while simulated results show increasing nitrate. This could be caused by a model underestimate of late spring flow, but without gaging data in the area that is difficult to confirm.

The model predicts a rising trend of nitrate when the river flow is diminishing. Refer to the Sensitivity Analysis section of this document for a discussion of the impact of septic systems in this part of the watershed. Red circles have been added to some plots to make observed data more visible.

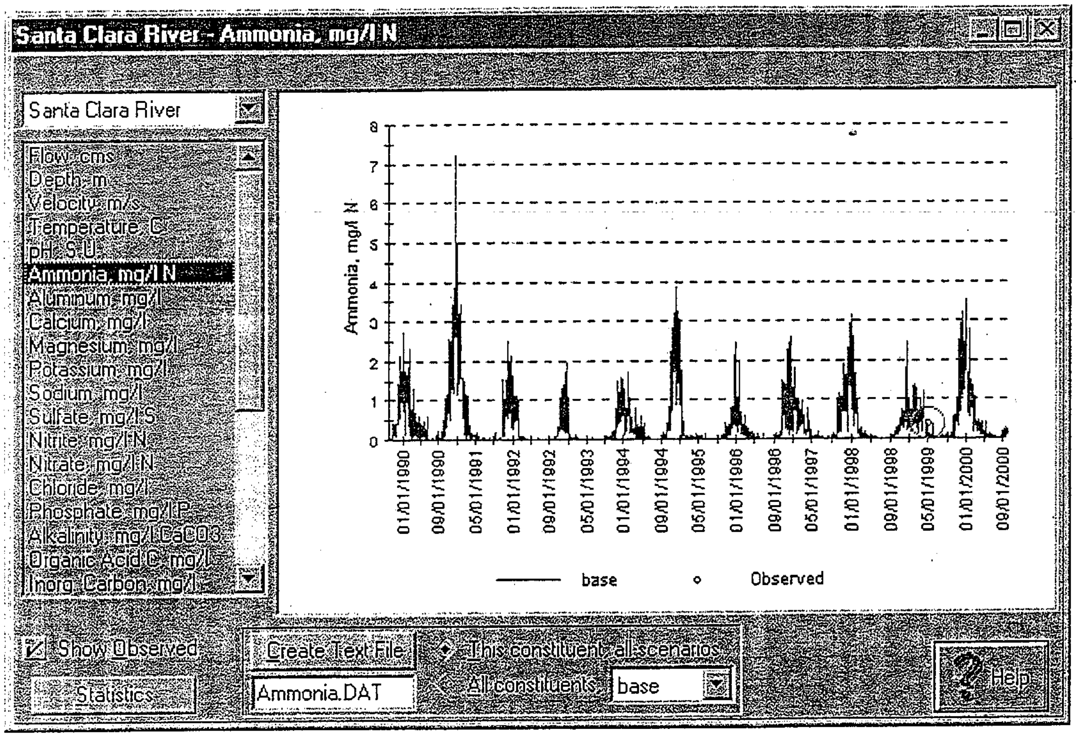


Figure 48: Simulated and Observed Ammonia for the Santa Clara River at Lang Lane (n = 1; relative error = -0.19 mg/l; absolute error = 0.19 mg/l)

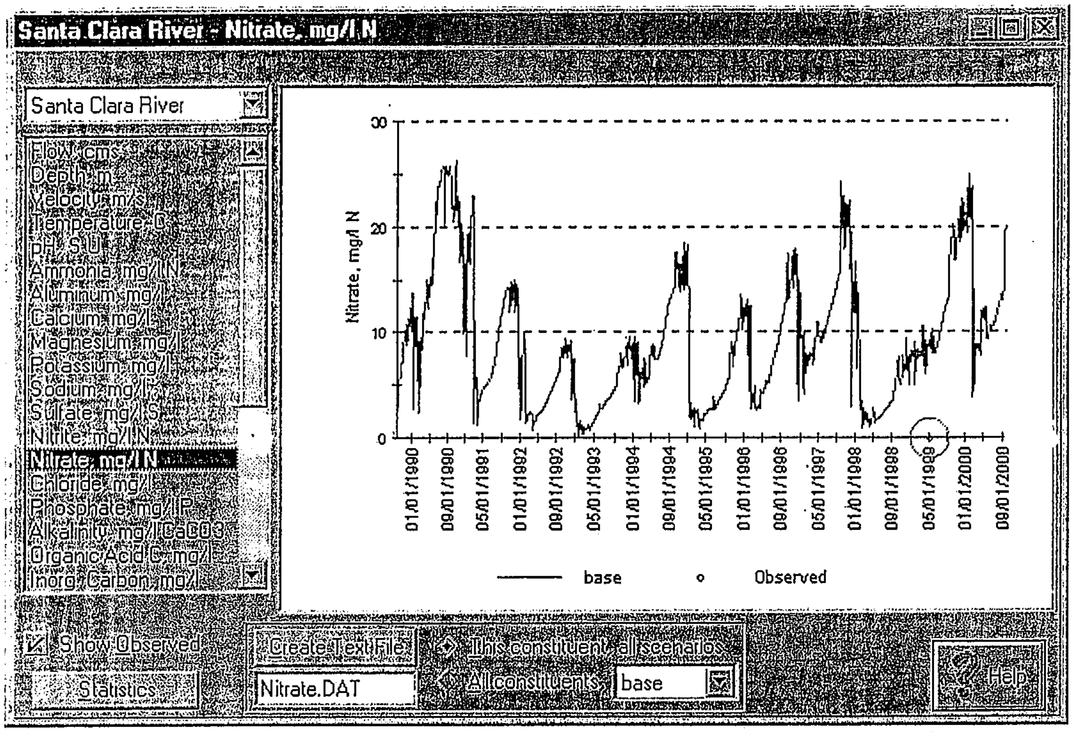


Figure 49: Simulated and Observed Nitrate for the Santa Clara River at Lang Lane (n = 1; relative error = 9.00 mg/l; absolute error = 9.00 mg/l)

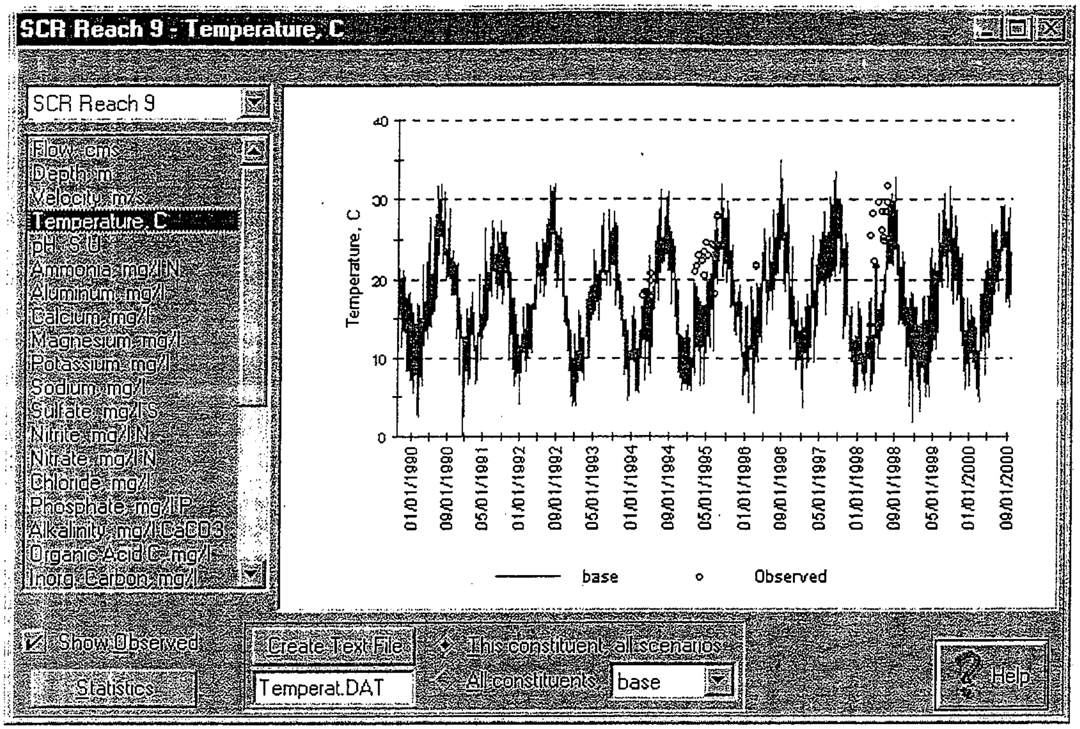


Figure 50: Simulated and Observed Temperature for the Santa Clara River at Bouquet Canyon (n = 36; relative error = -7.1 °C; absolute error = 7.3 °C)

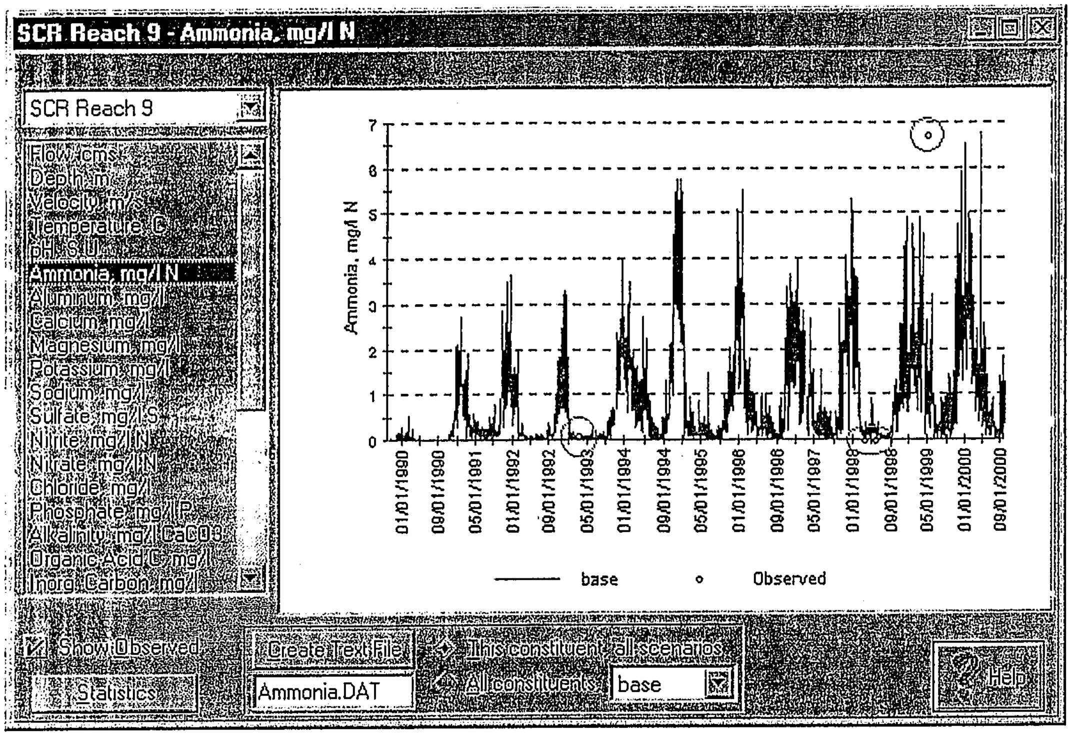


Figure 51: Simulated and Observed Ammonia for the Santa Clara River at Bouquet Canyon (n = 4; relative error = -1.20 mg/l; absolute error = 1.32 mg/l)

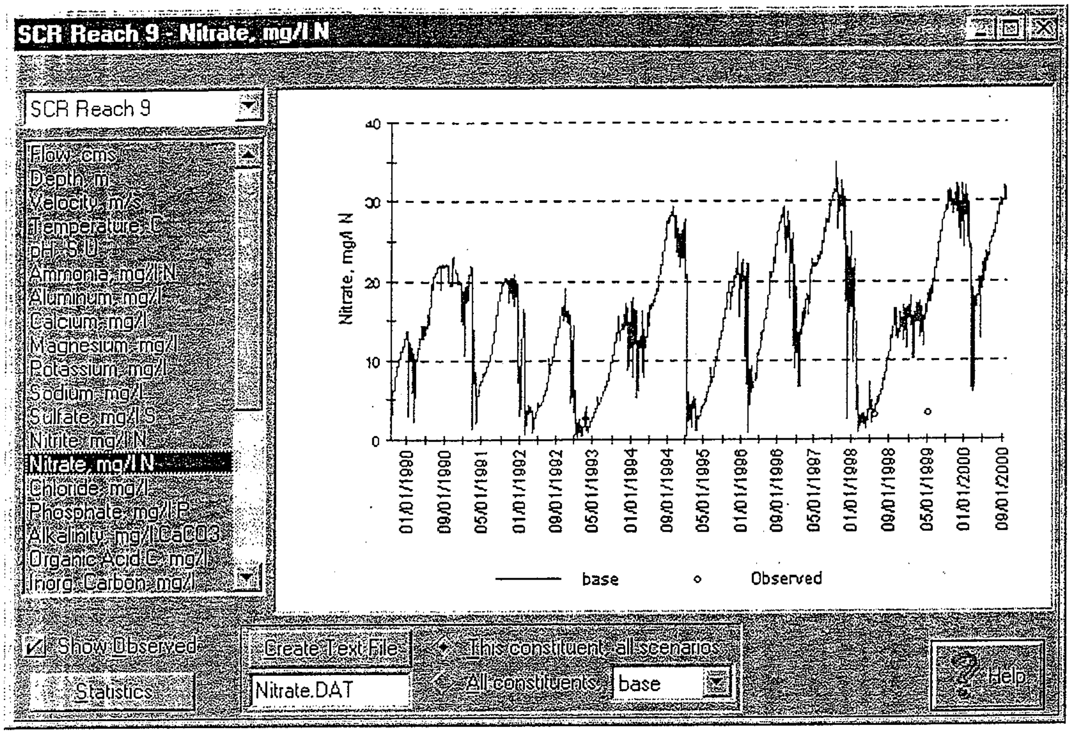


Figure 52: Simulated and Observed Nitrate for the Santa Clara River at Bouquet Canyon (n = 3; relative error = 4.62 mg/l; absolute error = 4.62 mg/l)

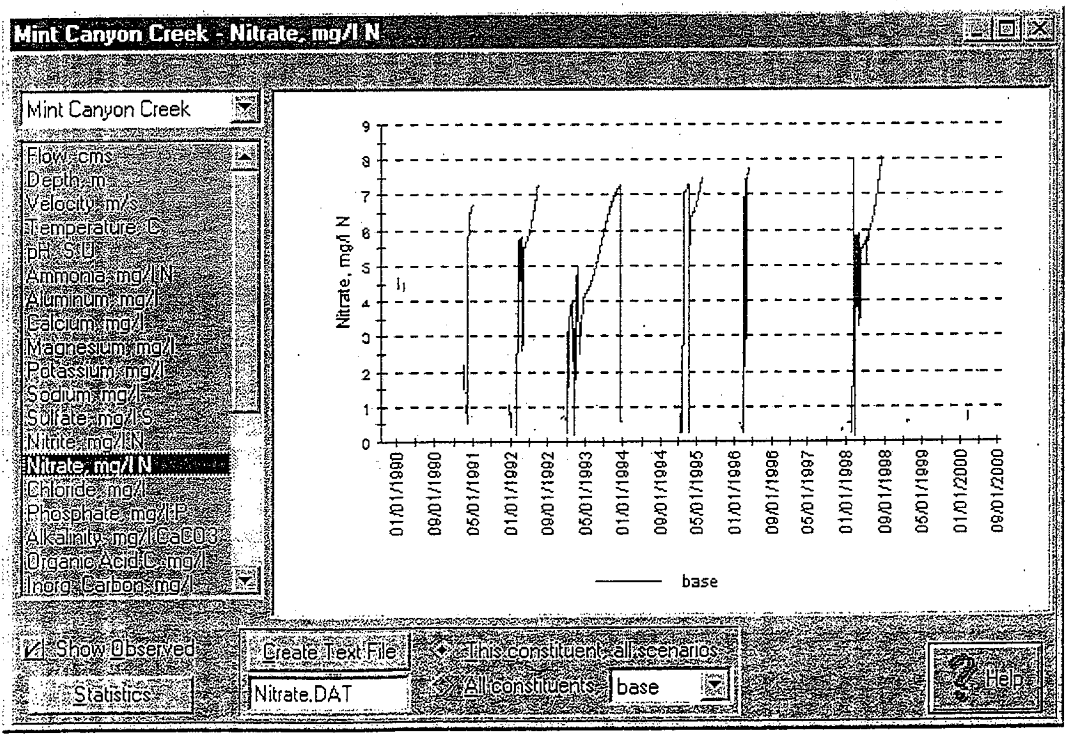


Figure 53: Simulated Nitrate for Mint Canyon Creek

Santa Clara River Reach 8: Bouquet Canyon to Old Road Bridge

This reach of the Santa Clara River (Figure 2) is in the rapidly growing Santa Clarita area. The hydrology and water quality of this reach is dictated not by precipitation, but rather by wastewater reclamation facilities and dewatering projects. These sources are augmented during spring by natural flow from the eastern tributaries and upstream reaches of the Santa Clara River. Modeling of this section of river is largely a matter of doing proper mass balance accounting of flow and water quality.

Hydrology

The hydrology of this section of the river is dominated by the discharge from the Saugus Wastewater Reclamation Facility (WWRF), whose outfall is located just downstream of the confluence of Bouquet Canyon Creek with the Santa Clara River. Another significant source is gain from groundwater in the Round Mountain area just upstream of the Old Road Bridge gage. Flow from the eastern tributaries of the Santa Clara River and the river itself upstream of Bouquet Canyon contributes a small portion of overall flow. The combined gaged flow from Mint Canyon Creek and Bouquet Canyon Creek is approximately 5% of the flow at the Old Road Bridge gage on an annual basis. About 58% of the flow from Mint Canyon and Bouquet Canyon Creeks occurs in February. The water from these sources is sometimes mixed with dewatering operations from local construction projects.

In Mint Canyon Creek and Bouquet Canyon Creek, temporary dewatering projects were identified by finding irregularities in the gaged hydrograph. The irregularities were clear because there was typically zero flow and suddenly increased without any storms. It is not possible to use the same technique to estimate dewatering flows in Reach 8 because flow is perennial and can potentially have many sources. However, there are records for certain dewatering projects beginning in December of 1998.

There are unexplained increases in gaged flow during dry weather: 8/10/1990 to 8/18/1990, 9/19/1990 to 2/26/1991, and 7/30/1991 to 11/27/1991. Some of these flows might be attributable to dewatering operations, but there is too much uncertainty in estimating their location and flow. Therefore, only the dewatering operations with reported flows were entered into WARMF.

Key Assumptions

Hydrology of this reach is modeled by flow balance. The data used includes discharge of the Saugus WWRF, two smaller point sources(H.R. Textron and Magic Mountain), and the gaged flows of Mint Canyon and Bouquet Canyon Creeks. There are also flow records from 20 known dewatering operations in operation at various times from December 1998 through the end of the simulation period. A groundwater model (CH2M Hill 2002) provides flow estimates from groundwater to the river in the Round Mountain area. The groundwater flow estimates were included in the watershed model as prescribed flows.

To estimate losses in this reach, the sum of all known inflows was subtracted from gaged flow at the Old Road Bridge. When the result was negative, that indicated a loss of flow by percolation into the river bed. Figure 54 presents the estimated water losses across the river bed for the river section extending from Saugus WWRF to the Old Road Bridge. Seasonal average loss was used for 10/1992-9/1996, when there is no data from the Old Road Bridge gage.

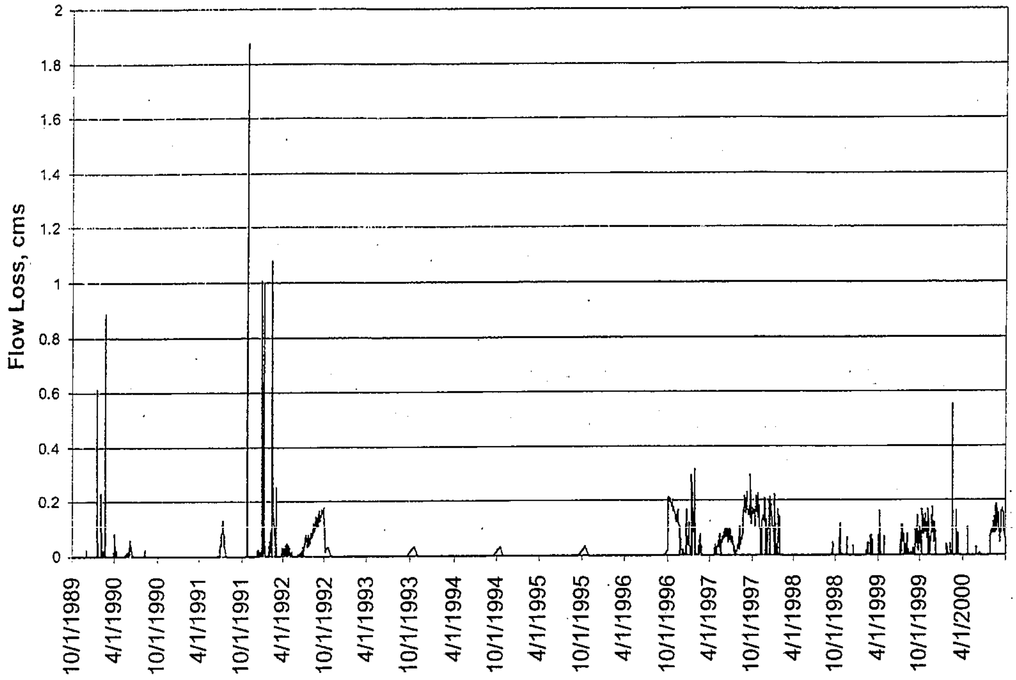


Figure 54: Estimated Flow Loss, Saugus WWRF to Old Road Bridge

Table 9 presents average monthly flow balances for water year 1991, a dry year. Table 10 shows the same flow balance for 1998, a wet year. The known dewatering projects are not shown because they were not in operation during water years 1991 and 1998. Each known source of flow is tabulated. There are no diversions in this reach of the river, so there are no known outputs.

The difference between net known flow and gaged flow is the net gain to the river or loss from the river. Note that since there is no gage on the Santa Clara River at the upstream end of Reach 8, the flows from upstream reaches of the Santa Clara River (9 and 10) are implicitly included within the net gains and losses. Net gains to the river are simulated as natural lateral flow and surface runoff in WARMF. Net losses are simulated with artificial diversions from the river reach at a constant rate per river mile. Losses are calculated on a daily basis for use in simulations.

Table 9: Flow Balance for Santa Clara River Reach 8, m^3/s, Water Year 1991

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Mean
Mint Canyon Creek	0	0	0	0	0	0	0	0	0	0	0	0	0
Bouquet Canyon Creek	0	0	0	0	0	0	0	0	0	0.004	0	0	0
Saugus WWRF	0.227	0.242	0.236	0.228	0.215	0.221	0.210	0.226	0.246	0.261	0.242	0.231	0.232
H.R. Textron, Inc.	0	0	0	0	0	0	0	0	0	0	0	0	0
Magic Mountain	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
Prescribed Groundwater Gains	0.046	0.071	0.039	0.076	0.048	0.189	0.077	0.034	0.00.0	0.000	0.000	0.000	0.049
TOTAL KNOWN INPUTS	0.277	0.318	0.279	0.309	0.268	0.415	0.292	0.265	0.250	0.269	0.247	0.236	0.285
TOTAL KNOWN OUTPUTS	0	0	0	0	0	0	0	0	0	0	0	0	0
NET KNOWN FLOW	0.277	0.318	0.279	0.309	0.268	0.415	0.292	0.265	0.250	0.269	0.247	0.236	0.285
GAGED FLOW	0.300	0.322	0.354	0.363	0.340	0.378	0.355	0.305	0.286	0.213	0.477	0.468	0.347
NET GAIN (+) / LOSS (-)	0.023	0.004	0.075	0.055	0.072	-0.04	0.062	0.040	0.036	-0.06	0.230	0.232	0.061

Table 10: Flow Balance for Santa Clara River Reach 8, m^3/s, Water Year 1998

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Mean
Mint Canyon Creek	0	0.003	0.004	0.002	0.439	0.046	0.005	0.039	0	0	0	0.001	0.045
Bouquet Canyon Creek	0.009	0.047	0.122	0.004	0.630	0.035	0.009	0.212	0.046	0.000	0.000	0.008	0.093
Saugus WWRF	0.240	0.299	0.380	0.250	1.344	0.332	0.257	0.535	0.325	0.196	0.184	0.226	0.381
H.R. Textron, Inc.	0	0	0	0	0	0	0	0	0	0	0	0	0
Magic Mountain	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
Prescribed Groundwater Gains	0.037	0.071	0.064	0.272	2.917	1.450	0.277	0.835	0.367	0.101	0.156	0.063	0.551
TOTAL KNOWN INPUTS	0.291	0.425	0.575	0.533	5.334	1.868	0.553	1.626	0.743	0.302	0.345	0.303	1.075
TOTAL KNOWN OUTPUTS	0	0	0	0	0	0	0	0	0	0	0	0	0
NET KNOWN FLOW	0.291	0.425	0.575	0.533	5.334	1.868	0.553	1.626	0.743	0.302	0.345	0.303	1.075
GAGED FLOW	0.075	0.308	1.069	0.501	17.53	1.906	1.575	2.630	0.663	0.300	0.251	0.355	2.263
NET GAIN (+) / LOSS (-)	-0.22	-0.12	0.494	-0.03	12.19	0.039	1.023	1.004	-0.08	-0.00	-0.09	0.052	1.189

Simulation Results

Model predictions are compared with observed data in Figure 55 and Figure 56 for the Santa Clara River at the Old Road Bridge. Figure 56 shows the same results as Figure 55, but only the flow range from 0 to 2 m^3/s.

The frequency distribution plot (Figure 57) shows similarity between the magnitude of flows represented in simulations as compared to observed data, with a small overprediction of flow in general. Some of the unexplained flow increases discussed above are evident in Figure 56, particularly 7/30/1991-11/27/1991.

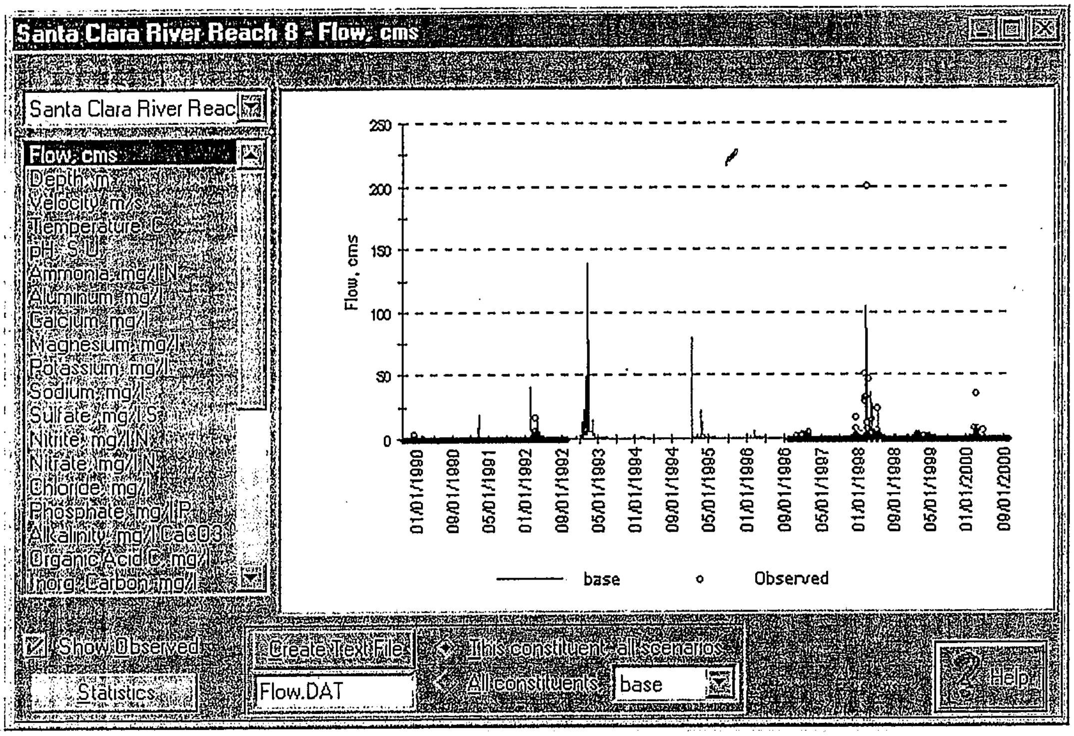


Figure 55: Simulated and Observed Flow, Santa Clara River at Old Road Bridge (n = 2557; r = 0.71; relative error = +16.2%)

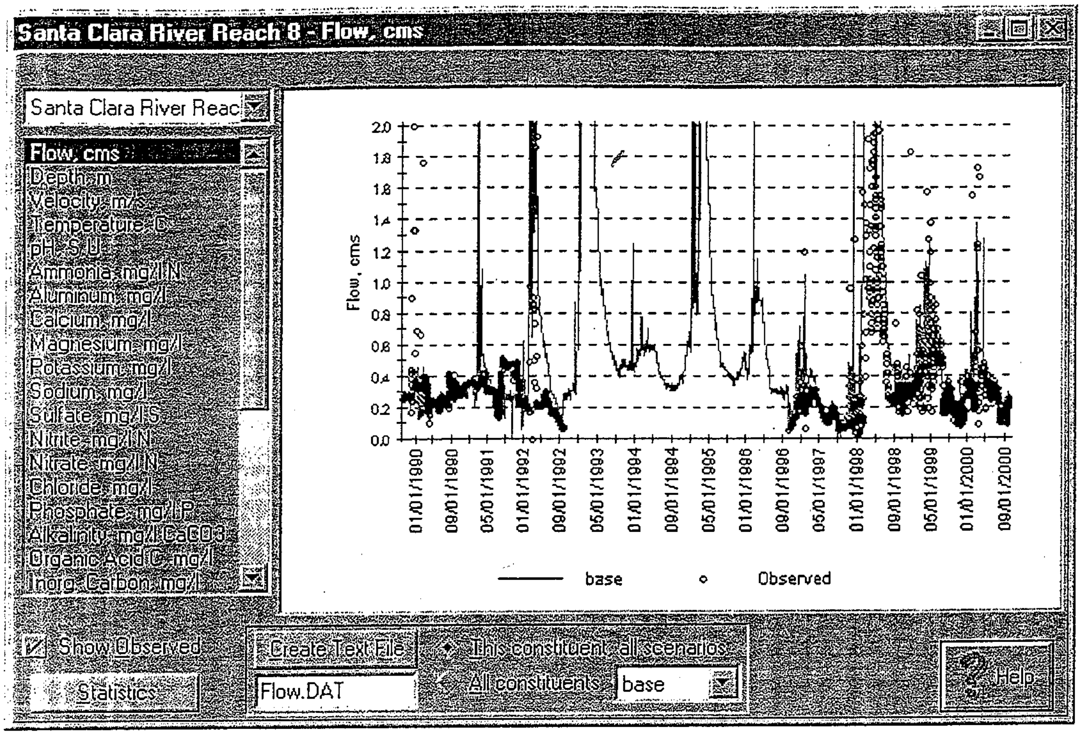


Figure 56: Simulated and Observed Flow: 0-2 m^3/s, Santa Clara River at Old Road Bridge (n = 2480; r = 0.42; relative error = +67.5%)

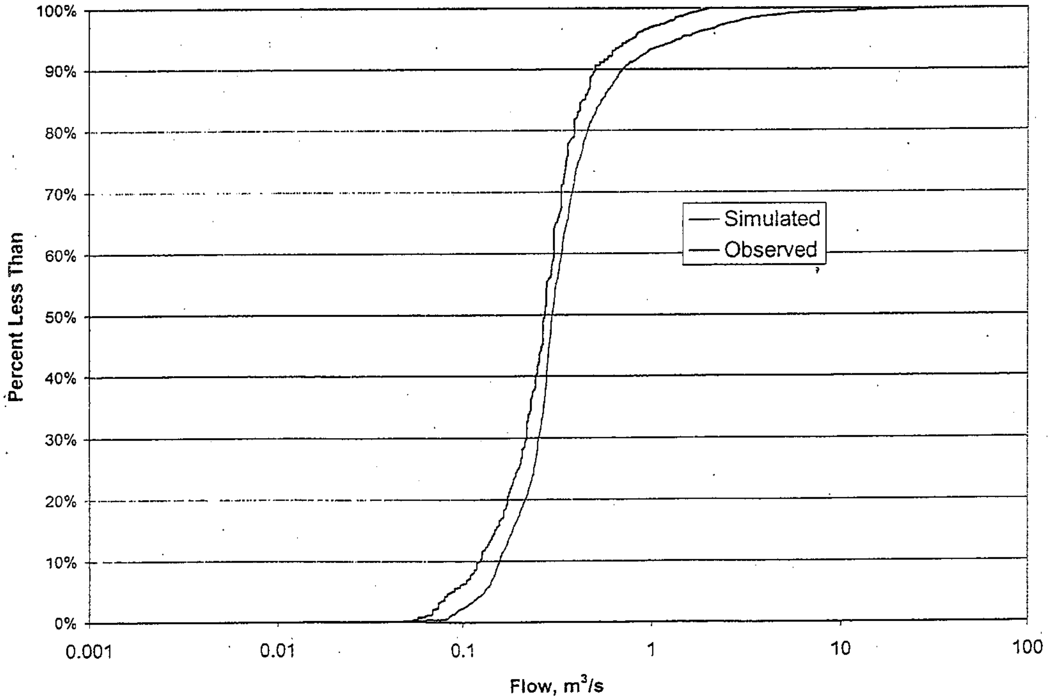


Figure 57: Frequency distribution of flow for Santa Clara River at Old Road Bridge

Water Quality

The Source Analysis Report (Systech 2002) indicates that most of the nutrient loading to Reach 8 of the Santa Clara River comes from direct point source discharges, primarily the Saugus WWRF. Table 9 and Table 10 show that, for most of the year, the effluent from the same treatment plant represents most of the flow in the river. The differences between measured effluent water quality and monitoring data are a result of other flow and loading sources and in-stream assimilation of nutrients.

Key Assumptions

Table 11 below shows a summary of loading from the Source Analysis Report (Systech 2002). Ammonia, nitrite, and nitrate are added together into total nitrogen loading. "Total Direct Loading" represents loading which enters the river directly. "Total Land Surface Loading" is loading applied to the land surface, a small portion of which may transported to the river by runoff. "Total In stream Loading" is the amount of nitrogen actually in the river as calculated from gaged flow and water quality monitoring data.

Table 11: Loading balance of total nitrogen for Santa Clara River Reach 8, kg/d N

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Total Direct Loading	397	1022	715	513	552	407	342	356	374	384	399	430	491
Total Land Surface Loading	427	712	720	1771	1566	1518	1508	1499	1490	372	297	402	1024
Total In stream Loading	541	3482	1188	693	896	434	327	288	283	177	330	505	761

The in-stream loading of total nitrogen is lower than total direct loading from July through November. This indicates that some in-stream processes are removing nitrogen from the river water. Nitrification converts ammonia to nitrate, so it cannot cause a decrease in total nitrogen. There are a few possibilities to explain the loss of nitrogen: losses of flow through the river bed, uptake by periphyton or macrophytes, adsorption by the river bed, and denitrification. Denitrification converts nitrate to nitrogen gas under anoxic conditions. It can occur in the river bed, despite the aerobic condition of the water column. A compilation of collected data indicates that the denitrification rate varies from 0.1/day to 1.6/day in a river not more than 0.5 meters deep (Hirsch 2001).

Simulation Results

The model was used to test the different potential mechanisms for nutrient removal from within Reach 8 of the Santa Clara River. Known flow losses are already simulated, but not frequent enough and large enough to account for the nitrogen loss. Periphyton requires a suitable substrate on which to grow. Suitable habitat includes gravel and bedrocks, so the sandy conditions of the river bed may not be ideal. Assuming that periphyton can grow, model simulations indicate that a reasonable productivity of periphyton can not account for the nitrogen assimilation. The sandy river bed may adsorb ammonia and phosphorus, but not nitrate. The phosphorus data (Figure 74) does not show assimilation in this river reach.

The remaining mechanism for nitrogen removal is denitrification in the river bed. The denitrification rate used was 0.5/day. Refer to the Sensitivity Analysis section of this document for an analysis of the effect of denitrification and of periphyton.

Simulated results show good matches to the observed monitoring data at the Old Road Bridge, as shown in Figure 58 through Figure 61. Red circles have been added to some figures to make some observed data points more visible, not to add emphasis.

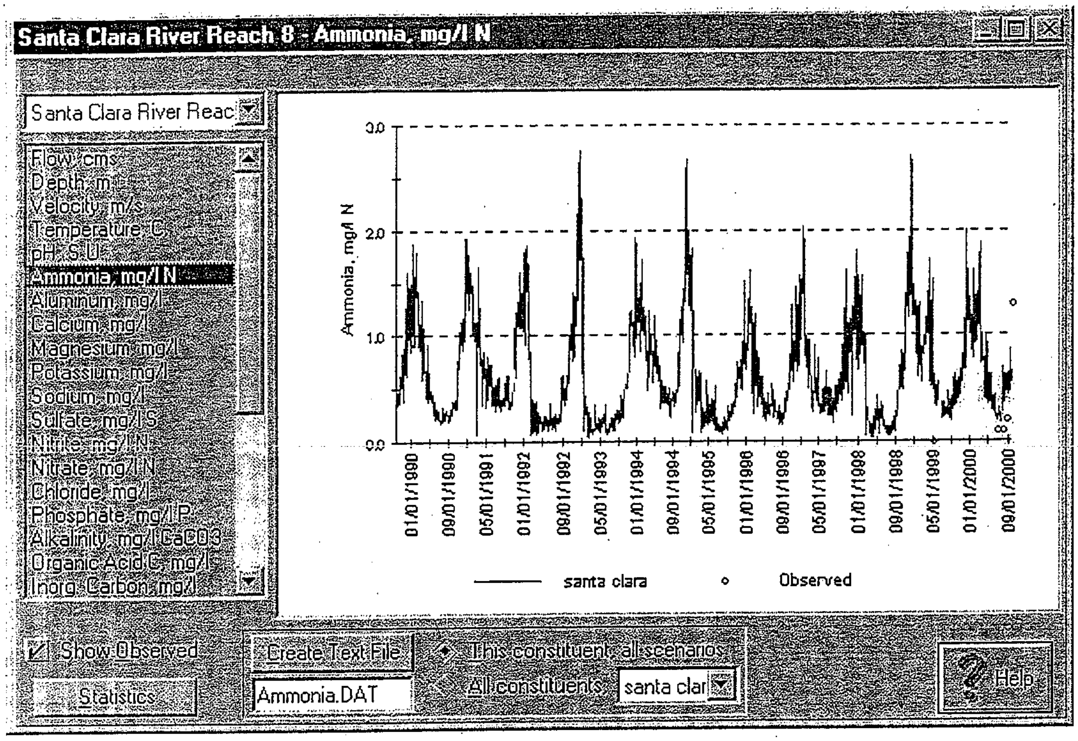


Figure 58: Simulated and Observed Ammonia for the Santa Clara River at Old Road Bridge (n = 5; relative error = 0.11 mg/l; absolute error = 0.37 mg/l)

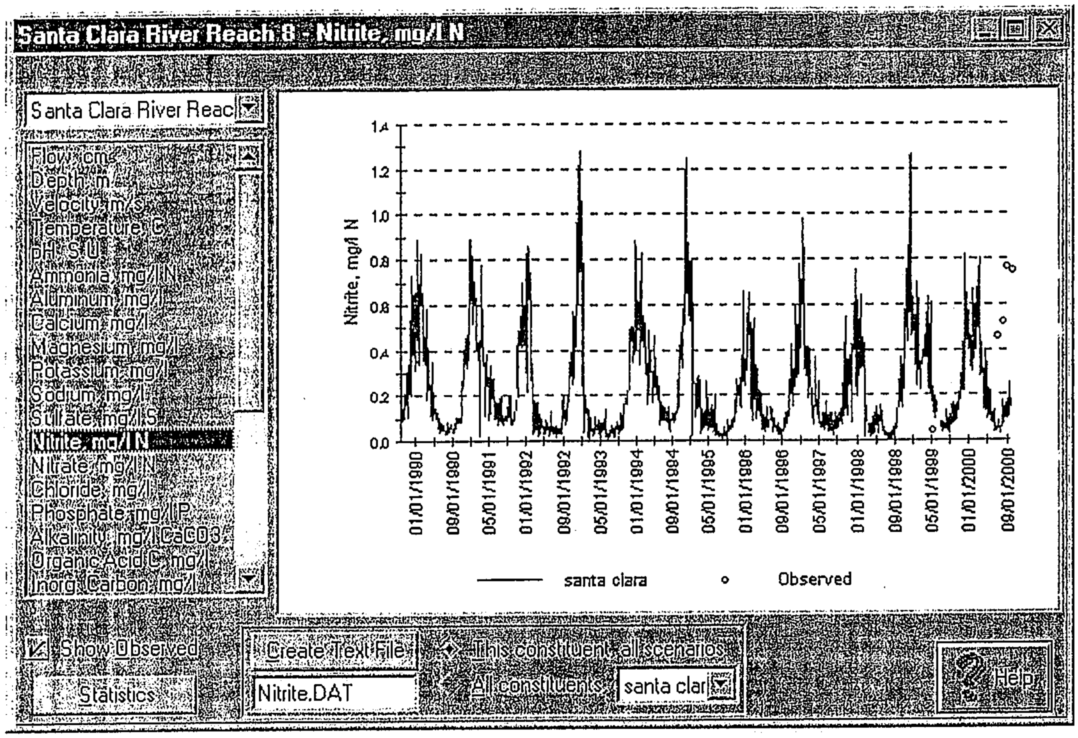


Figure 59: Simulated and Observed Nitrite for the Santa Clara River at Old Road Bridge (n = 5; relative error = -0.39 mg/l; absolute error = 0.43 mg/l)

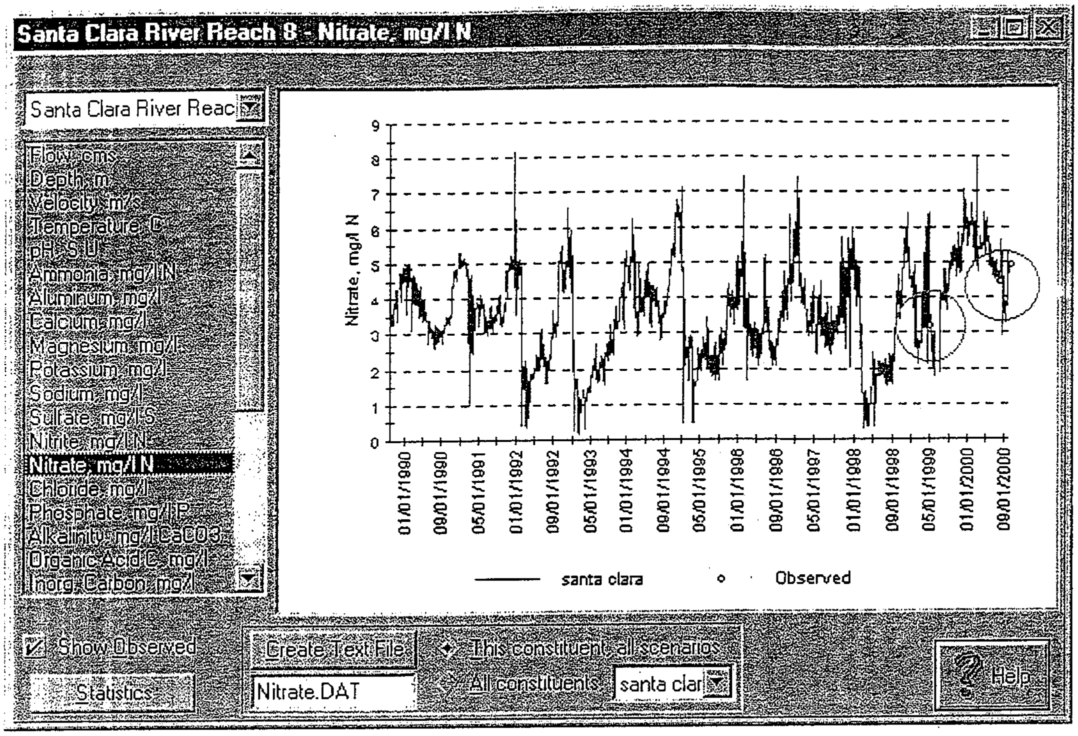


Figure 60: Simulated and Observed Nitrate for the Santa Clara River at Old Road Bridge (n = 5; relative error = -0.68 mg/l; absolute error = 0.74 mg/l)

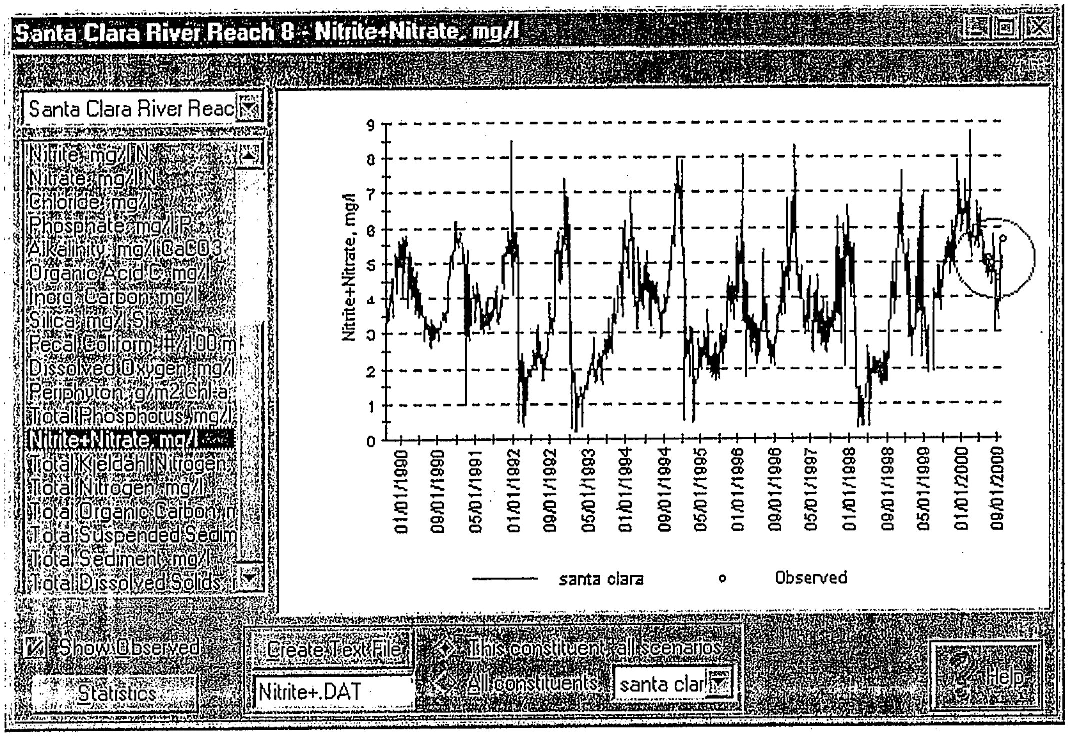


Figure 61: Simulated and Observed Nitrate+Nitrite for the Santa Clara River at Old Road Bridge (n = 4; relative error = -0.60 mg/l; absolute error = 0.60 mg/l)

Santa Clara River Reach 7: Old Road Bridge to Blue Cut

This reach of the Santa Clara River (shown in Figure 3) is between the City of Santa Clarita and the Blue Cut gage near the Los Angeles / Ventura county line. There are four main sources of water to this reach: the flow from Reach 8 of the Santa Clara river, the discharge from the Valencia WWRF, releases from Castaic Lake, and gains from groundwater throughout the reach.

Modeling of this section of river is largely a matter of accounting for flow and pollutants. In addition to the three main sources of water, there are unknown flow inputs from surface runoff and loss across the river bed.

Hydrology

During dry weather, hydrology in this reach is largely governed by discharges from wastewater reclamation facilities and release from Castaic Lake. During wet weather, however, there is significant local runoff. Peak flows at the Blue Cut gage are typically much higher than the peak flows at the Old Road Bridge gage.

Key Assumptions

Hydrology of this reach is modeled with a flow balance. The gage at the Old Road Bridge represents one major input of flow. There is one major point source for which there are daily flow records, the Valencia WWRF just downstream of the Old Road

Bridge. There is one very small point source in this reach, the Val Verde County Park Swimming Pool. Daily discharge from Castaic Lake is also known. A groundwater model predicts the gains from groundwater in the reach (CH2M Hill 2002). The estimated flows from the groundwater model were input to the watershed model as prescribed flows.

There are also two diversions: Rancho Camulos and Newhall Land (Isola). The Rancho Camulos flow was estimated from irrigated acreage and pumping records. Newhall Land provided flow for the Isola diversion.

The Blue Cut gage representing the downstream end of this reach was originally located at the Los Angeles / Ventura county line. On 10/1/1996, it was moved downstream to a location "near Piru". Before the gage moved, the diversions were downstream of the gage and thus not part of this reach. Figure 62 shows both the locations of the "Blue Cut" gage.

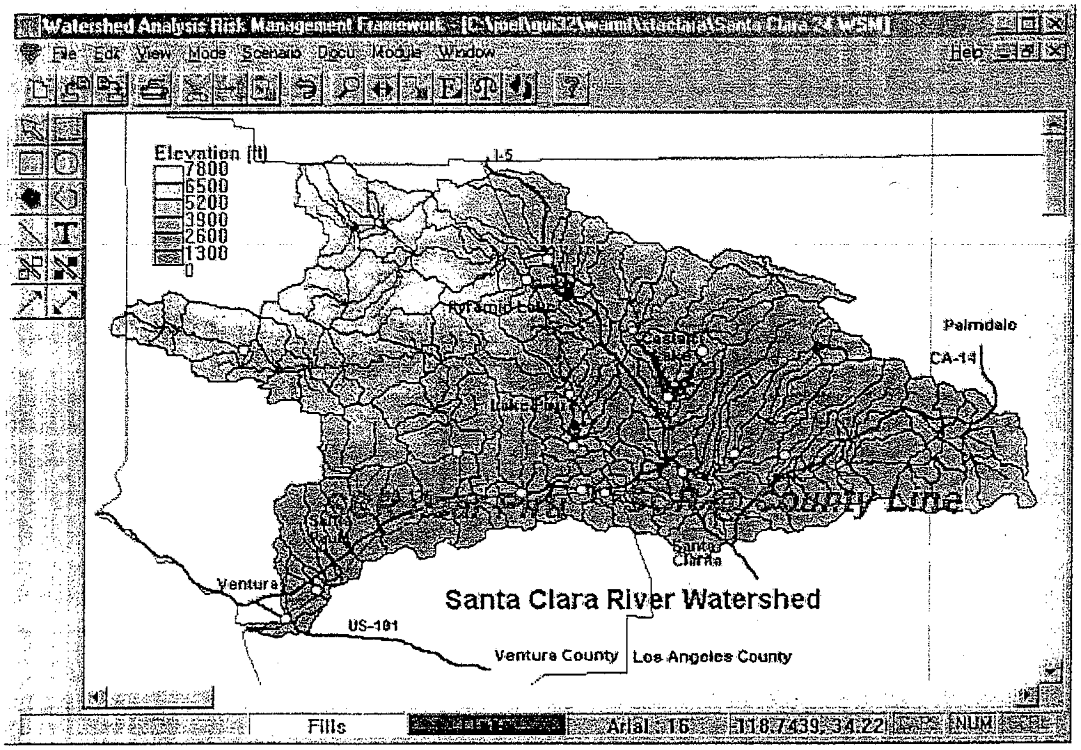


Figure 62: Stream gages for Santa Clara River Reach 7

Given the known inflow and outflow data, a water balance was conducted to determine when the river was gaining through groundwater accretion and when the river was losing by percolation through the river bed. Loss occurs in Castaic Creek when there is release from the Castaic Lake dam and in the Santa Clara River proper. Loss was infrequent in the Santa Clara River when Castaic Creek was not flowing. It was estimated that 50% of flow in Castaic Creek is lost when water is being released from Castaic Lake. This estimate kept the resulting loss from Santa Clara River in line with losses when Castaic Creek is not flowing. In the Santa Clara River Nutrient TMDL Steering Committee meeting of 8/19/2002, Murray McEachron of the United Water Conservation District concurred with the estimated water loss, and indicated that the first 20 ft^3/s was completely lost. Given that the first 20 ft^3/s of Castaic Lake release is lost, it was estimated that 35% of the remainder is lost so that the overall average loss is 50%.

Figure 63 shows the estimated loss of water from Castaic Creek and from the Santa Clara River in Reach 7. Monthly correlation equations were established relative to the Blue Cut gage was established to estimate losses from the Santa Clara River from 10/1992-9/1996, when there is no data from the Old Road Bridge gage with which to calculate daily losses.

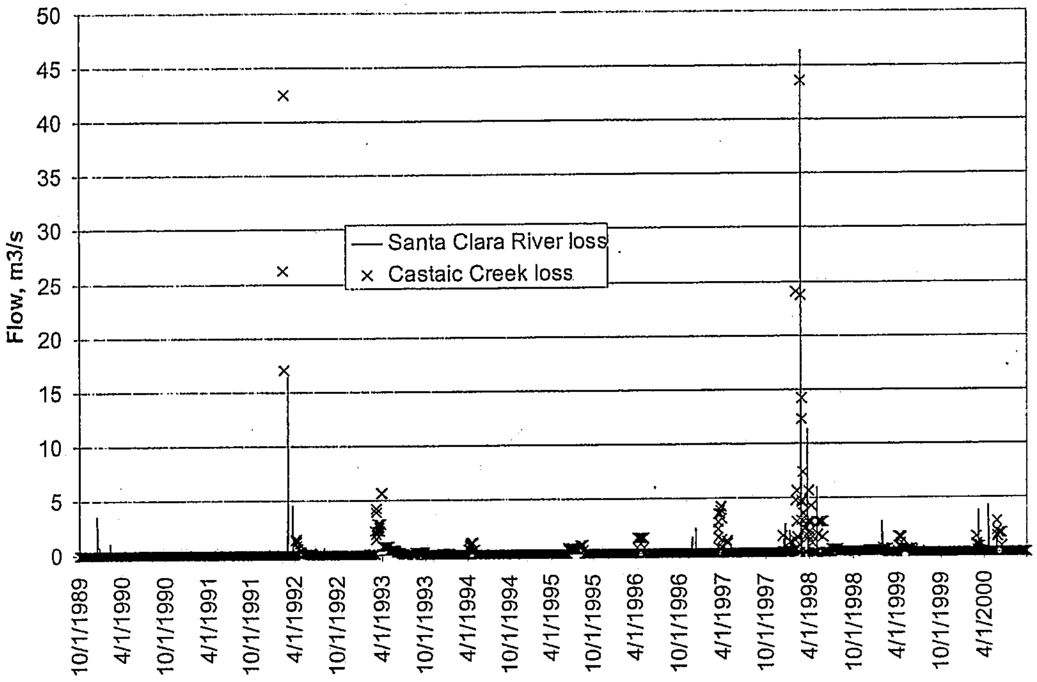


Figure 63: Estimated Flow Loss, Castaic Creek and Old Road Bridge to Blue Cut

Table 12 shows the monthly flow balances for water year 1991, which was a dry year. Table 13 shows the same balance for 1998,a wet year. The diversions are not shown in the 1991 table because at that time they were downstream of the Blue Cut gage.

The difference between net known flow and gaged flow is the net gain to the river or loss from the river. Gains to the river are input as prescribed flow at a constant rate per river mile. This water is pumped from the groundwater of the adjacent catchments. To prevent double accounting, the hydraulic conductivity of the groundwater soil layer in the adjacent land catchments was set to zero to prevent simulation of natural accretion to the river. Under such conditions, WARMF still simulates storm runoff from the land surface.

Losses are input to WARMF as prescribed diversions at a constant rate per river mile. Gains and losses are calculated on a daily basis for use in simulations.

Table 12: Flow Balance for Santa Clara River Reach 7, m^3/s, Water Year 1991

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Mean
Old Road Bridge gage	0.300	0.322	0.354	0.363	0.340	0.378	0.355	0.305	0.286	0.213	0.477	0.468	0.347
Valencia WWRF	0.322	0.313	0.313	0.329	0.338	0.324	0.298	0.308	0.307	0.298	0.318	0.337	0.317
Val Verde Community Park	0	0	0	0	0	0	0	0	0	0	0	0	0
Castaic Creek	0	0	0	0	0	0	0	0	0	0	0	0	0
Prescribed Groundwater Gains	0.171	0.266	0.146	0.285	0.179	0.708	0.289	0.128	0	0	0	0	0.181
TOTAL KNOWN INPUTS	0.793	0.901	0.814	0.977	0.857	1.409	0.942	0.740	0.593	0.511	0.795	0.806	0.845
TOTAL KNOWN OUTPUTS	0	0	0	0	0	0	0	0	0	0	0	0	0
NET KNOWN FLOW	0.793	0.901	0.814	0.977	0.857	1.409	0.942	0.740	0.593	0.511	0.795	0.806	0.845
GAGED FLOW	0.765	0.916	0.734	0.945	1.641	7.360	0.874	0.700	0.530	0.527	0.383	0.434	1.317
Castaic Ck Gain (+) / Loss (-)	0	0	0	0	0	0	0	0	0	0	0	0	0
NET SCR GAIN (+)/LOSS (-)	-0.03	0.015	-0.08	-0.03	0.784	5.951	-0.07	-0.04	-0.06	0.016	-0.41	-0.37	0.472

Table 13: Flow Balance for Santa Clara River Reach 7, m^3/s, Water Year 1998

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Mean
Old Road Bridge gage	0.075	0.308	1.069	0.501	17.53	1.906	1.575	2.630	0.663	0.300	0.251	0.355	2.263
Valencia WWRF	0.380	0.370	0.357	0.358	0.401	0.440	0.454	0.453	0.459	0.523	0.525	0.485	0.434
Val Verde Community Park	0	0	0	0	0	0	0	0	0	0	0	0	0
Castaic Creek	0	0	0.143	0.546	9.969	4.950	2.173	3.482	0.022	0.631	0.201	0.221	1.862
Prescribed Groundwater Gains	0.140	0.265	0.238	1.018	10.90	5.419	1.036	3.121	1.371	0.376	0.584	0.237	2.001
TOTAL KNOWN INPUTS	0.595	0.943	1.808	2.423	38.80	12.72	5.238	9.686	2.515	1.831	1.561	1.298	6.618
Rancho Camulos diversion	0	0	0	0	0	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.014
Newhall Land (Isola) diversion	0.029	0.029	0.029	0	0	0.015	0.029	0.029	0.029	0.029	0.029	0.029	0.023
TOTAL KNOWN OUTPUTS	0.029	0.029	0.029	0	0	0.038	0.053	0.053	0.053	0.053	0.053	0.053	0.037
NET KNOWN FLOW	0.565	0.914	1.779	2.423	38.80	12.68	5.186	9.634	2.462	1.778	1.509	1.245	6.581
GAGED FLOW	0.766	1.254	2.233	2.706	53.23	11.69	4.463	16.12	2.528	1.812	1.629	1.227	8.304
Castaic Ck Gain (+) / Loss (-)	0	0	-0.09	-0.40	-3.74	-1.98	-0.91	-1.46	-0.02	-0.59	-0.20	-0.22	-0.80
NET SCR GAIN (+)/LOSS (-)	0.200	0.340	0.547	0.677	18.16	0.992	0.185	7.939	0.088	0.623	0.321	0.203	2.523

Simulation Results

WARMF simulation results (blue) and observed data (black circles) are compared in Figure 64 through Figure 67 for the two gage locations: Santa Clara River at Blue Cut (Los Angeles/Ventura county line) and Santa Clara River "near Piru". In each case, the first plot shows the complete hydrograph and the second shows the portion with flow less than 5 m^3/s. Frequency distribution plots for each gage are shown in Figure 68 and Figure 69. The frequency distribution shows a very close match for both gages.

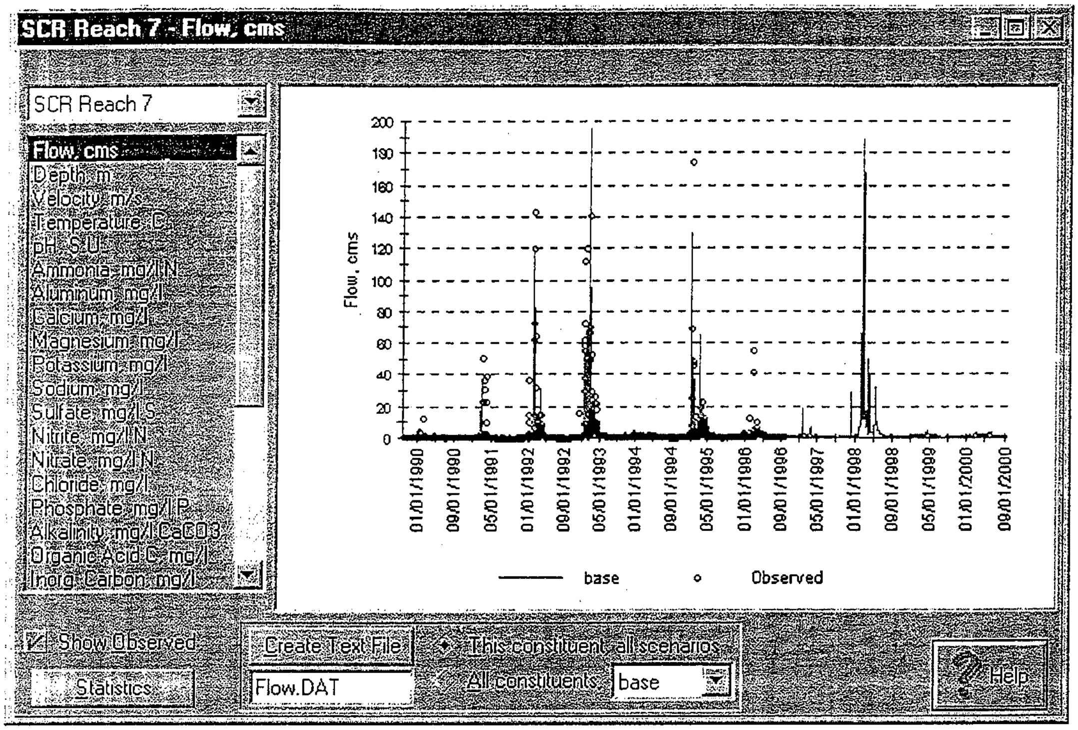


Figure 64: Simulated and Observed Flow, Santa Clara River at L.A./Ventura County Line (n = 2557; r = 0.83; relative error = +3.9%)

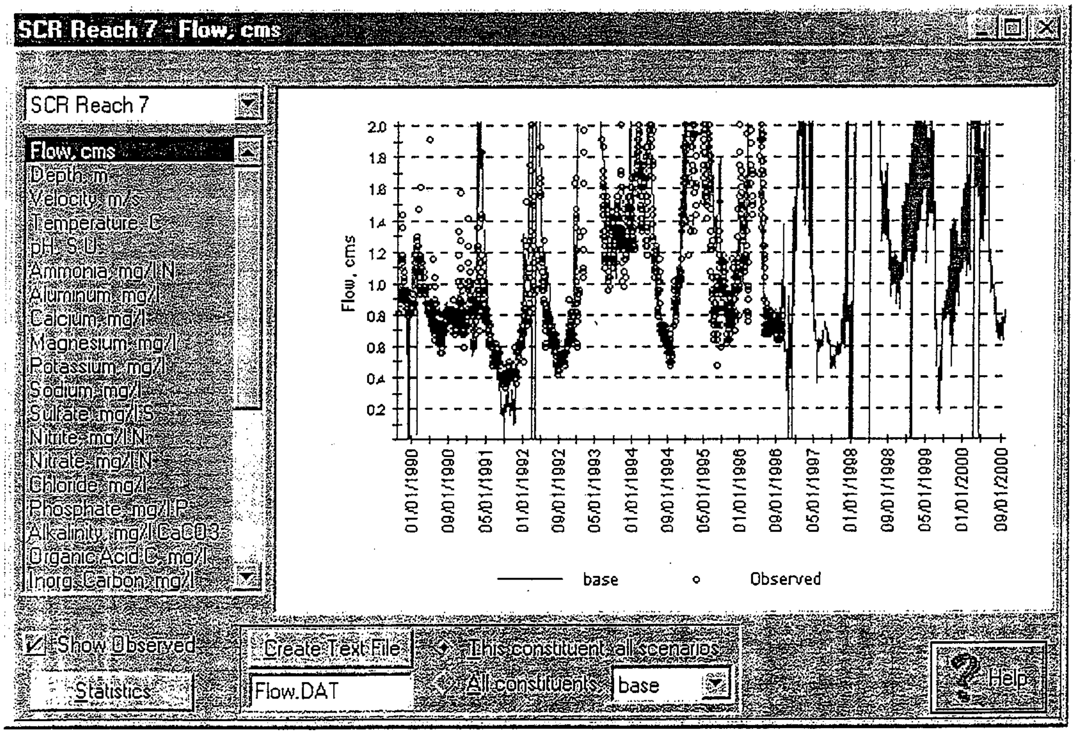
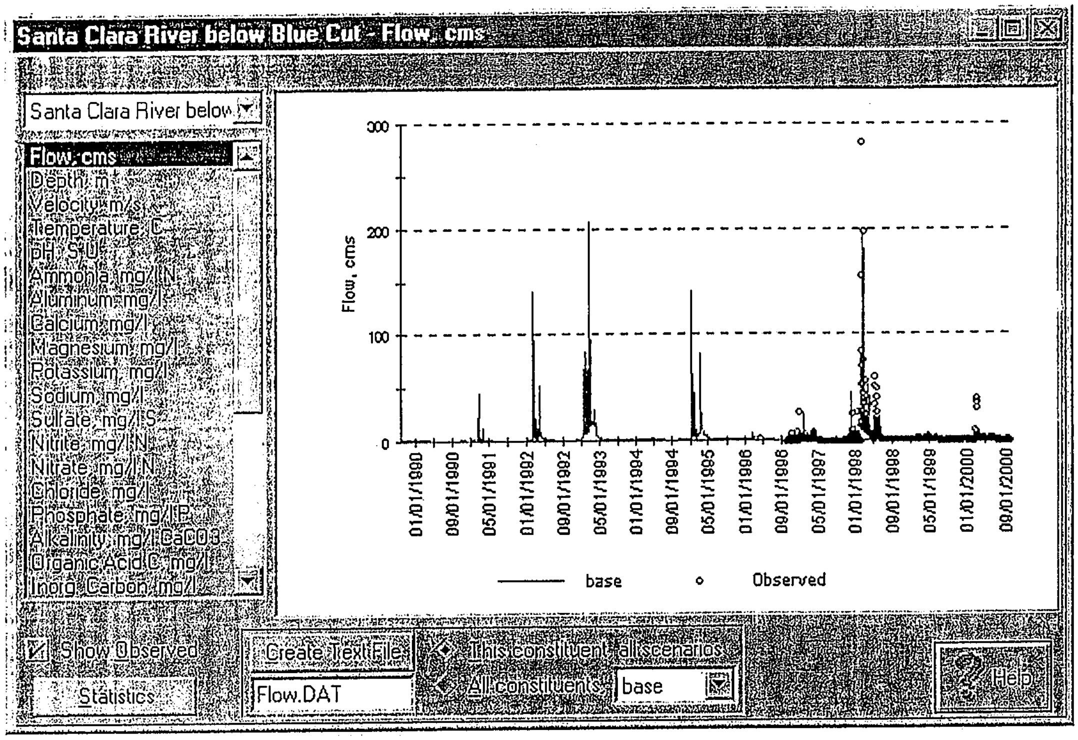


Figure 65: Simulated and Observed Flow: 0-2 m^3/s, Santa Clara River at L.A./Ventura County Line (n = 2151; r = 0.64; relative error = +18.4%)

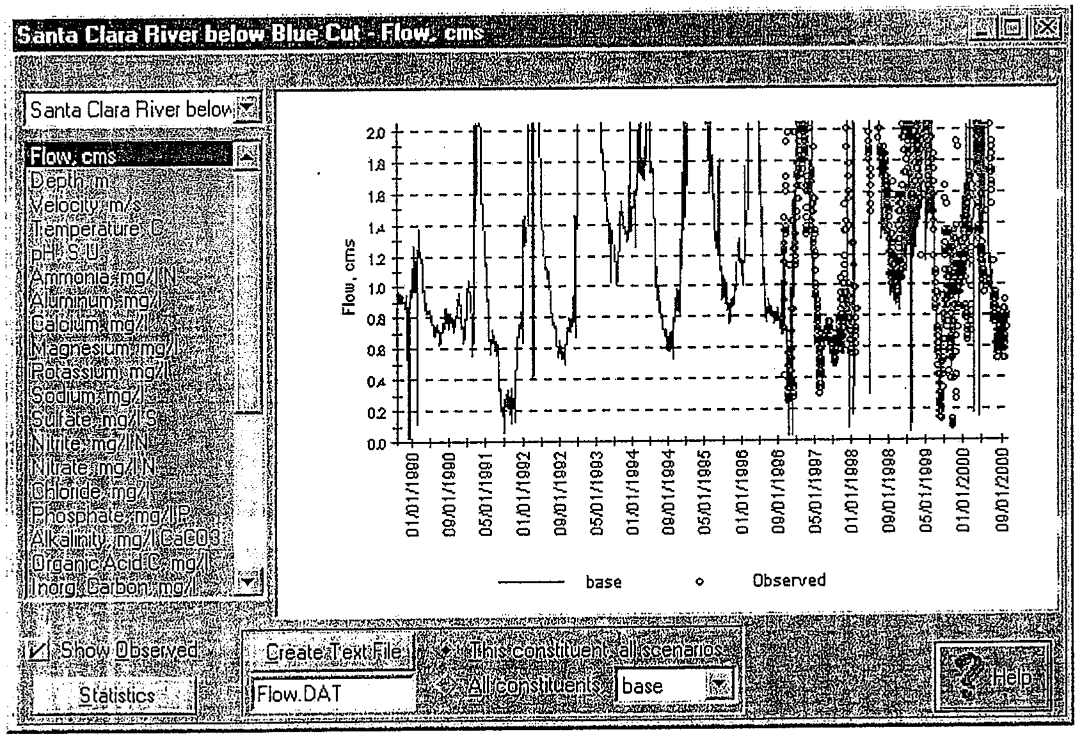


☑ Show Observed

Flow.DAT

base

Figure 66: Simulated and Observed Flow, Santa Clara River near Piru
(n = 1461; r = 0.67; relative error = -9.1%)



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Flow.DAT

base

Figure 67: Simulated and Observed Flow: 0-5 m^3/s, Santa Clara River near Piru
(n = 1042; r = 0.51; relative error = +8.3%)

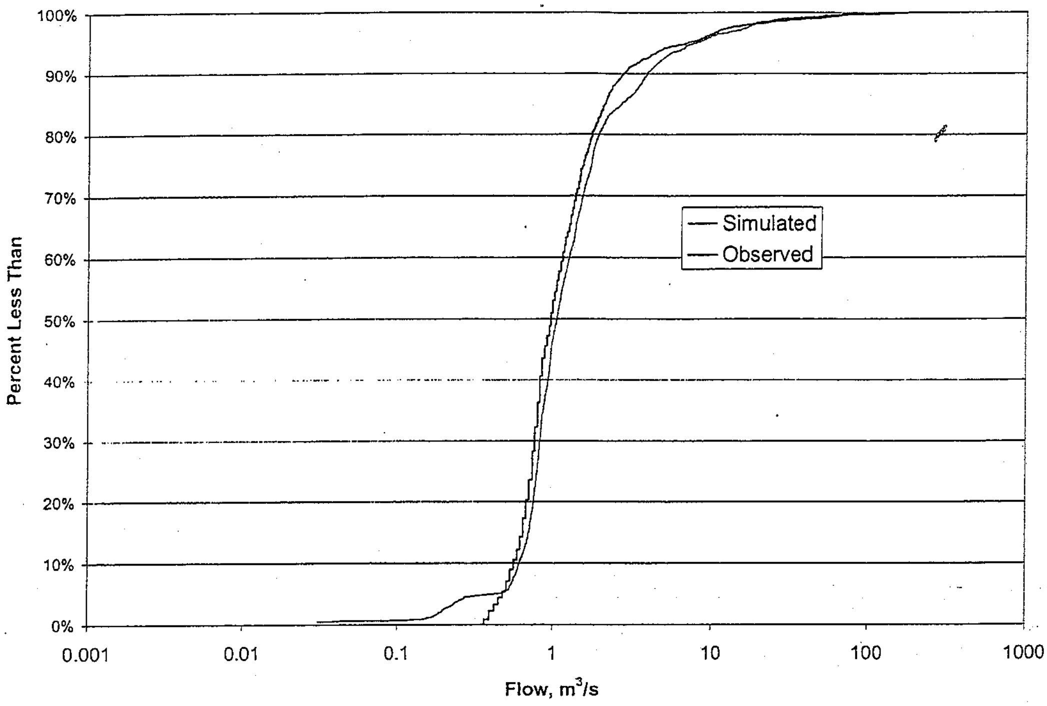


Figure 68: Frequency distribution of flow for Santa Clara River at L.A./Ventura county line

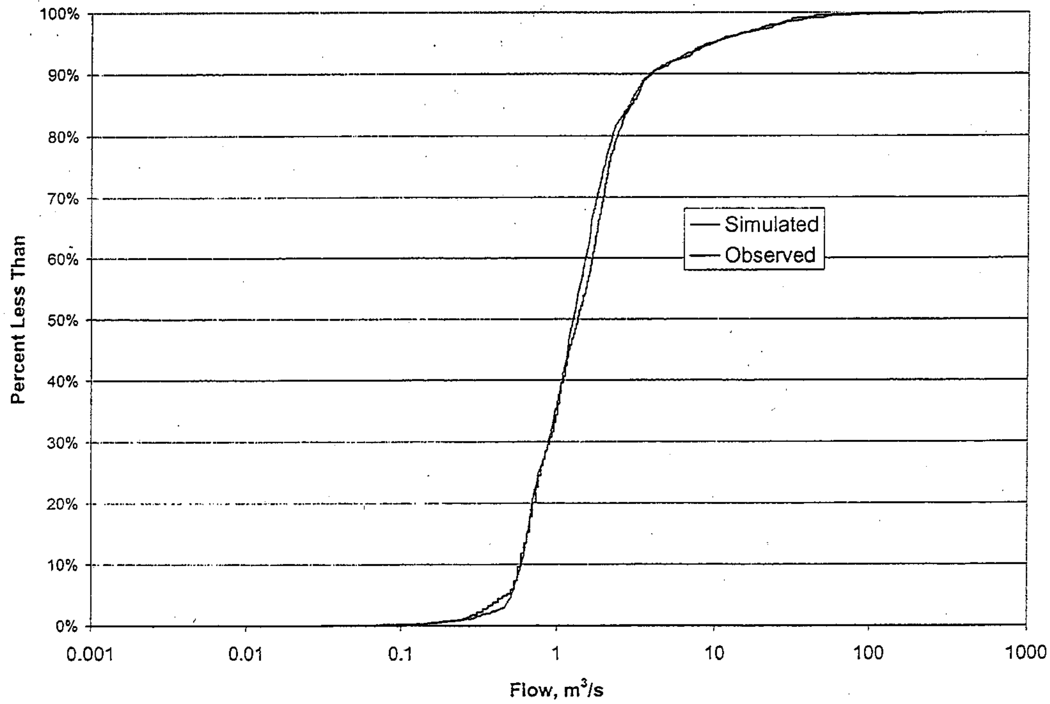


Figure 69: Frequency distribution of flow for Santa Clara River near Piru

Water Quality

During the dry season, the water quality of Reach 7 is dominated by the effluent from the Valencia and Saugus WWRFs and by gains from local groundwater. Castaic Lake releases have low nutrient concentrations and thus provide for dilution when present.

Key Assumptions

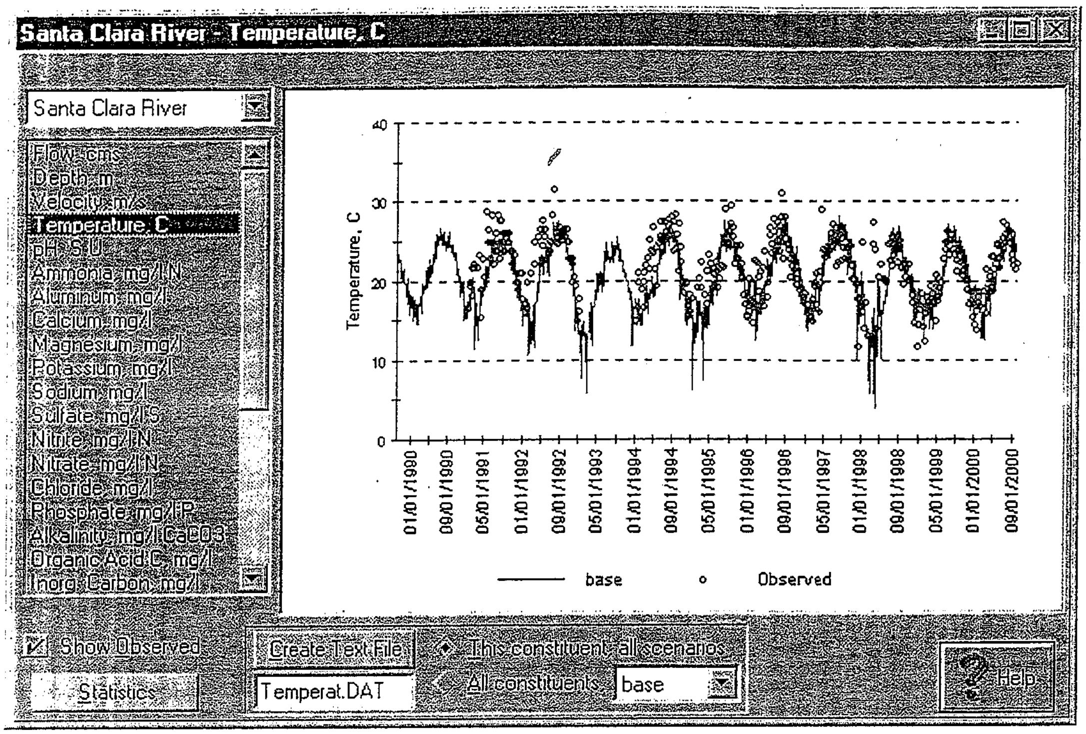
Like Reach 8 upstream, there is evidence of denitrification in the river segment downstream of the Valencia WWRF between the Old Road Bridge and Castaic Creek. Downstream of Castaic Creek, however, denitrification appears to be less important. Data recently made available indicates that well waters in the area vary in nitrate concentration from 0 to 9 mg/l as N, with a median of 1.1 mg/l (DWR 1993). The volume of groundwater is large enough so that the groundwater concentration does not change much over the course of the simulation period. A discussion of the sensitivity of simulation results to this initial concentration is included in the Sensitivity Analysis section of this report.

Simulation Results

Simulation of ammonia is good for the Santa Clara River at Castaic Creek except in 1995, 1996, and 2000. Ammonia data from the effluent of Valencia WWRF is available approximately every two weeks and show much variation, from 0 to 32 mg/l N. There was also inconsistency between consecutive measurements. The Saugus WWRF farther upstream shows less variation, having effluent ammonia concentrations ranging from 1 to 15 mg/l N. The conditions at the Valencia treatment plant could explain the highly variable observed data.

Simulation results match observed data well for nitrate in this reach. Simulated phosphorus matches the relatively high observed concentrations very well at Castaic Creek. The downward trend is the direct result of both Saugus and Valencia treatment plants loading less phosphorus to the river even as their flow increased.

At Blue Cut there is very little observed phosphorus over the entire simulation period, while model simulations show the phosphorus being transported downstream. The mass conservation principle suggests that phosphate must be transported downstream. It is not known what process is removing phosphorus in this reach. Red circles have been added to some figures to make some observed data points more visible, not to add emphasis.



☒ Show Observed

Temperat.DAT

● This constituent, all scenarios

○ All constituents base

Figure 70: Simulated and Observed Temperature for the Santa Clara River at Castaic Creek (n = 401; relative error = -0.96 °C; absolute error = 2.31 °C)

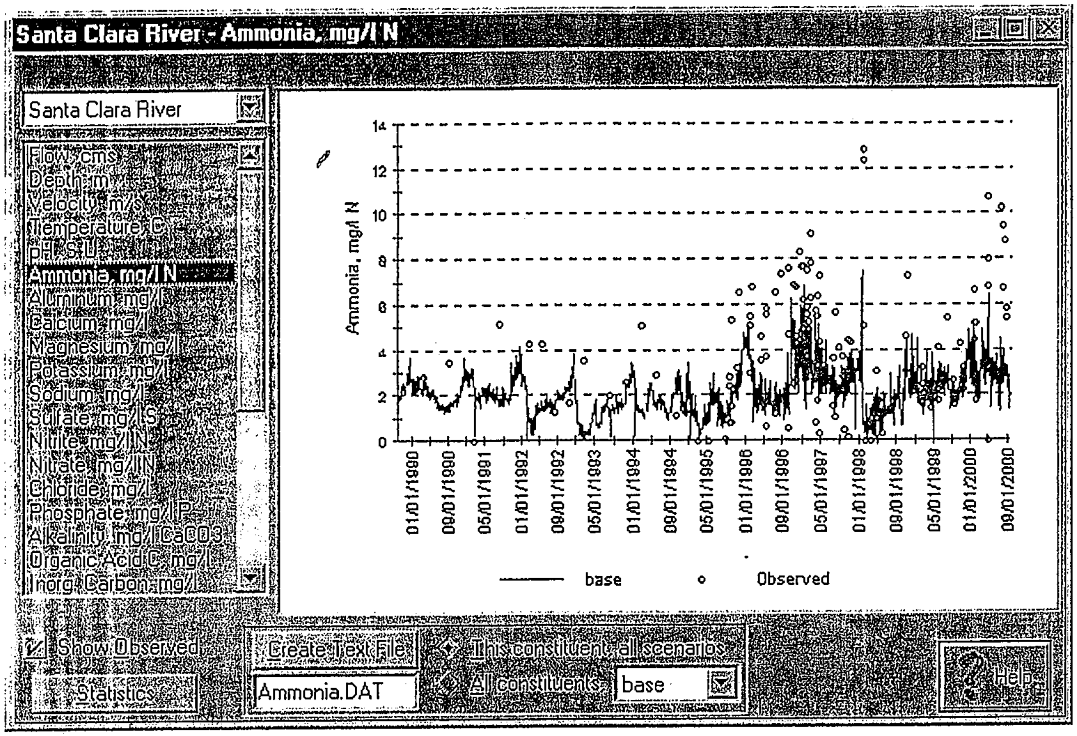


Figure 71: Simulated and Observed Ammonia for the Santa Clara River at Castaic Creek (n = 136; relative error = -1.43 mg/l; absolute error = 2.00 mg/l)

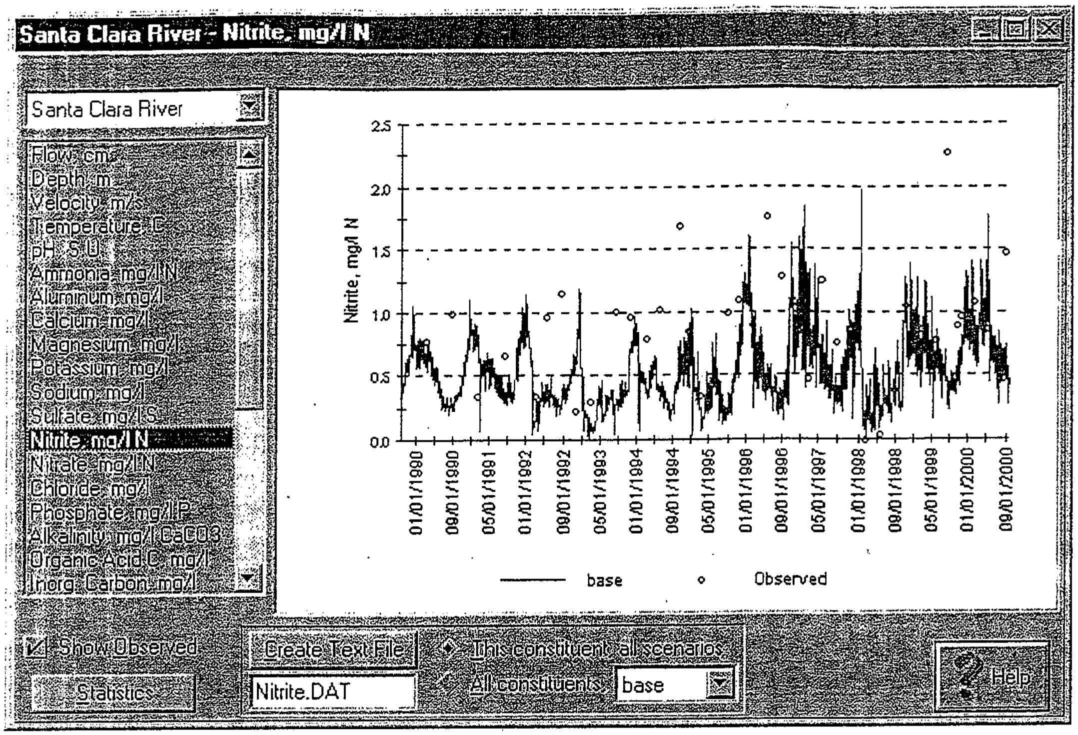
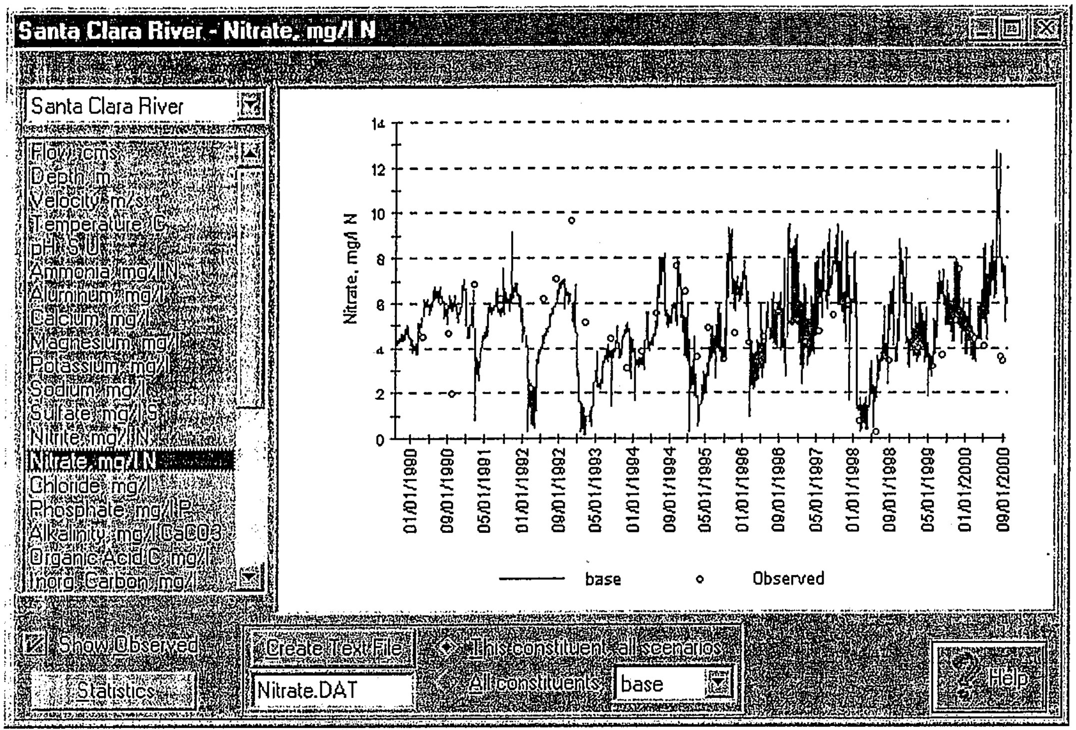


Figure 72: Simulated and Observed Nitrite for the Santa Clara River at Castaic Creek (n = 30; relative error = -0.35 mg/l; absolute error = 0.45 mg/l)


Santa Clara River - Nitrate, mg/l N

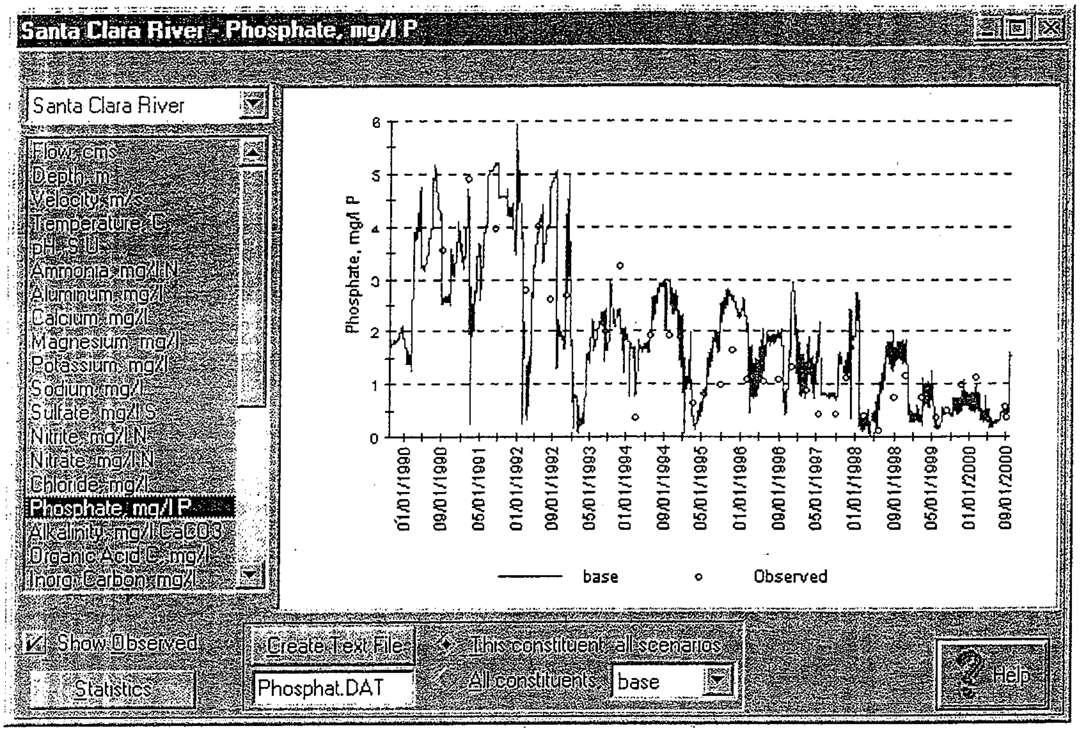
Santa Clara River

☑ Show Observed

Nitrate.DAT

base

Figure 73: Simulated and Observed Nitrate for the Santa Clara River at Castaic Creek (n = 40; relative error = 0.31 mg/l; absolute error = 1.56 mg/l)



☒ Show Observed

Phosphat.DAT

● This constituent, all scenarios

○ All constituents base

Figure 74: Simulated and Observed Phosphate for the Santa Clara River at Castaic Creek (n = 39; relative error = 0.14 mg/l; absolute error = 0.54 mg/l)

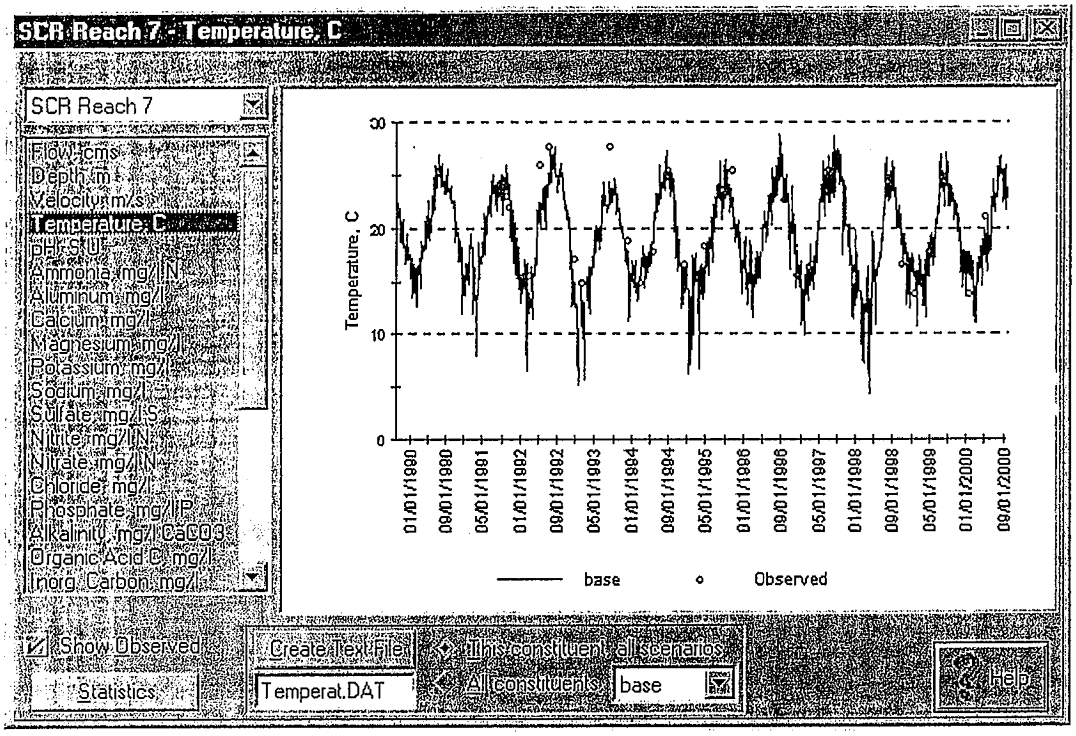


Figure 75: Simulated and Observed Temperature for the Santa Clara River at County Line (n = 20; relative error = -0.53 °C; absolute error = 1.90 °C)

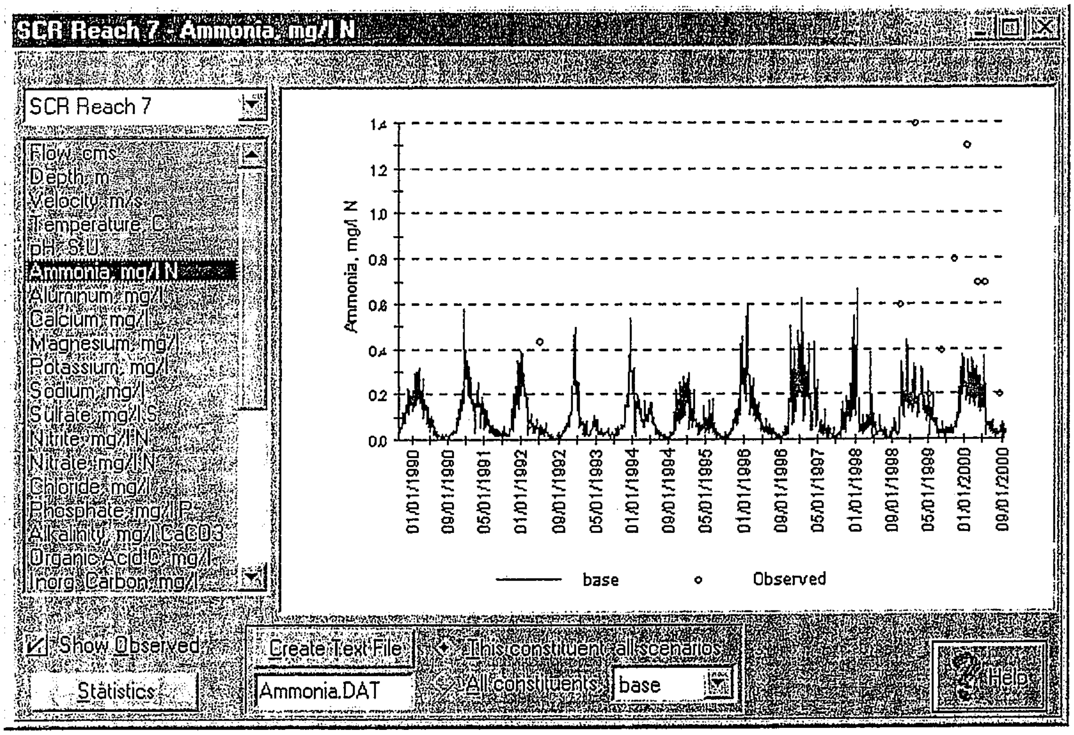
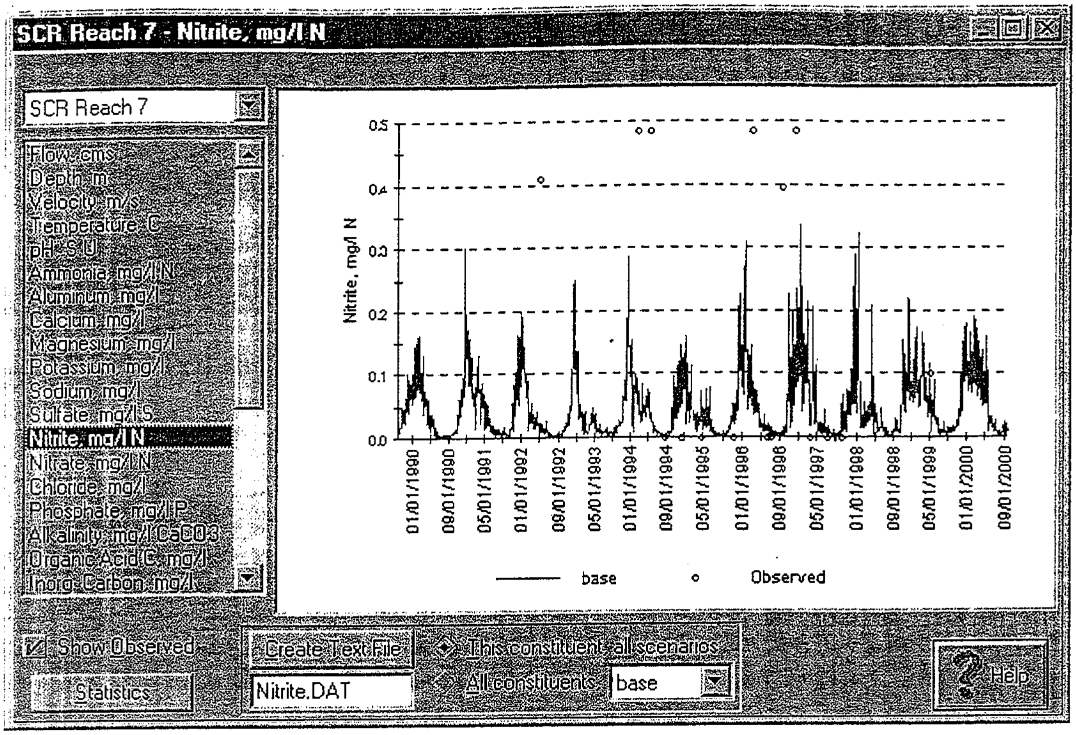


Figure 76: Simulated and Observed Ammonia for the Santa Clara River at County Line (n = 10; relative error = -0.55 mg/l; absolute error = 0.55 mg/l)



☑ Show Observed

Nitrite.DAT

base

Figure 77: Simulated and Observed Nitrite for the Santa Clara River at County Line (n = 16; relative error = -0.14 mg/l; absolute error = 0.17 mg/l)

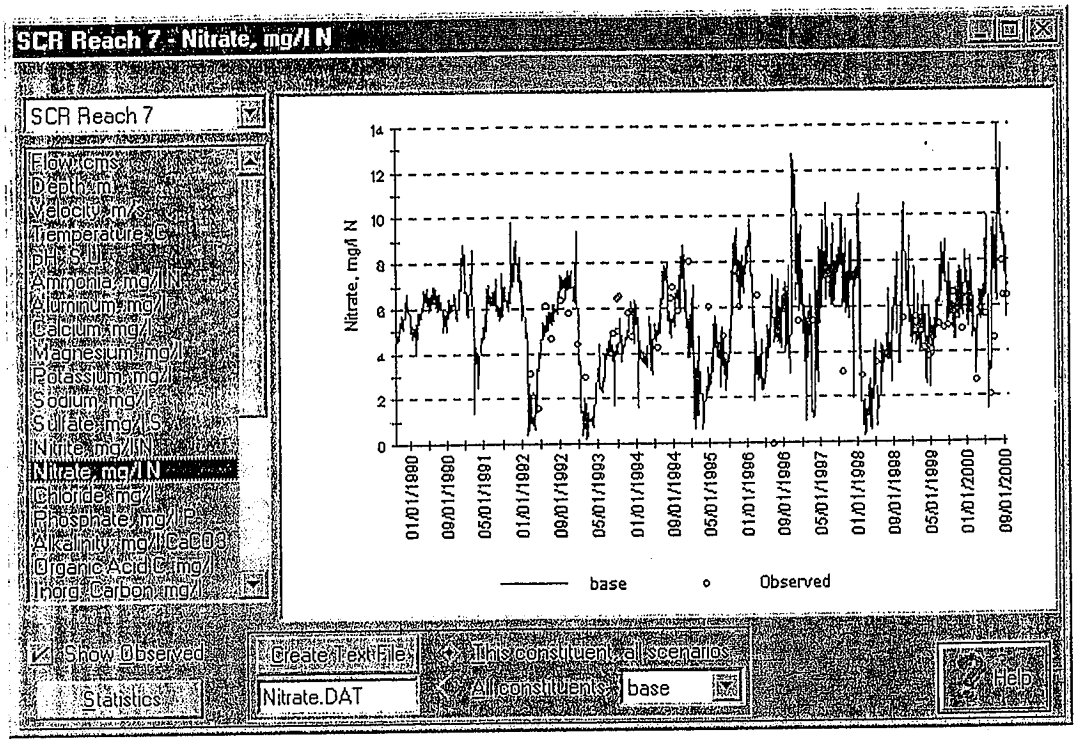


Figure 78: Simulated and Observed Nitrate for the Santa Clara River at County Line (n = 58; relative error = 0.53 mg/l; absolute error = 1.57 mg/l)

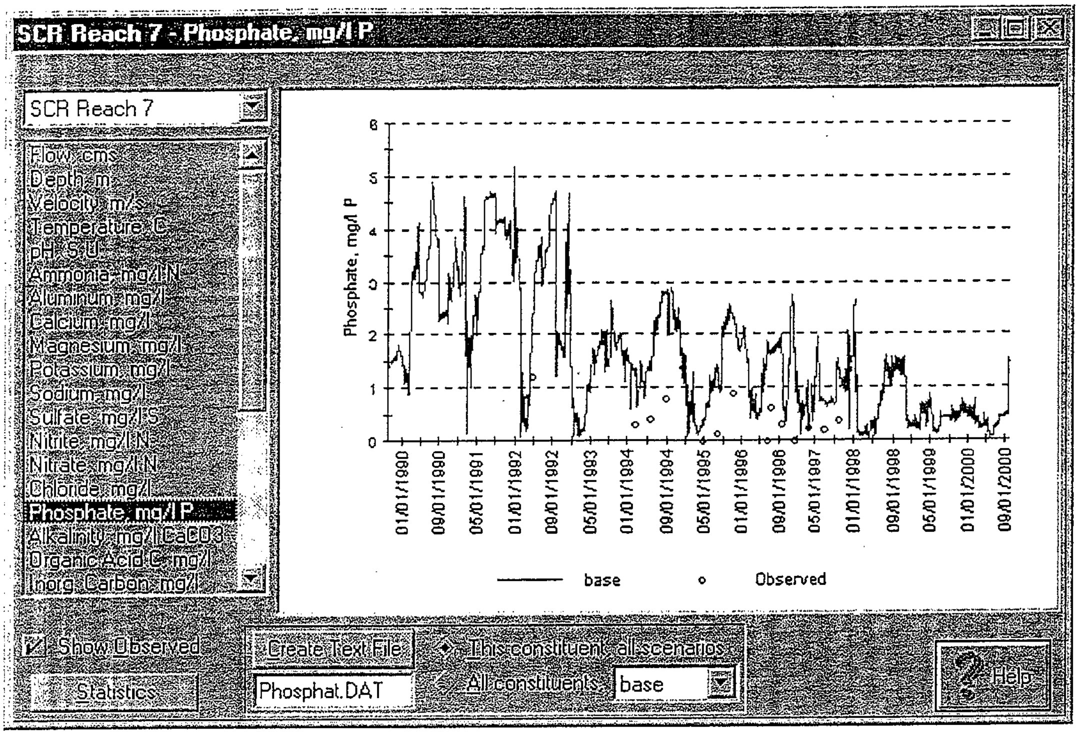


Figure 79: Simulated and Observed Phosphate for the Santa Clara River at County Line (n = 16; relative error = 1.04 mg/l; absolute error = 1.07 mg/l)

Santa Clara River Reaches 3-6: Blue Cut to Freeman Diversion

In these reaches, the Santa Clara River passes through the Piru, Fillmore, and Santa Paula groundwater basins. In this region, the exchange of water between surface water and groundwater is evident. Both hydrology and water quality are heavily dependent upon these interactions.

Agriculture is the key land use in the lowlands near the Santa Clara River. The cities of Fillmore and Santa Paula are also within this region. The downstream end of this reach is the Freeman Diversion, where much of the Santa Clara River's flow is diverted to recharge the local groundwater basin.

Hydrology

This is the most hydrologically complex section of the Santa Clara River. Known inflows of water include the gaged flow at Blue Cut, release from Lake Piru, and natural flow from Hopper, Sespe, and Santa Paula Creeks (Figure 4). Known outflows include the Piru Mutual and Piru Creek diversions, the Fillmore Irrigation Canal on Sespe Creek, the Farmers' Diversion on Santa Paula Creek, the Richardson Diversion on the Santa Clara River near Santa Paula, and the Freeman Diversion. When the Blue Cut gage was located at the Los Angeles/Ventura county line, until 10/1/1996, the Rancho Camulos and Newhall Land (Isola) diversions were also in this reach of the Santa Clara River.

Key Assumptions

The United Water Conservation District has extensively studied the surface and groundwater exchange from Blue Cut to Santa Paula Creek. The studies have led to estimate of flow gain and loss for various river segments within this reach (UWCD (McEachron) 2002). Simulated flows were also used in the generation of UWCD loss estimates. This reach can be further divided between the section upstream of Sespe Creek and the section downstream of Sespe Creek. The reaches on both sides of Sespe Creek have a combination of gains and losses.

Table 14 through Table 17 summarize the flow balance for Piru Creek and Hopper Creek, the two major tributaries upstream of Sespe Creek. Water year 1991 is a dry year and water year 1998 is a wet year.

Piru Creek has two diversions, the Piru Mutual Diversion and the Piru Creek Diversion. Some of the water remaining after these two diversions is lost to groundwater. The April outflows are greater than the inflows in Table 14 because at times the scheduled diversions exceed the release from Lake Piru. The net known flow for June and July in Table 15 is greater than the difference between total inflow and total outflow because at times the scheduled diversions are greater than the release flow, but the net river flow can not go below zero on any given day.

Table 14: Flow Balance for Piru Creek from Lake Piru to Santa Clara River, m³/s, Water Year 1991

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Mean
Lake Piru release	0.135	0.155	0.132	0.083	0.087	1.113	0.114	2.440	1.475	0.135	0.111	0.122	0.512
TOTAL KNOWN INPUTS	**0.135**	**0.155**	**0.132**	**0.083**	**0.087**	**1.113**	**0.114**	**2.440**	**1.475**	**0.135**	**0.111**	**0.122**	**0.512**
Piru Mutual diversion	0.044	0.044	0.044	0.023	0.023	0.023	0.066	0.066	0.066	0.066	0.066	0.066	0.050
Piru Creek diversion	0.001	0	0	0.009	0.000	0.084	0.041	0.000	0.006	0	0	0	0.012
Piru Creek loss (UWCD est.)	0.091	0.112	0.089	0.051	0.064	0.140	0.031	0.320	0.228	0.063	0.045	0.056	0.108
TOTAL KNOWN OUTPUTS	**0.135**	**0.155**	**0.132**	**0.083**	**0.087**	**0.247**	**0.137**	**0.386**	**0.299**	**0.129**	**0.111**	**0.122**	**0.169**
NET KNOWN FLOW	**0**	**0**	**0**	**0**	**0**	**0.884**	**0**	**2.054**	**1.175**	**0.005**	**0**	**0**	**0.343**

Table 15: Flow Balance for Piru Creek from Lake Piru to Santa Clara River, m^3/s, Water Year 1998

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Mean
Lake Piru release	5.285	0.721	0.165	0.169	3.930	3.945	2.790	2.861	2.453	0.605	0.604	3.474	2.235
TOTAL KNOWN INPUTS	5.285	0.721	0.165	0.169	3.930	3.945	2.790	2.861	2.453	0.605	0.604	3.474	2.235
Piru Mutual diversion	0.043	0.043	0.043	0.023	0.023	0.023	0.067	0.067	0.067	0.067	0.067	0.067	0.050
Piru Creek diversion	0.085	0.038	0	0.038	0.000	0.006	0.811	0.970	1.436	0.290	0	0	0.306
Piru Creek loss (UWCD est.)	0.501	0.220	0.122	0.108	0.428	0.485	0.126	0.063	0.000	0.150	0.230	0.443	0.238
TOTAL KNOWN OUTPUTS	0.629	0.301	0.165	0.169	0.451	0.514	1.004	1.100	1.503	0.508	0.298	0.510	0.596
NET KNOWN FLOW	4.656	0.420	0	0	3.479	3.431	1.786	1.761	0.950	0.097	0.306	2.964	1.639

Between the Hopper Creek gage at Highway 126 and the mouth of the creek at the Santa Clara River, some of Hopper Creek's flow percolates into the soil as shown in Table 16 and Table 17. Even in the wet year of 1998, most of Hopper Creek's flow is lost to the groundwater in August-October.

Table 16: Flow Balance for Hopper Creek from gage to Santa Clara River, m^3/s, Water Year 1991

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Mean
Hopper Creek gage	0	0	0	0	0.338	1.538	0.048	0.009	0	0	0	0	0.161
TOTAL KNOWN INPUTS	0	0	0	0	0.338	1.538	0.048	0.009	0	0	0	0	0.161
Hopper Creek loss (UWCD est.)	0	0	0	0	0.033	0.177	0.041	0.009	0	0	0	0	0.022
TOTAL KNOWN OUTPUTS	0	0	0	0	0.033	0.177	0.041	0.009	0	0	0	0	0.022
NET KNOWN FLOW	0	0	0	0	0.304	1.362	0.007	0	0	0	0	0	0.139

Table 17: Flow Balance for Hopper Creek from gage to Santa Clara River, m^3/s, Water Year 1998

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Mean
Hopper Creek gage	0.011	0.192	0.916	0.241	11.24	1.872	0.592	1.184	0.287	0.141	0.046	0.084	1.401
TOTAL KNOWN INPUTS	0.011	0.192	0.916	0.241	11.24	1.872	0.592	1.184	0.287	0.141	0.046	0.084	1.401
Hopper Creek loss (UWCD est.)	0.011	0.040	0.133	0.077	0.651	0.221	0.108	0.160	0.079	0.066	0.046	0.066	0.138
TOTAL KNOWN OUTPUTS	0.011	0.040	0.133	0.077	0.651	0.221	0.108	0.160	0.079	0.066	0.046	0.066	0.138
NET KNOWN FLOW	0	0.152	0.783	0.164	10.59	1.650	0.484	1.024	0.208	0.076	0	0.019	1.263

Given the known flow inputs from Piru Creek and Hopper Creek, a flow balance can be set up for the reach of the Santa Clara River between Blue Cut and Sespe Creek (Table 18 and Table 19). All listed losses and gains for various reaches of the Santa Clara River are from UWCD estimates.

Table 18: Flow Balance for Santa Clara River from Blue Cut to Sespe Creek, Water Year 1991

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Mean
Blue Cut gage	0.765	0.916	0.734	0.945	1.641	7.360	0.874	0.700	0.530	0.527	0.383	0.434	1.317
Net Piru Creek	0	0	0	0	0	0.884	0	2.054	1.175	0.005	0	0	0.343
Net Hopper Creek	0	0	0	0	0.304	1.362	0.007	0	0	0	0	0	0.139
Fish Hatchery gain	0	0	0	0	0	0	0	0	0	0	0	0	0
Fillmore WWTP	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL KNOWN INPUTS	**0.765**	**0.916**	**0.734**	**0.945**	**1.945**	**9.606**	**0.881**	**2.754**	**1.705**	**0.532**	**0.383**	**0.434**	**1.799**
Rancho Camulos diversion	0	0	0	0	0	0	0	0	0	0	0	0	0
Newhall Land (Isola) diversion	0.029	0.029	0.029	00	0	0.015	0.029	0.029	0.029	0.029	0.029	0.029	0.023
Newhall Bridge to Torrey loss	0.754	0.890	0.669	0.908	1.169	2.357	1.450	0.967	0.660	0.644	0.219	0.258	0.911
Torrey to Hopper Creek loss	0	0.026	0	0.025	0.196	0.685	0.141	1.794	1.008	0.005	0	0	0.325
Hopper Creek to Cavin loss	0	0	0	0	0.452	0.572	0.017	0.004	0	0	0	0	0.085
Cavin to Sespe loss	0	0	0	0	0.075	0.341	0.180	0.196	0.094	0	0	0	0.074
TOTAL KNOWN OUTPUTS	**0.783**	**0.945**	**0.698**	**0.934**	**1.891**	**3.970**	**1.817**	**2.990**	**1.791**	**0.678**	**0.248**	**0.287**	**1.418**
NET KNOWN FLOW	**0**	**0**	**0.036**	**0.011**	**0.054**	**5.636**	**0**	**0**	**0**	**0**	**0.135**	**0.147**	**0.502**

Table 19: Flow Balance for Santa Clara River from Blue Cut to Sespe Creek, Water Year 1998

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Mean
Blue Cut gage	0.766	1.254	2.233	2.706	53.23	11.69	4.463	16.12	2.528	1.812	1.629	1.227	8.304
Net Piru Creek	4.656	0.421	0	0	3.482	3.432	1.786	1.761	0.988	0.246	0.306	2.963	1.670
Net Hopper Creek	0	0.152	0.783	0.164	10.59	1.650	0.484	1.024	0.208	0.076	0	0.019	1.263
Fish Hatchery gain	0.060	0.043	0.061	0.106	0.610	1.065	1.236	1.286	1.270	1.130	0.941	0.834	0.720
Fillmore WWTP	0	0	0	0	0.010	0.037	0.036	0	0.006	0	0.039	0.043	0.014
TOTAL KNOWN INPUTS	**5.482**	**1.87**	**3.077**	**2.976**	**67.92**	**17.87**	**8.005**	**20.19**	**5.000**	**3.264**	**2.915**	**5.086**	**11.97**
Newhall Bridge to Torrey loss	0.786	0.977	1.776	1.784	10.45	7.184	5.587	5.586	2.828	2.024	1.735	1.268	3.451
Torrey to Hopper Creek loss	2.790	0.344	0.360	0.229	2.404	4.760	5.145	2.045	1.210	0.690	0.486	1.941	1.859
Hopper Creek to Cavin loss	1.038	0.052	0.436	0.031	8.705	2.309	0.000	1.590	0	0	0	0.611	1.181
Cavin to Sespe loss	0.376	0.074	0.204	0.112	1.799	1.518	1.196	0.959	0.643	0.529	0.443	0.580	0.695
TOTAL KNOWN OUTPUTS	**4.990**	**1.446**	**2.776**	**2.157**	**23.36**	**15.77**	**11.93**	**10.18**	**4.681**	**3.243**	**2.664**	**4.399**	**7.186**
NET KNOWN FLOW	**0.492**	**0.424**	**0.301**	**0.819**	**44.57**	**2.102**	**-3.92**	**10.01**	**0.319**	**0.021**	**0.251**	**0.687**	**4.672**

In addition to Piru Creek and Hopper Creek, there are two major tributaries between the Sespe Creek confluence and the Freeman Diversion: Sespe Creek and Santa Paula Creek. Table 20 through Table 23 summarize the flow balance for these tributaries for water year 1991, a dry year, and water year 1998, a wet year.

Below the Sespe Creek gage, there is one diversion, for the Fillmore Irrigation Canal. Until January 1993, the diversion for the Fillmore Irrigation Canal was upstream of the gage, so the gaged flow for 1991 is net flow after the diversion. Table 20 and Table 21 show the net Sespe Creek flow to the Santa Clara River. At times the scheduled diversion for the Fillmore Irrigation Canal is greater than the available water in Sespe Creek, so the net flow shown reflects the daily average flow which can not be negative.

Table 20: Flow Balance for Sespe Creek from gage to Santa Clara River, m^3/s, Water Year 1991

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Mean
Sespe Creek gage	0.006	0.007	0.009	0.071	2.242	25.82	6.355	1.362	0.404	0.103	0.016	0.007	3.033
TOTAL KNOWN INPUTS	0.006	0.007	0.009	0.071	2.242	25.82	6.355	1.362	0.404	0.103	0.016	0.007	3.033
TOTAL KNOWN OUTPUTS	0	0	0	0	0	0	0	0	0	0	0	0	0
NET KNOWN FLOW	0.006	0.007	0.009	0.071	2.242	25.82	6.355	1.362	0.404	0.103	0.016	0.007	3.033

Table 21: Flow Balance for Sespe Creek from gage to Santa Clara River, m^3/s, Water Year 1998

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Mean
Sespe Creek gage	0.017	0.272	5.427	6.233	122.7	19.65	13.40	12.05	5.748	2.575	1.397	1.069	15.88
TOTAL KNOWN INPUTS	0.017	0.272	5.427	6.233	122.7	19.65	13.40	12.05	5.748	2.575	1.397	1.069	15.88
Fillmore Irrigation Canal	0.052	0.052	0.052	0	0	0	0.052	0.052	0.052	0.078	0.078	0.078	0.045
TOTAL KNOWN OUTPUTS	0.052	0.052	0.052	0	0	0	0.052	0.052	0.052	0.078	0.078	0.078	0.045
NET KNOWN FLOW	0	0.231	5.375	6.233	122.7	19.65	13.35	12.00	5.695	2.497	1.319	0.991	15.84

Santa Paula Creek has one diversion between its gage and the Santa Clara River, as shown in Table 22 and Table 23. At times the scheduled flow for Farmers' Diversion is greater than the flow in Santa Paula Creek. The net flow is adjusted so that it can never go below zero on a daily basis.

Table 22: Flow Balance for Santa Paula Creek from gage to Santa Clara River, Water Year 1991

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Mean
Santa Paula Creek gage	0.020	0.016	0.027	0.042	0.313	3.879	1.911	0.398	0.217	0.145	0.084	0.056	0.592
TOTAL KNOWN INPUTS	0.020	0.016	0.027	0.042	0.313	3.879	1.911	0.398	0.217	0.145	0.084	0.056	0.592
Farmers' Diversion	0.055	0.055	0.055	0.014	0.014	0.014	0.064	0.064	0.064	0.090	0.090	0.090	0.056
TOTAL KNOWN OUTPUTS	0.055	0.055	0.055	0.014	0.014	0.014	0.064	0.064	0.064	0.090	0.090	0.090	0.056
NET KNOWN FLOW	0	0	0	0.028	0.299	3.865	1.847	0.334	0.153	0.056	0	0	0.548

Table 23: Flow Balance for Santa Paula Creek from gage to Santa Clara River, Water Year 1998

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Mean
Santa Paula Creek gage	0.094	0.210	0.628	0.543	24.08	4.181	3.317	3.458	1.491	0.817	0.505	0.396	3.310
TOTAL KNOWN INPUTS	0.094	0.210	0.628	0.543	24.08	4.181	3.317	3.458	1.491	0.817	0.505	0.396	3.310
Farmers' Diversion	0.041	0.041	0.041	0	0	0	0.020	0.020	0.020	0.057	0.057	0.057	0.030
TOTAL KNOWN OUTPUTS	0.041	0.041	0.041	0	0	0	0.020	0.020	0.020	0.057	0.057	0.057	0.030
NET KNOWN FLOW	0.053	0.169	0.587	0.542	24.08	4.181	3.297	3.438	1.471	0.760	0.448	0.339	3.280

Given these inflows from the Sespe Creek, Santa Paula Creek, and the Santa Clara River at Sespe Creek, a flow balance can be conducted as shown in Table 24 and Table 25. All the listed Willard Road gains and Sespe to Willard losses are from UWCD estimates. The balance must be conducted to the Montalvo gage downstream of the Freeman Diversion because there is no gaging available at the diversion itself.

Table 24: Flow Balance for Santa Clara River from Sespe Creek to Freeman, Water Year 1991

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Mean
Net SCR @ Sespe Creek	0	0	0.036	0.011	0.054	5.636	0	0	0	0	0.135	0.147	0.502
Net Sespe Creek	0.006	0.007	0.009	0.071	2.242	25.82	6.355	1.362	0.404	0.103	0.016	0.007	3.033
Willard Road gain	0.083	0.063	0.056	0.047	0.047	0.089	0.216	0.297	0.293	0.257	0.211	0.180	0.153
Net Santa Paula Creek	0	0	0	0.028	0.299	3.865	1.847	0.334	0.153	0.056	0	0	0.548
Santa Paula WWRP	0.079	0.078	0.077	0.077	0.075	0.080	0.074	0.075	0.077	0.079	0.081	0.082	0.078
TOTAL KNOWN INPUTS	**0.168**	**0.148**	**0.178**	**0.234**	**2.717**	**35.49**	**8.492**	**2.068**	**0.927**	**0.495**	**0.443**	**0.416**	**4.314**
Sespe Creek to Willard loss	0	0	0	0.029	0.657	6.060	2.744	0.927	0.479	0.187	0.116	0.069	0.943
Richardson Diversion	0.017	0.017	0.017	0.001	0.001	0.001	0.003	0.003	0.003	0.019	0.019	0.019	0.010
Freeman Diversion	0	0	0	0.015	0.338	6.849	6.686	1.913	0.915	0.550	0.315	0.250	1.486
TOTAL KNOWN OUTPUTS	**0.017**	**0.017**	**0.017**	**0.045**	**0.996**	**12.91**	**9.433**	**2.843**	**1.397**	**0.756**	**0.450**	**0.338**	**2.439**
NET KNOWN FLOW	**0.151**	**0.131**	**0.161**	**0.190**	**1.720**	**22.58**	**-0.94**	**-0.78**	**-0.47**	**-0.26**	**-0.01**	**0.077**	**1.880**
GAGED FLOW	**0**	**0**	**0**	**0**	**0.749**	**34.97**	**1.034**	**0**	**0**	**0**	**0**	**0**	**3.063**
NET GAIN (+) / LOSS (-)	**-0.15**	**-0.13**	**-0.16**	**-0.19**	**-0.97**	**12.39**	**1.975**	**0.775**	**0.470**	**0.261**	**0.007**	**-0.08**	**1.019**

Table 25: Flow Balance for Santa Clara River from Sespe Creek to Freeman, Water Year 1998

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Mean
Net SCR @ Sespe Creek	1.308	0.243	1.045	0.513	48.91	6.232	2.181	9.266	1.113	0.848	0.923	1.847	6.203
Net Sespe Creek	0	0.231	5.375	6.233	122.7	19.65	13.35	12.00	5.695	2.497	1.319	0.991	15.84
Willard Road gain	0.770	0.810	0.948	1.035	1.590	1.882	1.967	2.166	1.894	1.715	1.624	1.658	1.505
Net Santa Paula Creek	0.053	0.169	0.587	0.542	24.08	4.181	3.297	3.438	1.471	0.760	0.448	0.339	3.280
Santa Paula WWRP	0.072	0.086	0.089	0.089	0.125	0.103	0.097	0.099	0.094	0.093	0.092	0.091	0.094
TOTAL KNOWN INPUTS	**2.203**	**1.539**	**8.044**	**8.412**	**197.4**	**32.05**	**20.89**	**26.97**	**10.27**	**5.913**	**4.406**	**4.926**	**26.92**
Sespe Creek to Willard loss	0.528	0.320	3.548	4.341	17.92	14.91	10.22	9.579	3.453	1.937	1.171	1.064	5.670
Richardson Diversion	0.018	0.018	0.018	0.003	0.003	0.003	0.003	0.003	0.003	0.023	0.023	0.023	0.011
Freeman Diversion	3.186	1.505	3.442	4.571	2.281	8.309	7.224	6.108	7.081	5.515	3.044	4.157	4.702
TOTAL KNOWN OUTPUTS	**3.732**	**1.843**	**7.008**	**8.915**	**20.20**	**23.22**	**17.44**	**15.69**	**10.54**	**7.475**	**4.238**	**5.244**	**10.38**
NET KNOWN FLOW	**-1.53**	**-0.30**	**1.036**	**-0.50**	**177.2**	**8.831**	**3.450**	**11.28**	**-0.27**	**-1.56**	**0.168**	**-0.32**	**16.46**
GAGED FLOW	**0**	**0.229**	**11.64**	**2.580**	**201.8**	**30.19**	**45.59**	**31.20**	**7.597**	**2.757**	**0.676**	**0.486**	**27.89**
NET GAIN (+) / LOSS (-)	**1.530**	**0.533**	**10.60**	**3.083**	**24.60**	**21.36**	**42.14**	**19.92**	**7.867**	**4.319**	**0.508**	**0.804**	**11.43**

The dry year condition shown in Table 24 indicates that, in addition to those losses between Willard Road and Blue Cut, there are additional losses. These losses may be between Santa Paula Creek and the Freeman Diversion, or between Freeman Diversion and the Montalvo gage. The net gains during the wet season are from ungaged tributaries and local runoff.

Table 25 shows net gains every month of the year. This is from local runoff from storm events not accounted for in UWCD's gain estimates, flow from Pole Creek, and from tributaries and local runoff between Santa Paula Creek and the Montalvo gage.

Simulation Results

Figure 80 and Figure 81 show the simulated (blue) and observed (black circles) flow at Montalvo. The first figure shows the entire hydrograph; the second shows the same results but only the 0-5 m^3/s portion of the hydrograph. Calibration of that gage has not been done and would be very difficult. Table 24 shows net losses for much of the year. Without knowing actual losses, it would be impossible to calibrate the unknown flows. Table 25 shows net unknown flows which could theoretically calibrated, but the uncertainty in the prescribed groundwater flows is so great that calibration of the unknown flows would still be highly uncertain. The flow at Reach 3 is set based on calibrated flows upstream and specified gains and losses. The losses shown in Table 24 and Table 25 downstream of Santa Paula Creek are not simulated, causing the simulated flow to be too high during low flow as shown in Figure 81. Peak flows are underestimated in the model simulations, resulting in too little flow overall.

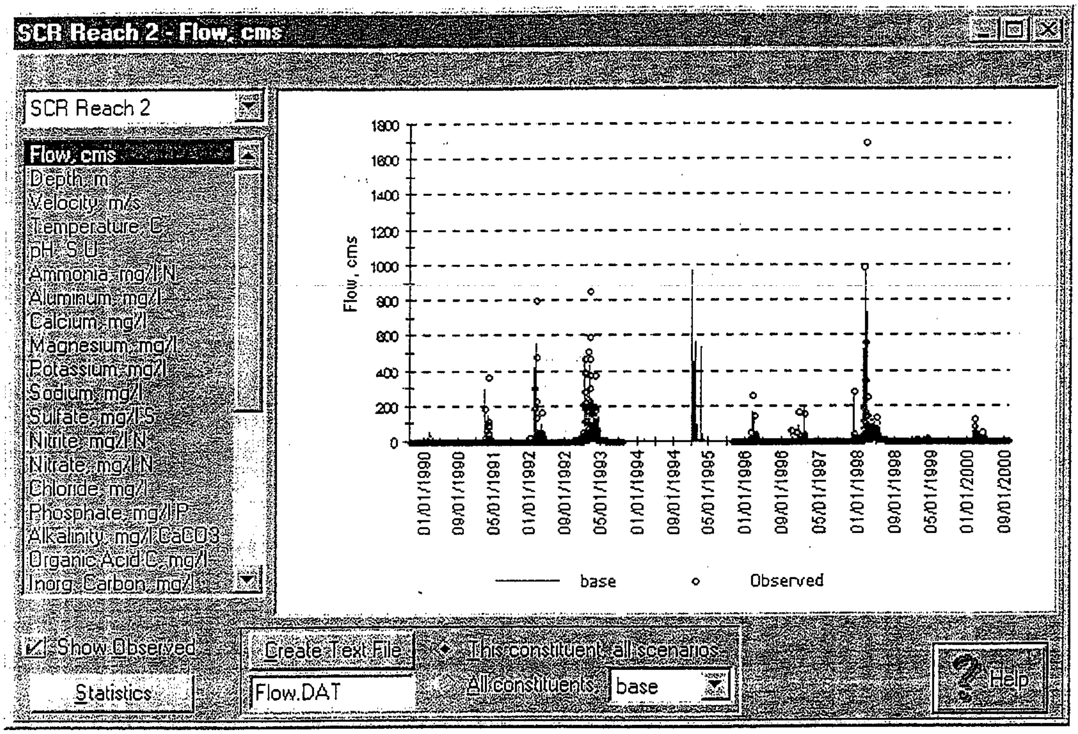


Figure 80: Simulated and Observed Flow, Santa Clara River at Montalvo (n = 3288; r = 0.78; relative error = -32.1%)

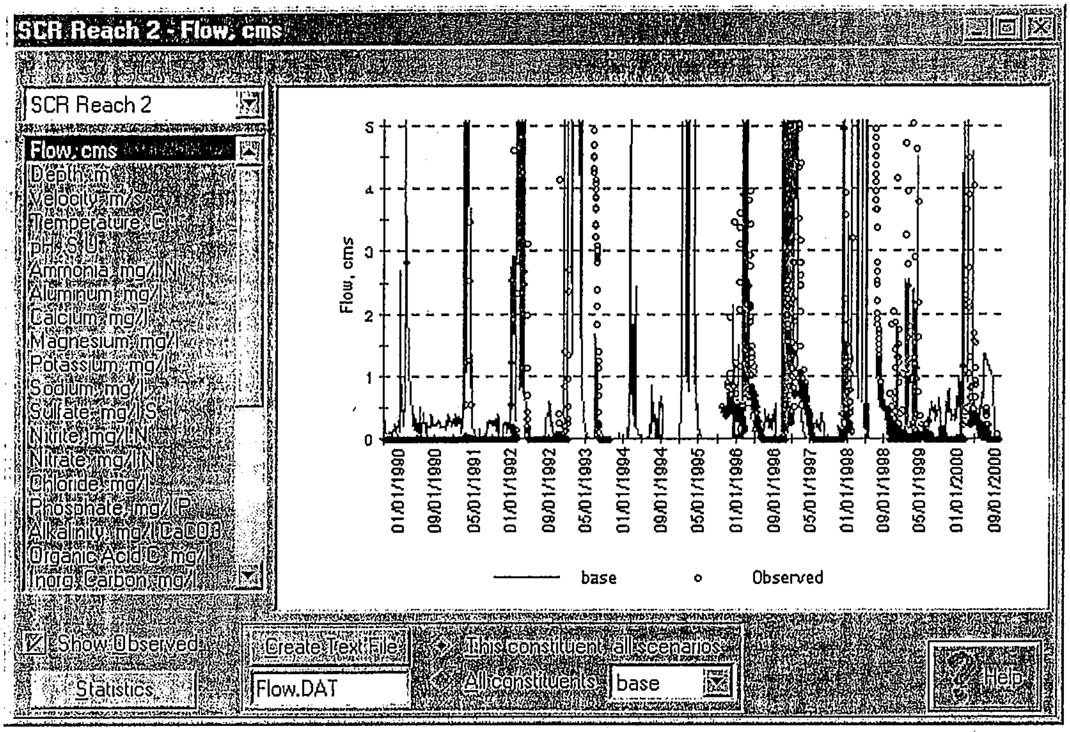


Figure 81: Simulated and Observed Flow: 0-5 m^3/s, Santa Clara River at Montalvo (n = 2670; r = 0.28; relative error = +35.7%)

Water Quality

Water quality in this river section is controlled by the different sources of water. The sources include the Santa Paula WWRF, gain from groundwater near Willard Road, and flow from Sespe Creek. The season of the year and whether or not the year is wet or dry can change the proportion of flow sources reaching the Freeman Diversion.

Table 24 shows that much of the flow reaching the Freeman Diversion in a dry year comes from groundwater gain at Willard Road and the Santa Paula Wastewater Reclamation Plant. That is augmented by Sespe Creek flow reaching Freeman in early spring. Table 25 shows that Sespe Creek and Willard Road groundwater contribute much more flow than the Santa Paula WWRP in a wet year.

Key Assumptions

The initial groundwater nitrate concentration in the Willard Road area is important to water quality simulation because of the large volume of groundwater accretion. Because there is a large amount of storage in the soil, the initial concentration does not change very much over the course of the simulation period. Therefore, the initial concentration represents the concentration of the accreted groundwater.

Well monitoring data in the Willard Road area has nitrate concentrations varying from 0 to 32 mg/l as N, with an average of 5.7 mg/l and a median of 3.4 mg/l. Water quality monitoring data from the Willard Road area show a maximum nitrate concentration of 3.5 mg/l and an average of 1.74 mg/l. Flow in the river at this location is at times exclusively from local groundwater but is often combined with flow from Sespe Creek, whose measured nitrate concentration is always less than 1 mg/l N. Based on this information, the concentration in the local groundwater should be above the observed average of 1.74 mg/l and below the observed maximum of 3.5 mg/l. Calibration of the initial concentration found that 2.5 mg/l provides the best fit with observed data. Refer to the Sensitivity Analysis section of this report for an analysis of how a different assumption about groundwater concentration affects simulation results in Reach 3.

As is the case for Reach 8 and Reach 7, denitrification was an important process in the area downstream of the Santa Paula WWRP. The denitrification rate used was the same as in the area near the Saugus and Valencia WWRFs, 0.5/day.

Simulation Results

Simulations of water quality between the Blue Cut gage and Sespe Creek (the "dry gap") are subject to intermittent flow. When there is zero flow, there is no water quality output. Figure 83 through Figure 91 show the water quality when flow is present in this section of the Santa Clara River. Red circles have been added to some figures to make observed data points more visible, not to add emphasis. Figure 82 shows the locations of the water quality monitoring stations.

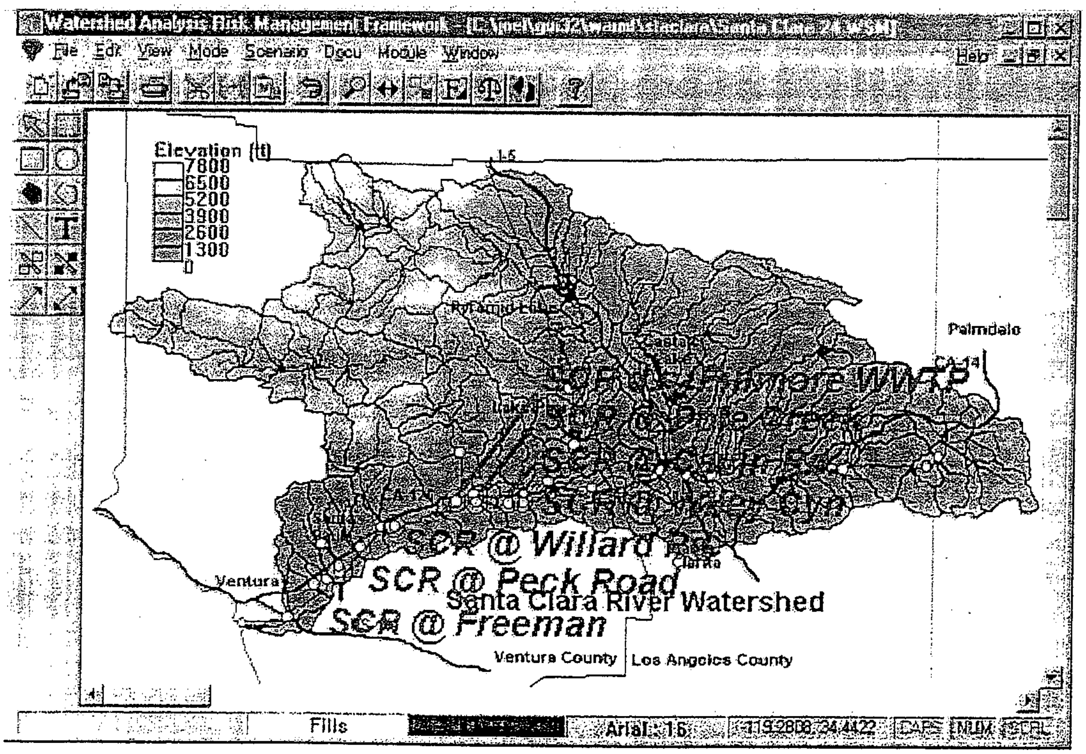


Figure 82: Water quality monitoring stations for Santa Clara River reaches 3-6

For the Santa Clara River at Wiley Canyon, the model matches the low nitrate concentrations for the times when there are observed data. At Cavin Road, the model matches the low nitrate data points but shows no flow when there is a measured value over 2 mg/l N. At Pole Creek, the model matched the observed nitrate concentrations in 1998 and 1999, but overpredicted nitrate in 2000. Downstream of the Fillmore WWTP, nitrite and nitrate are matched well.

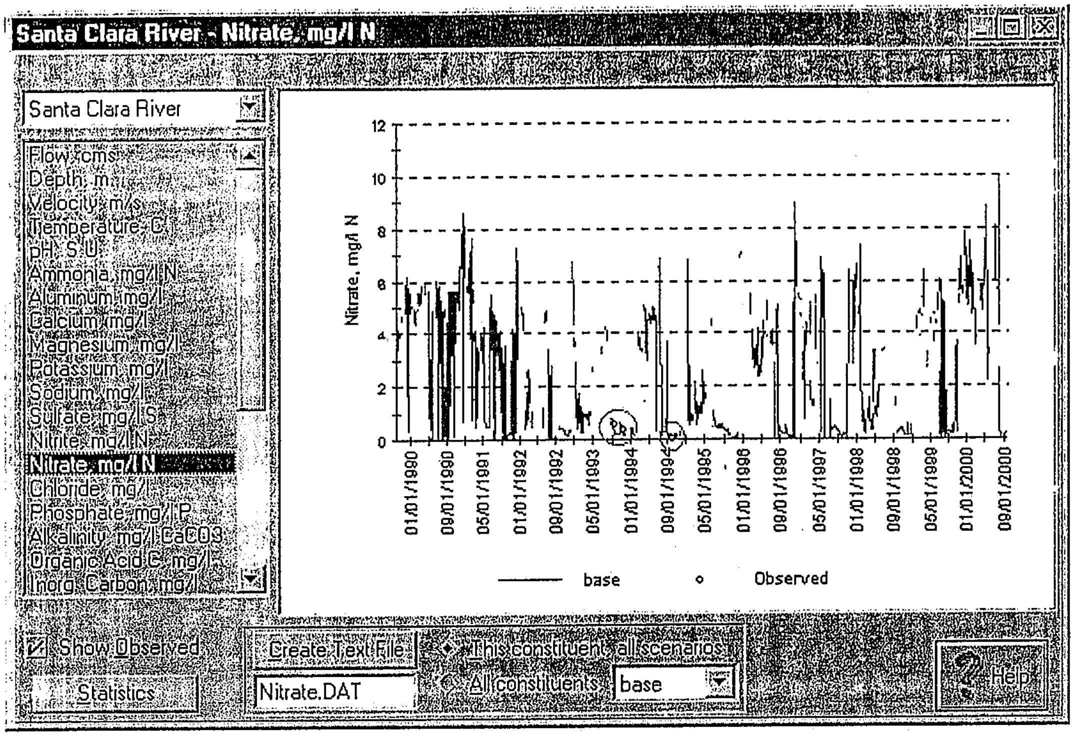
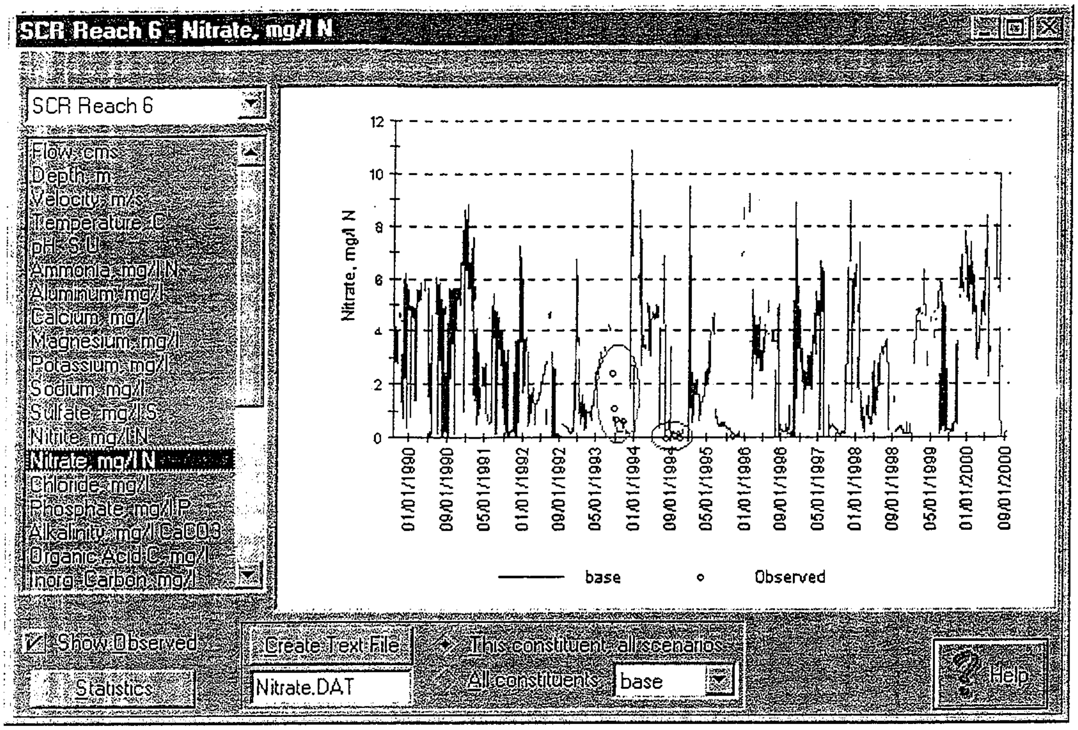


Figure 83: Simulated and Observed Nitrate for the Santa Clara River at Wiley Canyon (n = 3; relative error = 0.13 mg/l; absolute error = 0.13 mg/l)



SCR Reach 6

☑ Show Observed

Nitrate.DAT

● This constituent, all scenarios

○ All constituents: base

Figure 84: Simulated and Observed Nitrate for the Santa Clara River at Cavin Road (n = 7; relative error = -0.24 mg/l; absolute error = 0.13 mg/l)

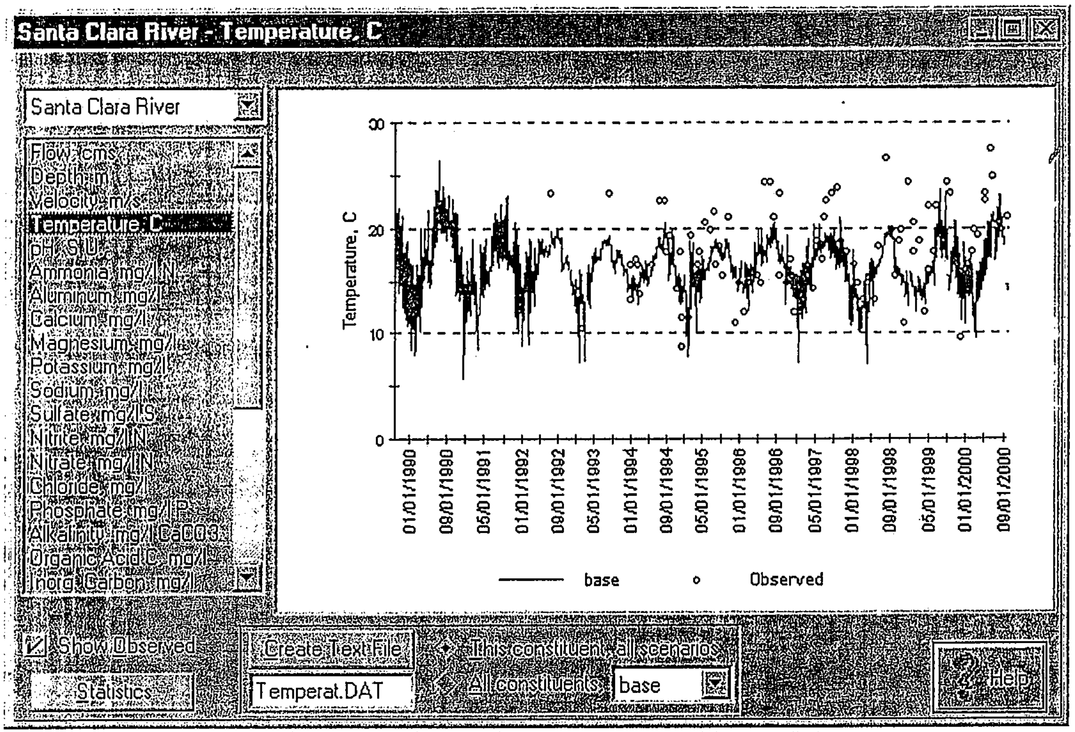


Figure 85: Simulated and Observed Temperature for the Santa Clara River at Pole Creek (n = 96; relative error = -1.83 °C; absolute error = 3.02 °C)

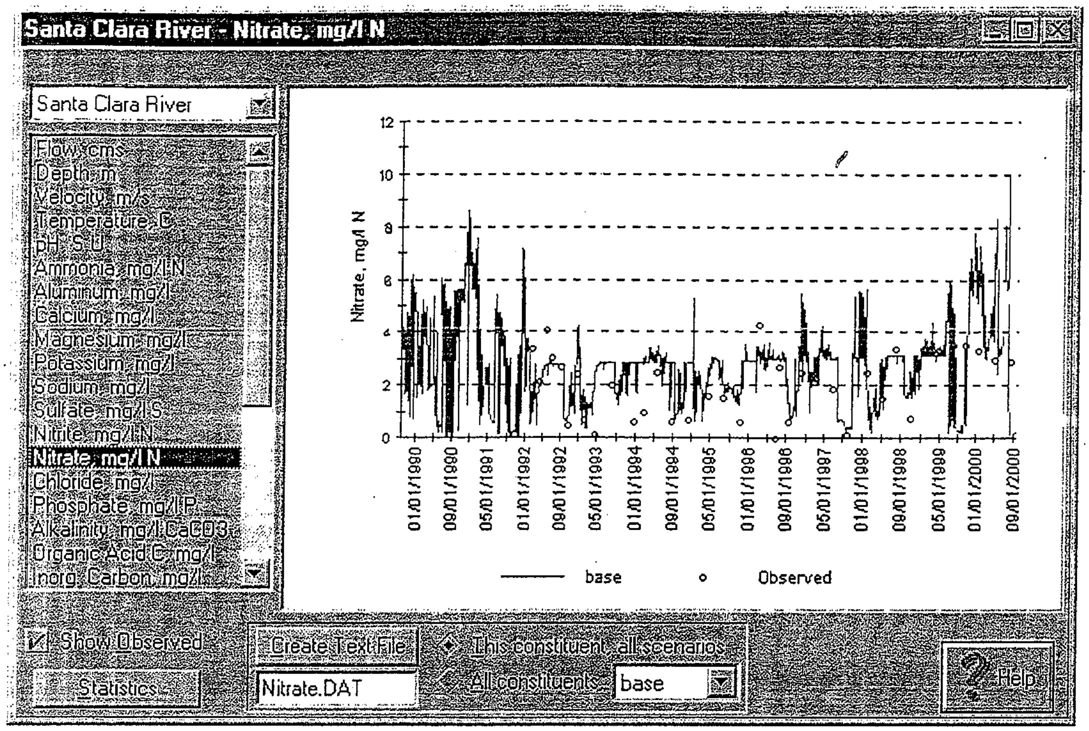


Figure 86: Simulated and Observed Nitrate for the Santa Clara River at Pole Creek (n = 37; relative error = 0.67 mg/l; absolute error = 1.17 mg/l)

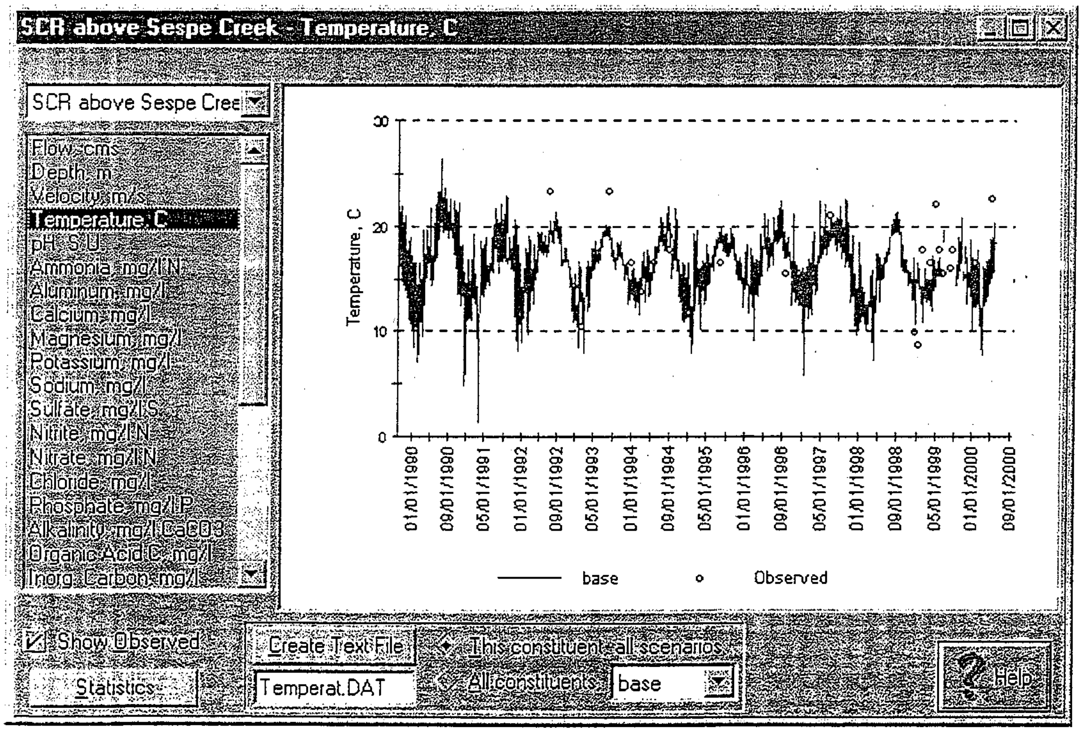


Figure 87: Simulated and Observed Temperature for the Santa Clara River d.s. of Fillmore WRP (n = 23; relative error = -0.91 mg/l; absolute error = 2.96 mg/l)

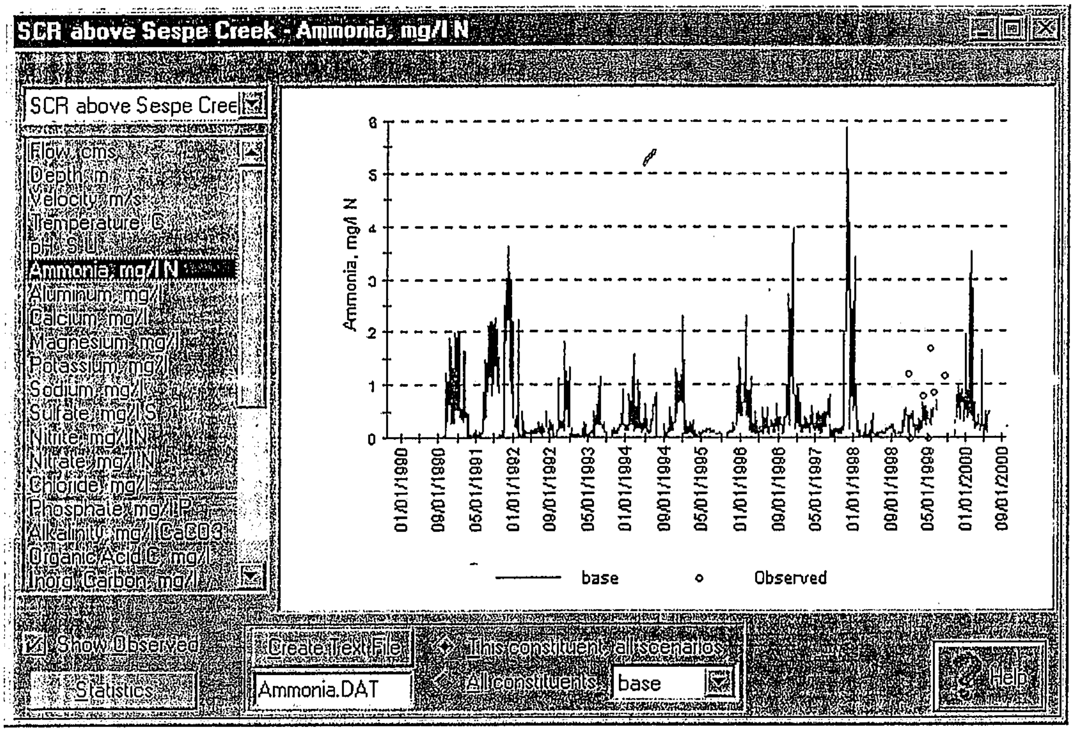
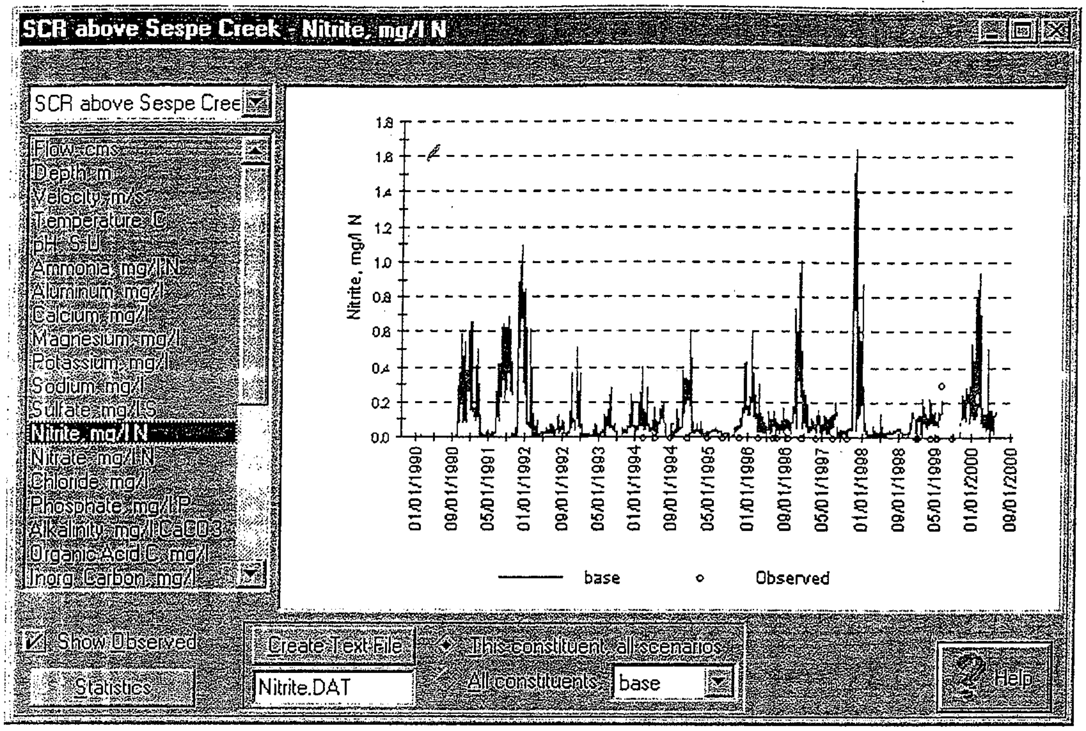


Figure 88: Simulated and Observed Ammonia for the Santa Clara River d.s. of Fillmore WRP (n = 6; relative error = -0.45 mg/l; absolute error = 0.68 mg/l)


SCR above Sespe Creek - Nitrite, mg/l N

SCR above Sespe Creek

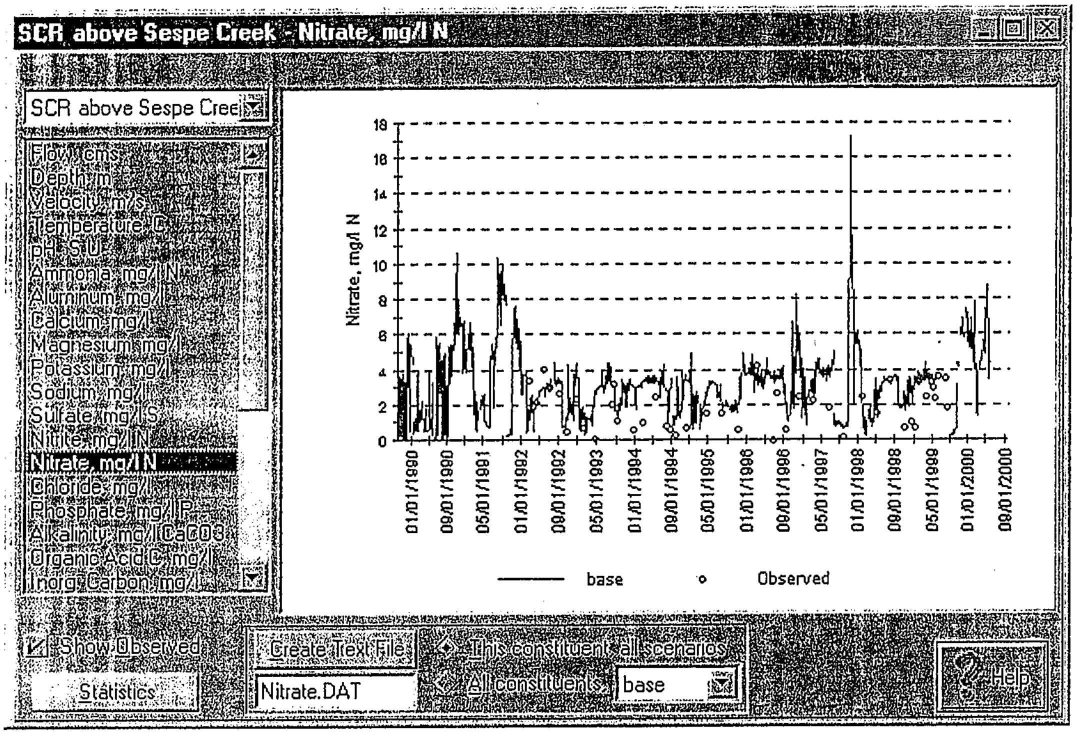
☑ Show Observed

Nitrite.DAT

◆ This constituent, all scenarios

All constituents: base

Figure 89: Simulated and Observed Nitrite for the Santa Clara River downstream of Fillmore WRP (n = 21; relative error = -0.07 mg/l; absolute error = -0.09 mg/l)



SCR above Sespe Cree

☑ Show Observed

Nitrate.DAT

base

Figure 90: Simulated and Observed Nitrate for the Santa Clara River downstream of Fillmore WRP (n =42; relative error = 0.99 mg/l; absolute error = 1.23 mg/l)

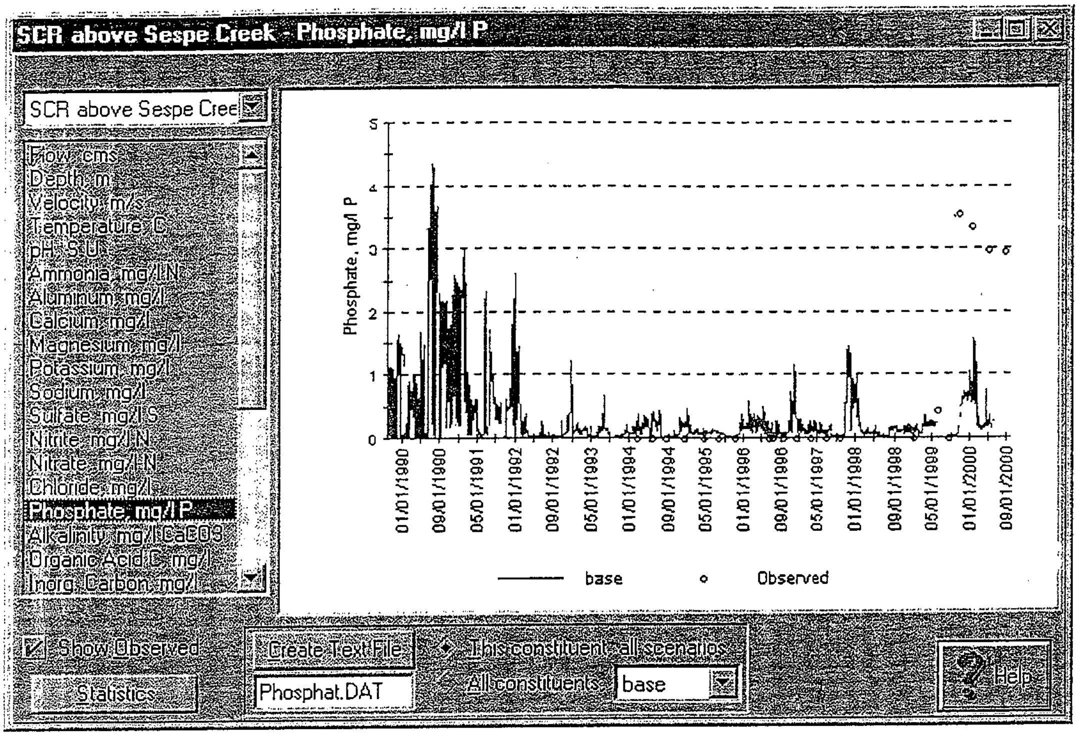


Figure 91: Simulated and Observed Phosphate for the Santa Clara River d.s. of Fillmore WRP (n = 21; relative error = -0.39 mg/l; absolute error = 0.55 mg/l)

From Willard Road to the Freeman Diversion, flow in the Santa Clara River is perennial. Water quality is primarily a blend of Sespe Creek, Willard Road gain from groundwater, and Santa Paula WWRP.

Figure 92 though Figure 95 compare simulation results with observed data for the Santa Clara River at Willard Road. The observed nitrite concentrations at Willard Road are zero. The simulated nitrite varies between 0 and 0.04 mg/l for most of the simulation, which is essentially zero. The predicted nitrate concentration ranges between 0.2 to 3 mg/l, which is in the same range of observed values. The flat spots on the graph correspond to time periods when estimated losses between Sespe Creek and Willard Road result in the flow at Santa Paula Creek being entirely from groundwater gains in the Willard Road area. Note also the gradual increase in nitrate concentration over the course of the simulation from 2.5 mg/l to 3.0 mg/l. Although WARMF is not intended to predict groundwater nitrate concentrations, it is showing a long-term increase in nitrate. The model predicts a phosphate concentration less than 0.2 mg/l, similar to the measured values. There is no phosphate monitoring data from 1990-1992 to corroborate the high phosphate concentrations predicted by the model. Red circles have been added to some figures to make observed data points more visible.

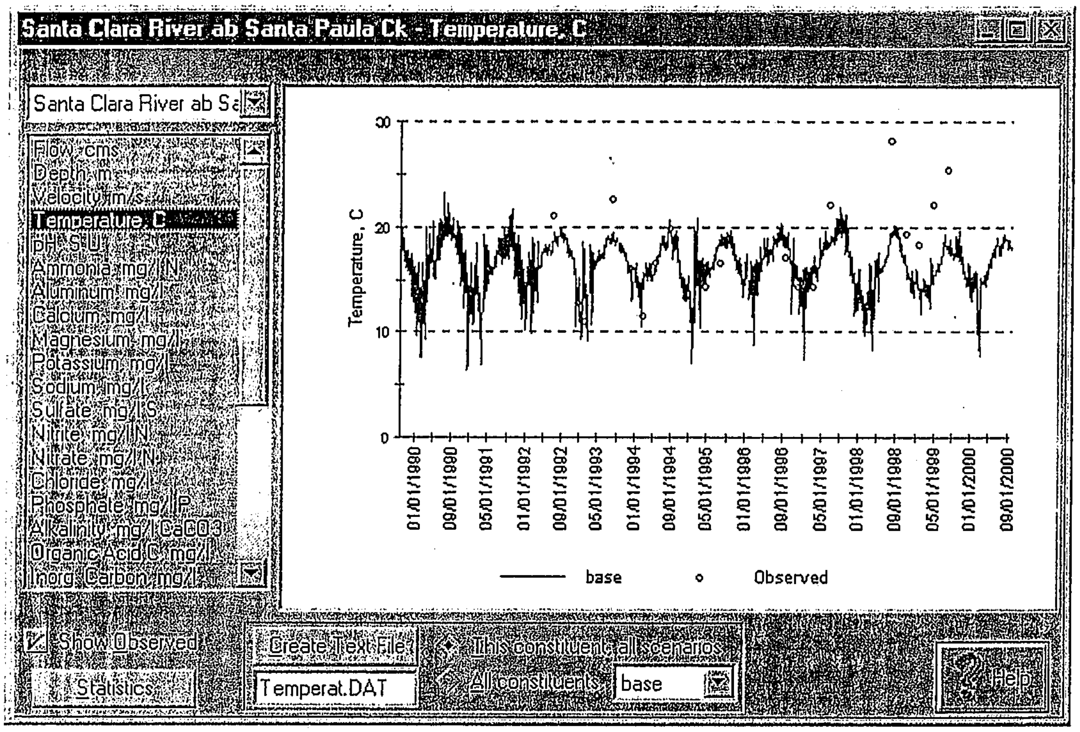
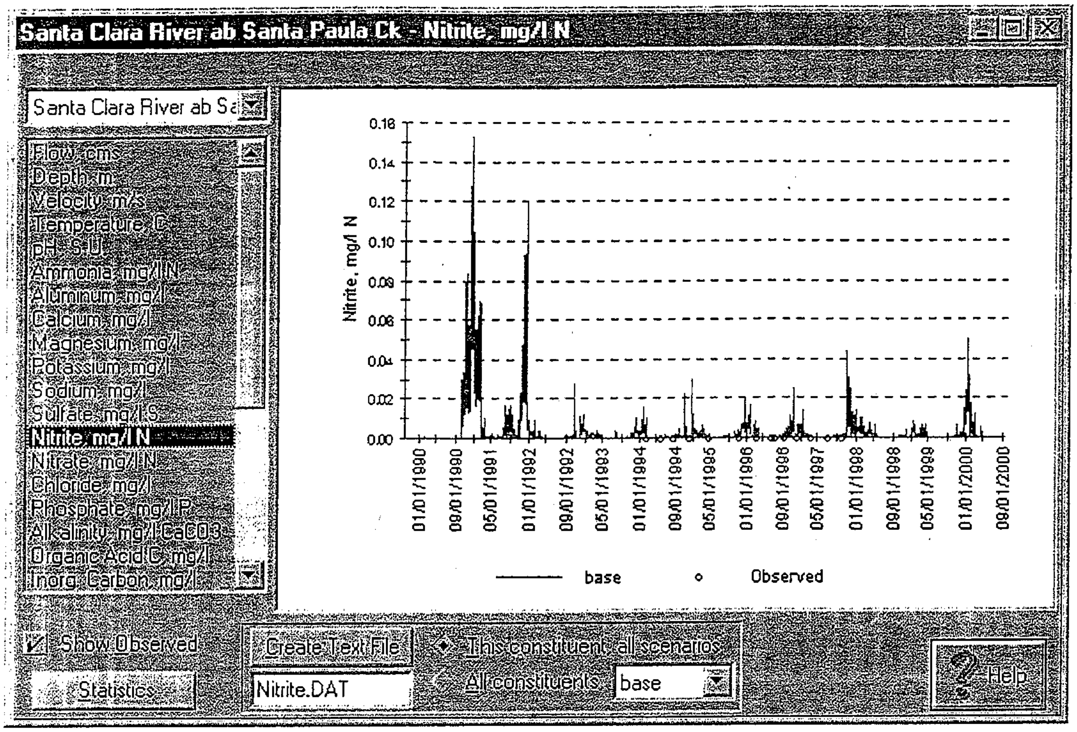


Figure 92: Simulated and Observed Temperature for the Santa Clara River at Willard Road (n = 20; relative error = -1.36 °C; absolute error = 2.83 °C)



☑ Show Observed

Nitrite.DAT

● This constituent, all scenarios

base

Figure 93: Simulated and Observed Nitrite for the Santa Clara River at Willard Road (n = 14; relative error = 0.00 mg/l; absolute error = 0.00 mg/l)

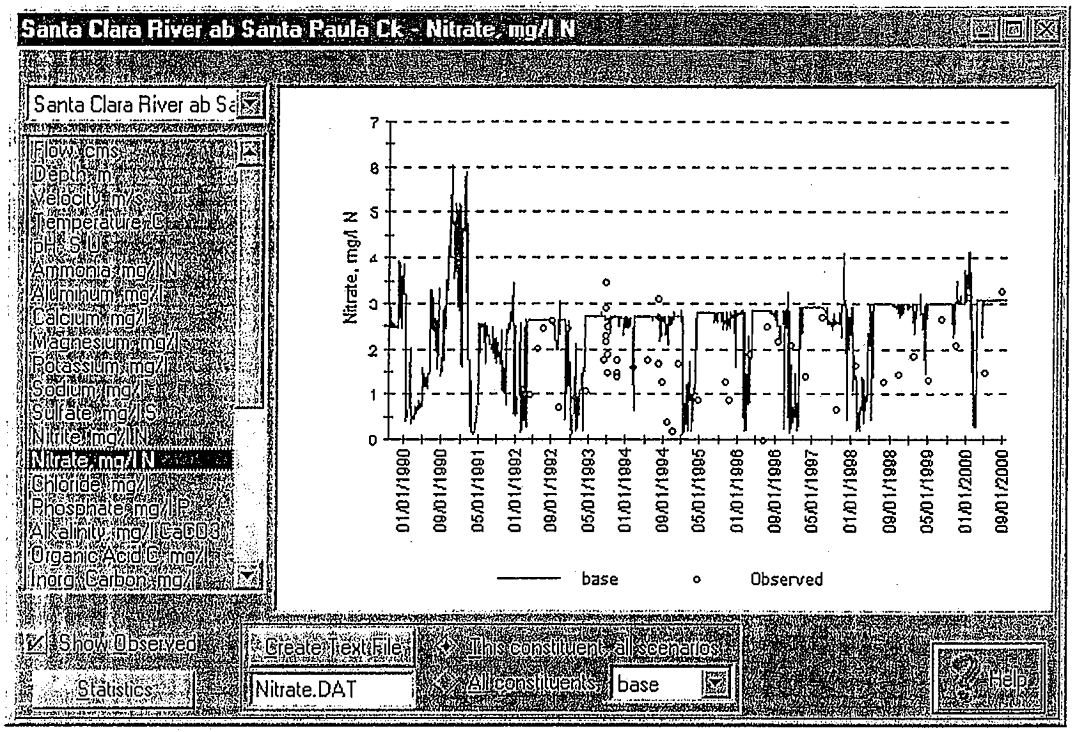
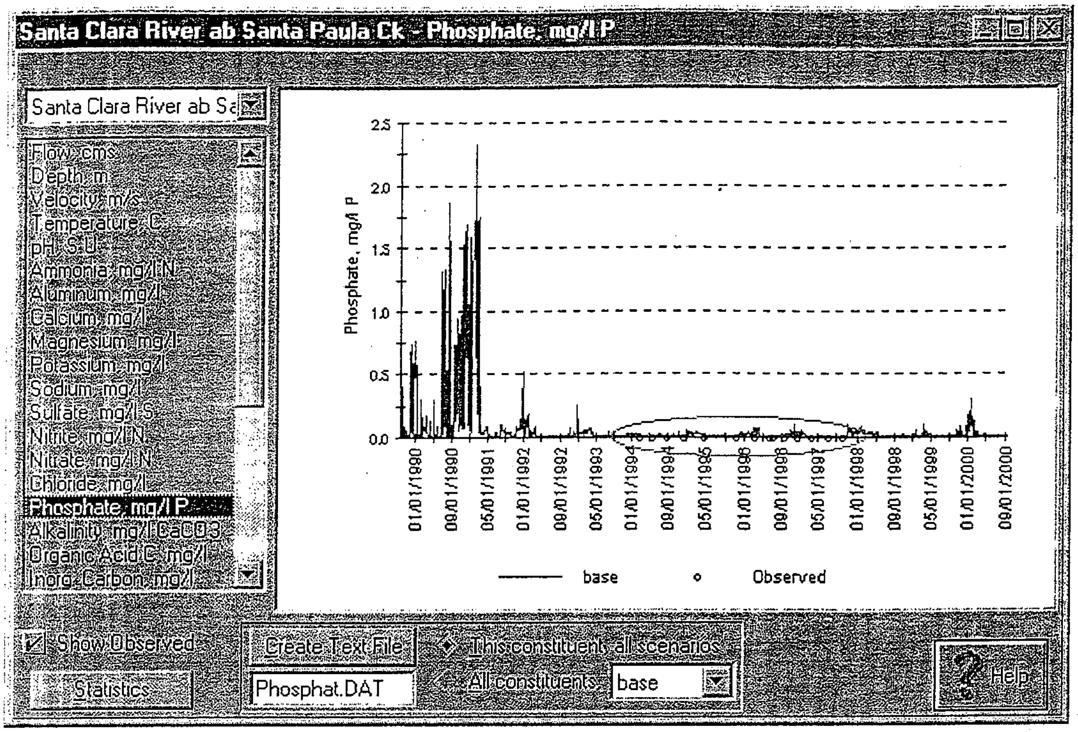


Figure 94: Simulated and Observed Nitrate for the Santa Clara River at Willard Road
(n = 48; relative error = 0.85 mg/l; absolute error = 0.95 mg/l)



Santa Clara River ab Sa

☑ Show Observed

Phosphat.DAT

◆ This constituent, all scenarios

All constituents: base

Figure 95: Simulated and Observed Phosphate for the Santa Clara River at Willard Road (n = 14; relative error = 0.02 mg/l; absolute error = 0.02 mg/l)

Figure 96 through Figure 100 compare the simulated and observed temperature and concentrations of nitrite, nitrate, and phosphate for the Santa Clara River at Peck Road, immediately downstream of the Santa Paula WWRP. Ammonia concentrations are underpredicted in the model, possibly because the model's representation of the watershed assumes that the effluent will be able to react throughout the entire reach from Santa Paula Creek to Peck Road, whereas the monitoring data was collected 300 feet downstream of where the effluent enters the river. The simulated nitrite concentration ranges generally from 0 to 0.2 mg/l compared to the observed values of 0 to 0.3 mg/l. The simulated nitrate concentration generally ranges from 0.1 to 2.5 mg/l, compared to the observed values of 1 to 3 mg/l. The simulated phosphate concentration is generally below 0.2 mg/l as observed. However, the observed data shows two data points with a concentration as high as 2 mg/l, which was not simulated by the model.

The peaks in nitrite and nitrate concentrations in fall 1990 / winter 1991 reflect a very dry flow condition when effluent from the Santa Paula WWRP represented as much as 50% of the total flow in the Santa Clara River. The discussion of model performance at Freeman Diversion has a more in-depth analysis of this time period.

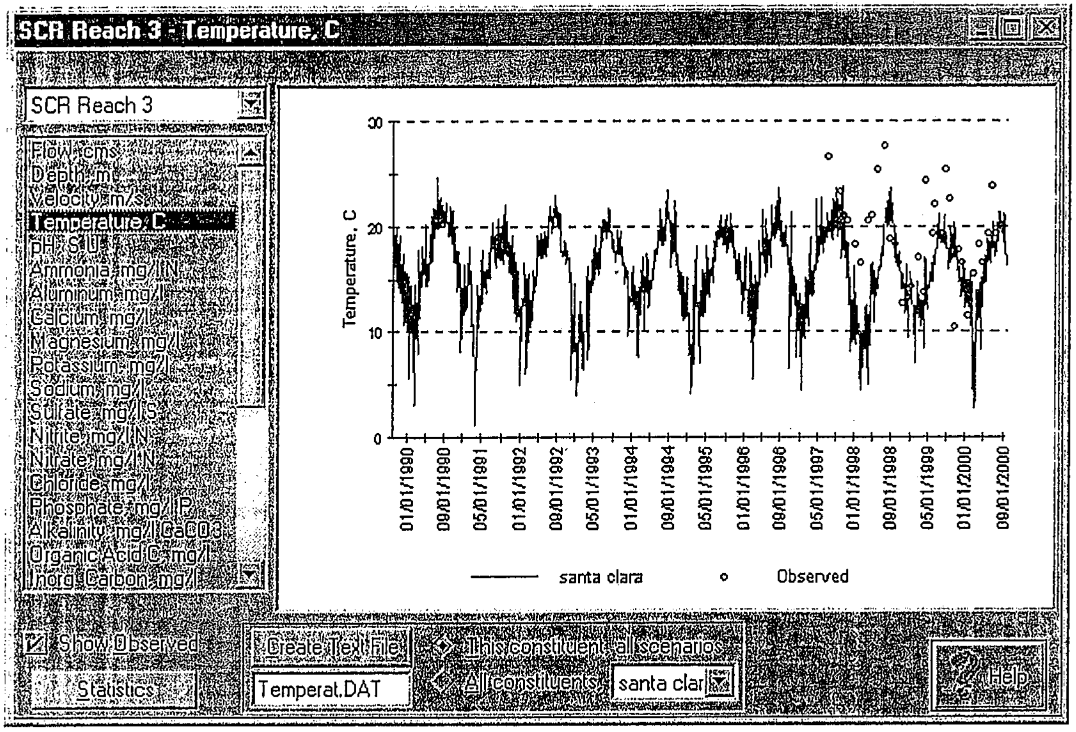
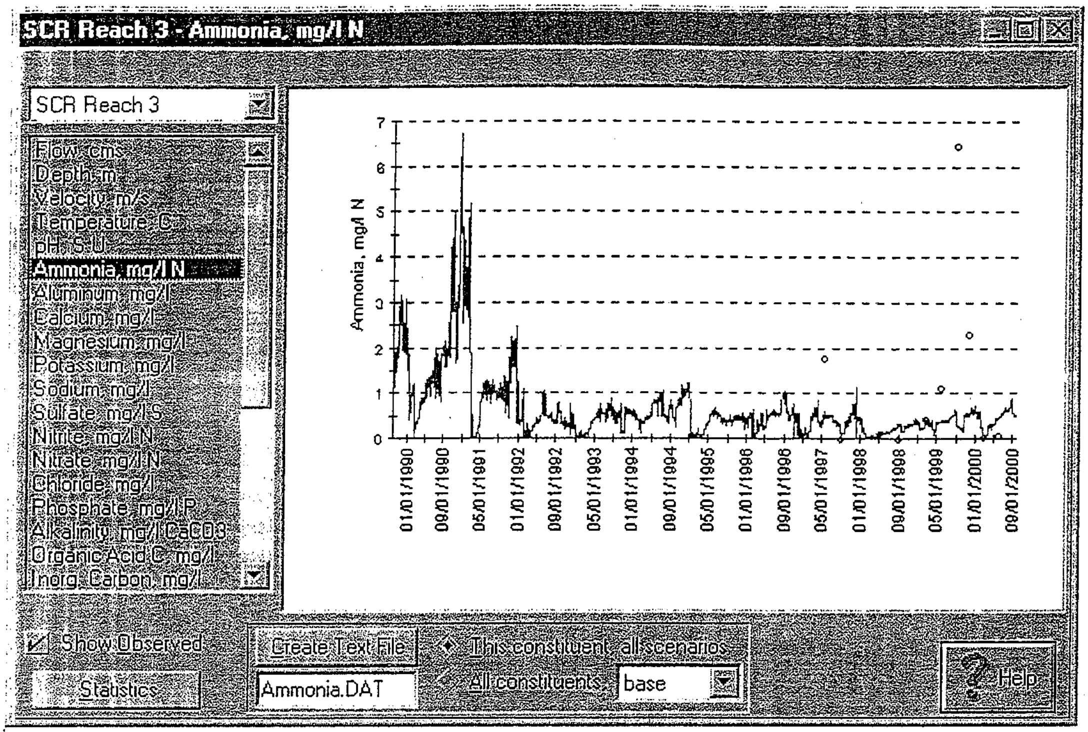


Figure 96: Simulated and Observed Temperature for the Santa Clara River at Peck Road (n = 36; relative error = -3.36 °C; absolute error = 4.10 °C)



☑ Show Observed

Ammonia.DAT

● This constituent, all scenarios

○ All constituents: base

Figure 97: Simulated and Observed Ammonia for the Santa Clara River at Peck Road (n = 9; relative error = -1.00 mg/l; absolute error = 1.16 mg/l)

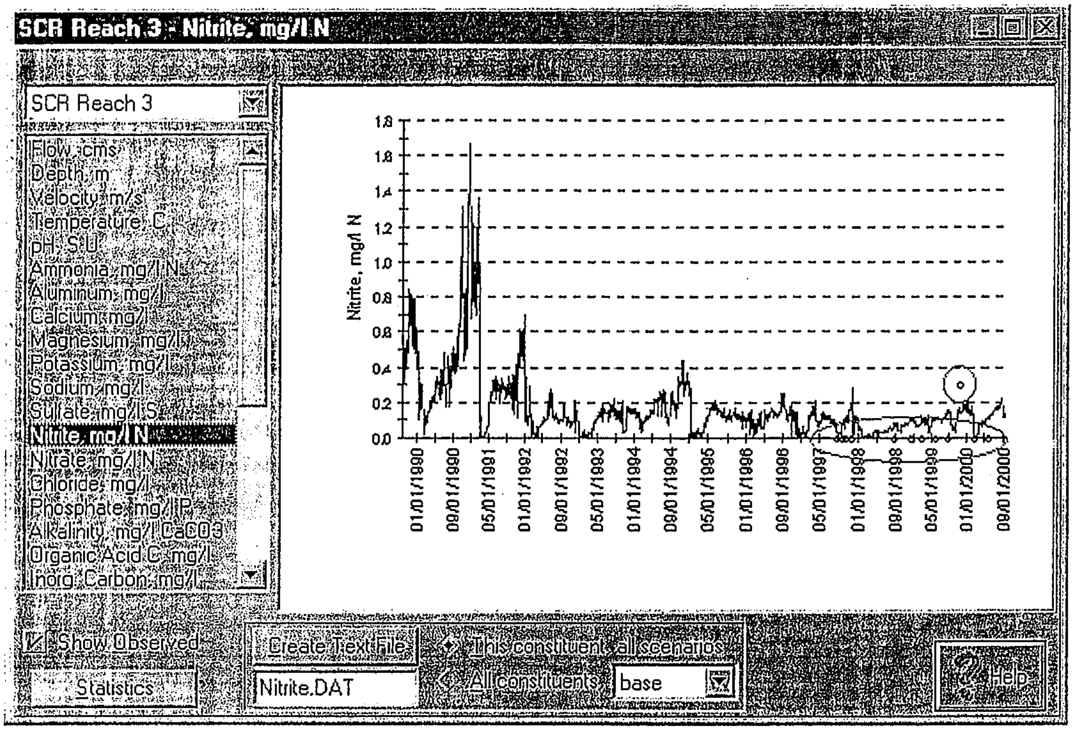


Figure 98: Simulated and Observed Nitrite for the Santa Clara River at Peck Road
(n = 12; relative error = 0.08 mg/l; absolute error = 0.10 mg/l)

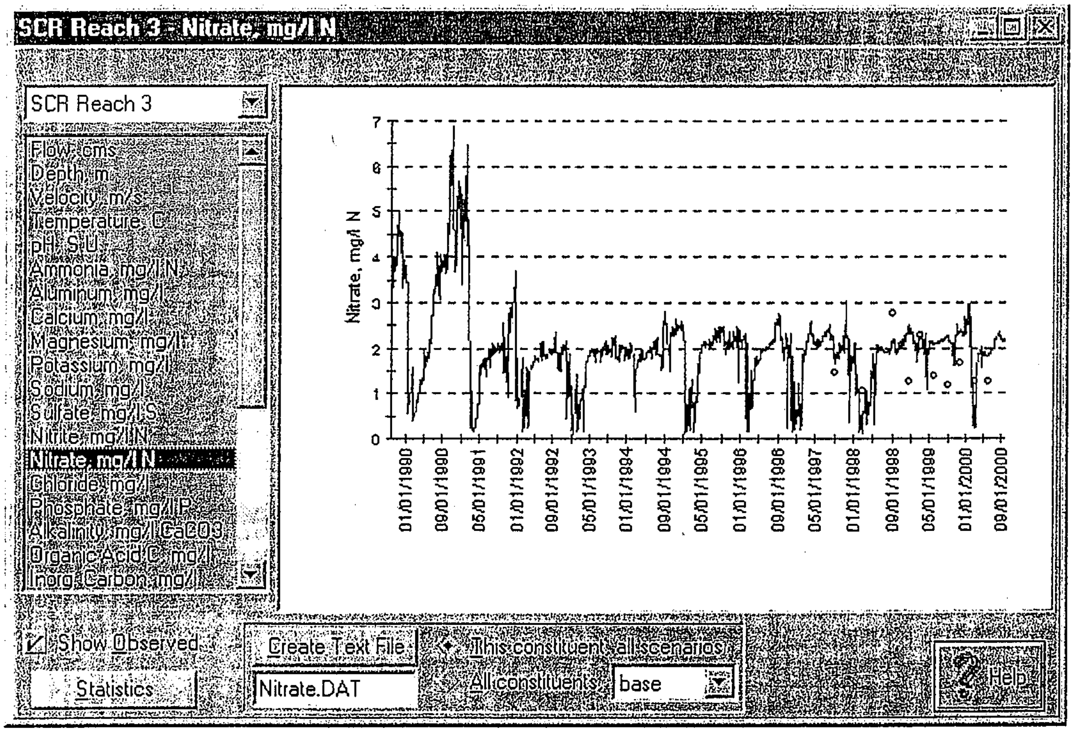


Figure 99: Simulated and Observed Nitrate for the Santa Clara River at Peck Road
(n = 11; relative error = 0.24 mg/l; absolute error = 0.56 mg/l

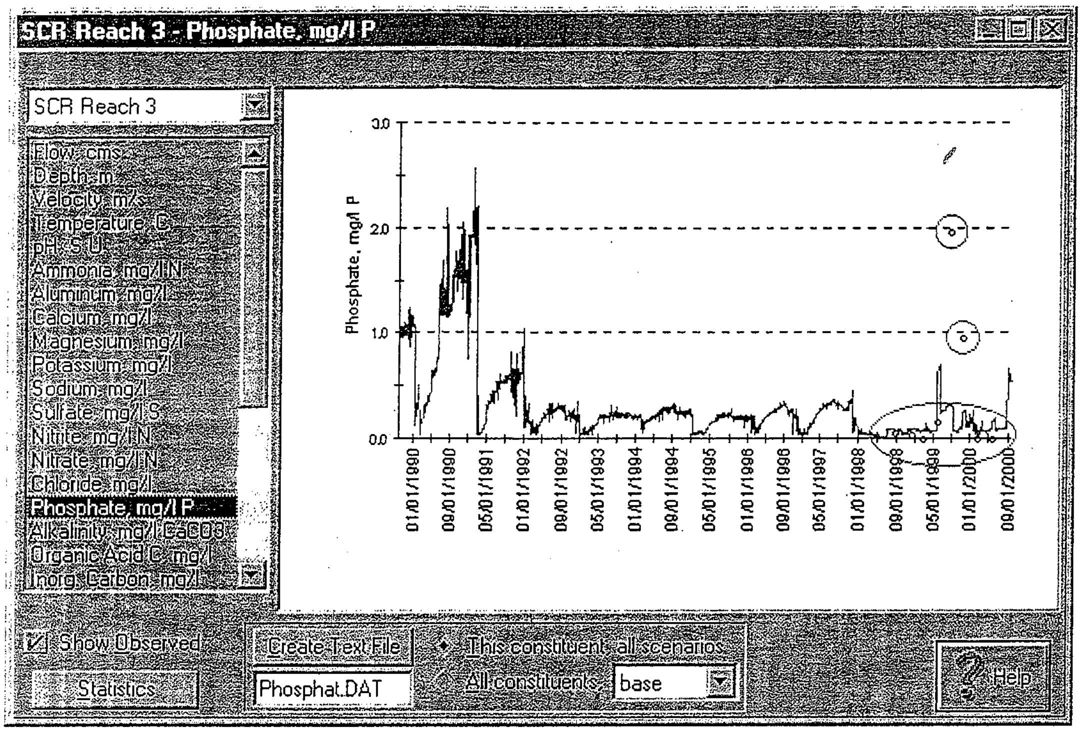


Figure 100: Simulated and Observed Phosphate for the Santa Clara River at Peck Road
(n = 8; relative error = -0.24 mg/l; absolute error = 0.35 mg/l)

Figure 102 through Figure 106 present the comparisons of simulated and observed temperature and concentrations of ammonia, nitrite, nitrate, and phosphate for the Santa Clara River at Freeman Diversion. The model predicts low ammonia concentrations as observed. The model also predicts near zero concentrations of nitrite as observed. The observed data show two high values of about 1.2 mg/l, which were not simulated by the model. The model follows the observed nitrate concentration well. Unfortunately, there is no monitoring data to confirm the high predicted nitrate concentration for 1990-1991. For phosphate, the model simulates the concentration below 0.5 mg/l as observed but data is lacking to confirm the high simulated concentrations in 1990-1992.

The concentration peaks of ammonia, nitrite, and nitrate in fall 1990 / winter 1991 occurred when flow was very low. Daily discharge data is available from 10/1/1991 through 2/26/1991 when flow was lowest for Sespe Creek, Santa Paula Creek, and the Santa Paula WWRP. Daily flow estimates for the Willard Road groundwater source were provided by UWCD. UWCD also estimated daily flow in the Santa Clara River above Sespe Creek to be zero during the whole time period (UWCD (McEachron) 2002). During this period, flow from the Santa Paula WWRP represented an average of 42%, and as much as 50%, of the flow reaching the Freeman diversion. On average, 33% of the flow came from Willard Road. The remaining 25% came from Santa Paula and Sespe Creeks, but the combined total from these sources ranged as low as 11% of the total. The daily breakdown of flow is shown in Figure 101.

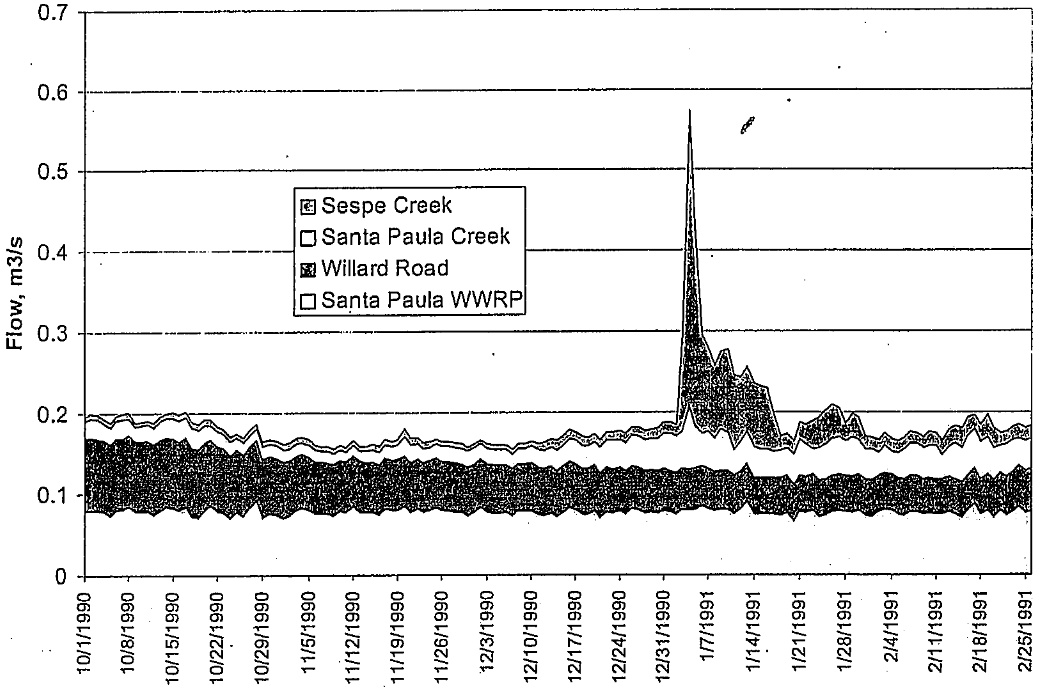


Figure 101: Breakdown of Flow at Freeman Diversion, 10/1/1990-2/26/1991

Observed data indicates that Sespe Creek and Santa Paula Creek have low nitrate concentration (< 1 mg/l N). Willard Road groundwater was estimated to have a concentration of 2.5 mg/l, which is lower than the median groundwater concentration from local well data. Effluent monitoring data from the Santa Paula WWRP indicates discharged nitrate concentrations from 1.4 to 8.7 mg/l as N. However, measured ammonia discharge concentrations from the Santa Paula WWRP ranged from 16 to 34 mg/l N. Much of that ammonia is nitrified in the river. Even taking denitrification of nitrate into account, a mass balance indicates that high nitrate must have occurred during that time period. A discussion of this has been added to the revised report.

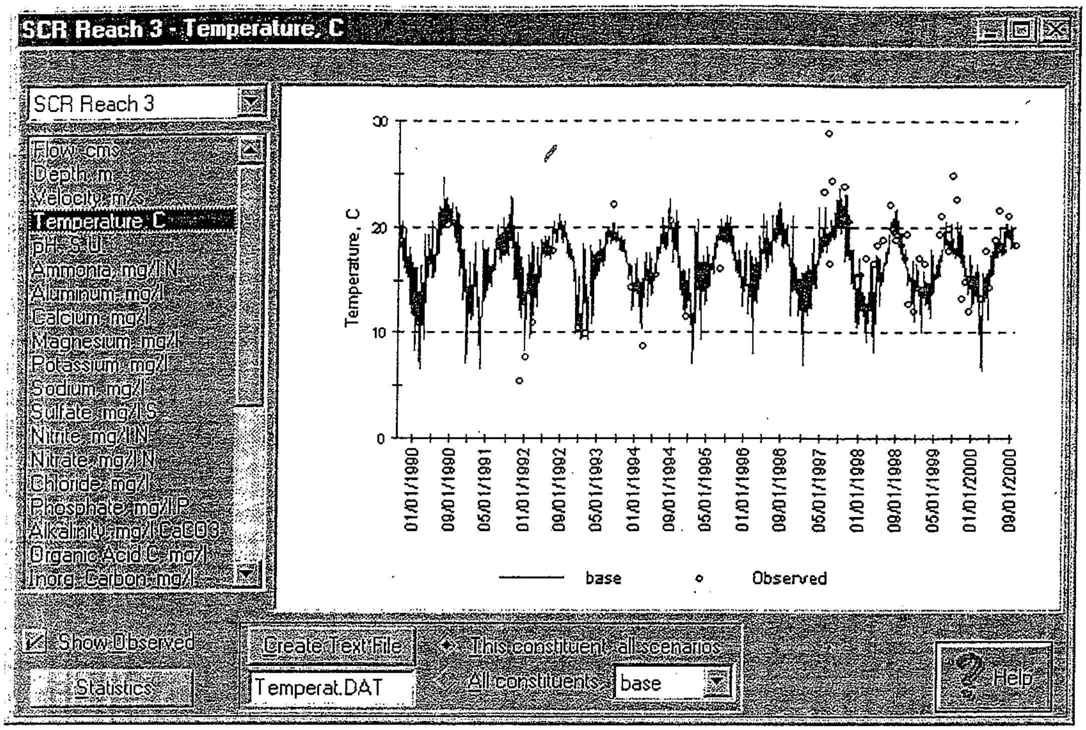
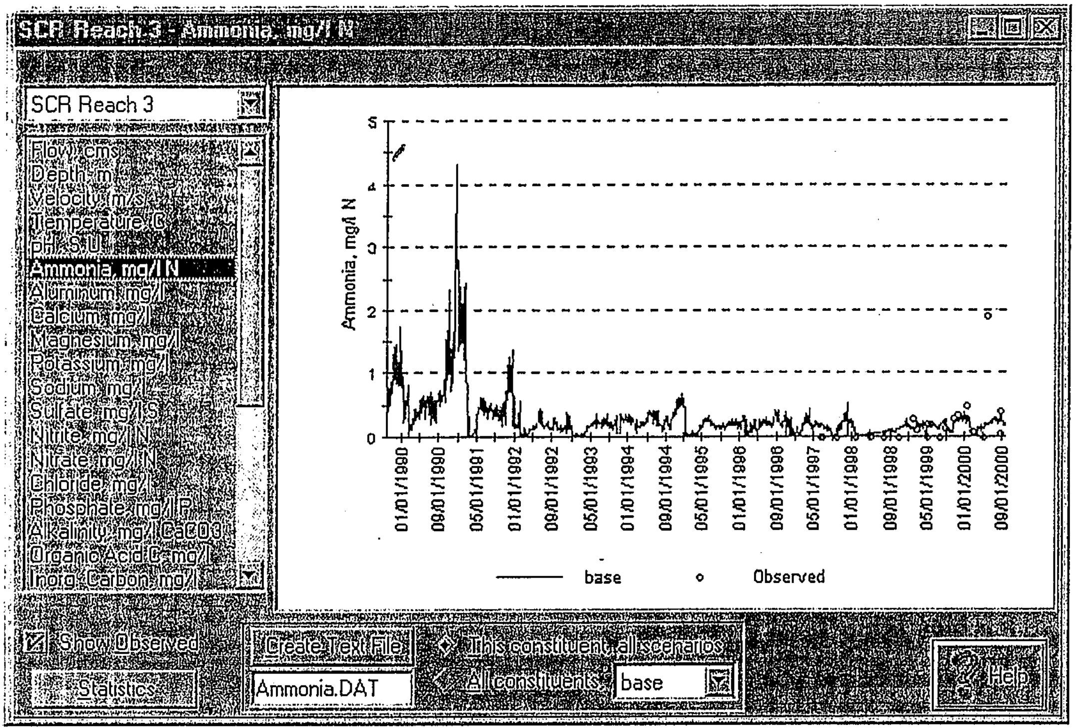


Figure 102: Simulated and Observed Temperature for the Santa Clara River at Freeman Diversion (n = 53; relative error = -0.70 °C; absolute error = 2.72 °C)

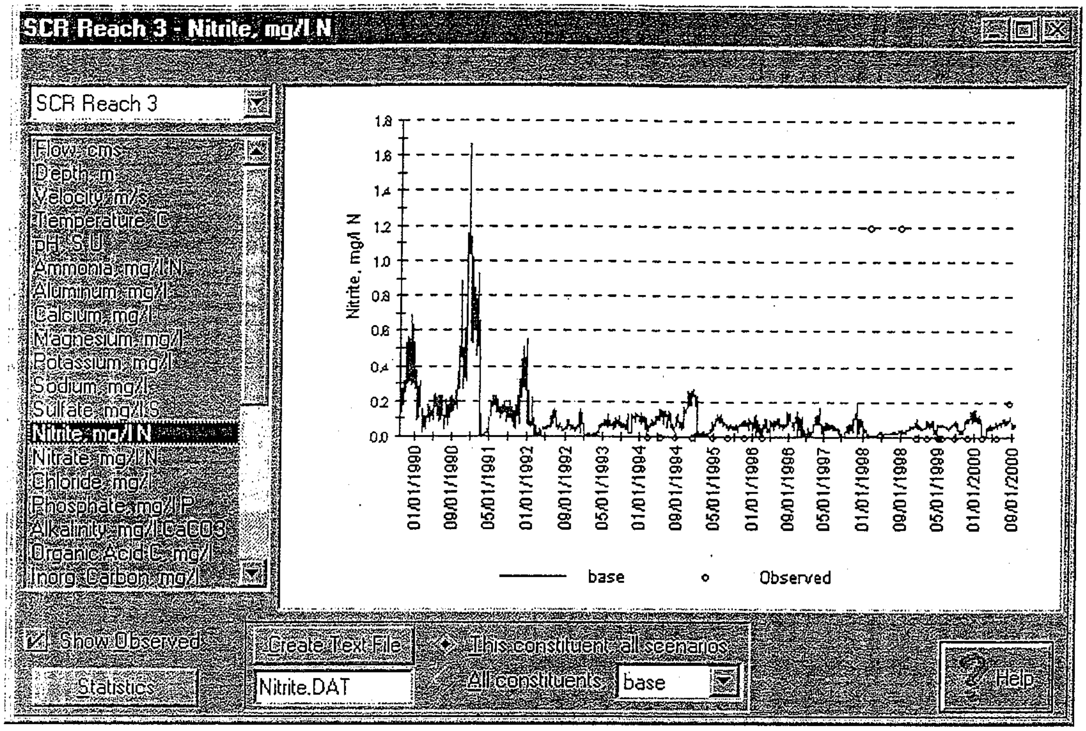


☒ Show Observed

Ammonia.DAT

base

Figure 103: Simulated and Observed Ammonia for the Santa Clara River at Freeman Diversion (n = 22; relative error = -0.04 mg/l; absolute error = 0.21 mg/l)



SCR Reach 3 - Nitrite, mg/l N

SCR Reach 3

Nitrite, mg/l N

☑ Show Observed

Nitrite.DAT

● This constituent, all scenarios

○ All constituents base

Figure 104: Simulated and Observed Nitrite for the Santa Clara River at Freeman Diversion (n = 19; relative error = -0.06 mg/l; absolute error = 0.20 mg/l)

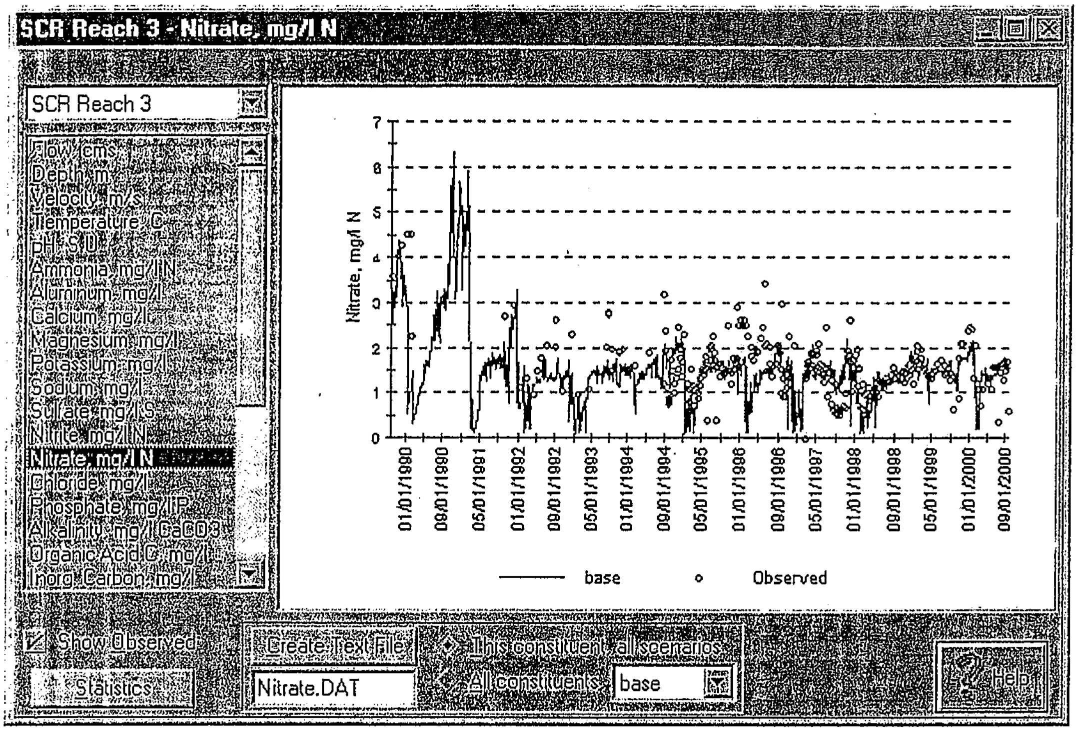


Figure 105: Simulated and Observed Nitrate for the Santa Clara River at Freeman Diversion (n = 276; relative error = -0.14 mg/l; absolute error = 0.43 mg/l)

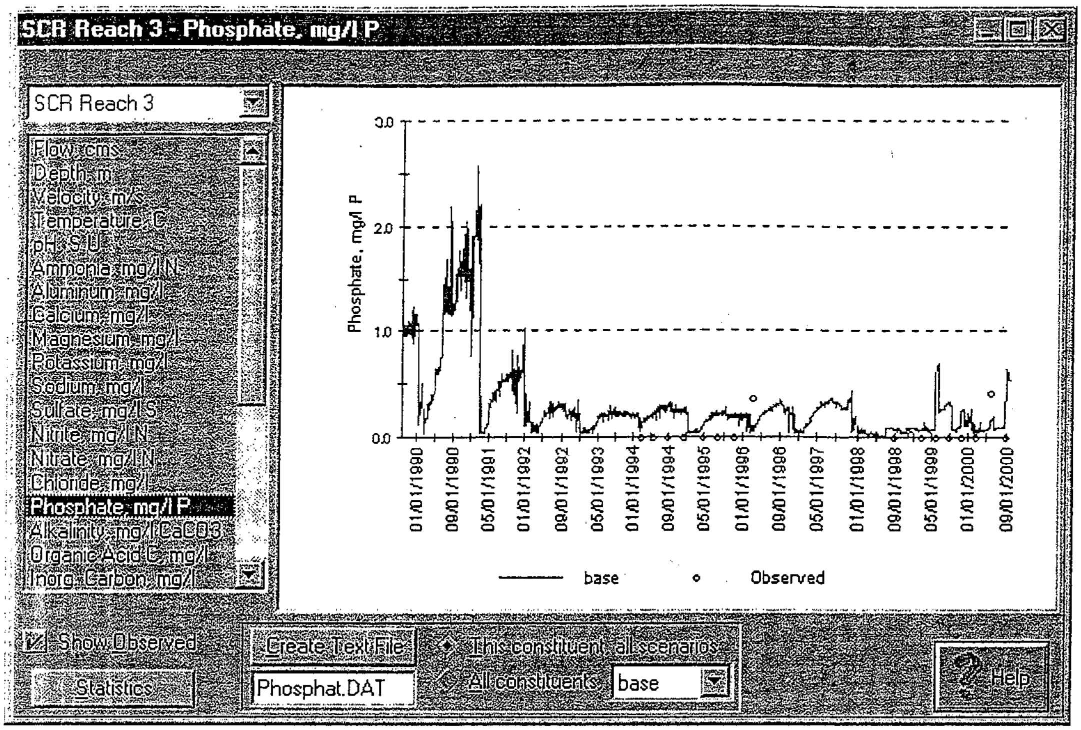


Figure 106: Simulated and Observed Phosphate for the Santa Clara River at Freeman Diversion (n = 17; relative error = 0.11 mg/l; absolute error = 0.18 mg/l)

Wheeler Canyon / Todd Barranca

This impaired tributary of the Santa Clara River is divided into two sections: Wheeler Canyon is in the mountains, and Todd Barranca is in the lowlands near the river. The watershed area of Todd Barranca is very small, but the area it passes through has agricultural use and groundwater discharges. The water table is high in this area, indicating the likelihood of groundwater entering Todd Barranca.

Hydrology

There is no gaging station for Todd Barranca, so its hydrology is largely unknown.

Key Assumptions

The only basis to use to calibrate the hydrology of the watershed was the observed nitrate data. Attempting to follow the range and pattern of this data can help provide a very rough estimate of the hydrology.

Simulation Results

Simulated flow for Todd Barranca is shown in Figure 107 and Figure 108, but there is no observed data with which to compare it. The hydrograph is typical of the area, with sharp peak flows during early spring storms but low base flow. The simulation almost always predicts more than zero flow.

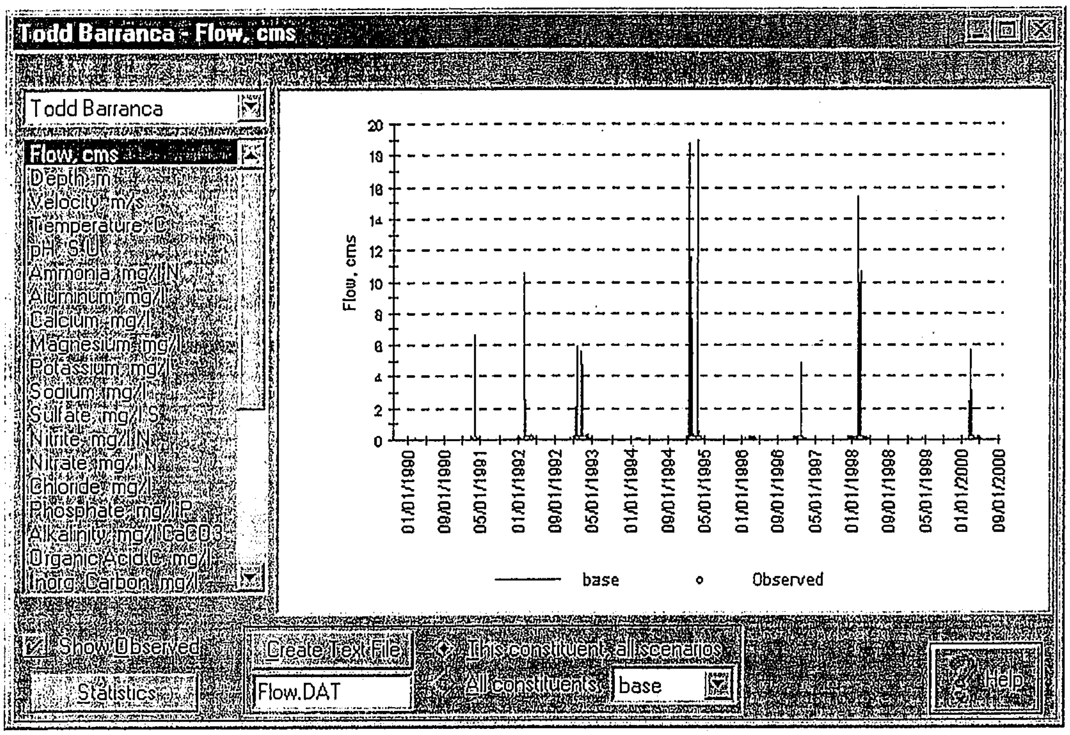


Figure 107: Simulated Flow for Lower Todd Barranca

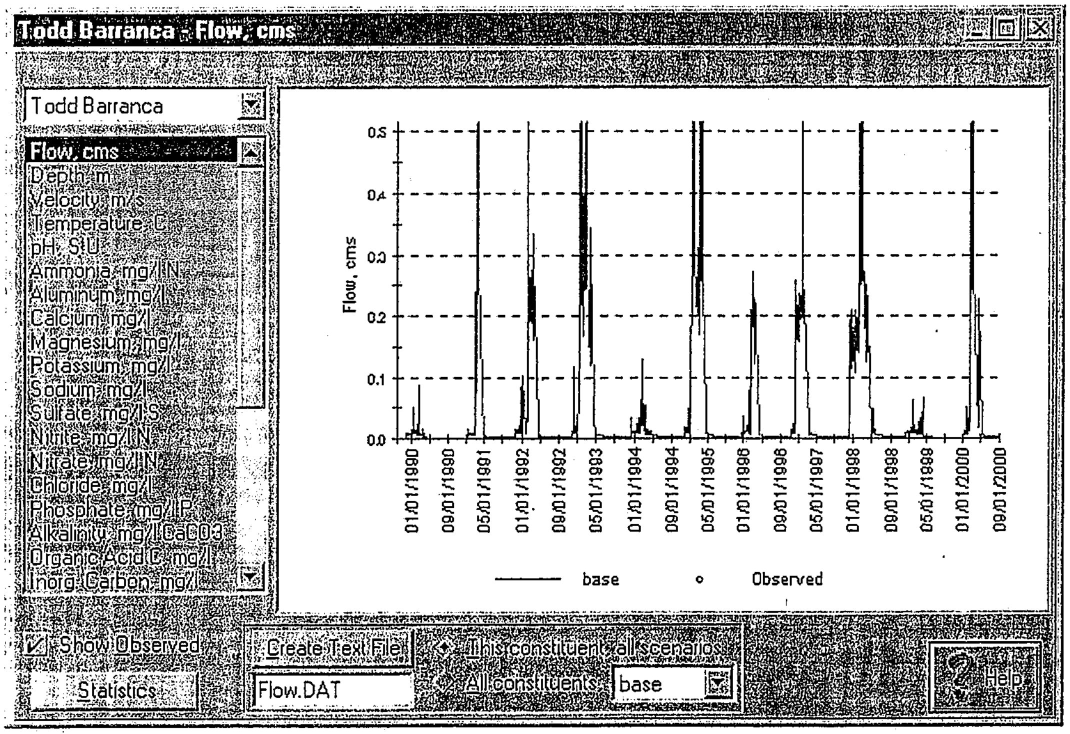


Figure 108: Simulated Flow: 0-0.5 m^3/s for Lower Todd Barranca

Water Quality

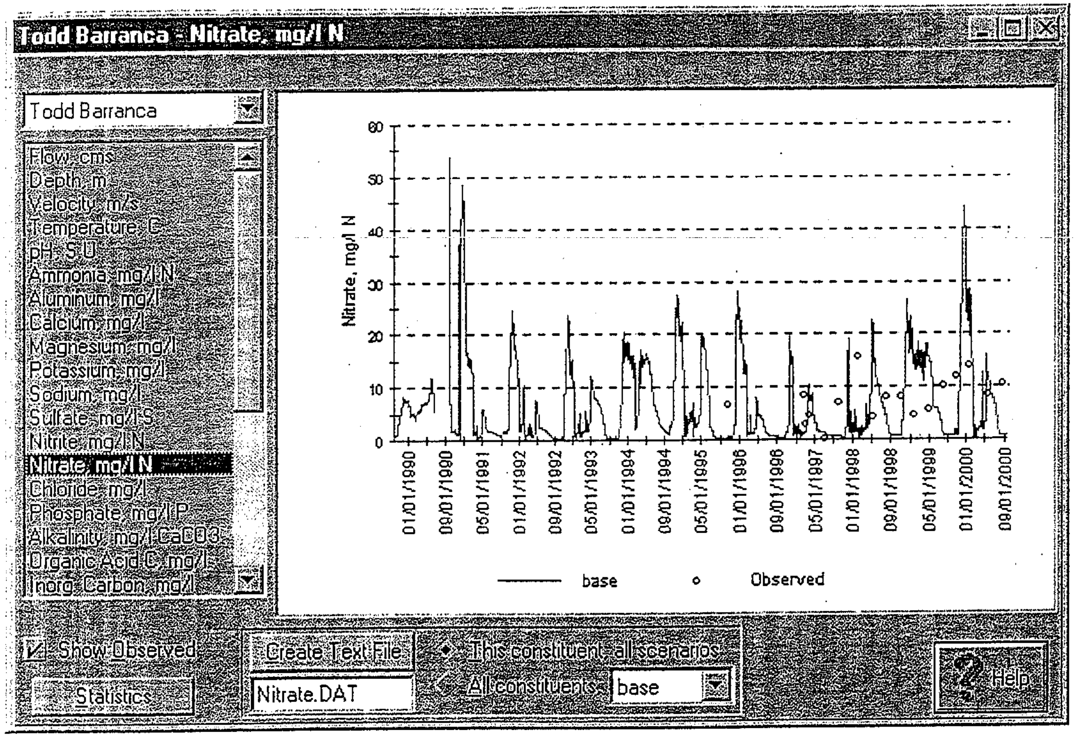
The water quality of Todd Barranca has low ammonia and phosphate concentrations typical of groundwater. Observed nitrate concentration is high, however, averaging 9.5 mg/l as nitrogen.

Key Assumptions

There are two permitted subsurface dischargers near Todd Barranca, the Todd Road Jail and Saticoy Food Corp. In both cases, the only data available is the "baseline flow" in the State of California groundwater discharge permit database. The discharge from each was assumed to have constant concentrations of 25 mg/l NH_4-N and 5 mg/l NO_3-N (refer to the Source Analysis Report for more information on this assumption).

Simulation Results

Figure 109 shows that the model simulates the nitrate concentration to fluctuate from 0 to 20 mg/l as observed.



☑ Show Observed

Nitrate.DAT

● This constituent, all scenarios

○ All constituents: base

Figure 109: Simulated and Observed Nitrate for Lower Todd Barranca (n = 16; relative error = -2.09 mg/l; absolute error = 7.67 mg/l)

Brown Barranca / Long Canyon

This tributary of the Santa Clara River is impaired by nitrite/nitrate. Its watershed occupies a 7 km^2 area, partly in the hills and partly in the lowlands near the Santa Clara River.

Hydrology

There is no gage on this tributary, and little basis to use to estimate hydrology.

Key Assumptions

The model's physical parameters which affect hydrology have been set to match Santa Paula Creek, the nearest gaged tributary of the Santa Clara River.

Simulation Results

There is no gaged flow to calibrate the hydrologic simulation for this section of the Santa Clara River. The pattern of simulated hydrograph is similar to gaged hydrograph for nearby streams. They are judged to be reasonable.

Water Quality

There is no water quality monitoring data of nutrients for this tributary.

Key Assumptions

There are no point sources in this watershed. Refer to the Source Analysis Report for the loading assumptions associated with potential nonpoint sources of pollution

Simulation Results

There is no water quality data in this section of the river to support model calibration.

Summary

In the Santa Clara River, water quality modeling requires proper hydrologic accounting. This includes the accounting of uncontrolled flows (natural unimpaired flow and water losses or gains across the riverbed), managed flows with good records (reservoir releases, large diversions, and point source discharges), managed flows with poor records (dewatering operations, small diversions, and small point source discharges). Simulations of Santa Paula, Sespe, and Hopper Creeks show good water balance and reasonable correlation. Simulations of Mint Canyon Creek and Bouquet Canyon Creek show the intermittent flow typical of the eastern tributaries. The flow accounting on the Santa Clara River is reasonable from Santa Clarita through Freeman diversion. In a heavily managed river like the Santa Clara River, the accuracy of simulation depends on the accuracy of managed flow data. The estimates of groundwater gains and losses between Blue Cut and Santa Paula Creek are also key to predicting flow and water quality. At this point, the model has been calibrated to match the seasonal pattern and range of observed values. Further improvement can be made with more data and time in the future.

V. Sensitivity Analysis

Introduction

The WARMF model for the Santa Clara River contains many different parameter inputs. For those listed in Table 5 and Table 7, there is little uncertainty. The parameters listed in Table 6 and Table 8 are less well known. For the lesser known parameters, sensitivity analysis can be performed to evaluate how their parameter values affect the match between model predictions and observed data. Appropriate parameter values can be selected quickly during the model calibration.

The sensitivity analysis can also be used to determine the effect of pollution sources on the predicted water quality responses. For the Santa Clara River nutrient TMDL study, the analysis can provide information about the relative importance of controlling point source discharges, atmospheric deposition (air quality), septic system, fertilizer applications, dewatering operations in order to meet the water quality standards for nutrients (ammonia, nitride and nitrate).

Sensitivity to Calibration Parameters

The following tests compare the calibrated base case for the Santa Clara River with hypothetical changes in calibration to examine their effect on the calibration. The first two cases change soil properties to examine the effect these have on hydrology and then water quality. The other four cases examine the sensitivity of the model results to key water quality assumptions made in calibration. In all cases, the parameter values are changed from the values used in the calibration base case. The responses are evaluated in terms of their effect on hydrologic and water quality calibrations.

Horizontal Hydraulic Conductivity and Soil Layer Thickness

The horizontal hydraulic conductivity and soil layer thickness control the groundwater accretion to the river segments. This is an important source of unregulated flow to the Santa Clara River. Both parameters will affect the hydrograph, particularly during low flow periods. With the steep canyon topography, any reasonable horizontal hydraulic conductivity will lead to a rapid rise of flow during a storm. A thin soil layer will provide very little groundwater storage to sustain low flow after the storms.

The Sespe Creek watershed was chosen for this sensitivity analysis. All the catchments upstream of the Sespe Creek gage near Fillmore have been simulated with three soil layers. The lowest of these in the calibrated base case has a thickness of 40 cm and a horizontal hydraulic conductivity of 150 cm/d. The conductivity is set so that simulation results follow gaging data reasonably well in both wet and dry years, without having an ideal match in either case.

The first test case uses a hydraulic conductivity of 300 cm/d instead of 150 cm/d and keeps the soil thickness the same as the base case. The second test case uses the same hydraulic conductivity as the base case but changes the soil thickness in the lowest layer from 40 cm to 30 cm. The complete hydrograph is very similar for the base case and the two test cases. Figure 110 shows a comparison of frequency distribution between the different cases and observed data. Table 26 summarizes the flow responses between the base case and two test cases as compared to observed data. Figure 111 and Table 27 show the hydrograph and statistics for flow between 0 and 2 m^3/s.

The results indicate that reducing horizontal hydraulic conductivity and/or reducing soil layer thickness do not improve the match between simulated and observed hydrographs, which are dominated by few high flows and many low flows. In the range of 0 to 2 m^3/s, the correlation coefficient of the test cases is similar to the base case. However, the relative error of the test cases is greater than in the base case.

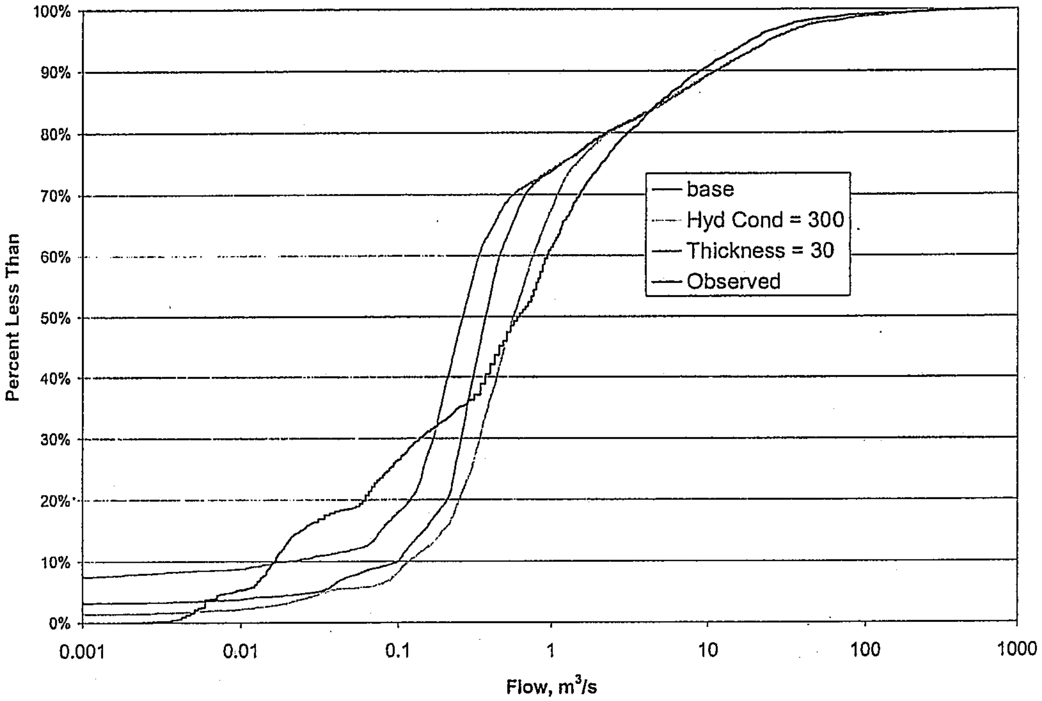


Figure 110: Simulated base case (blue), hydraulic conductivity test case (green), soil thickness test case (red), and observed flow frequency distribution for Sespe Creek near Fillmore

Table 26: Calibration statistics for flow at Sespe Creek near Fillmore

Model Scenario	Number of Points	Correlation Coeff r	Relative Error, %
Base Case	3394	0.83	12.7
H.C. = 150 cm/d	3394	0.83	13.5
Thickness = 30 cm	3394	0.83	14.1

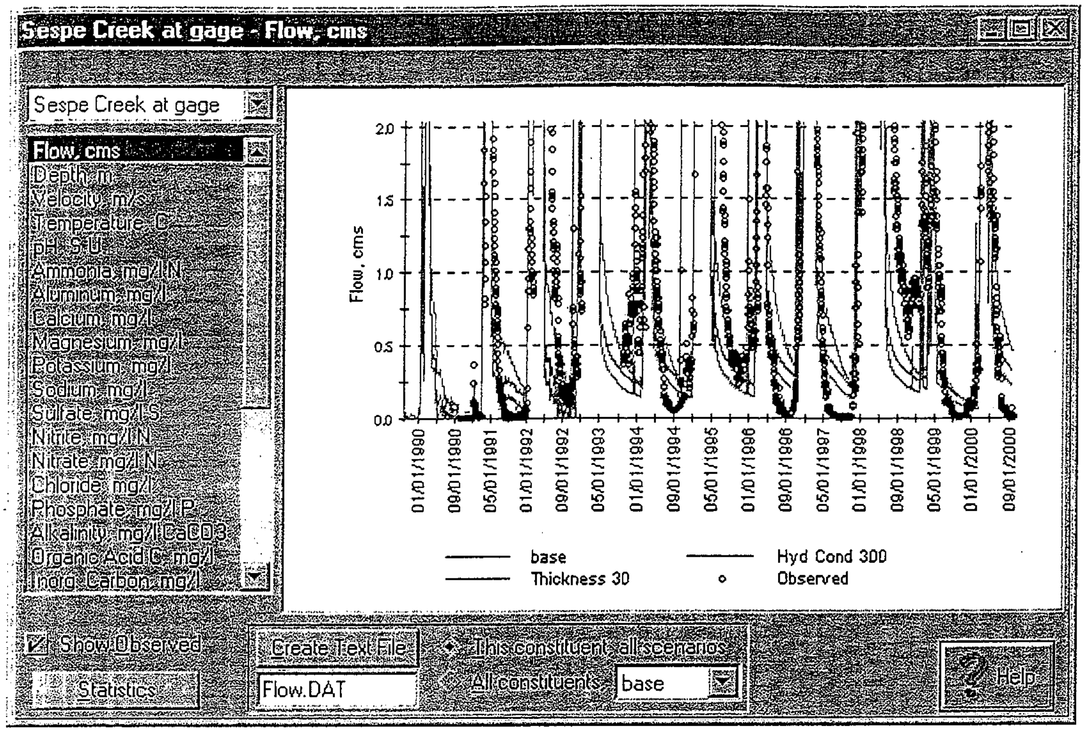
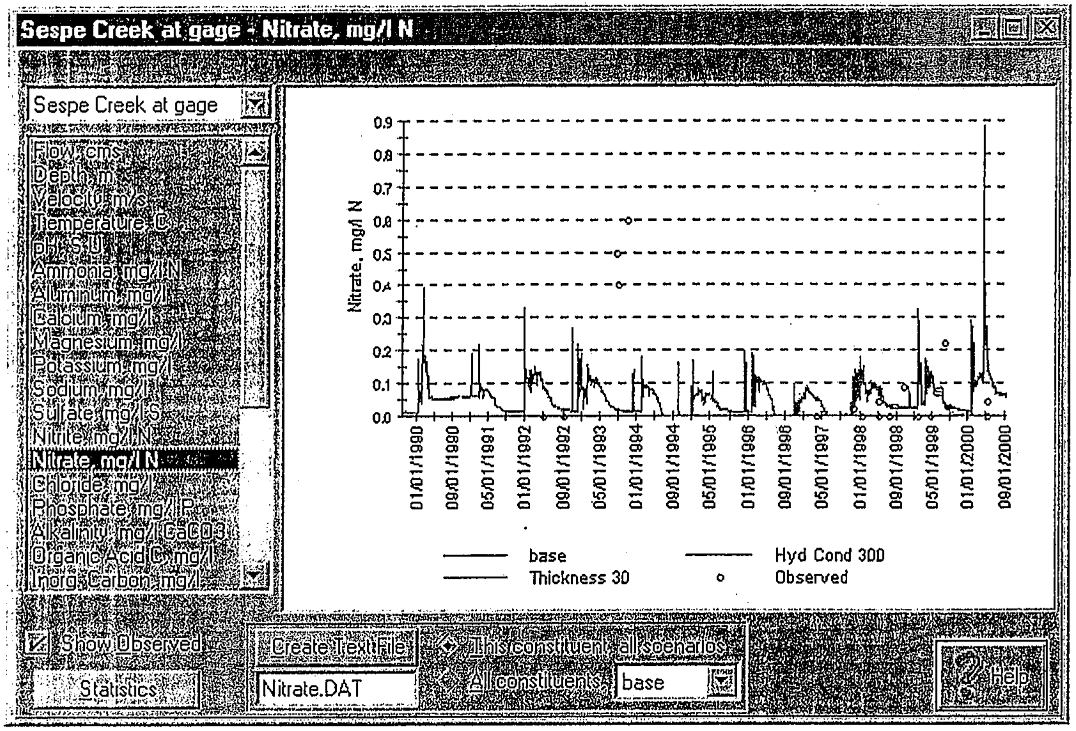


Figure 111: Simulated base case (blue), hydraulic conductivity test case (green), soil thickness test case (red), and observed flow: 0-2 m^3/s for Sespe Creek near Fillmore

Table 27: Calibration statistics for 0-2 m^3/s flow at Sespe Creek near Fillmore

Model Scenario	Number of Points	Correlation Coeff r	Relative Error, %
Base Case	2517	0.50	-9.5
H.C. = 300 cm/d	2517	0.56	16.9
Thickness = 30 cm	2517	0.48	-25.7

Changing the soil properties can have an effect on water quality in two ways: by changing the nitrate concentration in Sespe Creek itself and by changing the proportion of flow coming from Sespe Creek in the Santa Clara River downstream. Figure 112 through Figure 114 show graphical comparisons of nitrate in Sespe Creek and at two locations on the Santa Clara River downstream of Sespe Creek. The calibration statistics are shown in Table 28 through Table 30.

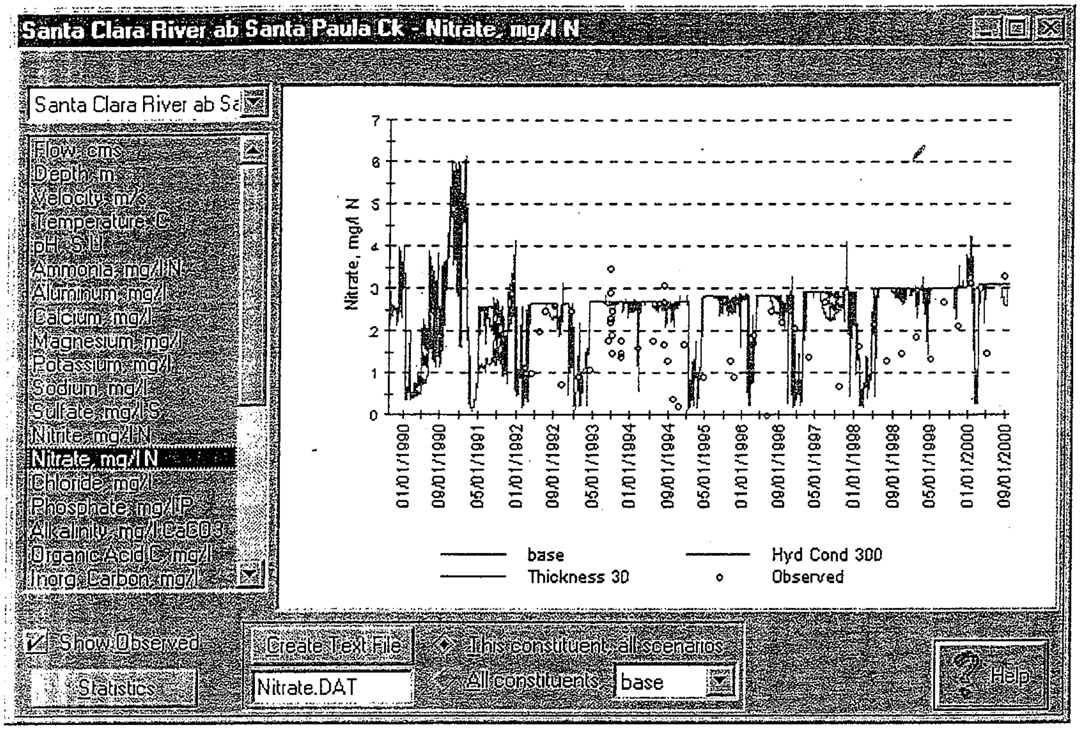


☒ Show Observed

Nitrate.DAT

All constituents: base

Figure 112: Simulated base case (blue), hydraulic conductivity test case (green), soil thickness test case (red), and observed nitrate for Sespe Creek near Fillmore



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Nitrate.DAT

base

Figure 113: Simulated base case (blue), hydraulic conductivity test case (green), soil thickness test case (red), and observed nitrate for Santa Clara River at Willard Road

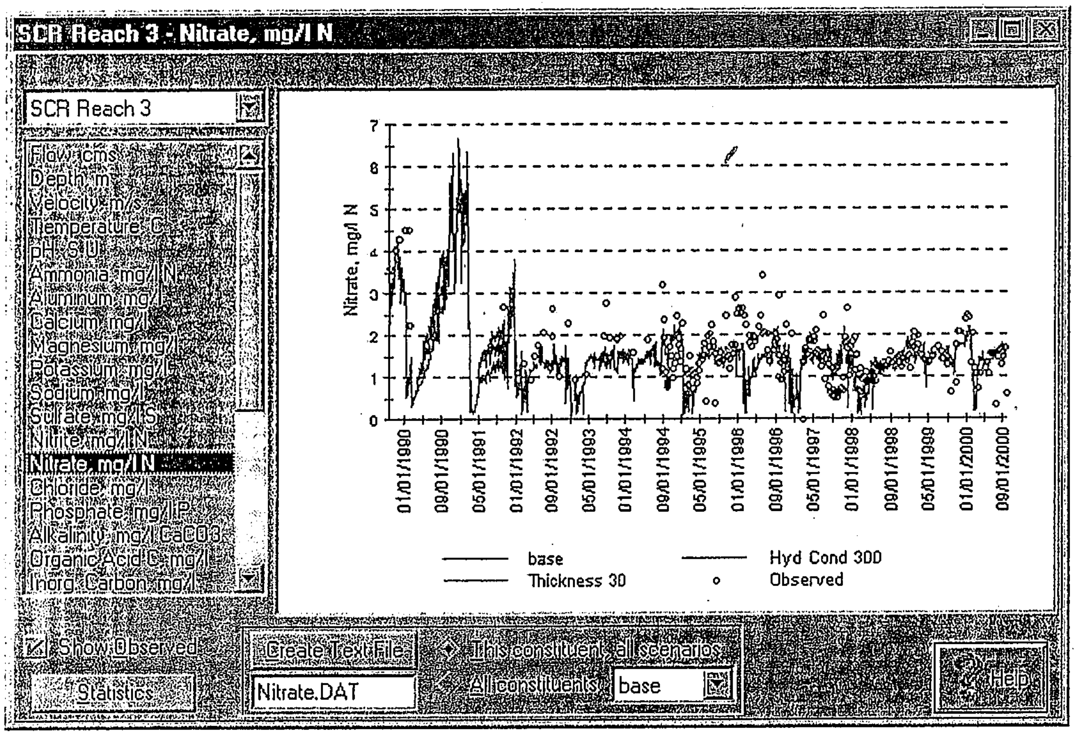


Figure 114: Simulated base case (blue), hydraulic conductivity test case (green), soil thickness test case (red), and observed nitrate for Santa Clara River at Freeman Diversion

Table 28: Base case and test case statistics for nitrate at Sespe Creek near Fillmore

Model Scenario	Number of Points	Relative Error, mg/l	Absolute Error, mg/l
Base Case	17	-0.05	0.16
H.C. = 150 cm/d	17	-0.05	0.15
Thickness = 30 cm	17	-0.04	0.17

Table 29: Base case and test case statistics for nitrate at Santa Clara River at Willard Road

Model Scenario	Number of Points	Relative Error, mg/l	Absolute Error, mg/l
Base Case	48	0.85	0.95
H.C. = 150 cm/d	48	0.77	0.91
Thickness = 30 cm	48	0.87	0.98

Table 30: Base case and test case statistics for nitrate at Santa Clara River at Freeman Diversion

Model Scenario	Number of Points	Relative Error, mg/l	Absolute Error, mg/l
Base Case	276	-0.14	0.43
H.C. = 150 cm/d	276	-0.17	0.43
Thickness = 30 cm	276	-0.12	0.44

Both the test cases showed only small changes in nitrate concentration resulting from the change in hydrology. The quality of the calibration was similar for the base case and the two test cases. The hydrologic calibration of Sespe Creek does not seem to greatly affect the nitrate concentration of the Santa Clara River downstream.

United Water Conservation District (UWCD) Estimated Flows

The United Water Conservation District has estimated gains and losses in various stretches of the Santa Clara River and its tributaries between Blue Cut and Santa Paula Creek. These estimates are based on measured flows, groundwater table elevations, and historic estimates of flow losses. These estimates have been refined once over the course of this modeling study, and they can be set in different ways to better simulate flows under one flow regime or another. These flows are key to the accounting of hydrology and its accompanying water quality from Blue Cut to Freeman Diversion.

The test case for this sensitivity analysis multiplies all estimated gains and losses between Blue Cut and Freeman Diversion by 0.8. Such a scenario is not necessarily a realistic alternative estimate of groundwater interactions with surface water, but it does provide a basis with which to estimate the sensitivity of the model to changes in estimated flows. The only gage for comparison is at Montalvo, downstream of the Freeman Diversion, which has not undergone calibration. The complete hydrograph is very similar for the base case and the two test cases. Figure 115 shows a comparison of frequency distribution between the different cases and observed data. Table 31 summarizes the flow responses between the base case and the test case as compared to observed data. Figure 116 and Table 32 show the hydrograph and statistics for flow between 0 and 5 m^3/s.

The results indicate that changing the estimated river gains and losses does affect flow at Montalvo in the flow range from about 0.01 m^3/s to 10 m^3/s. The correlation coefficients for the base case and test case are similar, but the relative error for the low flow range is much higher in the test case.

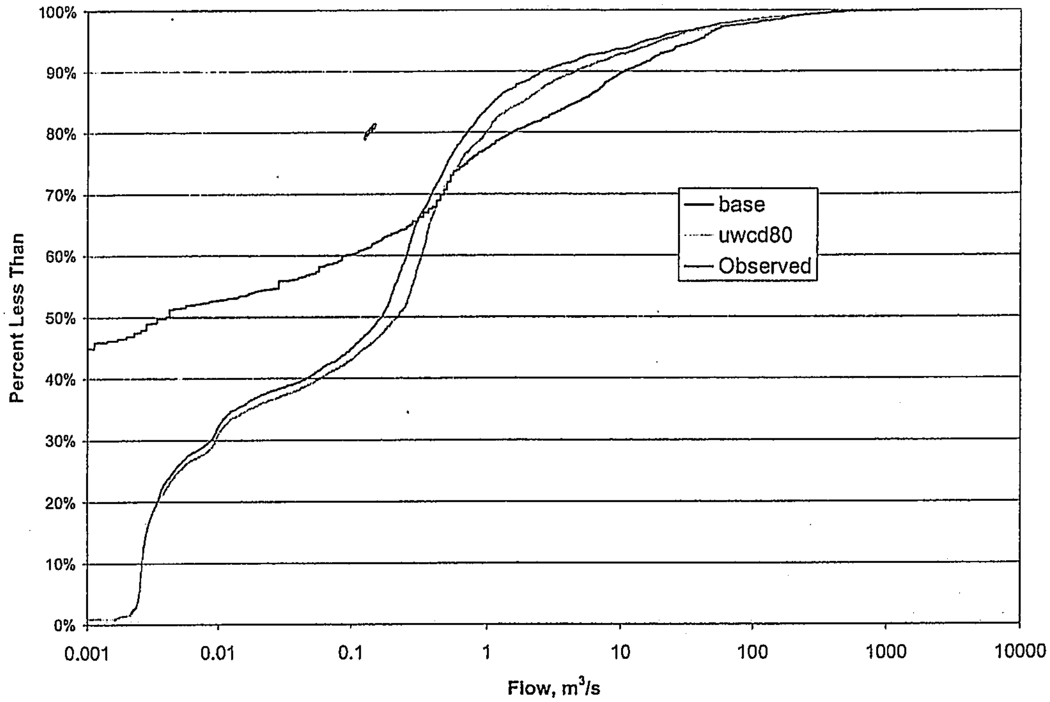


Figure 115: Simulated base case (blue), 80% UWCD flows test case (green), and observed flow frequency distribution for Santa Clara River at Montalvo

Table 31: Calibration statistics for flow at Santa Clara River at Montalvo

Model Scenario	Number of Points	Correlation Coeff r	Relative Error, %
Base Case	3288	0.78	-32.1
UWCD 80	3288	0.78	-25.7

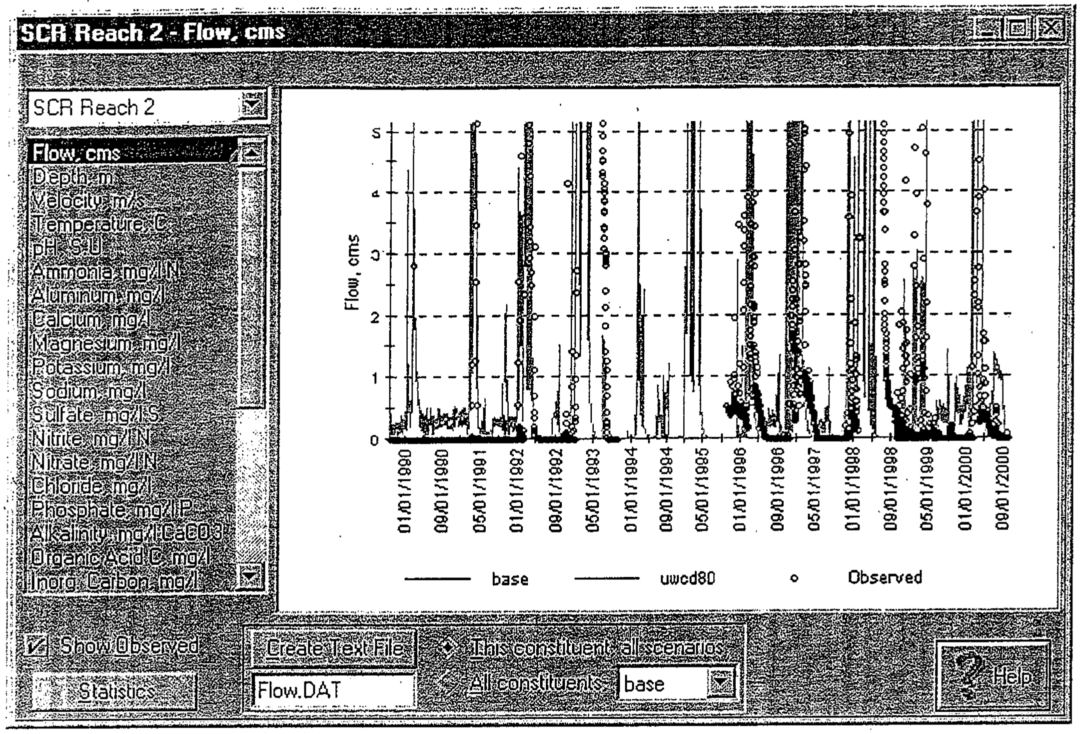


Figure 116: Simulated base case (blue), 80% UWCD flows test case (green), and observed flow: 0-5 m^3/s for Sespe Creek near Fillmore

Table 32: Calibration statistics for 0-5 m^3/s flow at Santa Clara River at Montalvo

Model Scenario	Number of Points	Correlation Coeff r	Relative Error, %
Base Case	2807	0.28	35.7
UWCD 80	2807	0.29	73.8

Changing the prescribed river gains and losses can have an affect on water quality by changing the proportion of flow coming from its various sources. Figure 112 through Figure 114 show graphical comparisons of nitrate in Sespe Creek and at two locations on the Santa Clara River downstream of Sespe Creek. The calibration statistics are shown in Table 28 through Table 30.

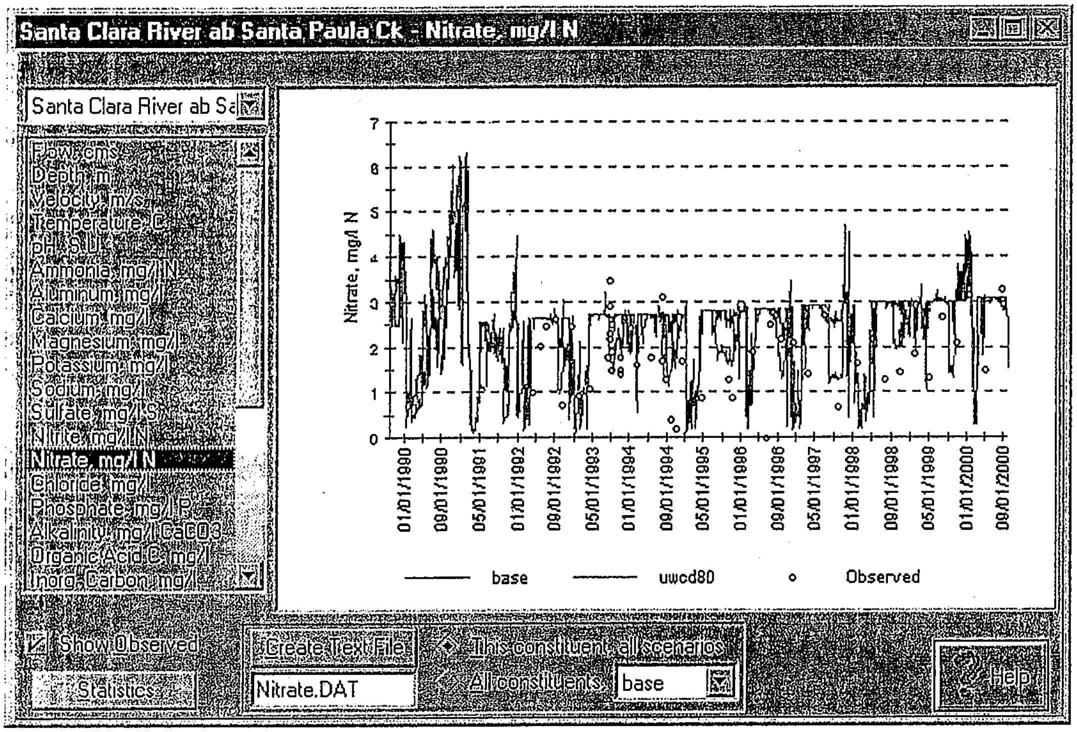


Figure 117: Simulated base case (blue), 80% UWCD flow test case (green), and observed nitrate for Santa Clara River at Willard Road

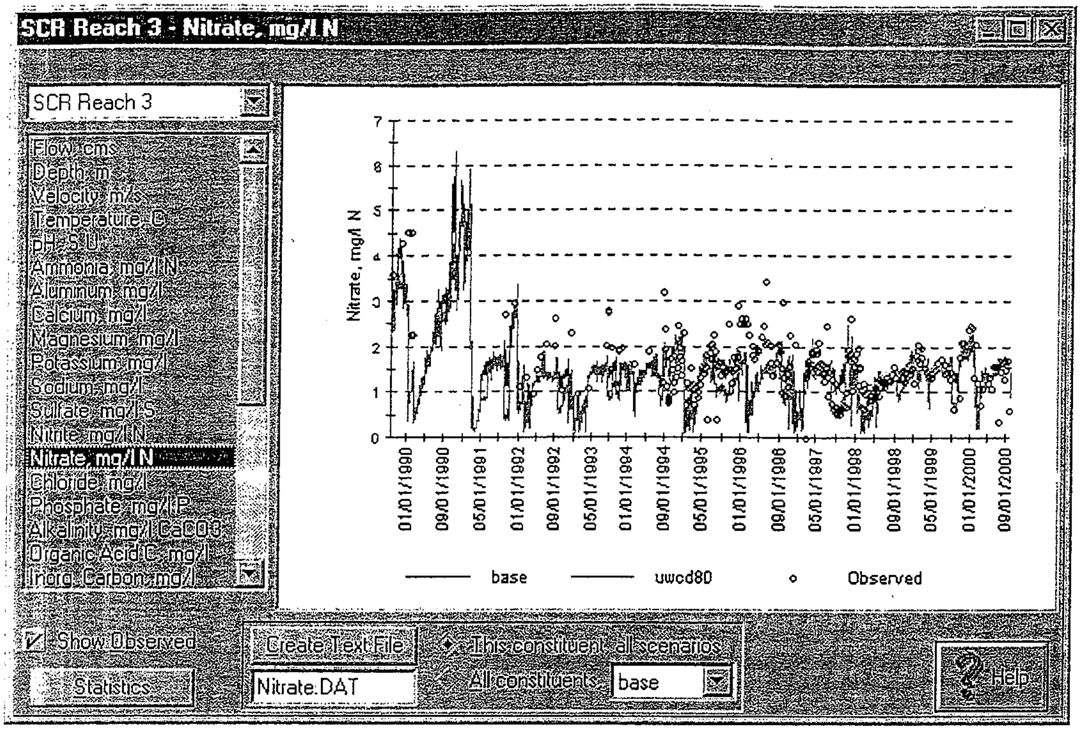


Figure 118: Simulated base case (blue), 80% UWCD flow test case (green), and observed nitrate for Santa Clara River at Freeman Diversion

Table 33: Base case and test case statistics for nitrate at Santa Clara River at Willard Road

Model Scenario	Number of Points	Relative Error, mg/l	Absolute Error, mg/l
Base Case	48	0.85	0.95
UWCD 80	48	0.44	0.68

Table 34: Base case and test case statistics for nitrate at Santa Clara River at Freeman Diversion

Model Scenario	Number of Points	Relative Error, mg/l	Absolute Error, mg/l
Base Case	276	-0.14	0.43
UWCD 80	276	-0.30	0.43

The test case seems to show a better fit to the observed data at Willard Road than the base case condition. The relative error of the test case is worse at Freeman Diversion, however.

Periphyton and Denitrification Rate

The Old Road Bridge is downstream of the Saugus WWRF. Water quality monitoring from that location shows less total nitrogen than is present in the effluent from the Saugus WWRF.

The base case hypothesized that denitrification in the river bed is removing nitrogen from the water column. The base case assumed that there was no periphyton to remove nitrogen. In one test case, the denitrification rate was set to zero to examine the impact of no nitrogen removal in that reach of the river. In the second test case, periphyton growth was added to remove more nitrogen from the water column. For this case, it was further assumed that the periphyton did not recycle its nitrogen content back to the water column at death.

Figure 119 presents the simulation results for the calibration base case and other test cases in comparison to the observed data. Table 35 shows the statistics of the comparisons.

Without denitrification, the model predicted much higher nitrate concentrations than indicated by the data. Clearly, there is a nitrogen removal process occurring in this reach of the Santa Clara River. The periphyton case shows modest additional removal of nitrate. Periphyton, by itself, cannot remove sufficient nitrate to match the observed data. Neither of the test cases appear to improve the statistics of the comparisons.

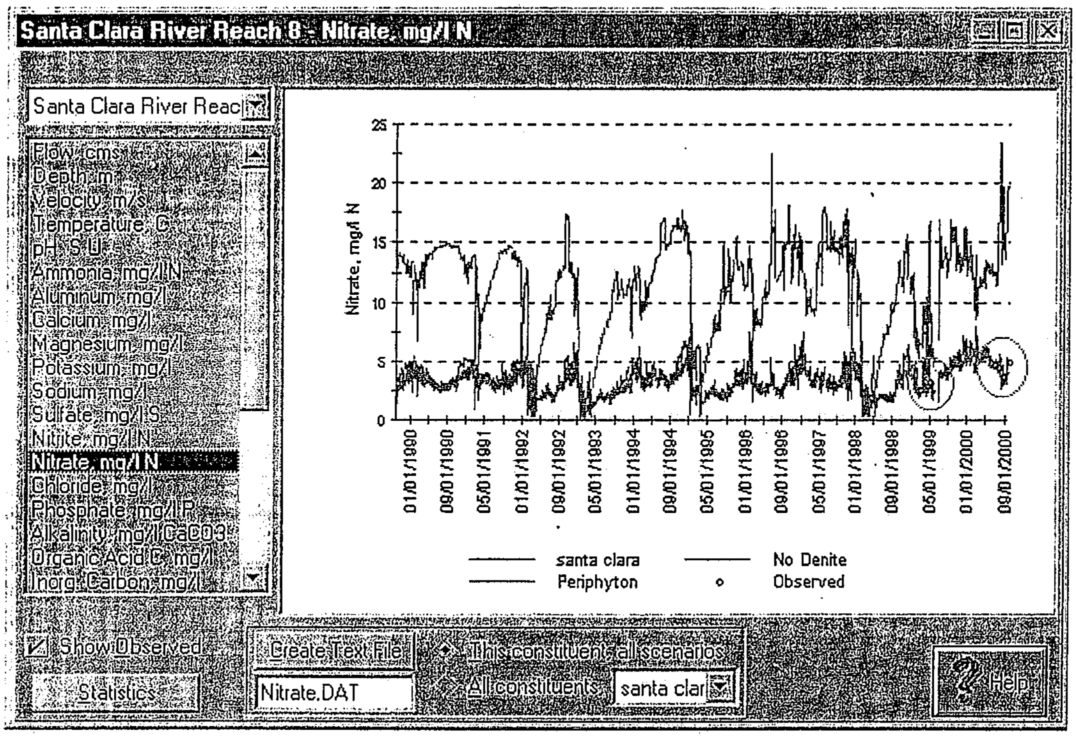


Figure 119: Simulated base case (blue), no denitfication test case (green), periphyton test case (red), and observed nitrate for Santa Clara River at Old Road Bridge

Table 35: Base case and test case statistics for NO_3-N at Santa Clara River at Old Road Bridge

Model Scenario	Number of Points	Relative Error, mg/l	Absolute Error, mg/l
Base Case	5	+0.09 mg/l	0.15 mg/l
No Denitrification	5	+10.30 mg/l	10.3 mg/l

Periphyton On	5	-0.44 mg/l	0.47 mg/l

Initial Groundwater Nitrate Concentration: Reach 7

Reach 7 of the Santa Clara River (Figure 3) receives groundwater accretion from the adjacent catchments. The initial nitrate concentration in the groundwater is directly linked to the resulting load of nitrate from the groundwater to the river.

The base case assumed NO_3-N concentration of 1.1 mg/l. This test case assumes 5 mg/l instead. A comparison of the two cases and observed data is shown in Figure 120, Figure 121, Table 36, and Table 37 for the two locations near Blue Cut with water quality monitoring data.

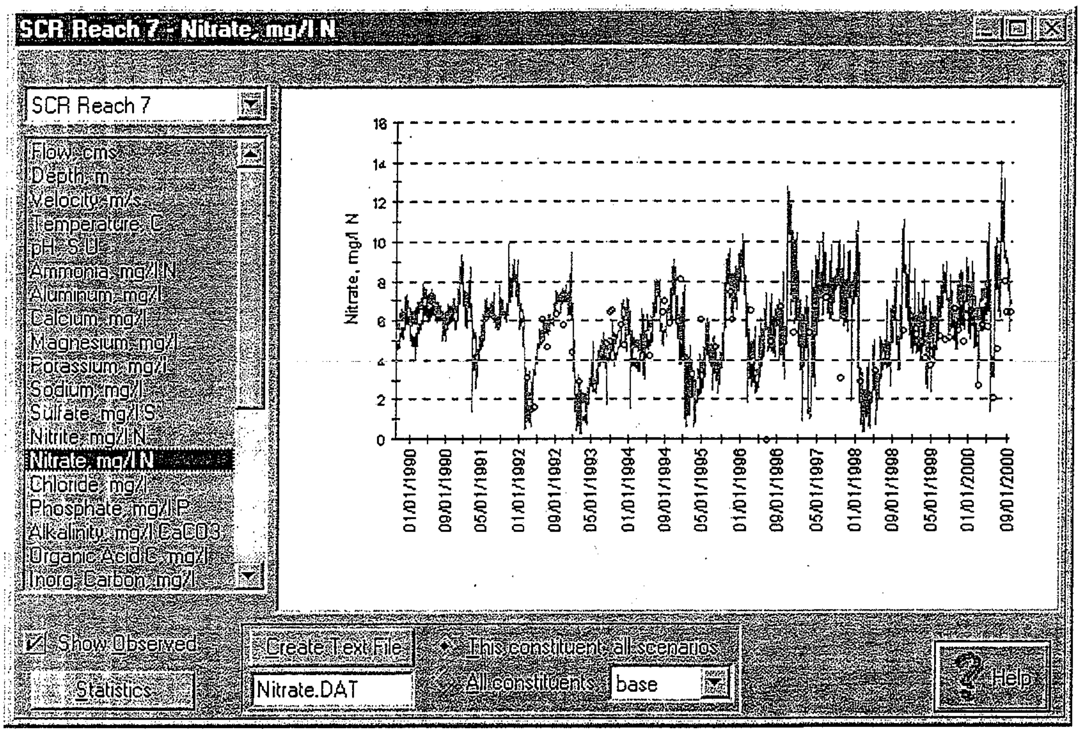


Figure 120: Simulated base case (blue), 5 mg/l initial NO_3-N test case (green), and observed nitrate for Santa Clara River at Los Angeles / Ventura county line

Table 36: Base case and test case statistics for nitrate at Santa Clara River at Los Angeles / Ventura county line

Model Scenario	Number of Points	Relative Error, mg/l	Absolute Error, mg/l
Base Case	58	0.53	1.57
5 mg/l Initial NO_3-N	58	1.14	1.76

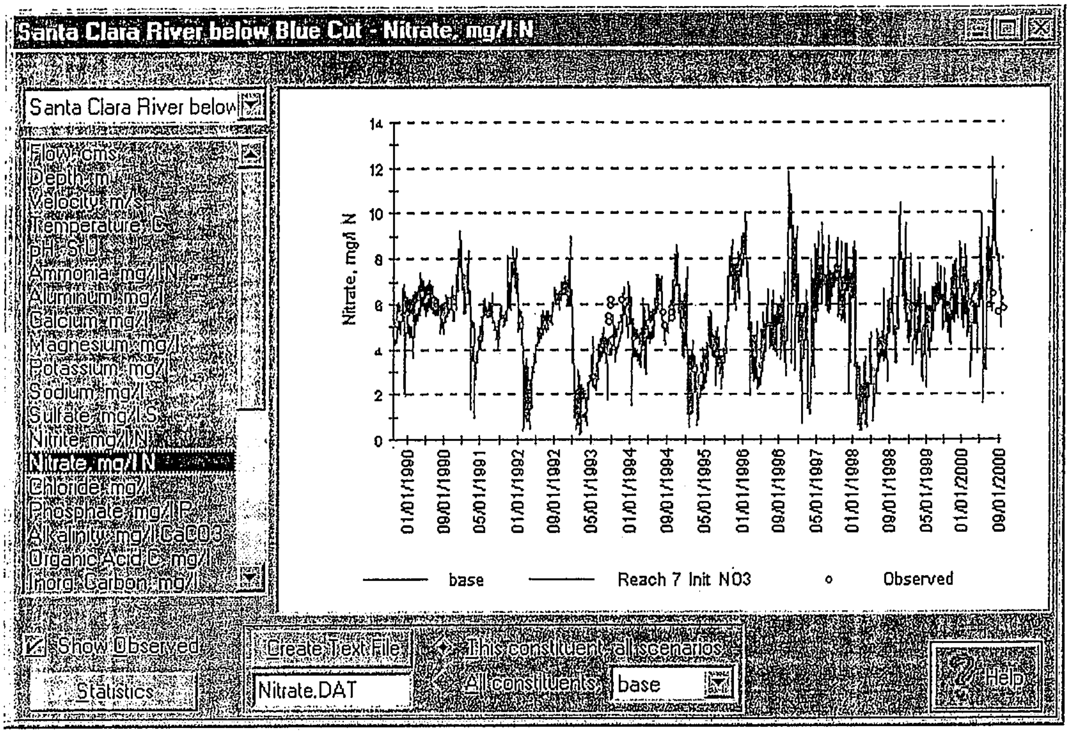


Figure 121: Simulated base case (blue), 5 mg/l initial NO_3-N test case (green), and observed nitrate for Santa Clara River near Piru

Table 37: Base case and test case statistics for nitrate at Santa Clara River near Piru

Model Scenario	Number of Points	Relative Error, mg/l	Absolute Error, mg/l
Base Case	11	0.26	1.36
5 mg/l Initial NO_3-N	11	0.49	1.26

From the test run, we can see that the simulation results do show a modest change in response to the large change in input initial groundwater nitrate concentration adjacent to Reach 7 of the Santa Clara River. Most of the flow and loading coming to this reach is from sources other than groundwater, but the above figures and tables indicate that the model does respond to different assumptions about groundwater nitrate concentrations.

Initial Groundwater Nitrate Concentration: Reach 3

Reach 3 of the Santa Clara River (Figure 4) receives groundwater accretion near Willard Road. The initial nitrate concentration in the groundwater at that location is directly linked to the resulting load of nitrate from the groundwater to the river.

The base case assumed nitrate concentration of 2.5 mg/l N for the groundwater. For the test case, that concentration was raised to 3.5 mg/l. A comparison of the two cases and observed data is shown in Figure 122, Figure 123, Table 38, and Table 39 for Willard Road and the Freeman Diversion.

The results indicate that nitrate concentrations at Reach 3 are sensitive to the initial nitrate concentration of groundwater at the Willard Road area. This is indicative of the relative importance of the groundwater accretion to the water quality downstream.

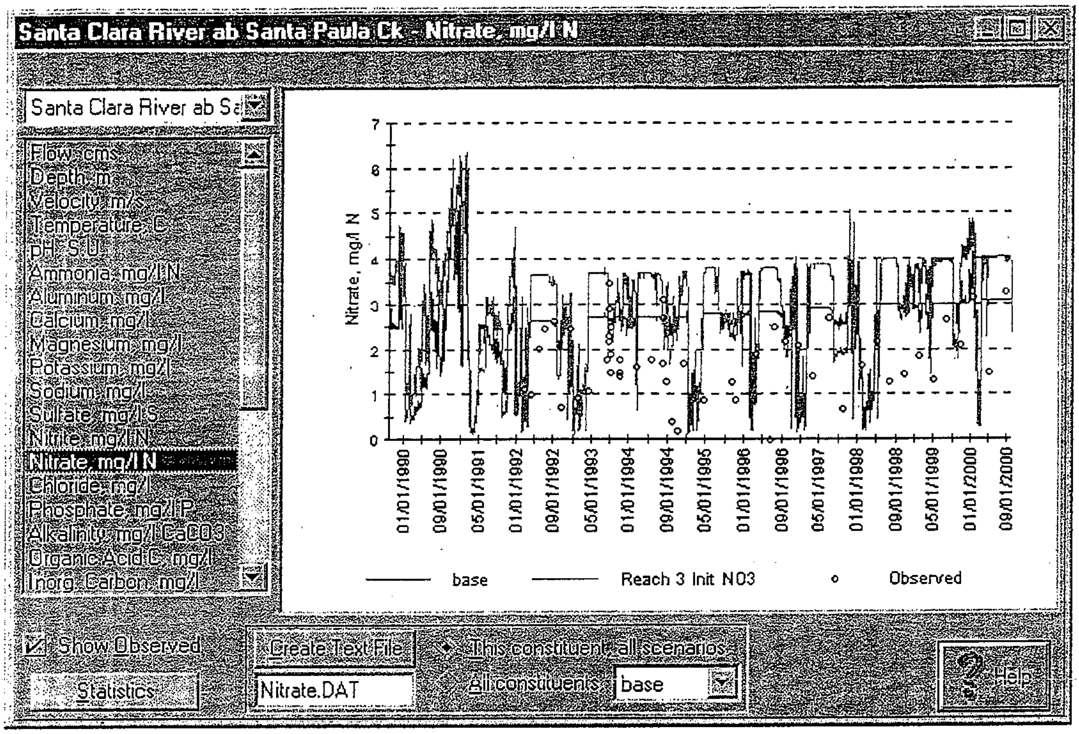


Figure 122: Simulated base case (blue), 3.5 mg/l initial NO_3-N test case (green), and observed nitrate for Santa Clara River at Willard Road

Table 38: Base case and test case statistics for nitrate at Santa Clara River at Willard Road

Model Scenario	Number of Points	Relative Error, mg/l	Absolute Error, mg/l
Base Case	48	0.85	1.31
3.5 mg/l Init. NO_3-N	48	0.95	1.33

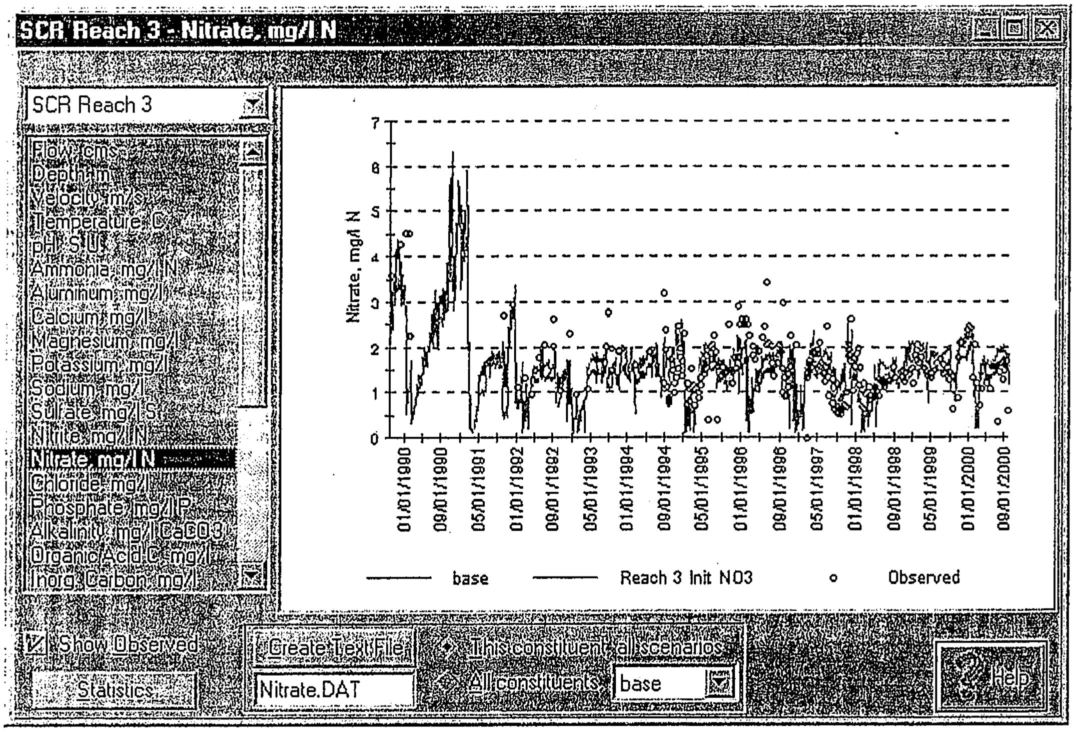


Figure 123: Simulated base case (blue), 3.5 mg/l initial NO_3-N test case (green), and observed nitrate for Santa Clara River at Freeman Diversion

Table 39: Base case and test case statistics for nitrate at Santa Clara River at Freeman Diversion

Model Scenario	Number of Points	Relative Error, mg/l	Absolute Error, mg/l
Base Case	276	-0.14	0.60
3.5 mg/l Init. NO_3-N	276	-0.05	0.56

Sensitivity to Nonpoint Source Loading of Nitrogen

There are point and nonpoint sources discharges of nitrogen to the Santa Clara watershed. The nonpoint source nitrogen can be derived from atmospheric deposition, fertilizer application, septic tank effluent, and subsurface discharges.

In this section, the sensitivity analysis is performed to examine the relative importance of nonpoint source nitrogen on the nitrate concentrations in the Santa Clara River. The nonpoint nitrogen loads used can be found in the Source Analysis Report (Systech 2002).

Atmospheric Deposition

According to the Source Analysis Report (Systech 2002), the primary source of nitrogen loading to the Sespe Creek watershed is from atmospheric deposition. The air quality data used by the model to calculate atmospheric deposition is based on a station at the city of Ojai southwest of the watershed.

The Sespe Creek watershed is large and mostly undeveloped area in the mountains. The air quality there is expected to be better than in the city. As a result, in the model assumes that the concentration of all air quality constituents in the Sespe Creek watershed are half that measured at the Ojai station. A sensitivity analysis was performed to determine the effect of this assumption on the water quality of Sespe Creek.

The calibration base case used half the concentrations in the air quality data of Ojai station to calculate atmospheric deposition. For the test case, the concentrations of all constituents (including ammonia and nitrate) in the air and in the precipitation were put back to their original values measured at Ojai. Figure 124 through Figure 126 and Table 40 through Table 42 show the results.

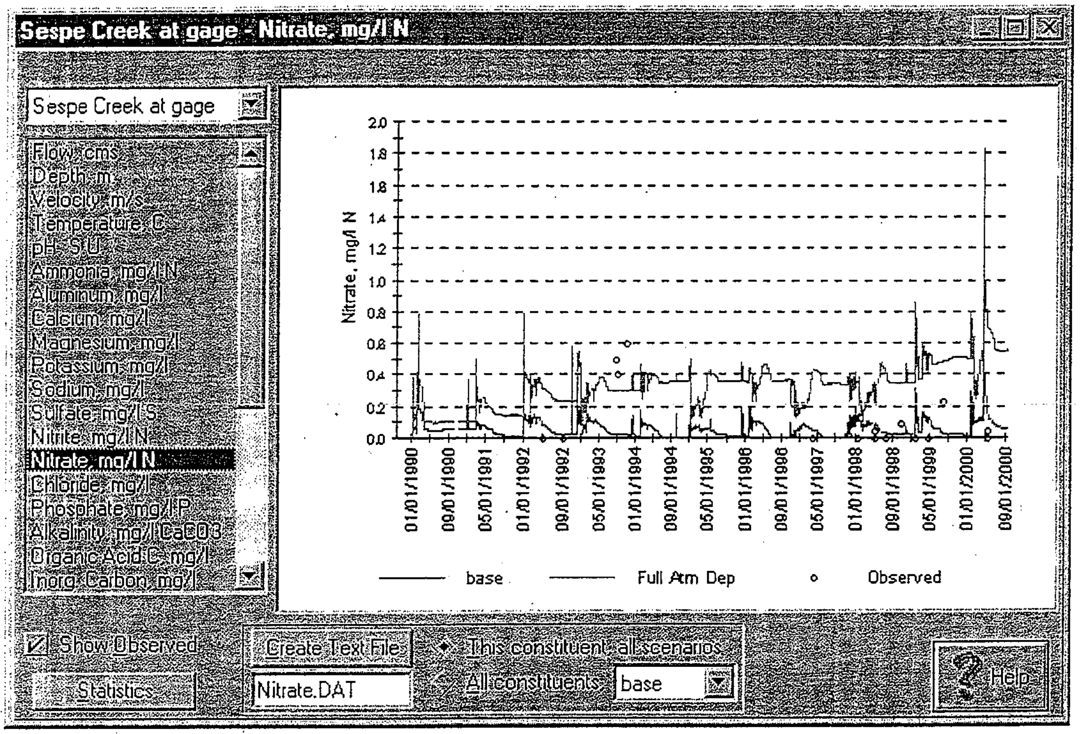


Figure 124: Simulated base case (blue), full atmospheric deposition test case (green), and observed nitrate for Sespe Creek near Fillmore

Table 40: Base case and test case statistics for nitrate at Sespe Creek near Fillmore

Model Scenario	Number of Points	Relative Error, mg/l	Absolute Error, mg/l
Base Case	17	-0.05	0.16
Full Atmos. Dep.	17	0.28	0.35

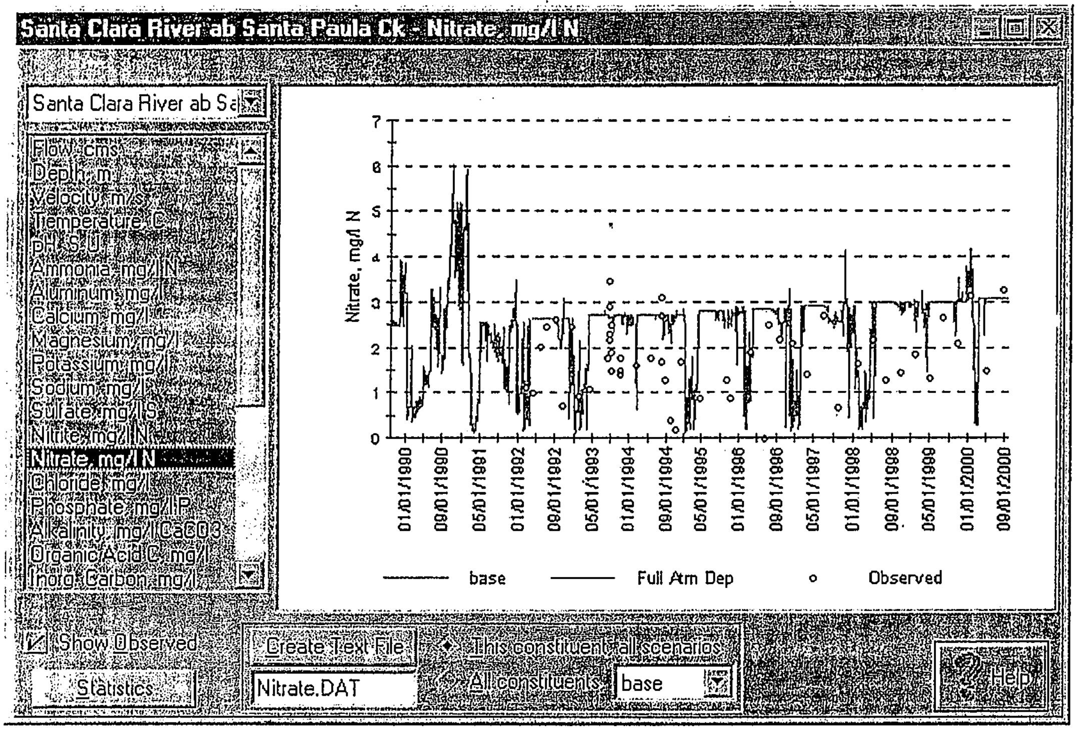


Figure 125: Simulated base case, full atmospheric deposition test case, and observed nitrate for Santa Clara River at Willard Road

Table 41: Base case and test case statistics for nitrate at Santa Clara River at Willard Road

Model Scenario	Number of Points	Relative Error, mg/l	Absolute Error, mg/l
Base Case	48	0.85	0.95
Full Atmos. Dep.	48	0.86	0.95

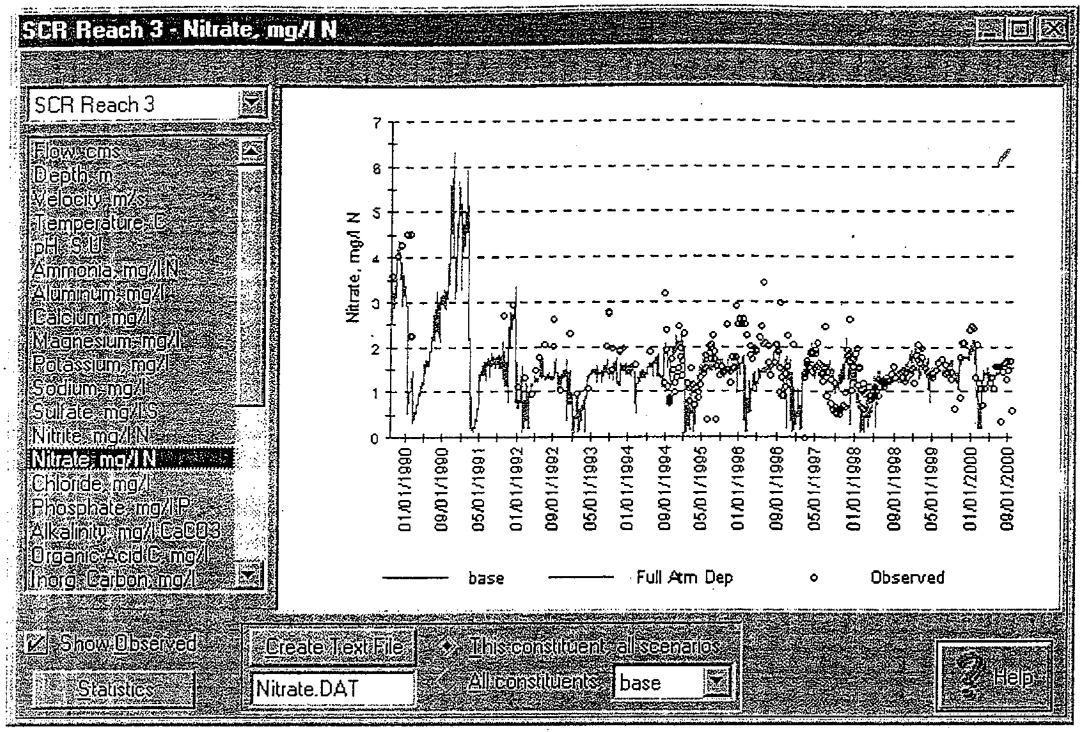


Figure 126: Simulated base case, full atmospheric deposition test case, and observed nitrate for Santa Clara River at Freeman Diversion

Table 42: Base case and test case statistics for nitrate at Santa Clara River at Freeman Diversion

Model Scenario	Number of Points	Relative Error, mg/l	Absolute Error, mg/l
Base Case	275	-0.14	0.43
Full Atmos. Dep.	275	-0.13	0.43

Using the full atmospheric deposition introduces error in the nitrate calibration in Sespe Creek, but has little effect on nitrate concentrations in the Santa Clara River downstream.

Fertilizer Application

A general consensus was reached among many stakeholders familiar with the Santa Clara River watershed on the approximate amount of fertilizer used on orchards, row crops, and golf courses as indicated in the Source Analysis Report (Systech 2002). However, there was some uncertainty in the final fertilization rates.

To test the sensitivity of model results to different fertilization rates, a test case was created cutting the fertilization rates in half for orchards, row crops, and golf courses in the region from Sespe Creek to the Freeman Diversion. A comparison of the two cases and observed data is shown in Figure 127, Figure 128, Table 43, and Table 44 for Willard Road and the Freeman Diversion.

The test shows little short-term impact on the simulated nitrate concentration of the Santa Clara River. The fertilizer is applied to the watershed catchments. Over fertilization in excess of the need of crops can in principle lead to raising the nitrate concentration in the groundwater. Such impact is gradual that may require a very long-term simulation, which is not performed by WARMF for this study. Long-term increase of nitrate concentration in the Willard Road groundwater system can affect the nitrate concentration in Reach 3 of the Santa Clara River, as discussed earlier in this report.

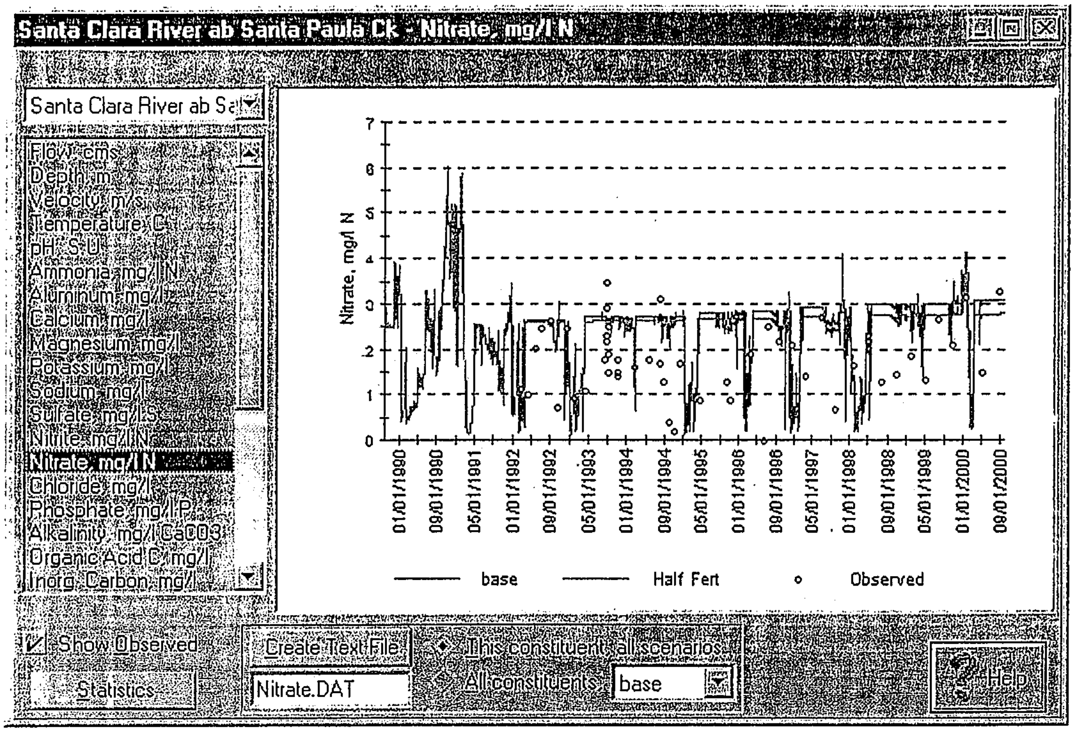
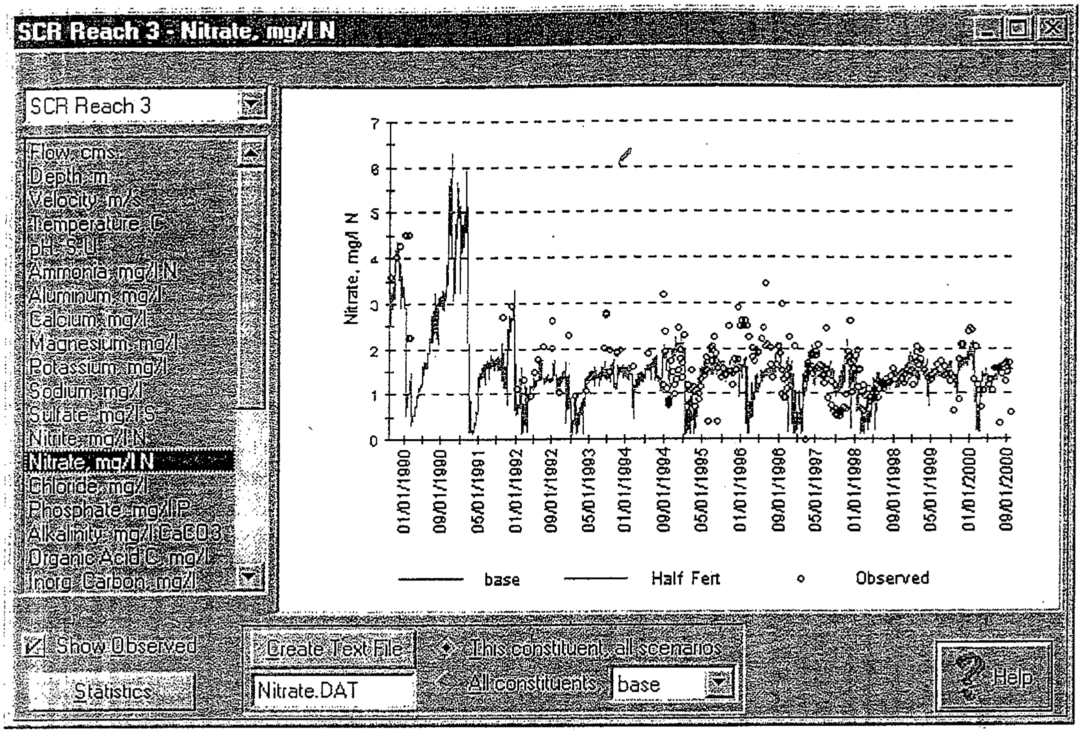


Figure 127: Simulated base case (blue), half fertilization test case (green), and observed nitrate for Santa Clara River at Willard Road

Table 43: Base case and test case statistics for nitrate at Santa Clara River at Willard Road

Model Scenario	Number of Points	Relative Error, mg/l	Absolute Error, mg/l
Base Case	48	0.85	0.95
Half Fertilization	48	0.72	0.85



SCR Reach 3

☑ Show Observed

Nitrate.DAT

base

Figure 128: Simulated base case (blue), half fertilization test case (green), and observed nitrate for Santa Clara River at Freeman Diversion

Table 44: Base case and test case statistics for nitrate at Santa Clara River at Freeman Diversion

Model Scenario	Number of Points	Relative Error, mg/l	Absolute Error, mg/l
Base Case	276	-0.14	0.43
Half Fertilization	276	-0.24	0.46

Septic Systems

Both Los Angeles County and Ventura County keep records of septic systems. The Ventura County database provides sufficient information for us to place each septic system to their respective catchments. Los Angeles County database does not lend itself to the same kind of analysis. We assumed that the total number of septic systems in the Los Angeles County portion of the Santa Clara River watershed were distributed uniformly throughout the watershed outside of the immediate Santa Clarita area.

This sensitivity analysis tests the water quality impact if there were actually only half as many septic systems as assumed in Los Angeles County. Figure 129 and Table 45 show the comparison between the base case and test case for ammonia upstream of the Saugus WWRF in Santa Clarita in Reach 9 of the Santa Clara River; Figure 130 and Table 46 show the sensitivity of the model for nitrate at the same location. Red circles are added to make observed data points more visible, not to add emphasis.

The comparison shows that septic systems contribute a very small fraction of the nitrogen to the Santa Clara River upstream of the Saugus WWRF. Below the Saugus WWRF, they represent an even smaller fraction of the overall loading of nitrogen to the Santa Clara River. The model is thus insensitive to the number of septic systems expected in the Los Angeles County portion of the watershed.

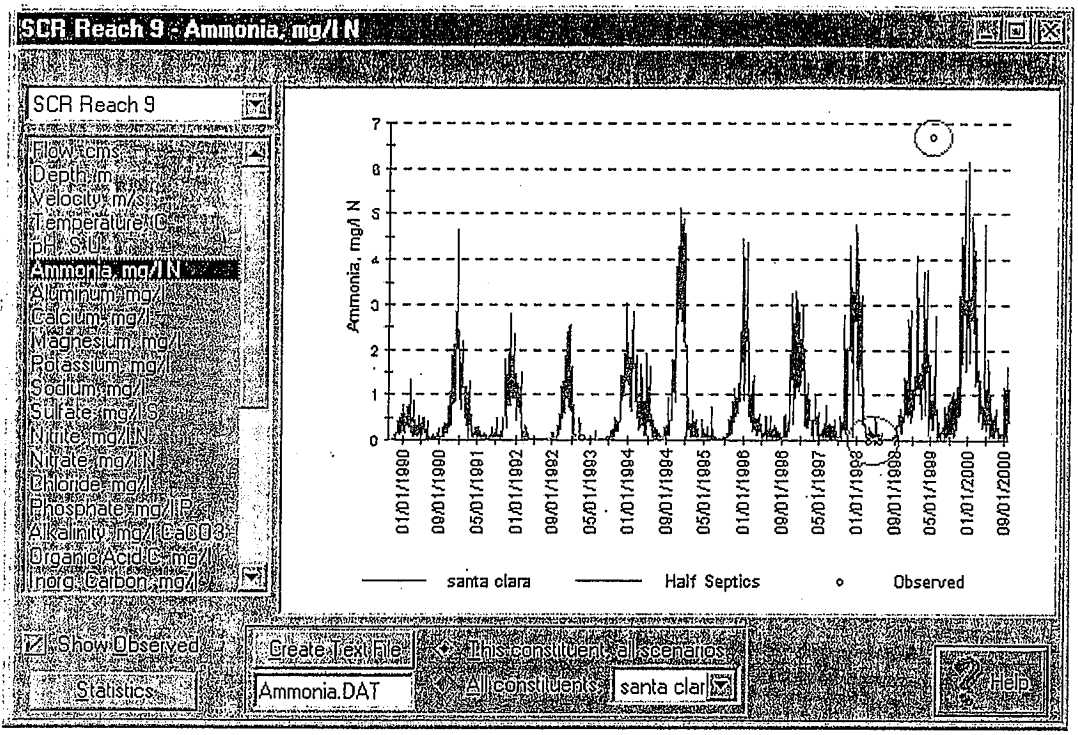


Figure 129: Simulated base case (blue), half septics test case (green), and observed ammonia for Santa Clara River at Bouquet Canyon

Table 45: Base case and test case statistics for NH_3-N at Santa Clara River at Bouquet Canyon

Model Scenario	Number of Points	Relative Error, mg/l	Absolute Error, mg/l
Base Case	4	-1.36	1.43
Half Septics	4	-1.37	1.43

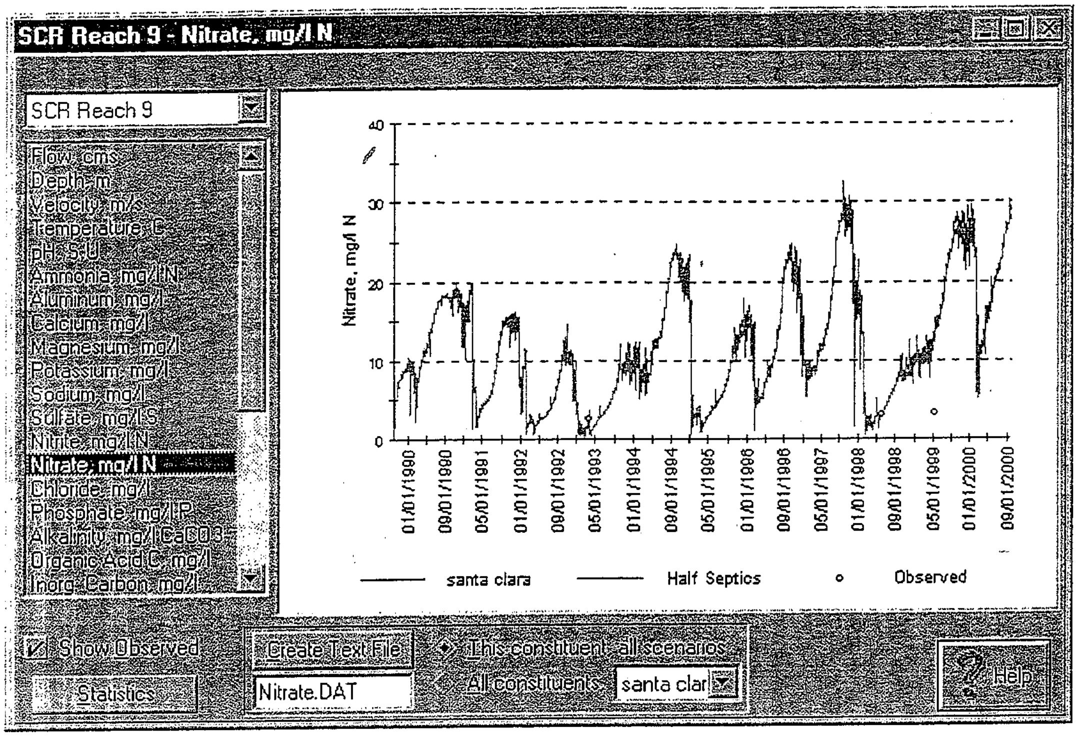


Figure 130: Simulated base case (blue), half septics test case (green), and observed nitrate for Santa Clara River at Bouquet Canyon

Table 46: Base case and test case statistics for NO_3-N at Santa Clara River at Bouquet Canyon

Model Scenario	Number of Points	Relative Error, mg/l	Absolute Error, mg/l
Base Case	3	2.77	3.32
Half Septics	3	2.43	3.07

VI. Linkage Analysis

Introduction

The purpose of the Santa Clara River watershed modeling is to determine the linkage between inputs to the Santa Clara River and the water quality of the river. WARMF provides such linkage by simulating the hydrology, the nonpoint source loads from land catchments, and then the resulting receiving water quality resulting from the point and nonpoint source loads of pollutants.

There are three ways to look at loading: from the source, where it enters the river, and when it is in the river. The Source Analysis Report (Systech 2002) details the loading from the source. This loading is input to the watershed model.

The second form of loading is referred to as "Regional Loading" in WARMF because it reflects the loading to streams within a region of the watershed. It includes direct point sources and that portion of nonpoint sources which is transported to rivers by runoff. Nonpoint sources such as atmospheric deposition and fertilization are classified by the land use in which they occur. Direct regional loading does not take into account any in-stream assimilation of pollutants.

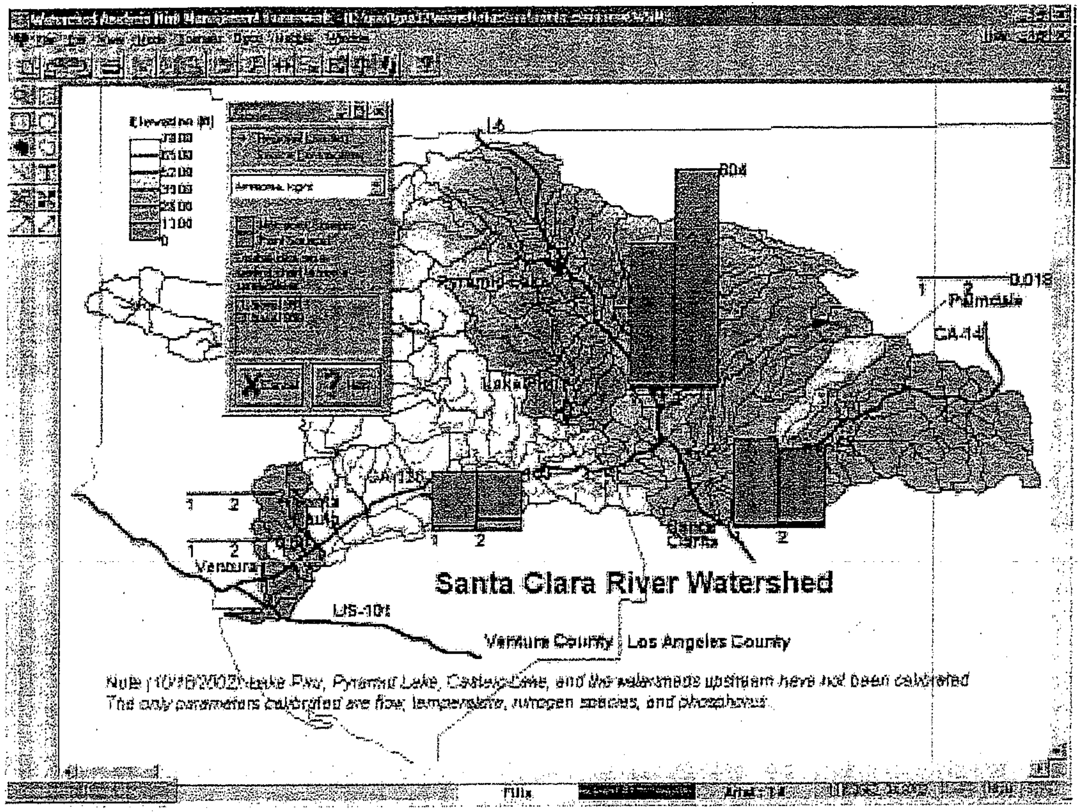
The third method of looking at loading is called "Source Contributions" in WARMF. Source Contributions traces the pollutants in the river at a certain location to its origins in terms of point and nonpoint sources. This view of loading does take into account in-stream processes which assimilate pollutants.

Regional Pollutant Loads

The regional loading output of WARMF shows direct pollutant loads to waterbodies within a region. The Santa Clara River watershed is divided into 6 regions: Mint Canyon Creek, Santa Clara River Reach 8, Santa Clara River, Reach 7, Santa Clara River Reach 3, Wheeler Canyon/Todd Barranca, and Brown Barranca/Long Canyon. The regions are color coded on the basin map (e.g. like blue for Mint Canyon Creek region in the eastern part of the watershed and yellow for the small Brown Barranca/Long Canyon region in the western part of the watershed). The break point of each region is a water quality impaired river segment for which a nutrient TMDL must be determined. The loading sources are tracked back to each land use, direct wet and dry atmospheric deposition to lakes, septic systems, and point sources (from surface and subsurface discharges). The direct precipitation and dry deposition to lakes only applies to Bouquet Reservoir in the Reach 8 region, since that is the only lake simulated by WARMF. Loading from prescribed groundwater flows is listed separately from point and nonpoint sources. The regional loads of ammonia, nitrite, nitrate, and phosphorus are discussed here.

Ammonia

Loading is displayed on bar charts on the WARMF map, as shown in Figure 131. Each bar chart represents a colored region on the map. Magenta represents point sources, green represents nonpoint sources, and light blue is loading from groundwater. In each case, the left bar is 1991 loading and the right bar is 1998 loading. Based on the bar charts, the primary source of ammonia is point sources.



Note (10/16/2002): Lake Piru, Pyramid Lake, Castaic Lake, and the watersheds upstream have not been calibrated. The only parameters calibrated are flow, temperature, nitrogen species, and phosphorus.

Figure 131: Ammonia regional direct loading, 1991 (left) and 1998 (right)

Double-clicking on a loading chart brings up a spreadsheet with a detailed breakdown of the loading between all sources. Table 47 and Table 48 show the breakdown of ammonia loading for each region of the watershed.

For water year 1991, which is a dry year, there is little point or nonpoint source load of ammonia to Mint Canyon, Wheeler Canyon/Todd Barranca, and Brown Barranca/ Long Canyon. The point source load to Todd Barranca is from subsurface discharges. The point source loads to Reach 8, Reach 7, and Reach 3 are 242, 397, and 163 kg/d respectively. The nonpoint source loads to Reaches 8, 7, and 3 are 2, 0, and 9 kg/d respectively. Groundwater loading was near zero in all cases.

For water year 1998, which is a wet year, there is more point and nonpoint source loads of ammonia to Mint Canyon, Wheeler Canyon/Todd Barranca, and Brown Barranca / Long Canyon. The point source loads to Reach 8, Reach 7, and Reach 3 are 208, 601, and 136 kg/d respectively. The nonpoint source loads to Reaches 8, 7, and 3 are 7, 3, and 26 kg/d respectively. As in 1991, groundwater loading was near zero in all cases.

There was a substantial increase of point source ammonia from the region tributary to Reach 7 between 1991 and 1998. This is caused by the growth of cities, unrelated to the weather conditions. The nonpoint point loads of ammonia to Reaches 8, 7, and 3 are all higher in 1998, which are attributable to storm runoff.

Table 47: Ammonia loading to each region's rivers for water year 1991, kg/d

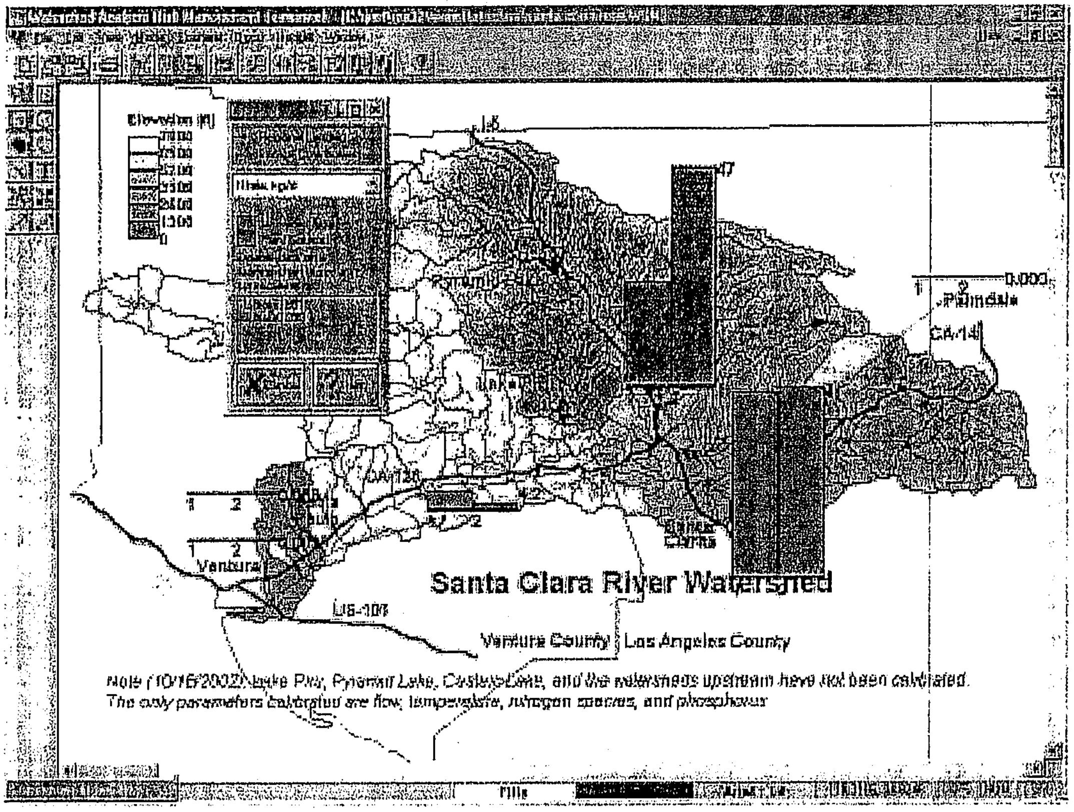
Source	Mint Cyn Creek	SCR Reach 8	SCR Reach 7	SCR Reach 3	Wheeler Cyn / Todd Barr.	Brown Barr. / Long Cyn
Groundwater	0	0.00389	0.0147	0.0120	0	0
Deciduous	0	0.000558	0.000499	0.0997	0	0
Mixed Forest	0	0.000152	0	0.118	0	0
Orchard	0	0.00117	0.00000813	0.614	0.0442	0.0235
Coniferous	0	0.00218	0.000118	2.05	0.0174	0
Shrub / Scrub	0.000761	0.0183	0.150	4.69	0.0185	0.0431
Grassland	0.0000300	0.00174	0.000107	0.0665	0.00277	0.00195
Park	0	0.000142	0	0.00136	0	0.000637
Golf Course	0	0.0333	0	0.0100	0	0
Pasture	0.0000222	0.000896	0.000897	0.000929	0	0
Farm	0	0.0352	0.0773	0.105	0.116	0.105
Marsh	0	0	0.00110	0.000161	0	0
Barren	0.00000291	0.000436	0.000129	0.000164	0.000100	0
Water	0	0.000289	0.00000884	0	0	0
Residential	0.00000812	0.00344	0.00354	0.0181	0.00169	0
High Dens. Res.	0.00000522	0.000920	0.00431	0.0183	0.00180	0
Comm./Industrial	0	0	0	0	0	0
Other Nonpoint	0	0	0	0	0	0
Direct Precip.	0	0.240	0	0	0	0
Direct Dry Depos.	0	0.322	0	0	0	0
Septic Systems	0.0000642	1.62	0.0267	0.422	0.0200	0.000733
Point Sources	0	240	397	154	0.874	0
TOTAL	0.000895	242	397	163	1.10	0.175

Table 48: Ammonia loading to each region's rivers for water year 1998, kg/d

Source	Mint Cyn Creek	SCR Reach 8	SCR Reach 7	SCR Reach 3	Wheeler Cyn / Todd Barr.	Brown Barr. / Long Cyn
Groundwater	0	0.0425	0.155	0.174	0	0
Deciduous	0	0.00178	0.00199	0.289	0	0
Mixed Forest	0	0.0174	0	0.333	0	0
Orchard	0	0.00816	0.0000515	1.77	0.102	0.0668
Coniferous	0	0.770	0.00311	5.67	0.0954	0
Shrub / Scrub	0.0133	2.43	1.43	15.2	0.0923	0.132
Grassland	0.000523	0.00913	0.00364	0.261	0.00713	0.00599
Park	0	0.00327	0	0.00656	0	0.00193
Golf Course	0	0.0246	0	0.00871	0	0
Pasture	0.000387	0.0584	0.00674	0.00405	0	0
Farm	0	0.0368	0.652	1.17	0.215	0.377
Marsh	0	0	0.00512	0.000798	0	0
Barren	0.0000514	0.0163	0.000418	0.000916	0.000572	0
Water	0.00000913	0.0127	0.0000409	0	0	0
Residential	0.000144	0.0678	0.0371	0.0778	0.00647	0
High Dens. Res.	0.0000925	0.0108	0.0444	0.0845	0.00372	0
Comm./Industrial	0	0	0	0	0	0
Other Nonpoint	0	0	0	0	0	0
Direct Precip.	0	0.859	0	0	0	0
Direct Dry Depos.	0	0.123	0	0	0	0
Septic Systems	0.00370	2.43	0.243	1.41	0.0527	0.00115
Point Sources	0.0000333	208	601	136	2.12	0
TOTAL	0.0182	215	604	162	2.70	0.585

Nitrite

Loading is displayed on bar charts on the WARMF map, as shown in Figure 132. Each bar chart represents a colored region on the map. Magenta represents point sources, green represents nonpoint sources, and light blue is loading from groundwater. In each case, the left bar is 1991 loading and the right bar is 1998 loading. Based on the bar charts, the primary source of nitrite is point sources.



Note (10/16/2002): Lake Piru, Pyramid Lake, Castaic Lake, and the watersheds upstream have not been calibrated. The only parameters calibrated are flow, temperature, nitrogen species, and phosphorus

Figure 132: Nitrite regional direct loading, 1991 (left) and 1998 (right)

Double-clicking on a loading chart brings up a spreadsheet with a detailed breakdown of the loading between all sources. Table 49 and Table 50 show the breakdown of nitrite loading for each region of the watershed for a dry year and a wet year, respectively.

For the dry year of 1991, there is very little loading of nitrite to Mint Canyon Creek, Wheeler Canyon/Todd Barranca, and Brown Barranca/ Long Canyon regions. The point source loads to Reach 8, Reach 7, and Reach 3 are 41, 23, and 4 kg/d respectively. The nonpoint source loads to Reaches 8, 7, and 3 are 0, 0, and 0.2 kg/d respectively.

For the wet year of 1998, there is very little loading of nitrite to Mint Canyon Creek, Wheeler Canyon/Todd Barranca, and Brown Barranca/ Long Canyon. The point source loads to Reach 8, Reach 7, and Reach 3 are 41, 47, and 1 kg/d respectively. The nonpoint source loads to Reaches 8, 7, and 3 are 0.1, 0, and 0.5 kg/d respectively.

Table 49: Nitrite loading to each region's rivers for water year 1991, kg/d

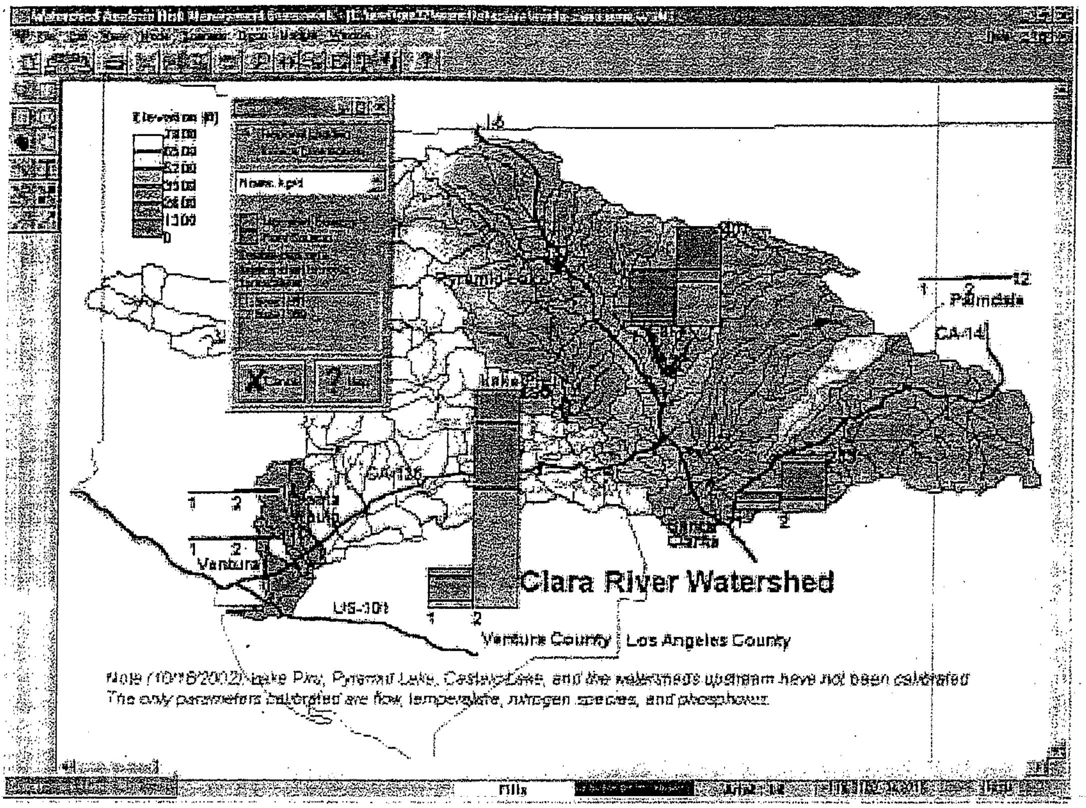
Source	Mint Cyn Creek	SCR Reach 8	SCR Reach 7	SCR Reach 3	Wheeler Cyn / Todd Barr.	Brown Barr. / Long Cyn
Groundwater	0	0.0000858	0.000327	0.000245	0	0
Deciduous	0	0.0000177	0.00000723	0.00240	0	0
Mixed Forest	0	0.00000664	0	0.00279	0	0
Orchard	0	0.0000316	0	0.0135	0.000651	0.000500
Coniferous	0	0.000200	0.00000868	0.0531	0.000425	0
Shrub / Scrub	0.0000221	0.00164	0.00164	0.102	0.000413	0.000675
Grassland	0	0.0000606	0.00000595	0.00113	0.0000463	0.0000306
Park	0	0.0000223	0	0.0000182	0	0.00000997
Golf Course	0	0.0000243	0	0.0000430	0	0
Pasture	0	0.000159	0.0000146	0.0000174	0	0
Farm	0	0.0000469	0.00135	0.00250	0.00179	0.00257
Marsh	0	0	0.0000162	0.00000341	0	0
Barren	0	0.0000680	0.00000303	0.00000320	0.00000236	0
Water	0	0.0000560	0	0	0	0
Residential	0	0.000424	0.0000389	0.000432	0.0000339	0
High Dens. Res.	0	0.000139	0.0000250	0.000306	0.0000281	0
Comm./Industrial	0	0	0	0	0	0
Other Nonpoint	0	0	0	0	0	0
Direct Precip.	0	0	0	0	0	0
Direct Dry Depos.	0	0	0	0	0	0
Septic Systems	0.00000721	0.000260	0.000565	0.0119	0.000363	0.000111
Point Sources	0	40.7	22.5	3.96	0.0126	0
TOTAL	0.0000314	40.7	22.5	4.15	0.0163	0.00389

Table 50: Nitrite loading to each region's rivers for water year 1998, kg/d

Source	Mint Cyn Creek	SCR Reach 8	SCR Reach 7	SCR Reach 3	Wheeler Cyn / Todd Barr.	Brown Barr. / Long Cyn
Groundwater	0	0.000982	0.00362	0.00355	0	0
Deciduous	0	0.0000319	0.0000347	0.00618	0	0
Mixed Forest	0	0.000416	0	0.00689	0	0
Orchard	0	0.0000527	0	0.0359	0.00223	0.00114
Coniferous	0	0.00129	0.0000679	0.119	0.00160	0
Shrub / Scrub	0.000147	0.0224	0.0108	0.282	0.00151	0.00182
Grassland	0.00000578	0.000143	0.0000784	0.00399	0.000105	0.0000826
Park	0	0.0000690	0	0.0000725	0	0.0000267
Golf Course	0	0.0000773	0	0.0000923	0	0
Pasture	0.00000428	0.00115	0.000101	0.0000737	0	0
Farm	0	0.000264	0.00792	0.0187	0.00436	0.00670
Marsh	0	0	0.0000667	0.0000119	0	0
Barren	0	0.000297	0.00000591	0.0000180	0.00000942	0
Water	0	0.000256	0	0	0	0
Residential	0.00000185	0.000955	0.000167	0.00153	0.000103	0
High Dens. Res.	0.00000119	0.000233	0.0000988	0.00109	0.0000517	0
Comm./Industrial	0	0	0	0	0	0
Other Nonpoint	0	0	0	0	0	0
Direct Precip.	0	0	0	0	0	0
Direct Dry Depos.	0	0	0	0	0	0
Septic Systems	0.000366	0.00387	0.00314	0.0319	0.00120	0.0000432
Point Sources	0.00000329	41.3	47.4	0.979	0.0449	0
TOTAL	0.000529	41.4	47.4	1.49	0.0561	0.00981

Nitrate

Loading is displayed on bar charts on the WARMF map, as shown in Figure 133. Each bar chart represents a colored region on the map. Magenta represents point sources, green represents nonpoint sources, and light blue is loading from groundwater. In each case, the left bar is 1991 loading and the right bar is 1998 loading.



Note (10/18/2002): Lake Piru, Pyramid Lake, Castaic Lake, and the watersheds upstream have not been calibrated. The only parameters calibrated are flow, temperature, nitrogen species, and phosphorus.

Figure 133: Nitrate regional direct loading, 1991 (left) and 1998 (right)

Double-clicking on a loading chart brings up a spreadsheet with a detailed breakdown of the loading between all sources. Unlike ammonia and nitrite, nonpoint sources and groundwater contribute a large amount of loading to the impaired river segments. Table 51 and Table 52 show the breakdown of nitrate loading for each region of the watershed for a dry year and a wet year, respectively.

For the dry year of 1991, the nonpoint source loads of nitrate to Mint Canyon Creek, Wheeler Canyon/Todd Barranca, and Brown Barranca/ Long Canyon are about 2 to 7 kg/d. The point source loads to Reach 8, Reach 7, and Reach 3 are 41, 200, and 41 kg/d respectively. The nonpoint source loads to Reaches 8, 7, and 3 are 32, 17, and 88 kg/d respectively. Loading from groundwater accounted for 5, 17, and 33 kg/d respectively. The large nonpoint source contribution of nitrate to Reach 3 is due to the groundwater accretion in the Willard Road and Fish Hatchery areas.

For the wet year of 1998, the nonpoint source loads of nitrate to Mint Canyon Creek, Wheeler Canyon/Todd Barranca, and Brown Barranca/ Long Canyon are about 10 to 12 kg/d. The point source loads to Reach 8, Reach 7, and Reach 3 are 39, 173, and 141 kg/d respectively. Loading from groundwater was much greater than in the dry year, accounting for 52, 182, and 491 kg/d respectively. The nonpoint source loads to Reaches 8, 7, and 3 are 132, 52, and 263 kg/d respectively.

As expected, nonpoint source and groundwater loads of nitrate are much higher during the wet year (1998) than the dry year (1991). About 20% of the load to Reach 3 was from groundwater in the dry year, but 55% in the wet year. Groundwater loading is also much higher as a percentage in the wet year in Reach 8 and Reach 7. The percentage of loading from point sources is correspondingly much lower in the wet year than the dry year. The percentage of nonpoint source loading was higher in the wet year for Reach 8 and Reach 7, but for Reach 3, 55% of the dry year loading was nonpoint source but only 30% of the wet year loading.

Table 51: Nitrate loading to each region for water year 1991, kg/d

Source	Mint Cyn Creek	SCR Reach 8	SCR Reach 7	SCR Reach 3	Wheeler Cyn / Todd Barr.	Brown Barr. / Long Cyn
Groundwater	0	4.65	17.4	33.4	0	0
Deciduous	0	0.0174	0.115	0.613	0	0
Mixed Forest	0	0.360	0	0.250	0	0
Orchard	0	0.0484	0.00586	12.5	0.594	1.29
Coniferous	0	1.58	0.0283	15.6	0.445	0
Shrub / Scrub	2.22	26.2	8.92	55.5	0.389	1.29
Grassland	0.0875	0.202	0.0355	0.940	0.0266	0.0583
Park	0	0.0866	0	0.0103	0	0.0190
Golf Course	0	0.200	0	0.295	0	0
Pasture	0.0648	1.29	0.148	0.100	0	0
Farm	0	0.392	6.76	3.63	1.10	4.18
Marsh	0	0	0.246	0.0284	0	0
Barren	0.00870	0.279	0.0369	0.0249	0.00237	0
Water	0.00154	0.158	0.00229	0.0000111	0	0
Residential	0.0236	0.818	0.152	0.125	0.0255	0
High Dens. Res.	0.0152	0.194	0.140	0.140	0.0126	0
Comm./Industrial	0	0	0	0	0	0
Other Nonpoint	0.000204	0.00247	0.00125	0.434	0.000326	0.000102
Direct Precip.	0	0.342	0	0	0	0
Direct Dry Depos.	0	0.191	0	0	0	0
Septic Systems	0.00113	0.0133	0.0980	0.904	0.0144	0.00754
Point Sources	0.0000344	41.3	200	41.2	2.88	0
TOTAL	2.42	78.4	234	166	5.49	6.84

Table 52: Nitrate loading to each region for water year 1998, kg/d

Source	Mint Cyn Creek	SCR Reach 8	SCR Reach 7	SCR Reach 3	Wheeler Cyn / Todd Barr.	Brown Barr. / Long Cyn
Groundwater	0	51.7	182	491	0	0
Deciduous	0	0.0385	0.216	1.46	0	0
Mixed Forest	0	1.93	0	0.866	0	0
Orchard	0	0.0879	0.00767	31.8	1.54	2.53
Coniferous	0	5.09	0.140	47.8	2.48	0
Shrub / Scrub	11.2	120	31.7	160	2.28	2.53
Grassland	0.440	1.03	0.171	3.61	0.114	0.115
Park	0	0.251	0	0.122	0	0.0370
Golf Course	0	0.150	0	0.557	0	0
Pasture	0.326	5.27	0.360	0.186	0	0
Farm	0	0.601	17.5	12.2	2.19	5.57
Marsh	0	0	0.459	0.0560	0	0
Barren	0.0438	1.05	0.0710	0.0443	0.0147	0
Water	0.00778	0.647	0.00155	0.0000156	0	0
Residential	0.119	3.13	0.526	0.582	0.141	0
High Dens. Res.	0.0765	0.621	0.395	1.37	0.0417	0
Comm./Industrial	0	0	0	0	0	0
Other Nonpoint	0.000671	0.00559	0.00152	0.725	0.000401	0.0000909
Direct Precip.	0	1.11	0	0	0	0
Direct Dry Depos.	0	0.0638	0	0	0	0
Septic Systems	0.00985	0.144	0.210	2.00	0.0464	0.00367
Point Sources	0.000252	39.1	173	141	5.33	0
TOTAL	12.2	233	407	895	14.2	10.8

Phosphorus

Loading is displayed on bar charts on the WARMF map, as shown in Figure 134. Each bar chart represents a colored region on the map. Magenta represents point sources, green represents nonpoint sources, and light blue is groundwater loading. In each case, the left bar is 1991 loading and the right bar is 1998 loading.

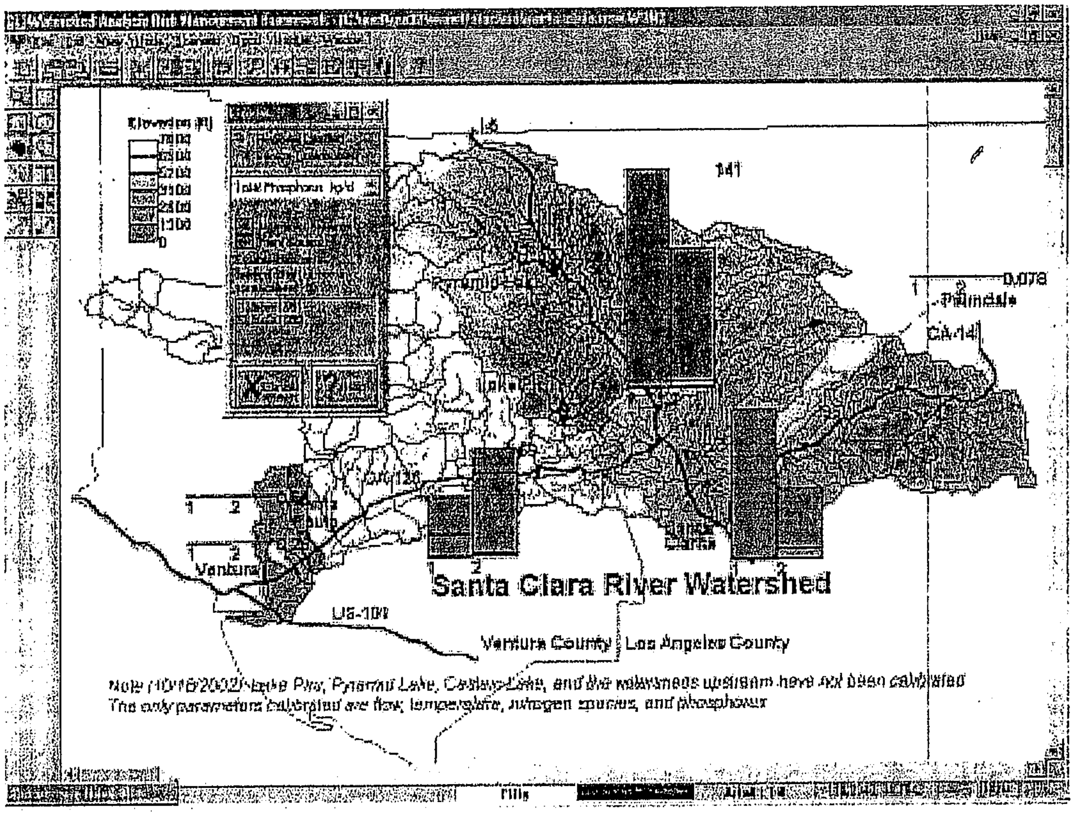


Figure 134: Phosphorus regional direct loading, 1991 (left) and 1998 (right)

Double-clicking on a loading chart brings up a spreadsheet with a detailed breakdown of the loading between all sources. Point sources contribute most phosphorus loading except in the Reach 3 region. Table 53 and Table 54 show the breakdown of phosphorus loading for each region of the watershed for a dry year and a wet year, respectively.

For the dry year of 1991, there is little point or nonpoint source loads of phosphorus to Mint Canyon Creek, Wheeler Canyon/Todd Barranca, and Brown Barranca / Long Canyon. The point source loads to Reach 8, Reach 7, and Reach 3 are 40, 85, and 17 kg/d respectively. The nonpoint source loads to Reaches 8, 7, and 3 are 0, 0, and 14 kg/d respectively. Groundwater contributed very little loading of phosphorus in all cases.

For the wet year of 1998, there is little point or nonpoint source loads of phosphorus from the Mint Canyon, Wheeler Canyon/Todd Barranca, and Brown Barranca/ Long Canyon regions. The point source loads to Reach 8, Reach 7, and Reach 3 are 46, 90, and 69 kg/d respectively. The nonpoint source loads to Reaches 8, 7, and 3 are 6, 3, and 51 kg/d respectively. Groundwater contributed less than 1, 2, and 2 kg/d, respectively, to Reaches 8, 7, and 3.

Table 53: Phosphorus loading to each region for water year 1991, kg/d

Source	Mint Cyn Creek	SCR Reach 8	SCR Reach 7	SCR Reach 3	Wheeler Cyn / Todd Barr.	Brown Barr. / Long Cyn
Groundwater	0	0.0419	0.157	0.133	0	0
Deciduous	0	0.000131	0.000473	0.00521	0	0
Mixed Forest	0	0.000628	0	0.00524	0	0
Orchard	0	0.0139	0.0000188	1.98	0.0219	0.000731
Coniferous	0	0.0151	0.000317	2.85	0.00901	0
Shrub / Scrub	0.00256	0.106	0.0421	8.14	0.00389	0.00135
Grassland	0.000101	0.00123	0.000290	0.0322	0.000124	0.0000611
Park	0	0.000485	0	0.0000126	0	0.0000197
Golf Course	0	0.000281	0	0.000379	0	0
Pasture	0.0000749	0.00526	0.000567	0.000456	0	0
Farm	0	0.00672	0.186	0.400	0.0184	0.0813
Marsh	0	0	0.00104	0.0000904	0	0
Barren	0.00000983	0.00328	0.0000942	0.0000744	0.0000218	0
Water	0.00000175	0.00152	0.00000375	0	0	0
Residential	0.0000270	0.00901	0.000702	0.00497	0.000204	0
High Dens. Res.	0.0000174	0.00270	0.000483	0.000829	0.0000136	0
Comm./Industrial	0	0	0	0	0	0
Other Nonpoint	0	0	0	0	0	0
Direct Precip.	0	0	0	0	0	0
Direct Dry Depos.	0	0	0	0	0	0
Septic Systems	0.00258	0.164	0.114	0.481	0.0549	0.0000801
Point Sources	0.0000297	95.8	141	24.2	0.0525	0
TOTAL	0.00540	96.1	141	38.3	0.161	0.0835

Table 54: Phosphorus loading to each region for water year 1998, kg/d

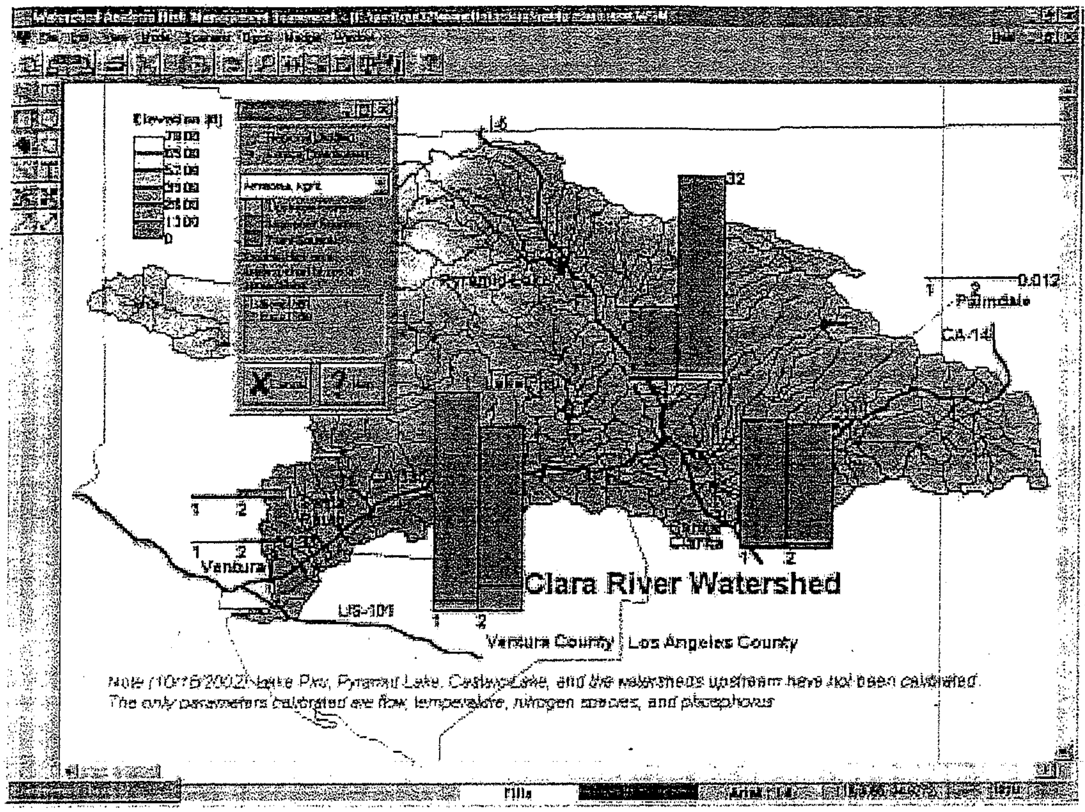
Source	Mint Cyn Creek	SCR Reach 8	SCR Reach 7	SCR Reach 3	Wheeler-Cyn / Todd Barr.	Brown Barr. / Long Cyn
Groundwater	0	0.465	1.68	1.92	0	0
Deciduous	0	0.00296	0.000587	0.0108	0	0
Mixed Forest	0	0.0371	0	0.0107	0	0
Orchard	0	0.216	0.0000146	7.29	0.159	0.00193
Coniferous	0	0.335	0.00353	10.5	0.0393	0
Shrub / Scrub	0.0161	1.71	0.237	28.3	0.0141	0.00258
Grassland	0.000633	0.0123	0.00220	0.130	0.000434	0.000117
Park	0	0.00788	0	0.0000976	0	0.0000378
Golf Course	0	0.00111	0	0.00105	0	0
Pasture	0.000469	0.0769	0.00179	0.00170	0	0
Farm	0	0.0738	1.52	3.16	0.0432	0.277
Marsh	0	0	0.00216	0.000177	0	0
Barren	0.0000562	0.0345	0.000502	0.000107	0.0000724	0
Water	0.00000999	0.0262	0.0000159	0	0	0
Residential	0.000169	0.105	0.00567	0.0190	0.000726	0
High Dens. Res.	0.000109	0.0257	0.00188	0.00288	0.0000372	0
Comm./Industrial	0	0	0	0	0	0
Other Nonpoint	0	0	0	0	0	0
Direct Precip.	0	0	0	0	0	0
Direct Dry Depos.	0	0	0	0	0	0
Septic Systems	0.0601	2.80	1.15	1.36	0.188	0.000219
Point Sources	0.000692	39.5	84.9	16.7	0.145	0
TOTAL	0.0783	45.5	89.5	69.4	0.590	0.282

Source Contribution Loads

The source contributions loading output of WARMF is the way to directly view the pollutant sources at a given location. Because of processes like flow loss to groundwater and denitrification, much of the regional loading detailed in the section above may be lost in certain sections of the watershed. Source contributions loading takes these processes into account. As in regional loading, the loading sources are tracked back to each land use, direct wet and dry atmospheric deposition to lakes, septic systems, and point sources (from surface and subsurface discharges). The direct precipitation and dry deposition to lakes only applies to Bouquet Reservoir upstream of Reach 8, since that is the only lake simulated by WARMF. There is also a portion of the loading from reservoir releases. Reservoir releases include flows from Bouquet Reservoir, Castaic Lake, and Lake Piru. Following are discussions of the sources of ammonia, nitrite, nitrate, and phosphorus.

Ammonia

Loading is displayed on bar charts on the WARMF map, as shown in Figure 135. Each bar chart represents an impaired segment pointed to by its red line. Magenta represents point sources, green represents nonpoint sources, and light blue represents reservoir releases and groundwater loading combined. In each case, the left bar is 1991 loading and the right bar is 1998 loading.



Note (10/16/2002): Lake Piru, Pyramid Lake, Castaic Lake, and the watersheds upstream have not been calibrated. The only parameters calibrated are flow, temperature, nitrogen species, and phosphorus

Figure 135: Ammonia source contributions loading, 1991 (left) and 1998 (right)

Double-clicking on a loading chart brings up a spreadsheet with a detailed breakdown of the loading between all sources. As with regional loading, the source contributions loading for ammonia shows that most of the ammonia in each impaired segment came from point sources. Table 55 and Table 56 show the breakdown of the sources of ammonia loading for each impaired river segment of the watershed for a dry year and a wet year respectively.

For the dry year 1991, the point source load contributions in Reaches 8, 7, and 3 are 20, 11, and 33 kg/d respectively. The nonpoint source contributions are near zero for Reaches 8 and 7 and 1 kg/d in Reach 3. For the wet year 1998, the point source load contributions in Reaches 8, 7, and 3 are 19, 31, and 25 kg/d respectively. The nonpoint source load contribution in Reach 3 is only 4 kg/d for the wet year of 1998. Loading from groundwater is minimal. The reason why nonpoint source and groundwater load of ammonia is low is because the background concentration of ammonia is low in groundwater and surface water as shown in water quality monitoring data for streams in undeveloped areas (Figure 26, Figure 31, Figure 48, and Figure 51).

Table 55: Ammonia source contributions in each impaired river segment for water year 1991, kg/d

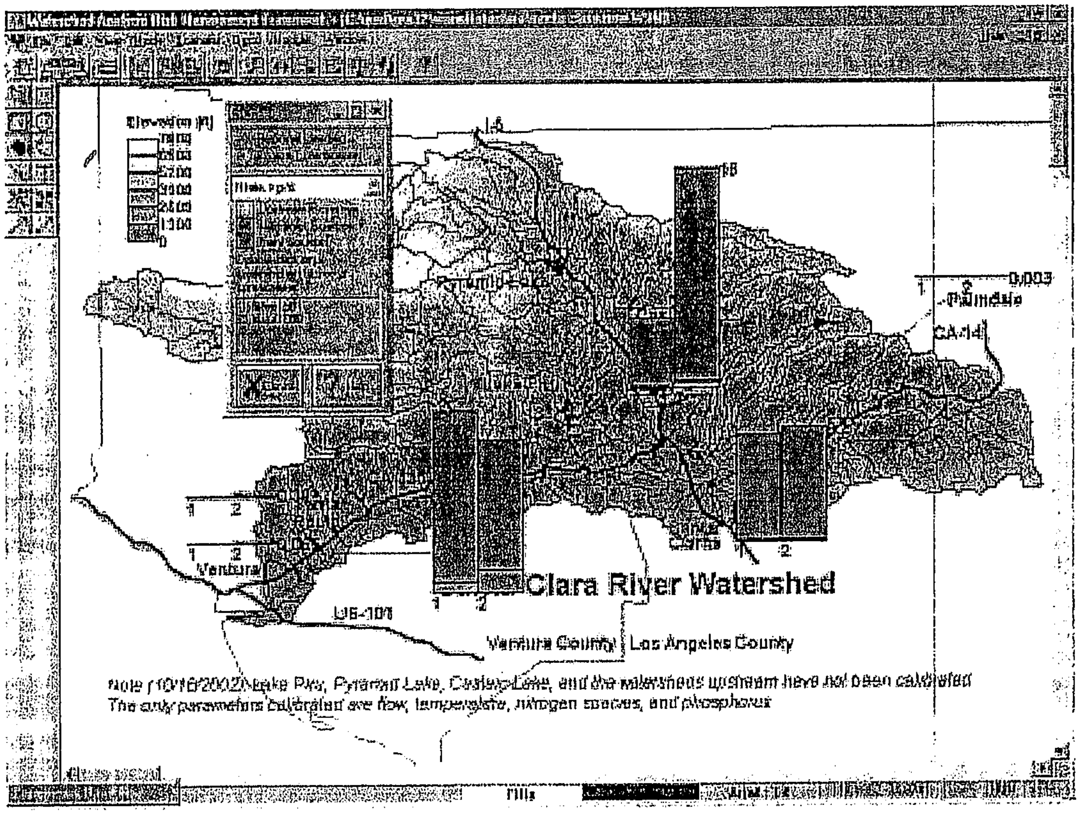
Source	Mint Cyn Creek	SCR Reach 8	SCR Reach 7	SCR Reach 3	Wheeler Cyn / Todd Barr.	Brown Barr. / Long Cyn
Reservoir Release	0	0.00000454	0.00000125	0.000748	0	0
Groundwater	0	0.00227	0.00421	0.00323	0	0
Deciduous	0	0.000309	0.000302	0.0178	0	0
Mixed Forest	0	0.0000149	0.00000472	0.0282	0	0
Orchard	0	0.000547	0.000136	0.106	0.0261	0.0141
Coniferous	0	0.000235	0.000123	0.325	0.00708	0
Shrub / Scrub	0.000421	0.00354	0.0550	0.614	0.00827	0.0263
Grassland	0.0000166	0.000822	0.000152	0.0108	0.00160	0.00119
Park	0	0.0000414	0.0000126	0.000463	0	0.000389
Golf Course	0	0.0120	0.000210	0.000492	0	0
Pasture	0.0000123	0.000225	0.000452	0.0000594	0	0
Farm	0	0.0128	0.0365	0.0321	0.0660	0.0622
Marsh	0	0	0.000511	0.0000142	0	0
Barren	0.00000161	0.000140	0.000106	0.0000170	0.0000412	0
Water	0	0.000120	0.0000424	0.00000331	0	0
Residential	0.00000449	0.00129	0.00129	0.00367	0.000861	0
High Dens. Res.	0.00000289	0.000378	0.00138	0.00644	0.00109	0
Comm./Industrial	0	0	0	0	0	0
Other Nonpoint	0.000108	0.00509	0.0119	0.0508	0.000634	0.0000223
Direct Precip.	0	0	0	0	0	0
Direct Dry Depos.	0	0	0	0	0	0
Septic Systems	0.0000323	0.00146	0.00766	0.0881	0.0111	0.000399
Point Sources	0	19.6	10.8	32.8	0.496	0
TOTAL	0.000601	19.6	10.9	34.1	0.619	0.105

Table 56: Ammonia source contributions in each impaired river segment for water year 1998, kg/d

Source	Mint Cyn Creek	SCR Reach 8	SCR Reach 7	SCR Reach 3	Wheeler Cyn / Todd Barr.	Brown Barr. / Long Cyn
Reservoir Release	0	0.000860	0.0477	0.0102	0	0
Groundwater	0	0.0276	0.0601	0.0399	0	0
Deciduous	0	0.000713	0.00109	0.0391	0	0
Mixed Forest	0	0.00464	0.00131	0.0648	0	0
Orchard	0	0.000556	0.000243	0.398	0.0553	0.0387
Coniferous	0	0.0125	0.00610	0.692	0.0338	0
Shrub / Scrub	0.00850	0.334	0.499	1.34	0.0342	0.0764
Grassland	0.000335	0.00363	0.00145	0.0428	0.00350	0.00346
Park	0	0.000660	0.000227	0.00234	0	0.00112
Golf Course	0	0.00774	0.000313	0.00191	0	0
Pasture	0.000248	0.0174	0.00705	0.000863	0	0
Farm	0	0.00922	0.267	0.466	0.120	0.214
Marsh	0	0	0.00188	0.000120	0	0
Barren	0.0000330	0.00438	0.00155	0.000287	0.000203	0
Water	0.00000586	0.00280	0.000752	0.0000881	0	0
Residential	0.0000921	0.0135	0.0142	0.0155	0.00265	0
High Dens. Res.	0.0000592	0.00290	0.0132	0.0283	0.00207	0
Comm./Industrial	0	0	0	0	0	0
Other Nonpoint	0.000202	0.0331	0.0706	0.185	0.00199	0.0000344
Direct Precip.	0	0	0	0	0	0
Direct Dry Depos.	0	0	0	0	0	0
Septic Systems	0.00221	0.0200	0.0631	0.304	0.0275	0.000650
Point Sources	0.0000199	18.6	30.6	25.1	1.17	0
TOTAL	0.0117	19.1	31.7	28.7	1.45	0.335

Nitrite

Loading is displayed on bar charts on the WARMF map, as shown in Figure 136. Each bar chart points to the impaired segment it refers to with a red line. Magenta represents point sources, green represents nonpoint sources, and light blue represents reservoir releases and groundwater loading combined. In each case, the left bar is 1991 loading and the right bar is 1998 loading.



Note (10/16/2002): Lake Piru, Pyramid Lake, Castaic Lake, and the watersheds upstream have not been calibrated
The only parameters calibrated are flow, temperature, nitrogen sources, and phosphorus

Figure 136: Nitrite source contributions loading, 1991 (left) and 1998 (right)

Double-clicking on a loading chart brings up a spreadsheet with a detailed breakdown of the loading between all sources. Most nitrite comes from point sources, although a significant amount comes from the nitrification of nonpoint source ammonia in Reach 3. Table 57 and Table 58 show the breakdown of the sources of nitrite loading for each impaired river segment of the watershed for a dry year and a wet year respectively.

For the dry year 1991, the point source load contributions in Reaches 8, 7, and 3 are 8, 5, and 13 kg/d respectively. The nonpoint source contributions are zero for Reaches 8 and 7 and 1 kg/d for Reach 3. For the wet year 1998, the point source load contributions in Reaches 8, 7, and 3 are 8, 16, and 11 kg/d respectively. The nonpoint source load contribution to Reach 3 is 2 kg/d for the wet year of 1998. Very little nitrite load comes from nonpoint sources and groundwater because the background concentration of nitrite in groundwater and surface water is naturally very low.

Table 57: Nitrite source contributions in each impaired river segment for water year 1991, kg/d

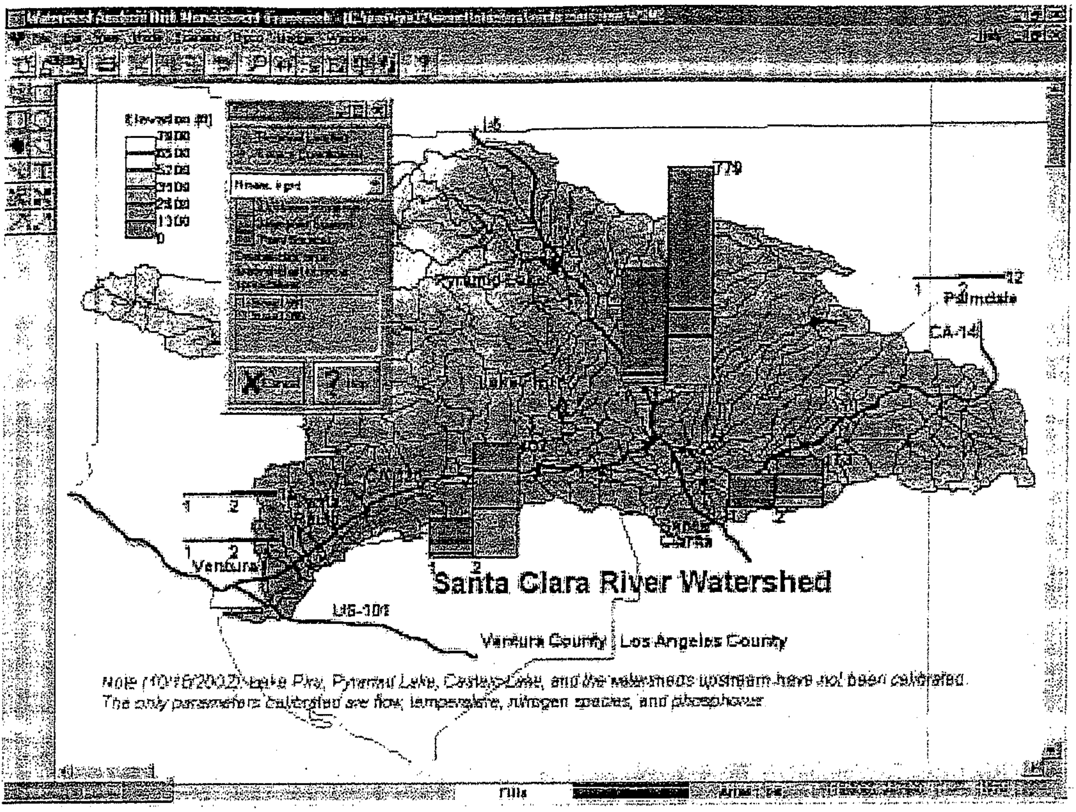
Source	Mint Cyn Creek	SCR Reach 8	SCR Reach 7	SCR Reach 3	Wheeler Cyn / Todd Barr.	Brown Barr. / Long Cyn
Reservoir Release	0	0.00000243	0	0.000269	0	0
Groundwater	0	0.000576	0.00144	0.00115	0	0
Deciduous	0	0.0000793	0.0000928	0.00922	0	0
Mixed Forest	0	0.00000530	0.00000163	0.0138	0	0
Orchard	0	0.000138	0.0000477	0.0494	0.00653	0.00354
Coniferous	0	0.000102	0.0000471	0.165	0.00272	0
Shrub / Scrub	0.000112	0.00142	0.0217	0.325	0.00289	0.00651
Grassland	0.00000440	0.000216	0.0000691	0.00496	0.000420	0.000295
Park	0	0.0000149	0.00000524	0.000175	0	0.0000960
Golf Course	0	0.00276	0.0000917	0.000174	0	0
Pasture	0.00000326	0.0000973	0.000156	0.0000282	0	0
Farm	0	0.00296	0.0121	0.0133	0.0166	0.0158
Marsh	0	0	0.000145	0.00000598	0	0
Barren	0	0.0000594	0.0000404	0.00000717	0.0000158	0
Water	0	0.0000429	0.0000173	0.00000124	0	0
Residential	0.00000120	0.000405	0.000583	0.00178	0.000260	0
High Dens. Res.	0	0.000119	0.000633	0.00257	0.000272	0
Comm./Industrial	0	0	0	0	0	0
Other Nonpoint	0.0000240	0.00151	0.00358	0.0183	0.000158	0.00000530
Direct Precip.	0	0	0	0	0	0
Direct Dry Depos.	0	0	0	0	0	0
Septic Systems	0.0000108	0.000816	0.00337	0.0422	0.00286	0.000129
Point Sources	0	7.71	4.95	12.4	0.125	0
TOTAL	0.000157	7.72	4.99	13.0	0.158	0.0264

Table 58: Nitrite source contributions in each impaired river segment for water year 1998, kg/d

Source	Mint Cyn Creek	SCR Reach 8	SCR Reach 7	SCR Reach 3	Wheeler Cyn / Todd Barr.	Brown Barr. / Long Cyn
Reservoir Release	0	0.000392	0.0268	0.00396	0	0
Groundwater	0	0.00689	0.0229	0.0148	0	0
Deciduous	0	0.000207	0.000412	0.0202	0	0
Mixed Forest	0	0.00162	0.000697	0.0318	0	0
Orchard	0	0.000176	0.0000974	0.159	0.0145	0.00983
Coniferous	0	0.00647	0.00291	0.334	0.0130	0
Shrub / Scrub	0.00210	0.136	0.227	0.632	0.0126	0.0193
Grassland	0.0000829	0.00122	0.000749	0.0168	0.00101	0.000873
Park	0	0.000311	0.000111	0.000873	0	0.000281
Golf Course	0	0.00176	0.000157	0.000679	0	0
Pasture	0.0000614	0.00706	0.00349	0.000363	0	0
Farm	0	0.00231	0.1000	0.152	0.0309	0.0546
Marsh	0	0	0.000684	0.0000500	0	0
Barren	0.00000813	0.00192	0.000764	0.000118	0.0000779	0
Water	0.00000145	0.00114	0.000371	0.0000351	0	0
Residential	0.0000229	0.00600	0.00682	0.00671	0.000893	0
High Dens. Res.	0.0000147	0.00118	0.00615	0.0112	0.000533	0
Comm./Industrial	0	0	0	0	0	0
Other Nonpoint	0.0000449	0.0111	0.0246	0.0674	0.000498	0.00000817
Direct Precip.	0	0	0	0	0	0
Direct Dry Depos.	0	0	0	0	0	0
Septic Systems	0.000672	0.00948	0.0292	0.132	0.00741	0.000172
Point Sources	0.00000604	8.03	15.4	9.39	0.303	0
TOTAL	0.00302	8.22	15.9	11.0	0.384	0.0850

Nitrate

Loading is displayed on bar charts on the WARMF map, as shown in Figure 137. Each bar chart refers to an impaired river segment pointed to by its red line. Magenta represents point sources and green represents nonpoint sources, and light blue represents reservoir releases and groundwater loading combined. In each case, the left bar is 1991 loading and the right bar is 1998 loading.



Note (10/16/2002): Lake Piru, Pyramid Lake, Castaic Lake, and the watersheds upstream have not been calibrated. The only parameters calibrated are flow, temperature, nitrogen species, and phosphorus.

Figure 137: Nitrate source contributions loading, 1991 (left) and 1998 (right)

Double-clicking on a loading chart brings up a spreadsheet with a detailed breakdown of the loading between all sources. Nitrate in the impaired reaches is a blend of point sources, nonpoint sources, and reservoir releases. Table 59 and Table 60 show the breakdown of the sources of nitrate loading for each impaired river segment of the watershed for a dry year and a wet year respectively.

In the dry year, nonpoint sources represented 15% of nitrate in Reach 8 (17 kg/d), 6% of nitrate in Reach 7 (24 kg/d), and 28% of nitrate in Reach 3 (38 kg/d). In the wet year, nonpoint sources were 45% of the loading in Reach 8 (78 kg/d), 12% of the loading in Reach 7 (93 kg/d), and 32% of the loading in Reach 3 (128 kg/d). Reservoir releases contributed minimal loading in the dry year. Release from Castaic Lake contributed 3% of the nitrate in Reach 7 in the wet year (21 kg/d). The combination of releases from Castaic Lake and Lake Piru represented 1% of the nitrate in Reach 3 in the wet year (5 kg/d). In the dry year, groundwater contributed 3% of nitrate in Reach 8 (3 kg/d), 3% of nitrate in Reach 7 (14 kg/d), and 11% of nitrate in Reach 3 (14 kg/d). In the wet year, groundwater was 20% of the loading in Reach 8 (35 kg/d), 20% of the loading in Reach 7 (154 kg/d), and 42% of the loading in Reach 3 (170 kg/d).

Table 59: Nitrate source contributions in each impaired river segment for water year 1991, kg/d

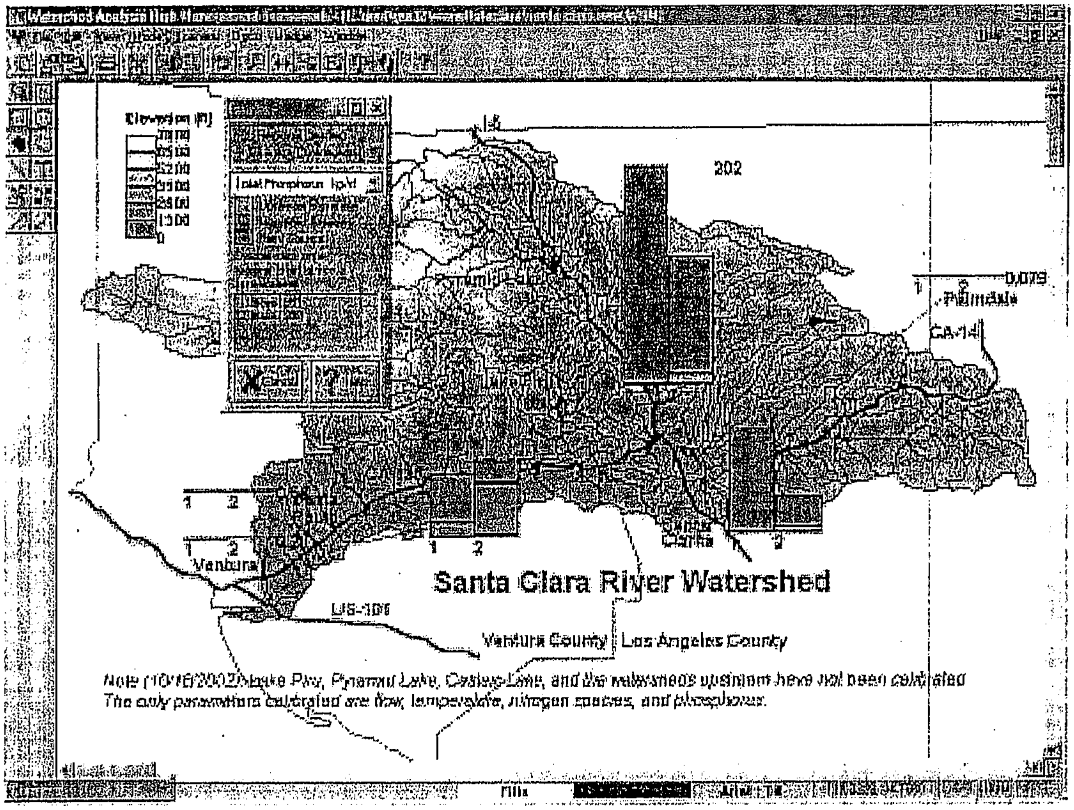
Source	Mint Cyn Creek	SCR Reach 8	SCR Reach 7	SCR Reach 3	Wheeler Cyn / Todd Barr.	Brown Barr. / Long Cyn
Reservoir Release	0	0.00187	0.00104	0.277	0	0
Groundwater	0	3.06	13.6	14.3	0	0
Deciduous	0	0.0111	0.114	0.178	0	0
Mixed Forest	0	0.220	0.116	0.175	0	0
Orchard	0	0.0204	0.0161	5.72	0.606	1.30
Coniferous	0	0.435	0.246	7.68	0.455	0
Shrub / Scrub	2.22	14.4	15.6	20.8	0.399	1.30
Grassland	0.0875	0.140	0.109	0.342	0.0275	0.0589
Park	0	0.0308	0.0181	0.00686	0	0.0192
Golf Course	0	0.131	0.0486	0.117	0	0
Pasture	0.0648	0.727	0.528	0.0487	0	0
Farm	0	0.199	6.44	2.39	1.13	4.21
Marsh	0	0	0.227	0.0182	0	0
Barren	0.00870	0.145	0.116	0.0122	0.00242	0
Water	0.00154	0.0806	0.0481	0.00376	0	0
Residential	0.0236	0.396	0.363	0.0943	0.0262	0
High Dens. Res.	0.0152	0.100	0.183	0.0974	0.0130	0
Comm./Industrial	0	0	0	0	0	0
Other Nonpoint	0.000957	0.0129	0.0565	0.234	0.000915	0.000168
Direct Precip.	0	0	0	0	0	0
Direct Dry Depos.	0	0	0	0	0	0
Septic Systems	0.00116	0.384	0.281	0.614	0.0208	0.00786
Point Sources	0.0000347	89.6	376	82	3.15	0
TOTAL	2.44	110	414	135	5.83	6.89

Table 60: Nitrate source contributions in each impaired river segment for water year 1998, kg/d

Source	Mint Cyn Creek	SCR Reach 8	SCR Reach 7	SCR Reach 3	Wheeler Cyn / Todd Barr.	Brown Barr. / Long Cyn
Reservoir Release	0	0.228	20.5	4.74	0	0
Groundwater	0	35.4	154	170	0	0
Deciduous	0	0.0174	0.211	0.597	0	0
Mixed Forest	0	1.02	0.606	0.634	0	0
Orchard	0	0.0308	0.0253	16.8	1.58	2.55
Coniferous	0	1.99	1.33	23.2	2.53	0
Shrub / Scrub	11.2	68.1	68.1	71.1	2.34	2.57
Grassland	0.440	0.591	0.479	1.60	0.117	0.116
Park	0	0.0869	0.0525	0.0711	0	0.0376
Golf Course	0	0.0926	0.0517	0.261	0	0
Pasture	0.326	3.15	2.16	0.298	0	0
Farm	0	0.231	16.6	10.0	2.26	5.68
Marsh	0	0	0.421	0.0605	0	0
Barren	0.0438	0.549	0.380	0.0612	0.0151	0
Water	0.00778	0.280	0.164	0.0200	0	0
Residential	0.119	1.52	1.42	0.561	0.144	0
High Dens. Res.	0.0765	0.317	0.560	0.810	0.0429	0
Comm./Industrial	0	0	0	0	0	0
Other Nonpoint	0.00155	0.0485	0.185	0.631	0.00181	0.000166
Direct Precip.	0	0	0	0	0	0
Direct Dry Depos.	0	0	0	0	0	0
Septic Systems	0.0110	0.713	0.761	1.68	0.0654	0.00405
Point Sources	0.000263	59.1	512	99.3	6.03	0
TOTAL	12.2	173	779	402	15.1	11.0

Phosphorus

Loading is displayed on bar charts on the WARMF map, as shown in Figure 138. Each bar chart represents an impaired river segment pointed to by a red line. Magenta represents point sources, green represents nonpoint sources, and light blue represents reservoir releases and groundwater loading combined. In each case, the left bar is 1991 loading and the right bar is 1998 loading.



Note (10/16/2002): Lake Piru, Pyramid Lake, Castaic Lake, and the watersheds upstream have not been calibrated
The only parameters calibrated are flow, temperature, nitrogen species, and phosphorus.

Figure 138: Phosphorus source contributions loading, 1991 (left) and 1998 (right)

Double-clicking on a loading chart brings up a spreadsheet with a detailed breakdown of the loading between all sources. Point sources contribute most of the phosphorus in the impaired reaches of the watershed, although there is significant phosphorus from nonpoint sources in Reach 3. Table 61 and Table 62 show the breakdown of the sources of phosphorus loading for each impaired river segment of the watershed for a dry year and a wet year respectively.

As with ammonia, background concentrations of phosphorus are low in groundwater and surface waters without point sources (Figure 29 and Figure 33). In the dry year, most phosphorus in the Santa Clara River comes from point sources. In 1998, however, 67% of phosphorus in Reach 3 came from nonpoint sources, especially from the dominant natural land covers, scrubland and coniferous forest. Orchard contributed 14% of the nonpoint source portion of phosphorus in 1998 in Reach 3. Groundwater contributed less than 1% of phosphorus in the dry year. In the wet year, groundwater contributed 1%, 2%, and 3%, respectively, in Reaches 8, 7, and 3. In Todd Barranca, 25% of the phosphorus was from point sources. In Mint Canyon Creek and Brown Barranca, most or all of the phosphorus was from nonpoint sources.

Table 61: Phosphorus source contributions in each impaired river segment for water year 1991, kg/d

Source	Mint Cyn Creek	SCR Reach 8	SCR Reach 7	SCR Reach 3	Wheeler Cyn / Todd Barr.	Brown Barr. / Long Cyn
Reservoir Release	0	0.0000704	0.0000710	0.00836	0	0
Groundwater	0	0.0419	0.198	0.162	0	0
Deciduous	0	0.000129	0.000598	0.00384	0	0
Mixed Forest	0	0.000317	0.000313	0.00508	0	0
Orchard	0	0.0138	0.0137	1.69	0.0219	0.000731
Coniferous	0	0.0146	0.0138	2.34	0.00900	0
Shrub / Scrub	0.00256	0.106	0.142	6.63	0.00389	0.00135
Grassland	0.000101	0.00132	0.00158	0.0254	0.000124	0.0000611
Park	0	0.000481	0.000479	0.0000996	0	0.0000197
Golf Course	0	0.000284	0.000279	0.000430	0	0
Pasture	0.0000748	0.00529	0.00581	0.00116	0	0
Farm	0	0.00671	0.190	0.464	0.0183	0.0813
Marsh	0	0	0.00103	0.000145	0	0
Barren	0.00000983	0.00327	0.00336	0.000669	0.0000218	0
Water	0.00000175	0.00148	0.00148	0.000295	0	0
Residential	0.0000270	0.00895	0.00952	0.00563	0.000204	0
High Dens. Res.	0.0000174	0.00270	0.00314	0.00130	0.0000136	0
Comm./Industrial	0	0	0	0	0	0
Other Nonpoint	0.000115	0.00652	0.0161	0.0619	0.000547	0.000170
Direct Precip.	0	0	0	0	0	0
Direct Dry Depos.	0	0	0	0	0	0
Septic Systems	0.00257	0.159	0.246	0.393	0.0549	0.0000801
Point Sources	0.0000296	92.1	201	44.5	0.0525	0
TOTAL	0.00551	92.5	202	56.3	0.161	0.0837

Table 62: Phosphorus source contributions in each impaired river segment for water year 1998, kg/d

Source	Mint Cyn Creek	SCR Reach 8	SCR Reach 7	SCR Reach 3	Wheeler Cyn / Todd Barr.	Brown Barr. / Long Cyn
Reservoir Release	0	0.00106	0.367	0.129	0	0
Groundwater	0	0.463	2.11	1.94	0	0
Deciduous	0	0.00286	0.00321	0.0103	0	0
Mixed Forest	0	0.0169	0.0158	0.0177	0	0
Orchard	0	0.207	0.193	6.44	0.159	0.00193
Coniferous	0	0.318	0.299	8.66	0.0393	0
Shrub / Scrub	0.0160	1.63	1.72	23.5	0.0141	0.00258
Grassland	0.000633	0.0123	0.0131	0.109	0.000434	0.000117
Park	0	0.00672	0.00617	0.00316	0	0.0000378
Golf Course	0	0.00110	0.000982	0.00162	0	0
Pasture	0.000469	0.0673	0.0641	0.0284	0	0
Farm	0	0.0675	1.56	3.91	0.0432	0.277
Marsh	0	0	0.00210	0.000657	0	0
Barren	0.0000562	0.0292	0.0270	0.0144	0.0000724	0
Water	0.00000998	0.0172	0.0158	0.00613	0	0
Residential	0.000169	0.101	0.0981	0.0660	0.000726	0
High Dens. Res.	0.000109	0.0223	0.0221	0.0134	0.0000371	0
Comm./Industrial	0	0	0	0	0	0
Other Nonpoint	0.000407	0.0339	0.0739	0.245	0.00205	0.000546
Direct Precip.	0	0	0	0	0	0
Direct Dry Depos.	0	0	0	0	0	0
Septic Systems	0.0601	2.62	3.48	2.62	0.188	0.000219
Point Sources	0.000692	27.1	109	20.8	0.145	0
TOTAL	0.0787	32.7	119	68.5	0.592	0.282

Summary

Regional pollution loads and source contributions of pollutants to the water quality impaired segments were calculated by WARMF. The results show that point source loads contribute almost all of ammonia, nitrite, and phosphorus in the water quality impaired segments of the Santa Clara River watershed. Nitrate in impaired segments comes from a combination of point, nonpoint, and groundwater sources. The nonpoint source load contribution is higher in the wet year.

VII. Conclusion

To provide a linkage between pollution loads and water quality in the Santa Clara River requires a watershed model. The success of the watershed model is largely dependent upon proper hydrologic accounting. The accounting of uncontrolled flows in the western part of the watershed and the accounting of managed flows for point source waste discharges, groundwater accretion, water gains and losses across the river bed and groundwater dewatering operations are all important.

Simulations of Santa Paula, Sespe, and Hopper Creeks show good water balance and reasonable correlation. Simulations of Mint Canyon Creek and Bouquet Canyon Creek show the intermittent flow typical of the eastern tributaries. The flow accounting on the Santa Clara River is reasonable from Santa Clarita through Freeman diversion. In a heavily managed system like the Santa Clara River, the reliability of managed flow data is uncertain. The calibrated model is set up to minimize the errors of the data by flow balance.

The primary purpose of the model is to calculate TMDLs for the water quality impaired river segments in the watershed. There is little data to calibrate the three smaller impaired tributaries (Mint Canyon Creek, Wheeler Canyon / Todd Barranca, and Brown Barranca.Long Canyon). The flow and pollutants are routed downstream to the main stem of the Santa Clara River where data is more plentiful. The linkage analysis indicates the importance of point sources, managed flows, and groundwater interactions between Blue Cut and Santa Paula Creek, for which there is good data available.

The water quality of concern is nutrients, principally ammonia, nitrite, and nitrate. Point source loads contribute ammonia, nitrite, and nitrate to the impaired river segments. Nonpoint source loads also contribute nitrate to the impaired river segments through groundwater accretion. Denitrification, which removes nitrate from the water, appears to occur in the river bed of the impaired river segments, located in most cases below the wastewater treatment plant discharges. Because of the assimilation processes occurring within river segments of the watershed, it is important to distinguish between loading *to* the rivers, and loading *in* the rivers, the latter of which is directly reflective of water quality.

VIII. Acknowledgements

We wish to thank those people who provided assistance in collecting and analyzing data for the watershed modeling. Murray McEachron at UWCD provided a thorough analysis and estimates of river gains and losses between Blue Cut and Freeman Diversion. Dan Detmer of UWCD provided a variety of data, including GIS layers, well pumping data, well water quality data, and surface water quality data. Suk Chong of the Los Angeles Department of Public Works provided precipitation and gaging data for the eastern part of the watershed. Elizabeth Erickson provided water quality monitoring data. Arturo Keller and Tim Robinson compiled most of the electronic data for this project. Thanks

also to the members of the Santa Clara River Nutrient TMDL Steering Committee as a whole for providing their feedback to help the modeling project.

IX. References

California Department of Water Resources (DWR), Souther District. 1993. "Investigation of Water Quality and Beneficial Uses Upper Santa Clara River Hydrological Area". Glendale, CA.

California Department of Water Resources (DWR). 2002. CD: Draft Land Use Data: 2000 Ventura County.

California Air Resources Board (CARB). 2002. California Ambient Air Quality Data 1980-1999. CD No. PTSD-00-014-CD

CH2M Hill (J. Porcello). 2002. MicroFem groundwater flow model results ("CH2M rising gw for WARMF 1.xls" and "CH2M rising gw for WARMF 2.xls").

Chen, C.W., J. Herr, and L. Weintraub. 2001. "Watershed Analysis Risk Management Framework (WARMF): Update One – A Decision Support System for Watershed Analysis and Total Maximum Daily Load Calculation, Allocation and Implementation" Publication No. 1005181, Electric Power Research Institute, Palo Alto, CA.

Daugovich, Oleg (University of California at Davis). 2002. personal e-mails to Arturo Keller.

Herr J., L. H. Z. Weintraub, and C. Chen, 2000 "Watershed Analysis Risk Management Framework (WARMF) User's Guide: Documentation of Graphical User Interface", Electric Power Research Institute, Palo Alto, CA. Technical Report 1000729.

Hirsch, R.M., 2001. "TMDLs: Science for Solutions". Presented at the Water Environment Federation TMDL Science Issue Conference, March 4-7 2001.

Los Angeles County Department of Public Works (LAC DPW). 2002. Daily Precipitation Summary database. Web site: http://www.ladpw.org/wrd/precip/data/ .

Los Angeles Regional Water Quality Control Board (LA RWQCB) (Arturo Keller, Santa Clara River Nutrient TMDL Facilitator). 2002. Request for Proposals for Santa Clara River Nutrient TMDL Analysis.

National Atmospheric Deposition Program (NADP). 2002. NADP/NTN Monitoring Location CA42, Tanbark Flat. Web site: http://nadp.sws.uiuc.edu/nadpdata/

National Climatic Data Center (NCDC). 2002. Summary of the Day Database.

United States Department of Agriculture, National Resources Conservation Service (USDA NRCS). 1994. Map Unit Interpretation Record (MUIR) Database. Fort Worth, TX.

Newhall Land (Mark Subbotin). 2002. Personal e-mail communication with Arturo Keller with diversion information.

Southern California Association of Governments (SCAG). 1993. Land Use Database for Ventura and parts of Los Angeles County.

Southern California Association of Governments (SCAG). 2001. Land Use Database for the City of Santa Clarita.

Systech Engineering (Systech). 2002. "Final Task 1 Report for Santa Clara River Nutrient TMDL Analysis: Source Identification and Characterization". Prepared for the Santa Clara River Nutrient TMDL Steering Committee.

United States Environmental Protection Agency (US EPA). 2001. BASINS software version 3.0

United States Geological Survey (USGS). 2002. Daily Streamflow for the Nation Database. Web site: http://waterdata.usgs.gov/nwis/discharge .

United States Geological Survey (USGS). 2002. Digital Elevation Models. Web site: http://www.gisdatadepot.com/dem/ .

United Water Conservation District (UWCD). 2002. "Surface and Groundwater Conditions Report Water Year 2000 Supplement". Web site: www.unitedwater.org .

United Water Conservation District (UWCD) (Dan Detmer). 2002. Spreadsheets with 6 month pumping resolution for all WARMF catchments.

United Water Conservation District (UWCD) (Dan Detmer). 2002. Spreadsheets with daily and quarterly diversion data for Ventura County.

United Water Conservation District (UWCD) (Murray McEachron). 2002. "PERCTOJOEL.xls" Spreadsheet including Hopper Creek flow data and river loss estimates for the Piru and Fillmore groundwater basins.

Ventura County Flood Control District (VC FCD). 2002. Daily rainfall data.

CALIFORNIA DEPARTMENT OF FISH AND GAME

CERTIFICATE OF FEE EXEMPTION

De Minimus Impact Finding

Project Title:	Amendment to the *Water Quality Control Plan for the Los Angeles Region* to include a Total Maximum Daily Load (TMDL) for Nitrogen Compounds in the Santa Clara River
Project Location:	Los Angeles Region (coastal watersheds of Los Angeles and Ventura Counties)
Project Proponent:	California Regional Water Quality Control Board, Los Angeles Region 320 West 4th Street, Suite 200, Los Angeles, CA 90013

Project Description:

The amendment incorporates into the *Water Quality Control Plan for the Los Angeles Region* (Basin Plan) a TMDL to reduce nitrogen compounds in the Santa Clara River. The Regional Board's goal in incorporating the above-mentioned TMDL is to reduce aquatic toxicity, eutrophication, and stimulation of algae growth in the Santa Clara River. National studies compel the conclusion that there is a causal relationship between toxicity and eutrophication associated with nitrogen compounds such as ammonia and nitrate. The Regional Board has prepared this TMDL to address the documented water quality impairments associated with elevated concentrations of nitrogen compounds.

The TMDL establishes a 5- or 8-year plan for reducing nitrogen compounds that exceed aquatic life habitat objectives in the Santa Clara River. The purpose of this project is to remove the water quality impairments associated with nitrogen compounds that prevent the Santa Clara River from supporting aquatic life habitat beneficial uses. It involves holding publicly owned treatment works and non-point source dischargers within the watershed accountable for treating effluent to remove nitrogen compounds, mitigating storm water discharges from the storm drains, and encourages the use of a variety of methods to prevent these discharges.

Findings of Exemption: (See attached CEQA Checklist).

This project will improve bacteriological water quality at Marina del Rey Mother's Beach and Back Basins and will have no negative impact on the environment.

Certification;

I hereby certify that the California Regional Water Quality Control Board, Los Angeles Region, has made the above findings of fact and that based upon the Environmental Checklist and written report and hearing record, the project will not individually or cumulatively have an adverse effect on wildlife resources as detailed in Section 711.2 of the Fish and Game Code.

Dennis A. Dickerson
Executive Officer
California Regional Water Quality Control Board
Los Angeles Region

March 23, 2004
Date

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		➢ Ambrose, R.F. and A. R. Orme. 2000. Lower Malibu Creek and Lagoon Resource Enhancement and Management. Final Report to the California State Coastal Conservancy. University of California, Los Angeles May 2000.	25-23 to 25-126
		➢ Ambrose, R.F.., I.H. Suffet, and S.S. Que Hee. 1995. Enhanced Environmental Monitoring Program at Malibu Lagoon and Malibu Creek. Prepared for the Las Virgenes Municipal Water District by the Environmental Science and Engineering Program at the University of California, Los Angeles.	25-127 to 25-198
		➢ American Society of Agricultural Engineers, 1998. ASAE Standards. Manure Production Characteristics. ASAE D384.1 DEC93	25-199 to 25-202

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		➢ Los Angeles Regional Water Quality Control Board. 1994. Water Quality Control Plan for the Los Angeles Region. California Regional Water Quality Control Board, Los Angeles Region.	25-713 to 25-721

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		➢ Los Angeles Regional Water Quality Control Board. 2004. Malibu Creek TMDL Water Quality Model and Data Input Files [CD-ROM].(Hard Copy Index)	CD-ROM 25-819 to 25-836

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		➢ Lund, L.J., M.A. Anderson, and C. Amrhein. 1994. Evaluation of Water Quality for Selected Lakes in the Los Angeles Hydrological Basin. Prepared for the Los Angeles Regional Water Quality Control Board by the Department of Soil Science, University of California, Riverside, CA.	25-921 to 25-1000
		➢ Manion, B.S. and J.H. Dillingham.1989. Malibu Lagoon: A Baseline Ecological Survey. Prepared for Los Angeles County Department of Beaches and Harbors and California State Department of Parks and Recreation. Topanga-Las Virgenes Resources Conservation District.	25-1001 to 25-1023
		➢ Orton, Randall. 2001. Personal Communications.	25-1024
		➢ PCR Services Corporation. 2001. Watershed Management Plan for the Malibu Creek Watershed. Prepared for the Las Virgenes Malibu Conejo Council of Governments.	25-1025 to 25-1056

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		➢ Solomon, C., Peter Casey, Colleen Mackne, and Andrew Lake. 1998. Fact Sheet on Mound Systems. Funded by the united State Environmental Protection Agency.	25-1069 to 25-1072
		➢ Stenstrom, M. K., E.W. Strecker, L. Armstrong, C. Forrest, R. Freeman, S. Lau, and K. Wong. 1993. Assessment of Storm Drain Sources of Contaminants to Santa Monica Bay, Volume I: Annual Pollutants Loadings to Santa Monica Bay from Stormwater Runoff. Department of Civil and Environmental Engineering, University of California, Los Angeles and Woodward-Clyde Consultants.	25-1073 to 25-1094
		➢ Tetra Tech. 2002. Nutrient and Coliform Modeling for the Malibu Creek Watershed TMDL Studies. Prepared for US Environmental Protection Agency Region 9 and the Los Angeles Regional Water Quality Control Board by Tetra Tech, Inc. Lafayette CA.	25-1095 to 25-1434

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		➢ United States Department of Agriculture. 1995. Malibu Creek Watershed Natural Resources Plan, Los Angeles and Ventura Counties, California. USDA National Resources Conservation Service, Davis, CA. For Topanga-Las Virgenes Resource Conservation District.	25-1445 to 25-1479
		➢ United States Department of Agriculture-Natural Resources Conservation Service (NRCS). 1995. Malibu Creek Watershed Technical Documentation; Nitrogen and Phosphorus Analysis.	25-1480 to 25-1484
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		➢ United States Environmental Protection Agency. 2000a. Exfiltration in Sewer Systems, December, 2000. EPA 600-R-01-034	25-1517 to 25-1518

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		➢ Warshall, P. and P. Williams. 1992. Malibu Wastewater Management Study: A Human Ecology of the New City. Prepared for the City of Malibu. Peter Warshall & Associates and Philip Williams & Associates, Ltd.	25-1697 to 25-1706
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State of California
California Regional Water Quality Control Board, Los Angeles Region

RESOLUTION NO. 2004-019R
December 13, 2004

Amendment to the Water Quality Control Plan for the Los Angeles Region to Incorporate a Total Maximum Daily Load for Bacteria in the Malibu Creek Watershed.

WHEREAS, the California Regional Water Quality Control Board, Los Angeles Region, finds that:

1. The Federal Clean Water Act (CWA) requires the California Regional Water Quality Control Board, Los Angles Region (Regional Board) to develop water quality objectives, which are sufficient to protect beneficial uses for each water body found within its region.

2. A consent decree between the U.S. Environmental Protection Agency (USEPA), Heal the Bay, Inc. and BayKeeper, Inc. was approved on March 22, 1999. This court order directs the USEPA to complete Total Maximum Daily Loads (TMDLs) for all impaired waters within 13 years. A schedule was established in the consent decree for the completion of the first 29 TMDLs within 7 years, including completion of a TMDL to reduce bacteria at Malibu Creek and Lagoon by March 22, 2003. The remaining TMDLs will be scheduled by Regional Board staff within the 13-year period.

3. The elements of a TMDL are described in 40 CFR 130.2 and 130.7 and section 303(d) of the CWA, as well as in USEPA guidance documents (Report No. EPA/440/4-91/001). A TMDL is defined as the sum of the individual waste load allocations for point sources and load allocations for nonpoint sources and natural background (40 CFR 130.2). Regulations further stipulate that TMDLs must be set at levels necessary to attain and maintain the applicable narrative and numeric water quality standards with seasonal variations and a margin of safety that takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality (40 CFR 130.7(c)(1)). The regulations in 40 CFR 130.7 also state that TMDLs shall take into account critical conditions for stream flow, loading and water quality parameters.

4. The numeric targets in this TMDL are not water quality objectives and do not create new bases for enforcement against dischargers apart from the water quality objectives they translate. The targets merely establish the bases through which load allocations (LAs) and waste load allocations (WLAs) are calculated. WLAs are only enforced for a discharger's own discharges, and then only in the context of its National Pollutant Discharge Elimination System (NPDES) permit, which must be consistent with the assumptions and requirements of the WLA. The Regional Board will develop permit requirements through a subsequent permit action that will allow all interested persons, including but not limited to municipal storm water dischargers, to provide comments on how the WLA will be translated into permit requirements.

5. Upon establishment of TMDLs by the State or USEPA, the State is required to incorporate the TMDLs along with appropriate implementation measures into the State Water Quality

Management Plan (40 CFR 130.6(c)(1), 130.7). This Water Quality Control Plan for the Los Angeles Region (Basin Plan), and applicable statewide plans, serve as the State Water Quality Management Plans governing the watersheds under the jurisdiction of the Regional Board.

6. The Malibu Creek watershed is located about 35 miles west of Los Angeles. The 109-square mile watershed extends from the Santa Monica Mountains and adjacent Simi Hills to the Pacific Coast at Santa Monica Bay. Several creeks and lakes are located in the upper portions of the watershed, and these ultimately drain into Malibu Creek at the downstream end of the watershed. Historically, there is little flow in the summer months; much of the natural flow that does occur in the summer in the upper tributaries comes from springs and seepage areas. During rain storms the runoff from the watershed may increase flows in the creeks dramatically. Flows from watershed drain into Malibu Lagoon and ultimately into Santa Monica Bay when the lagoon is breached

7. The Regional Board's goal in establishing the Malibu Creek Watershed Bacteria TMDL is to reduce the risk of illness associated with swimming in waters contaminated with human sewage and other sources of bacteria. Local and national epidemiological studies compel the conclusion that there is a causal relationship between adverse health effects, such as gastroenteritis, and recreational water quality, as measured by bacteria indicator densities.

8. USEPA established a TMDL for bacteria on March 21, 2003. The USEPA TMDL was not required to include an implementation plan. Therefore, the Regional Board has developed a revised TMDL, which includes an implementation plan which requires reduction of bacteria loading to the Malibu Creek watershed from the largest anthropogenic sources, within 6 years for dry weather, and 10 years for wet weather.

9. Regional Board staff have prepared a detailed technical document that analyzes and describes the specific necessity and rationale for the development of this TMDL. The technical document entitled "Total Maximum Daily Loads for Bacteria in the Malibu Creek Watershed" is an integral part of this Regional Board action and was reviewed, considered, and accepted by the Regional Board before acting. Further, the technical document provides the detailed factual basis and analysis supporting the problem statement, numeric targets (interpretation of the numeric water quality objective, used to calculate the load allocations), source analysis, linkage analysis, waste load allocations (for point sources), load allocation (for nonpoint sources), margin of safety, and seasonal variations and critical conditions of this TMDL.

10. On January 29, 2004, prior to the Board's action on this resolution, public hearings were conducted on the TMDL for Bacteria in Malibu Creek and Lagoon. Notice of the hearing for the Malibu Creek Watershed Bacteria TMDL was published in accordance with the requirements of Water Code Section 13244. This notice was published in the Los Angeles Times on December 6, 2004.

11. The public has had reasonable opportunity to participate in review of the amendment to the Basin Plan. A draft of the TMDL for bacteria at Malibu Creek Watershed was released for public comment on October 10, 2003. A public workshop was conducted at the City of Malibu on October 22, 2003, and at the regularly scheduled Regional Board meeting on November 6, 2003. Staff responded to comments and revised the draft TMDL in response to comments. A revised draft of the TMDL for bacteria at Malibu Creek Watershed was released for public comment on December 5, 2003; a Notice of Hearing and Notice of Filing

were published and circulated 45 days preceding Board action; Regional Board staff responded to oral and written comments received from the public; and the Regional Board held a public hearing on January 29, 2004 to consider adoption of the TMDL.

12. On January 29, 2004, the Los Angeles Regional Water Quality Control Board adopted Resolution No. 2004-019, "Amendment to the Water Quality Control Plan for the Los Angeles Region to Incorporate a Total Maximum Daily Load (TMDL) for the Malibu Creek and Lagoon Bacteria TMDL."

13. Based on subsequent review and comments from the public a revised draft of the TMDL for bacteria at Malibu Creek Watershed was released for public comment on September 14, 2004; a Notice of Hearing and Notice of Filing were published and circulated 45 days preceding Board action; Regional Board staff responded to oral and written comments received from the public; and the Regional Board held a public hearing on December 13, 2004 to consider adoption of the revision to the TMDL.

14. In amending the Basin Plan, the Regional Board considered the factors set forth in sections 13240 and 13242 of the California Water Code.

15. The amendment is consistent with the State Antidegradation Policy (State Board Resolution No. 68-16), in that the changes to water quality objectives (i) consider maximum benefits to the people of the state, (ii) will not unreasonably affect present and anticipated beneficial use of waters, and (iii) will not result in water quality less than that prescribed in policies. Likewise, the amendment is consistent with the federal Antidegradation Policy (40 CFR 131.12).

16. The basin planning process has been certified as functionally equivalent to the California Environmental Quality Act requirements for preparing environmental documents (Public Resources Code, Section 21000 et seq.) and as such, the required environmental documentation and CEQA environmental checklist have been prepared. A CEQA Scoping hearing was conducted on October 22, 2003 at the City of Malibu Council Chambers, 23815 Stuart Ranch Road. A notice of the CEQA Scoping hearing was sent to interested parties including cities and/or counties with jurisdiction in or bordering the Malibu Creek Watershed.

17. The proposed amendment results in no potential for adverse effect (de minimis finding), either individually or cumulatively, on wildlife.

18. The regulatory action meets the "Necessity" standard of the Administrative Procedures Act, Government Code, Section 11353, and Subdivision (b).

19. This TMDL is adopted pursuant to Water Code sections 13240 and 13242, and consistent with Section 303(d) of the Clean Water Act to implement existing water quality standards. These sections do not require the weighing of cost versus benefits. With respect to this TMDL, economics were considered when the water quality objectives were originally adopted, and the TMDL implements these existing water quality objectives.

Nonetheless, as a matter of sound public policy, the Regional Board developed estimates of costs associated with potential implementation strategies, and those cost are identified in the TMDL document.

20. In order to reduce the risk of illness associated with contact recreation in waterbodies located in the Malibu Creek watershed, the Regional Board finds it necessary to require local agencies to investigate and report on bacterial water quality within their jurisdictions pursuant to Water Code section 13225. Local agencies are encouraged to coordinate regional monitoring programs to avoid fragmented analyses and to ensure cost efficiencies for private property owners.

    Certain reports and monitoring programs are contemplated in the TMDL, but those programs/reports will require the issuance of subsequent directives by the Executive Officer. To the extent those programs/reports are required by Water Code sections 13267 and 13225, the Executive Officer will comply with the requirements of Water Code sections 13267 and 13225.

21. The Basin Plan amendment incorporating a TMDL for bacteria for the Malibu Creek Watershed must be submitted for review and approval by the State Water Resources Control Board (State Board), the State Office of Administrative Law (OAL), and the USEPA. The Basin Plan amendment will become effective upon approval by OAL and USEPA. A Notice of Decision will be filed.

22. If during its approval process the SWRCB or OAL determines that minor, non-substantive corrections to the language of the amendment are needed for clarity or consistency, the Executive Officer may make such changes, and shall inform the Board of any such changes.

THEREFORE, be it resolved that pursuant to sections 13240 and 13242 of the Water Code, the Regional Board hereby amends the Basin Plan as follows:

1. Pursuant to Sections 13240 and 13242 of the California Water Code, the Regional Board, after considering the entire record, including oral testimony at the hearing, hereby adopts the amendments to Chapter 7 of the Water Quality Control Plan for the Los Angeles Region, as set forth in Attachment A hereto, to incorporate the elements of the Malibu Creek Watershed Bacteria TMDL, and so doing, amends Resolution No. 2004-19 accordingly.

2. The Executive Officer is directed to forward copies of the Basin Plan amendment to the State Board in accordance with the requirements of section 13245 of the California Water Code.

3. The Regional Board requests that the State Board approve the Basin Plan amendment in accordance with the requirements of sections 13245 and 13246 of the California Water Code and forward it to OAL and the USEPA.

4. If during its approval process the State Board or OAL determines that minor, non-substantive corrections to the language of the amendment are needed for clarity or consistency, the Executive Officer may make such changes, and shall inform the Board of any such changes.

5. The Executive Officer is authorized to sign a Certificate of Fee Exemption.

6. The Executive Officer is directed to bring the Basin Plan amendment before for Regional Board for reconsideration within 120 days, or as soon as practical, of adoption by the State Board of proposed regulations for onsite waterwater treatment systems.

I, Jonathan S. Bishop, Executive Officer, do hereby certify that the foregoing is a full, true, and correct copy of a resolution adopted by the California Regional Water Quality Control Board, Los Angeles Region, on December 13, 2004.

Jonathan S. Bishop
Executive Officer

Attachment A to Resolution No. 2004-019R

Proposed Amendment to the Water Quality Control Plan – Los Angeles Region to incorporate the Malibu Creek and Lagoon Bacteria TMDL

Adopted by the California Regional Water Quality Control Board, Los Angeles Region on December 13, 2004

Amendments:

Table of Contents
Add:

List of Figures, Tables and Inserts
Add:

Chapter 7. Total Maximum Daily Loads (TMDLs) Summaries, Section 7-10 (Malibu Creek and Lagoon Bacteria TMDL)

This TMDL was adopted by the Regional Water Quality Control Board on December 13, 2004.

This TMDL was approved by:

The State Water Resources Control Board on September 22, 2005.
The Office of Administrative Law on December 1, 2005.
The U.S. Environmental Protection Agency on January 10, 2006.

The following table includes the elements of this TMDL.

Attachment A to Resolution No. 2004-019R

Table 7-10.1. Malibu Creek and Lagoon Basins Bacteria TMDL: Elements

Element	Key Findings and Regulatory Provisions
Problem Statement	Elevated bacterial indicator densities are causing impairment of the water contact recreation (REC-1) beneficial use at Malibu Creek, Lagoon, and adjacent beach. Swimming in waters with elevated bacterial indicator densities has long been associated with adverse health effects. Specifically, local and national epidemiological studies compel the conclusion that there is a causal relationship between adverse health effects and recreational water quality, as measured by bacterial indicator densities.
Numeric Target *(Interpretation of the numeric water quality objective, used to calculate the waste load allocations)*	The TMDL has a multi-part numeric target based on the bacteriological water quality objectives for marine and fresh water to protect the water contact recreation use. These targets are the most appropriate indicators of public health risk in recreational waters. These bacteriological objectives are set forth in Chapter 3 of the Basin Plan.[1] The objectives are based on four bacterial indicators and include both geometric mean limits and single sample limits. The Basin Plan objectives that serve as the numeric targets for this TMDL are: In Marine Waters Designated for Water Contact Recreation (REC-1) 1. Geometric Mean Limits a. Total coliform density shall not exceed 1,000/100 ml. b. Fecal coliform density shall not exceed 200/100 ml. c. Enterococcus density shall not exceed 35/100 ml. 2. Single Sample Limits a. Total coliform density shall not exceed 10,000/100 ml. b. Fecal coliform density shall not exceed 400/100 ml. c. Enterococcus density shall not exceed 104/100 ml. d. Total coliform density shall not exceed 1,000/100 ml, if the ratio of fecal-to-total coliform exceeds 0.1. In Fresh Waters Designated for Water Contact Recreation (REC-1) 1. Geometric Mean Limits a. E. coli density shall not exceed 126/100 ml. b. Fecal coliform density shall not exceed 200/100 ml. 2. Single Sample Limits a. E. coli density shall not exceed 235/100 ml. b. Fecal coliform density shall not exceed 400/100 ml.

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[1] The bacteriological objectives were revised by a Basin Plan amendment adopted by the Regional Board on October 25, 2001, and subsequently approved by the State Water Resources Control Board, the Office of Administrative Law and finally by U.S. EPA on September 25, 2002.

Element	Key Findings and Regulatory Provisions
	These objectives are generally based on an acceptable health risk for marine recreational waters of 19 illnesses per 1,000 exposed individuals as set by the US EPA (US EPA, 1986). The targets apply throughout the year. The final compliance point for the targets is the point at which the effluent from a discharge initially mixes with the receiving water. Implementation of the above bacteria objectives and the associated TMDL numeric targets is achieved using a 'reference system/anti-degradation approach' rather than the alternative 'natural sources exclusion approach' or strict application of the single sample objectives. As required by the CWA and Porter-Cologne Water Quality Control Act, Basin Plans include beneficial uses of waters, water quality objectives to protect those uses, an anti-degradation policy, collectively referred to as water quality standards, and other plans and policies necessary to implement water quality standards. The 'reference system/anti-degradation approach' means that on the basis of historical exceedance levels at existing monitoring locations, including a local reference beach within Santa Monica Bay, a certain number of daily exceedances of the single sample bacteria objectives are permitted. The allowable number of exceedance days is set such that (1) bacteriological water quality at any site is at least as good as at a designated reference site within the watershed and (2) there is no degradation of existing bacteriological water quality. This approach recognizes that there are natural sources of bacteria that may cause or contribute to exceedances of the single sample objectives and that it is not the intent of the Regional Board to require treatment or diversion of natural coastal creeks or to require treatment of natural sources of bacteria from undeveloped areas. The geometric mean targets may not be exceeded at any time. The rolling 30-day geometric means will be calculated on each day. If weekly sampling is conducted, the weekly sample result will be assigned to the remaining days of the week in order to calculate the daily rolling 30-day geometric mean. For the single sample targets, each existing monitoring site is assigned an allowable number of exceedance days for three time periods (1) summer dry-weather (April 1 to October 31), (2) winter dry-weather (November 1 to March 31), and (3) wet-weather (defined as days with 0.1 inch of rain or greater and the three days following the rain event.)
Source Analysis	Fecal coliform bacteria may be introduced from a variety of sources including storm water runoff, dry-weather runoff, onsite wastewater treatment systems, and animal wastes. An inventory of possible point and nonpoint sources of fecal coliform bacteria to the waterbody was compiled, and both simple methods and computer modeling were used to estimate bacteria loads for those sources. Source inventories were

Element	Key Findings and Regulatory Provisions
	used in the analysis to identify all potential sources within the Malibu Creek watershed, modeling was used to identify the potential delivery of pathogens into the creeks and the lagoon
Loading Capacity	The loading capacity is defined in terms of bacterial indicator densities, which is the most appropriate for addressing public health risk, and is equivalent to the numeric targets, listed above. As the numeric targets must be met at the point where the effluent from storm drains or other discharge initially mixes with the receiving water throughout the day, no degradation or dilution allowance is provided.
Waste Load Allocations (for point sources)	Waste Load Allocations (WLAs) are expressed as the number of daily or weekly sample days that may exceed the single sample limits or 30-day geometric mean limits as identified under "Numeric Target." WLAs are expressed as allowable exceedance days because the bacterial density and frequency of single sample exceedances are the most relevant to public health protection. Zero days of exceedance are allowed for the 30-day geometric mean limits. The allowable days of exceedance for the single sample limits differ depending on season, dry weather or wet-weather, and by sampling locations as described in Table 7-10.2. The allowable number of exceedance days for a monitoring site for each time period is based on the lesser of two criteria (1) exceedance days in the designated reference system and (2) exceedance days based on historical bacteriological data at the monitoring site. This ensures that bacteriological water quality is at least as good as that of a largely undeveloped system and that there is no degradation of existing water quality. However, existing data indicates that the number of exceedance days for all locations assessed in this TMDL were greater than the allowable exceedance days (i.e., number of exceedance days greater than the number at the reference sites). For each monitoring site, allowable exceedance days are set on an annual basis as well as for three time periods. These three periods are: 1. summer dry-weather (April 1 to October 31) 2. winter dry-weather (November 1 to March 31) 3. wet-weather (defined as days of 0.1 inch of rain or more plus three days following the rain event). The responsible jurisdictions and responsible agencies are the County of Los Angeles, County of Ventura, the cities of Malibu, Calabasas, Agoura Hills, Hidden Hills, Simi Valley, Westlake Village, and Thousand Oaks; Caltrans, and the California Department of Parks and Recreation.The responsible jurisdictions and responsible agencies include the permittees and co-permittees of the municipal storm water (MS4) permits for Los Angeles County and Ventura County, and Caltrans. The storm water permittees are individually responsible for the discharges from their municipal separate storm sewer systems to Malibu Creek, Malibu Lagoon or tributaries thereto. The California

Element	Key Findings and Regulatory Provisions
	Department of Parks and Recreation (State Parks), as the owner of the Malibu Lagoon and Malibu Creek State Park, is the responsible agency for these properties. However, since the reference watershed approach used in developing this TMDL is intended to make allowances for natural sources, State Parks is only responsible for: conducting a study of bacteria loadings from birds in the Malibu Lagoon, water quality monitoring, and compliance with load allocations applicable to anthropogenic sources on State Park property (e.g., onsite wastewater treatment systems). The Santa Monica Mountains Conservancy and the National Park Service as the owner of natural parkland also are responsible for water quality monitoring and compliance with load allocations resulting from anthropogenic sources (e.g.,onsite wastewater treatment systems) from lands under their jurisdiction. As discussed in "Source Analysis", discharges from Tapia WWRF and effluent irrigation, and general construction storm water permits are not expected to be a significant source of bacteria. Therefore, the WLAs for these discharges are zero (0) days of allowable exceedances for all three time periods and for the single sample limits and the rolling 30-day geometric mean.
Load Allocations (for nonpoint sources)	Load Allocations (LA) are expressed as the number of daily or weekly sample days that may exceed the single sample limits or 30-day geometric mean limits as identified under "Numeric Target." LAs are expressed as allowable exceedance days because the bacterial density and frequency of single sample exceedances are the most relevant to public health protection. Zero days of exceedance are allowed for the 30-day geometric mean limits. The allowable days of exceedance for the single sample limits differ depending on season, dry weather or wet-weather, and by sampling locations as described in Table 7-10.2. The allowable number of exceedance days for a monitoring site for each time period is based on the lesser of two criteria (1) exceedance days in the designated reference system and (2) exceedance days based on historical bacteriological data at the monitoring site. This ensures that bacteriological water quality is at least as good as that of a largely undeveloped system and that there is no degradation of existing water quality. However, existing data indicates that the number of exceedance days for all locations assessed in this TMDL were greater than the allowable exceedance days. For each monitoring site, allowable exceedance days are set on an annual basis as well as for three time periods. These three periods are: 1. summer dry-weather (April 1 to October 31) 2. winter dry-weather (November 1 to March 31) 3. wet-weather (defined as days of 0.1 inch of rain or more plus three days following the rain event).

Element	Key Findings and Regulatory Provisions
	Onsite wastewater treatment systems were identified as the major nonpoint anthropogenic source within the watershed. The responsible agencies are the county and city health departments and/or other local agencies that oversee installation and operation of on-site wastewater treatment systems. However, owners of on-site wastewater treatment systems are responsible for actual discharges.
Implementation	The regulatory mechanisms to implement the TMDL may include, but are not limited to the Los Angeles County Municipal Storm Water NPDES Permit (MS4), Ventura County Municipal Storm Water NPDES Permit, the Caltrans Storm Water Permit, waste discharge requirements (WDRs), MOUs, revised MOUs, general NPDES permits, general industrial storm water permits, general construction storm water permits, and the authority contained in Sections 13225, 13263 and 13267 of the Water Code. Each NPDES permit assigned a WLA shall be reopened or amended at reissuance, in accordance with applicable laws, to incorporate the applicable WLAs as a permit requirement. This TMDL will be implemented in three phases over a ten-year period as outlined in Table 7-10.3. Within three years of the effective date of the TMDL, compliance with the allowable number of summer dry-weather exceedance days and the rolling 30-day geometric mean targets must be achieved. In response to a written request from the responsible jurisdiction or responsible agency subject to conditions described in Table 7-10.3, the Executive Officer of the Regional Board may extend the compliance date for the summer dry-weather allocations from 3 to up to six years from the effective date of this TMDL Within six years of the effective date of the TMDL, compliance with the allowable number of winter dry-weather exceedance days and the rolling 30-day geometric mean targets must be achieved.Within ten years of the effective date of the TMDL, compliance with the allowable number of wet-weather exceedance days and rolling 30-day geometric mean targets must be achieved. To be consistent with the Santa Monica Bay (SMB) Beaches TMDLs, the Regional Board intends to reconsider this TMDL in coordination with the reconsideration of the SMB Beaches TMDLs. The SMB Beaches TMDLs are scheduled to be reviewed in July 2007 (four years from the effective date of the SMB Beaches TMDLs). The review will include a possible revision to the allowable winter dry-weather and wet-weather exceedance days based on additional data on bacterial indicator densities in the wave wash; to re-evaluate the reference system selected to set allowable exceedance levels; and to re-evaluate the reference year used in the calculation of allowable exceedance days. In addition, the method for applying the 30-day geometric mean limit also will be reviewed. The Malibu Creek Bacteria TMDL is scheduled to be reconsidered in three years from the effective date, which is expected to approximately coincide with the reassessment required under the SMB Beaches TMDLs.

Element	Key Findings and Regulatory Provisions
Margin of Safety	A margin of safety has been implicitly included through the following conservative assumptions. • The watershed loadings were based on the 90th percentile year for rain (1993) based on the number of wet weather days. This should provide conservatively high runoff from different land uses for sources of storm water loads • The watershed loadings were also based on a very dry rain year (1994). This ensures compliance with the numeric target during low flows when septic systems and dry urban runoff loads are the major bacterial sources. • The TMDL was based on meeting the fecal 30-day geometric mean target of 200 MPN/ 100 ml, which for these watersheds was estimated to be more stringent level than the allowable exceedance of the single sample standard. This approach also provides assurance that the E. coli single sample standard will not be exceed. • The load reductions established in this TMDL were based on reduction required during the two different critical year conditions. A wet year when storm loads are high, and a more typical dry year when base flows and assimilative capacity is low. This adds a margin of safety for more typical years. In addition, an explicit margin of safety has been incorporated, as the load allocations will allow exceedances of the single sample targets no more than 5% of the time on an annual basis, based on the cumulative allocations proposed for dry and wet weather. Currently, the Regional Board concludes that there is water quality impairment if more than 10% of samples at a site exceed the single sample bacteria objectives annually.
Seasonal Variations and Critical Conditions	Seasonal variations are addressed by developing separate waste load allocations for three time periods (summer dry-weather, winter-dry weather, and wet-weather) based on public health concerns and observed natural background levels of exceedance of bacterial indicators. To establish the critical condition for the wet days, we used rain data from 1993. Based on data from the Regional Board's Santa Monica Bay TMDL this represents the 90th percentile rain year based on rain data from 1947 to 2000. To further evaluate the critical conditions, we modeled a representative dry year. The dry-year critical condition was based on 1994, which was the 50th percentile year in terms of dry weather days for the period of 1947-2000.
Compliance Monitoring	Responsible jurisdictions and agencies shall submit a compliance monitoring plan to the Executive Officer of the Regional Board for approval. The compliance monitoring plan shall specify sampling frequency (daily or weekly) and sampling locations and that will serve

Element	Key Findings and Regulatory Provisions
	as compliance points. This compliance monitoring program is to determine the effectiveness of the TMDL and not to determine compliance with individual load or wasteload allocations for purposes of enforcement. If the number of exceedance days is greater than the allowable number of exceedance days the water body segment shall be considered out-of-compliance with the TMDL. Responsible jurisdictions or agencies shall not be required to initiate an investigation detailed in the next paragraph if a demonstration is made that bacterial sources originating within the jurisdiction of the responsible agency have not caused or contributed to the exceedance. If a single sample shows the discharge or contributing area to be out of compliance, the Regional Board may require, through permit requirements or the authority contained in Water Code section 13267, daily sampling at the downstream location (if it is not already) until all single sample events meet bacteria water quality objectives. Furthermore, if a creek location is out of compliance as determined in the previous paragraph, the Regional Board shall require responsible agencies to initiate an investigation, which at a minimum shall include daily sampling in the target receiving waterbody reach or at the existing monitoring location until all single sample events meet bacteria water quality objectives. The County of Los Angeles, County of Ventura, and municipalities within the Malibu Creek watershed, Caltrans, and the California Department of Parks and Recreation are strongly encouraged to pool efforts and coordinate with other appropriate monitoring agencies in order to meet the challenges posed by this TMDL by developing cooperative compliance monitoring programs.

Note: The complete staff report for the TMDL is available for review upon request.

Attachment A to Resolution No. 2004-019R

Table 7-10.2. Malibu Creek and Lagoon Bacteria TMDL: Final Annual Allowable Exceedance Days for Single Sample Limits by Sampling Location

Compliance Deadline		3* years after effective date		6 years after effective date		10 years after effective date	
		Summer Dry Weather ^		Winter Dry Weather ^**		Wet Weather ^**	
		April 1 – October 31		November 1 - March 31		November 1 - October 31	
Station ID	Location Name	Daily sampling (No. days)	Weekly sampling (No. days)	Daily sampling (No. days)	Weekly sampling (No. days)	Daily sampling (No. days)	Weekly sampling (No. days)
LA RWQCB	Triunfo Creek	0	0	3	1	17	3
LA RWQCB	Lower Las Virgenes Creek	0	0	3	1	17	3
LA RWQCB	Lower Medea Creek	0	0	3	1	17	3
LVMWD (R-9)	Upper Malibu Creek, above Las Virgenes Creek	0	0	3	1	17	3
LVMWD (R-2)	Middle Malibu Creek, below Tapia discharge 001	0	0	3	1	17	3
LVMWD (R-3)	Lower Malibu Creek, 3 mi below Tapia	0	0	3	1	17	3
LVMWD (R-4)	Malibu Lagoon, above PCH	0	0	3	1	17	3
LVMWD (R-11)	Malibu Lagoon, below PCH	0	0	3	1	17	3
------	Other sampling stations as identified in the Compliance Monitoring Plan as approved by the Executive Officer including at least one sampling station in each subwatershed, and areas where frequent REC-1 use is known to occur.	0	0	3	1	17	3

Notes: The number of allowable exceedances is based on the lesser of (1) the reference system or (2) existing levels of exceedance based on historical monitoring data.
The allowable number of exceedance days during winter dry-weather is calculated based on the 10th percentile storm year in terms of dry days at the LAX meteorological station
The allowable number of exceedance days during wet-weather is calculated based on the 90th percentile storm year in terms of wet days at the LAX meteorological station.
^ A dry day is defined as a non-wet day. A wet day is defined as a day with a 0.1-inch or more of rain and the three days following the rain event.
* The compliance date may be extended by the Executive Officer to up to 6 years from the effective date.
* *A revision of the TMDL is scheduled for four years after the effective date of the Santa Monica Bay Beaches TMDLs in order to re-evaluate the allowable exceedance days during winter dry-weather and wet-weather based on additional monitoring data and the results of the study of relative loading from storm drains versus birds.

Table 7-10.3. Malibu Creek and Lagoon Bacteria TMDL: Significant Dates

Date	Action
120 days after the effective date of this TMDL	Responsible jurisdictions and responsible agencies must submit a comprehensive bacteria water quality monitoring plan for the Malibu Creek Watershed to the Executive Officer of the Regional Board. The plan must be approved by the Executive Officer before the monitoring data can be considered during the implementation of the TMDL. In developing the 13267 order, the EO will consider costs in relation to the need for data. With respect to benefits to be gained, the TMDL staff report demonstrates the significant impairment and bacteria loading. Further documenting success or failure in achieving waste load allocations will benefit the responsible agencies and all recreational water users. The purpose of the plan is to better characterize existing water quality as compared to water quality at the reference watershed,- and ultimately, to serve as a compliance monitoring plan. The plan must provide for analyses of all applicable bacteria indicators for which the Basin Plan has established objectives including E. coli. For fresh water and enterococcus for marine water. The plan must also include sampling locations that are specified in Table 7-10.2, at least one location in each subwatershed, and areas where frequent REC-1 use is known to occur. However, this is not to imply that a mixing zone has been applied; water quality objectives apply throughout the watershed—not just at the sampling locations.
1 year after effective date of this TMDL	1. Responsible jurisdictions and responsible agencies shall provide a written report to the Regional Board outlining how each intends to cooperatively achieve compliance with the TMDL. The report shall include implementation methods, an implementation schedule, and proposed milestones. Specifically, the plan must include a comprehensive description of all steps to be taken to meet the 3-year summer dry weather compliance schedule, including but not limited to a detailed timeline for all category of bacteria sources under their jurisdictions including but not limited to nuisance flows, urban stormwater, on-site wastewater treatment systems, runoff from homeless encampments, horse facilities, and agricultural runoff. 2. If the responsible jurisdiction or agency is requesting an extension of the summer dry-weather compliance schedule, the plan must include a description of all local ordinances necessary to implement the detailed workplan and assurances that such ordinances have been adopted before the request for an extension is granted. 3. Local agencies regulating on-site wastewater treatment systems shall provide a written report to the Regional Board's Executive Officer detailing the rationale and criteria used to identify high-risk areas where on-site systems have a potential to impact surface waters in the Malibu Creek watershed. Local agencies may use the approaches outlined below in (a) and (b), or an alternative approach as approved

Date	Action
	by the Executive Officer. (a) Responsible agencies may screen for high-risk areas by establishing a monitoring program to determine if discharges from OWTS have impacted or are impacting water quality in Malibu Creek and/or its tributaries. A surface water monitoring program demonstration must include monitoring locations upstream and downstream of the discharge, as well as a location at mid-stream (or at the approximate point of discharge to the surface water) of single or clustered OWTS. Surface water sampling frequency will be weekly for bacteria indicators and monthly for nutrients. A successful demonstration will show no statistically significant increase in bacteria levels in the downstream sampling location(s). (b) Responsible agencies may define the boundaries of high-risk or contributing areas or identify individual OWTS that are contributing to bacteria water quality impairments through groundwater monitoring or through hydrogeologic modeling as described below: (1) Groundwater monitoring must include monitoring in a well no greater than 50-feet hydraulically downgradient from the furthermost extent of the disposal area, or property line of the discharger, whichever is less. At a minimum, sampling frequency for groundwater monitoring will be quarterly. The number, location and construction details of all monitoring wells are subject to approval of the Executive Officer. (2) Responsible agencies may use a risk assessment approach, which uses hydrogeologic modeling to define the boundaries of the high-risk and contributing areas. A workplan for the risk assessment study must be approved by the Executive Officer of the Regional Board. 4. OWTS located in high-risk areas are subject to system upgrades as necessary to demonstrate compliance with applicable effluent limits and/or receiving water objectives. 5. If a responsible jurisdiction or agency is requesting an extension to the wet-weather compliance schedule, the plan must include a description of the integrated water resources (IRP) approach to be implemented, identification of potential markets for water re-use, an estimate of the percentage of collected stormwater that can be re-used, identification of new local ordinances that will be required, a description of new infrastructure required, a list of potential adverse environmental impacts that may result from the IRP, and a workplan and schedule with significant milestones identified. Compliance with the wet-weather allocations

Date	Action
	shall be as soon as possible but under no circumstances shall it exceed 10 years for non-integrated approaches or extend beyond July 15, 2021 for an integrated approach. The Regional Board staff will bring to the Regional Board the aforementioned plans for consideration of extension of the wet-weather compliance date as soon as possible.
2 years after the effective date of this TMDL	The California Department of Parks and Recreation shall provide the Regional Board Executive Officer, a report quantifying the bacteria loading from birds to the Malibu Lagoon. The Regional Board's Executive Officer shall require the responsible jurisdictions and responsible agencies to provide the Regional Board with a reference watershed study. The study shall be designed to collect sufficient information to establish a defensible reference condition for the Malibu Creek and Lagoon watershed.
3 years after effective date of this TMDL** ** May be extended to up to 6 years from the effective date of this TMDL	Achieve compliance with the applicable Load Allocations and Waste Load Allocations, as expressed in terms of allowable days of exceedances of the single sample bacteria limits and the 30-day geometric mean limit during summer dry-weather (April 1 to October 31). In response to a written request from a responsible jurisdiction or responsible agency, the Executive Officer of the Regional Board may extend the compliance date for the summer dry-weather allocations from 3 years to up to 6 years from the effective date of this TMDL. The Executive Officer's decision to extend the summer dry-weather compliance date must be based on supporting documentation to justify the extension, including a detailed work plan, budget and contractual or other commitments by the responsible jurisdiction or responsible agency.
3 years after effective date of this TMDL	The Regional Board shall reconsider this TMDL to: (1) Consider a natural source exclusion for bacteria loadings from birds in the Malibu Lagoon if all anthropogenic sources to the Lagoon have been controlled. (2) Reassess the allowable winter dry-weather and wet-weather exceedances days based on additional data on bacterial indicator densities, and an evaluation of site-specific variability in exceedance levels to determine whether existing water quality is better than water quality at the reference watershed, (3) Reassess the allowable winter dry-weather and wet-weather exceedance days based on a re-evaluation of the selected

Date	Action
	reference watershed and consideration of other reference watersheds that may better represent reaches of the Malibu Creek and Lagoon. (4) Consider whether the allowable winter dry-weather and wet-weather exceedance days should be adjusted annually dependent on the rainfall conditions and an evaluation of natural variability in exceedance levels in the reference system(s), (5) Re-evaluate the reference year used in the calculation of allowable exceedance days, and (6) Re-evaluate whether there is a need for further clarification or revision of the geometric mean implementation provision.
6 years after the effective date of this TMDL	Achieve compliance with the applicable Load Allocations and Waste Load Allocations, expressed as allowable exceedance days during winter dry weather (November 1-March 31) single sample limits and the rolling 30-day geometric mean limit.
10 years after the effective date of this TMDL ** May be extended up to July 15, 2021.	Achieve compliance with the wet-weather Load Allocations and Waste Load Allocations (expressed as allowable exceedance days for wet weather and compliance with the rolling 30-day geometric mean limit.) The Regional Board may extend the wet-weather compliance date up to July 15, 2021 at the Regional Board's discretion, by adopting a subsequent Basin Plan amendment that complies with applicable law.

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STATE WATER BOARD
RESOLUTION NO. 2005-0072

APPROVING AN AMENDMENT TO THE WATER QUALITY CONTROL PLAN FOR THE LOS ANGELES REGION INCORPORATING A TOTAL MAXIMUM DAILY LOAD (TMDL) FOR BACTERIA IN THE MALIBU CREEK WATERSHED

WHEREAS:

1. The Los Angeles Regional Water Quality Control Board (Los Angeles Water Board) adopted a revised Water Quality Control Plan (Basin Plan) for the Los Angeles region on June 13, 1994, which was approved by the State Water Resources Control Board (State Water Board) on November 17, 1994 and by the Office of Administrative Law (OAL) on February 23, 1995.

2. On December 13, 2004, the Los Angeles Water Board adopted Resolution No. 2004-019R (Attachment) amending the Basin Plan to incorporate a TMDL for bacteria in the Malibu Creek watershed.

3. During consultations between the Los Angeles Water Board staff and the County of Los Angeles, the County raised concerns about some of the language of the TMDL. Findings 3 through 7 of this resolution are intended to provide clarification. As the Regional Board noted in finding 4 of its approval resolution, the numeric targets and wasteload allocations of the TMDL are only enforced for a "discharger's own discharges". Wasteload allocations are implemented when the Regional Board develops subsequent permit requirements to implement the TMDL. As a result, municipal storm water dischargers are only responsible for discharges from the municipal separate storm sewer system. The compliance of responsible agencies and jurisdictions (as defined in the TMDL) with the TMDL's wasteload allocations, is based on discharges from the municipal separate storm sewer system, if any, and then only in the context of the NPDES permit, or from permitted point sources for which the responsible agency or jurisdiction is the permittee.

4. The analysis identified in Regional Board finding 4 and State Board finding 3 applies equally to the TMDL's load allocations, which likewise, are not self-implementing.

5. To the extent cities and counties regulate single-family onsite wastewater treatment systems through local oversight, their oversight of system design criteria and/or operations provides an important mechanism to achieve the load allocations. The cities' and counties' responsibilities for single-family onsite wastewater treatment systems under the TMDL relate to that oversight. The Regional Board and responsible jurisdictions and agencies will work cooperatively to identify and to abate discharges from single-family onsite wastewater treatment systems and other nonpoint sources causing exceedances of the load allocations. As defined in the TMDL, the responsible jurisdictions or agencies would not be subject to an enforcement action as a result of the TMDL for discharges from onsite wastewater treatment systems or other nonpoint sources they do not own or operate.

6. Consistent with State Board and U.S. EPA guidance, the TMDL's basin plan amendment includes an element that identifies various monitoring steps designed to determine the

effectiveness of the TMDL and to determine whether wasteload allocations and load allocations are being achieved. This element appears in a section entitled "Compliance Monitoring;" however, as discussed in Regional Board finding 4 and State Board findings 3 and 5, compliance for purposes of any enforcement action is determined in the context of a specific discharger's permit.

7. To the extent the Regional Board or a responsible jurisdiction or agency determines that a particular source (including a single-family onsite wastewater treatment system) is causing bacteria loading to Malibu Creek, nothing in the TMDL restricts the Regional Board or Executive Officer's authority to take appropriate action against the discharger. Appropriate action may include, without limitation, requesting technical reports and monitoring data or issuing a cleanup and abatement order. Similarly, nothing in the TMDL limits the ability of the Executive Officer to tailor to specific circumstances any information requests pursuant to the Water Code sections 13267 and 13225.

8. Los Angeles Regional Water Board staff prepared documents and followed procedures satisfying environmental documentation requirements in accordance with the California Environmental Quality Act and other State laws and regulations.

9. The Los Angeles Water Board found that the additions of this amendment would result in no adverse effect on wildlife, and the amendment would be consistent with the State Antidegradation Policy (State Water Board Resolution No. 68-16) and federal antidegradation requirements.

10. The State Water Board finds that the Basin Plan amendment is in conformance with Water Code section 13240, which specifies that Regional Water Boards may revise Basin Plans, and section 13242, which requires a program of implementation of water quality objectives. The State Water Board also finds that the TMDL as reflected in the Basin Plan amendment is consistent with the requirements of federal Clean Water Act section 303(d).

11. State Water Board staff determined that provisions of the amendment as adopted warranted minor, non-substantive clarification of the language of various provisions.

12. A Basin Plan amendment does not become effective until approved by the State Water Board and until the regulatory provisions are approved by OAL. The TMDL must also be approved by the U.S. Environmental Protection Agency (USEPA).

THEREFORE BE IT RESOLVED THAT:

The State Water Board:

1. Approves the amendment to the Los Angeles Water Board Basin Plan to incorporate a TMDL for bacteria in the Malibu Creek watershed as approved in Los Angeles Water Board Resolution No. 2004-019R. and as corrected by the Los Angeles Water Board Executive Director.

2. Authorizes the Executive Director to transmit the amendment and administrative record for this action to OAL and the TMDL to USEPA for approval.

CERTIFICATION

The undersigned, Clerk to the Board, does hereby certify that the foregoing is a full, true, and correct copy of a resolution duly and regularly adopted at a meeting of the State Water Board held on September 22, 2005.

AYE:	Tam M. Doduc Peter S. Silva Arthur G. Baggett, Jr. Gerald D. Secundy
NO:	None.
ABSENT:	None.
ABSTAIN:	Richard Katz

Debbie Irvin
Clerk to the Board

STATE OF CALIFORNIA
OFFICE OF ADMINISTRATIVE LAW

In re:

STATE WATER RESOURCES CONTROL BOARD

REGULATORY ACTION:

Title 23, California Code of Regulations
Adopt sections 3939.15

NOTICE OF APPROVAL OF REGULATORY ACTION

Government Code Section 11353

OAL File No. 05-1018-03 S

This basin plan amendment establishes a Total Maximum Daily Load (TMDL) for bacteria in Malibu Creek and Lagoon for summer (April 1 to October 31) dry-weather, winter (November 1 to March 31) dry-weather and wet-weather days.

OAL approves this regulatory action pursuant to section 11353 of the Government Code.

DATE: 12/01/05

CRAIG S. TARPENNING
Senior Staff Counsel

for: WILLIAM L. GAUSEWITZ
Director

Original : Celeste Cantu, Executive Director
cc : Greg Frantz

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, CA 94105-3901

JAN 10 2006

JAN 10

Ms. Celeste Cantú
Executive Director
State Water Resources Control Board
P.O. Box 100
Sacramento, CA 95812-0100

Dear Ms. Cantú:

Thank you for submitting the Basin Plan amendment containing total maximum daily loads (TMDLs) for bacteria in Malibu Creek watershed. The TMDL submittal was dated December 5, 2005 and received by EPA on December 12, 2005. The State adopted bacteria TMDLs to address the following water bodies identified on California's 2002 Clean Water Act Section 303(d) list:

- Malibu Creek
- Medea Creek
- Las Virgenes Creek
- Malibu Lagoon
- Lindero Creek
- Stokes Creek
- Palo Comado Creek

Based on EPA's review of the TMDL submittals under Clean Water Act Section 303(d)(2), I have concluded the TMDLs adequately address the pollutant of concern and, upon implementation, will result in attainment of the water quality standards adopted by the State. These TMDLs include waste load and load allocations as needed, take into consideration seasonal variations and critical conditions, and provide an adequate margin of safety.

The State provided sufficient opportunities for public review and comment on the TMDLs and demonstrated how public comments were considered in the final TMDLs. All required elements are adequately addressed; therefore, the TMDLs are hereby approved pursuant to Clean Water Act Section 303(d)(2).

As you are aware, on March 21, 2002, EPA established TMDLs for bacteria for the Malibu Creek watershed in order to meet the March 22, 2002 deadline specified in the consent decree entered to settle the *Heal the Bay, et al. v. Browner* lawsuit. The approved State TMDLs for bacteria in Malibu Creek watershed now supercede the TMDLs established by EPA in March 2002; therefore, the State's TMDLs are now the applicable TMDLs for Clean Water Act purposes.

The State submittal also contains a detailed plan for implementing these TMDLs. Current federal regulations do not define TMDLs as containing implementation plans; therefore, EPA is not taking action on the implementation plan provided with the TMDLs. However, EPA generally concurs with the State's proposed implementation approaches.

The enclosed review discusses the basis for this decision in greater detail. I appreciate the State and Regional Board's work to adopt these TMDLs and look forward to our continuing partnership in TMDL development. If you have questions concerning this action, please call me at (415) 972-3572 or David Smith at (415) 972-3416.

Sincerely yours,

Alexis Strauss

Alexis Strauss
Director
Water Division

10 January 2006

enclosures

cc: Jonathan Bishop, LARWQCB

Total Maximum Daily Loads for Bacteria
Malibu Creek Watershed

California Regional Water Quality Control Board
Los Angeles

Adopted January 29, 2004

Revised December 13, 2004

ES. EXECUTIVE SUMMARY

This TMDL[1] addresses bacteria water quality impairments in the Malibu Creek Watershed. The TMDL is consistent with the Santa Monica Bay Beaches Bacteria TMDL, which was approved by the United States Environmental Protection Agency (EPA) in June 2003. The Santa Monica Bay Beaches TMDL expressed the Waste Load Allocation for bacteria at Santa Monica Bay Beaches in terms of the number of days that the single sample bacteria water quality objectives in the Basin Plan may be exceeded. The Santa Monica Bay Beaches TMDL applies to Surfrider Beach, which is located at the mouth of the Malibu Creek Watershed. In terms of the number of days that the single sample bacteria limits are exceeded, Surfrider ranks among the most impaired beaches in the Bay. This TMDL addresses the bacteria sources from Malibu Creek and Lagoon, but does not address other coastal sources that may impact the impairment at Surfrider Beach.

The Malibu Creek Watershed Bacteria TMDL was developed using available monitoring data and surface water quality models. The data available for the Creek and Lagoon were not as robust as the data for the Santa Monica Bay Beaches. The county and city health departments monitor the beaches on weekly, or in some cases, daily basis. However, Malibu Creek and Lagoon are monitored only monthly by volunteer monitoring groups and the Las Virgenes Municipal Water District during dry weather. The Los Angeles County Department of Public Works monitors stormwater bacteria counts during wet weather. Due to the lack of monitoring data, this TMDL relied heavily on modeled output data. The models were calibrated against actual in-stream monitoring data, but data were not sufficient to validate the models. In other words, the multiple variables in the models were adjusted to reasonably match historical creek water quality data, however data were not sufficient to confirm that the models would be able to predict the bacteria concentrations in the creek if one or more of the assumed inputs of bacteria are changed. Although, available monitoring data for the Malibu Lagoon were sparse, the model predicted a substantially higher number of exceedances in the Lagoon than for Malibu Creek or it tributaries during dry weather.

The responsible jurisdictions and responsible agencies, primarily the incorporated cities, Los Angeles County and Ventura County, are responsible for meeting the final pollutant allocations. Consistent with the Santa Monica Bay Beaches TMDLs, Waste Load Allocations and Load Allocations are expressed in terms of allowable days of exceedance of the single sample bacteria limits and no exceedance of the 30-day geometric mean limits. In addition, this TMDL provides an estimated reduction in bacteria loading necessary to meet the allocations. Based upon the model output, stormwater from commercial/industrial and high density development generate the highest annual bacteria loading. However, these loads are a result of episodic storm events. Bacteria loads from on-site wastewater treatment systems, especially in the Malibu Civic Center area, are believe to contribute bacteria loading year round and may have a greater impact on impairments during dry weather. Another significant finding is that based on the model output, loading reductions designed to meet the allowable days of exceedance of the single sample limits were not sufficient to meet the 30-day geometric mean. In addition, the model indicates that it may not be possible to achieve the 30-day geometric mean in the Lagoon due to fecal contamination from birds.

This TMDL, provides an implementation schedule allowing the responsible jurisdictions and responsible agencies time to gather additional monitoring data to validate the model and to better quantify the loading from birds in the Lagoon. The Regional Board may reconsider the TMDL in three years from the effective date to consider the impact of birds in the Lagoon and to refine the days of allowable exceedance based on additional studies. At that time, the Regional Board may revise the TMDL to allow for a Natural Source Exclusion, as provided for in the Basin Plan. The Natural Source Exclusion can only be applied after all anthropogenic sources of bacteria have been controlled. The schedule would allow six years from the effective date to meet both summer and winter dry-weather Waste Load and Load allocations. This is a longer schedule than generally provided for in the Santa Monica Bay TMDL for summer dry weather. However, it is warranted due to the disperse nature of the sources and the foreseeable implementation

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[1] A Total Maximum Daily Load (TMDL) is the sum of pollutant loading from point sources (Waste Load Allocation) and nonpoint sources (Load Allocation), and natural background that can be assimilated by a water body, without exceeding water quality standards.

measures. In Santa Monica Bay, the City of Los Angeles and the County of Los Angeles already had started construction of the implementation measure, which is dry-weather diversion of major storm drains. Therefore a three year schedule for summer dry weather was feasible. In Malibu, the likely primary implementation for dry weather compliance will be to evaluate and upgrade individual on-site wastewater treatment systems if necessary, or the construction of a centralized wastewater treatment plant in the Civic Center area of the City of Malibu. In addition, strategies for dealing with on-site wastewater treatment systems will be impacted by the upcoming Malibu Creek nutrient TMDL, scheduled for release in 2004. While properly sited and maintained systems are an effective method for treating bacteria, advanced treatment may be required to reduce total nitrogen. Therefore, the responsible jurisdictions and responsible agencies may wish to consider the implications of the nutrient TMDL before finalizing plans to address on-site systems.

It is anticipated that wet-weather allocations will be met primarily through on-site stormwater collection and treatment devices rather than widespread reliance on diversion of major storm drains. This is due to the rural nature of the watershed, which is not served by a major stormwater network. In addition, the diversion of natural creeks and drainages could have adverse impact on aquatic life and wildlife, and should be avoided. This TMDL allows 10 years for compliance with the wet-weather allocations.

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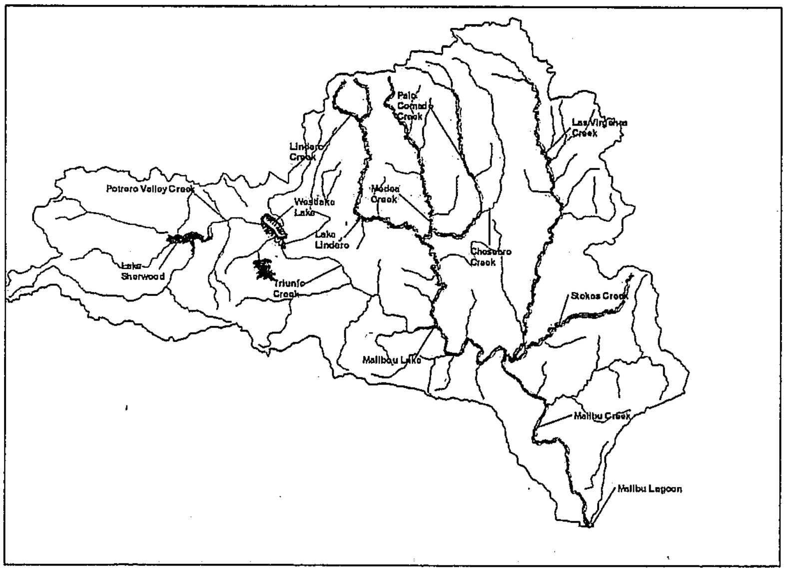
1. INTRODUCTION

This document describes the Total Maximum Daily Load (TMDLs) for bacteria indicators for the Malibu Creek Watershed, which includes Malibu Lagoon, Malibu Creek and its tributaries. The target bacteria indicators addressed in this TMDL are fecal coliform, total coliform, E. coli, and enterococcus. Malibu Creek, five of its tributaries (Stokes Creek, Las Virgenes Creek, Palo Comado Creek, Medea Creek, and Lindero Creek) exceed the water quality objectives (WQOs) for bacterial indicators (RWQCB, 1996 and 1998).

This TMDL complies with 40 CFR 130.2 and 130.7, Section 303(d) of the Clean Water Act and U.S. Environmental Protection Agency (EPA) guidance for developing TMDLs in California (U.S. EPA, 2000). This document summarizes the information used by the EPA and the California Regional Water Quality Control Board, Los Angeles Region (Regional Board) to develop waste load and load allocations for bacterial indicators. The TMDL also includes an Implementation Plan and cost estimates for complying with the TMDL. The water bodies in this TMDL are highlighted in Figure 1 and described in Table 1.

Figure 1 - Malibu Creek Watershed Impaired Creeks



1.1 Regulatory Background

Section 303(d) of the Clean Water Act (CWA) requires that each State "shall identify those waters within its boundaries for which the effluent limitations are not stringent enough to implement any water quality objective applicable to such waters." The CWA also requires states to establish a priority ranking for waters on the 303(d) list of impaired waters and establish TMDLs for such waters. For the purpose of this document, 303(d) listed water bodies and impaired water bodies are synonymous.

The elements of a TMDL are described in 40 CFR 130.2 and 130.7 and Section 303(d) of the CWA, as well as in the U.S. Environmental Protection Agency guidance (U.S. EPA, 2000). A TMDL is defined as the "sum of the individual waste load allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources and natural background" (40 CFR 130.2) such that the capacity of the water body to assimilate pollutant loading (the Loading Capacity) is not exceeded. A TMDL is also required to account for seasonal variations and include a margin of safety to address uncertainty in the analysis (USEPA, 2000).

The Environmental Protection Agency has oversight authority for the 303(d) program and is required to review and either approve or disapprove the TMDLs submitted by states. In California, the State Water Resources Control Board (State Board) and the nine Regional Boards are responsible for preparing lists of impaired water bodies under the 303(d) program and for preparing TMDLs, both subject to EPA approval. If EPA does not approve a TMDL submitted by a state, it is required to establish a TMDL for that water body. The Regional Boards hold regulatory authority for many of the instruments used to implement the TMDLs, such as the National Pollutant Discharge Elimination System (NPDES) and state-specified Waste Discharge Requirements (WDRs).

The Regional Board identified over 700 water body-pollutant combinations in the Los Angeles Region where TMDLs would be required (LARWCQB, 1996, 1998). These are referred to as "listed" or "303(d) listed" water bodies . A schedule for development of TMDLs in the Los Angeles Region was established in a consent decree (Heal the Bay Inc., et al. v. Browner C 98-4825 SBA) approved on March 22, 1999. For the purpose of scheduling TMDL development, the consent decree combined the more than 700 water body-pollutant combinations into 92 TMDL analytical units.

This TMDL addresses Analytical Unit 47 of the consent decree, which consists of Malibu Lagoon, segments of the Malibu Creek and tributaries. These listings were included on the 1996 and 1998 303(d) lists and were retained on the 2002 303(d) list. The listed water bodies are identified in Table 1. Malibu Beach and Surfrider Beach are covered under the Santa Monica Bay Beaches (Analytical unit #48). The consent decree schedule requires that this TMDL and the Malibu Creek nutrient TMDL be completed by March 22, 2003. EPA established bacteria and nutrient TMDLs in fulfillment of the consent decree requirement in March 2003.

This TMDL represents an independent analysis of the EPA TMDL and includes an implementation schedule for meeting the allocations. If adopted by the Regional Board and the State Board, and subject to EPA's approval, this TMDL will supercede the EPA TMDL. Regional Board staff are scheduled to release a revised nutrient TMDLs in late 2004, based on additional studies.

Both this TMDL and EPA's TMDL are consistent with the Santa Monica Bay Beaches Bacteria TMDLs, which were adopted by the Regional Board in 2002, and approved by EPA in June 2003. The Santa Monica Bay Beaches Bacteria TMDLs were developed by Regional Board staff in cooperation with a Technical Advisory Committee (TAC), composed of key stakeholders. This was a precedent setting TMDL, which grappled with two difficult aspects of bacteria exceedances:

- The difficulty of controlling high bacteria counts during wet weather and
- The need to balance the needs of human recreational use and wildlife, which can be a significant source of bacteria loading.

The TAC recognized that even relatively undeveloped watersheds exceed bacteria standards on occasion due to natural sources such as birds and other wildlife. The Water Quality Control Plan for the Los Angeles Region (the Basin Plan) contains bacteria limits for single samples and the 30-day geometric mean values. The Santa Monica Bay Beaches Bacteria TMDL limits the number of allowable days that the single sample bacteria standards may be exceeded, but requires compliance with the 30-day geometric mean at all times. The number of days that the single sample limits may be exceeded were based on the historical days of exceedance at Leo Carillo Beach, the beach at the base of the Arroyo Sequit reference watershed.

1.2 TMDL Elements

Guidance from USEPA (2000) identifies seven elements of a TMDL. These elements of the Malibu Creek Bacteria TMDL are described in Sections 2 through 8 of this document. The elements are:

1. Problem Identification. This section reviews the evidence used to add the water body to the 303(d) list, and summarizes existing conditions using that evidence along with any new information acquired since the listing. The problem identification reviews those reaches that fail to support all designated beneficial uses; the beneficial uses that are not supported for each reach; the water quality objectives (WQOs) designed to protect those beneficial uses; and the data and information regarding the decision to list each reach, such as the number and severity of exceedences observed.

2. Numeric Targets. For this TMDL, the numeric targets are based on the numeric water quality objectives for coliform bacteria that apply to the watershed and the allowable number of exceedance days established in the Santa Monica Bay Beaches TMDL.

3. Source Assessment. This is a quantitative estimate of point sources and nonpoint sources of bacteria into the Malibu Creek Watershed. The source assessment considers factors such as seasonality and flow, which may influence the relative magnitude of contributions from various sources.

4. Linkage Analysis. This analysis demonstrates how the sources of coliform bacteria in the water body are linked to the observed conditions in the impaired water body. The linkage analysis includes an assessment of critical conditions, which are periods when the changing pollutant sources and changing assimilative capacity of the water body combine to produce either critical conditions or conditions especially resistant to improvement.

5. Pollutant Allocation and TMDL. The allocations are expressed in terms of allowable days of exceedance of the single sample limit and the rolling 30-day geometric limits. However, for informational purposes, the TMDL estimates the loading that will achieve the allocations. Allocations are designed such that the water body will meet the applicable numeric targets in all reaches. Point sources are given waste load allocations and nonpoint sources are given load allocations. Allocations need to consider the worst-case conditions that are expected to re-occur with some recognized return frequency (e.g., 90th percentile event), so that the pollutant loads may be expected to remove the impairment under critical conditions.

6. Implementation Recommendations. This section describes the plans, regulatory tools, or other mechanisms by which the waste load allocations and load allocations may be achieved and recommends several implementation options

7. Monitoring Recommendations. This TMDL provides for the monitoring plan that will be used to determine compliance with the TMDL and to provide additional assessment of the current impairment.

2. PROBLEM IDENTIFICATION

In this section, we identify the 303(d) listed impairments and describe the environmental setting of the Malibu Creek Watershed. Table 1 includes a listing of the impaired segments of the Creek system and the area or stream miles affected.

The Malibu Creek Watershed is located about 35 miles west of Los Angeles. The 109-square mile watershed extends from the Santa Monica Mountains and adjacent Simi Hills to the Pacific Coast at Santa Monica Bay. Several creeks and lakes are located in the upper portions of the watershed, and these ultimately drain into Malibu Creek at the downstream end of the watershed. Historically, there is little flow in the summer months; much of the natural flow that does occur in the summer in the upper tributaries comes from springs and seepage areas. During rain storms the runoff from the watershed may increase flows in the creeks dramatically. The natural hydrology of the watershed has been modified by the creation of several dams and man-made lakes, the importation of water to the system for human use which provides most of the base flow to the system, and the presence of the Tapia Wastewater Reclamation Facility (WRF), which provides significant dry-weather flow to the system in the winter months. Flows from watershed drain into Malibu Lagoon and ultimately into Santa Monica Bay when the Lagoon is breached.

In terms of land use patterns, about 80% of the land in Malibu Creek Watershed is undeveloped. The developed land is a mixture of residential (13%), commercial/industrial (4%) and agricultural (3%) land uses.

A number of water bodies in the Malibu Creek Watershed are hydrologically connected to the water bodies listed in the 1998 and 2002 Water Quality Assessment (See Table 1). These unimpaired or unassessed water bodies include Hidden Valley Creek, Potrero Canyon Creek, Triunfo Creek, Cheeseboro Creek, and Cold Creek and four lakes (Lake Sherwood, Westlake, Lake Lindero and Malibou Lake). These water bodies have been considered within the analytical framework of this TMDL because they have the potential to contribute significant bacterial indicator loading to the downstream impaired water bodies.

The western part of the watershed drains the areas around Hidden Valley, Portero Creek, Westlake and Triunfo Creek (total area about 25,210 acres). These areas are largely undeveloped. There is some limited agricultural land use, located mostly in the Hidden Valley subwatershed. Most of the residential and commercial/industrial land use is in the area around Westlake Village. Nearly all the runoff from this large watershed area is funneled to Triunfo Creek and ultimately to Malibou Lake. None of the creek reaches in this western-most portion of the watershed have been listed for fecal coliform bacterial impairments. However, it is important to note that the water bodies in these areas were largely unassessed by the Regional Board due to a lack of data. It is highly probable that the runoff from these areas contributes fecal coliform loading to the listed segments downstream of Malibou Lake and need to be considered in TMDL development.

Malibou Lake also receives flows from a number of water bodies that are listed for bacterial impairments, specifically Lindero Creek, Medea Creek and Palo Camodo Creek. These 15,900-acre area drains watersheds associated with these three creeks and the watersheds associated with Cheeseboro Creek which is not listed. The land use in these areas while still largely undeveloped has a higher percentage of residential and commercial land uses especially in the areas around Lindero Creek and Medea Creek watersheds.

Malibou Lake discharges to Malibu Creek, which is listed as impaired for its entire 10-mile length from the Lake to the Lagoon. Malibu Creek also receives flow from Las Virgenes Creek and Stokes Creek, both of which are listed as impaired. Land use at the bottom of the watershed near the lagoon is much more developed with significant residential and commercial development.

Table 1 - Water bodies within the Malibu Creek Watershed that are listed as impaired due to high fecal coliform counts (LARWQCB, 2002a)

Water body	Extent impaired
Lindero Creek Reach 2 (above Lake Lindero)	4.8 miles
Lindero Creek Reach 1 (Medea Creek to Lake Lindero)	2.2 miles
Medea Creek Reach 2 (above confluence with Lindero Creek)	5.4 miles
Medea Creek Reach 1 (from Malibou Lake to confluence with Lindero Creek	3.0 miles
Palo Comado Creek	7.8 miles
Las Virgenes Creek	11.5 miles
Stokes Creek	5.3 miles
Malibu Creek	9.5 miles
Malibu Lagoon	13 acres

3. NUMERIC TARGETS AND CONFIRMATION OF 303(d) LISTINGS

This section provides a review of the data used by the Regional Board to list the water bodies within the Malibu Creek Watershed for fecal coliforms. Where appropriate the data have been updated with more recent information. As the Regional Board's listing decisions are based on impairments to water quality, it is appropriate to begin this section with a discussion of the applicable water quality standards. In addition, the numeric targets for this TMDL are defined and the data are compared with those targets.

3.1 Applicable Water Quality Standards

Water quality standards consist of the following elements: 1) beneficial uses, 2) narrative and/or numeric water quality objectives and 3) an antidegradation policy. In California, beneficial uses are defined by the Regional Water Quality Control Boards (Regional Boards) in the Water Quality Control Plans (Basin Plans). Numeric and narrative water quality objectives are specified in each of the Regional Board's Basin Plans. The water quality objectives are designed to be protective of the beneficial uses in each water body in the region. The Basin Plan for the Los Angeles Regional Board (1994) defines 14 beneficial uses for the Malibu Creek Watershed. All the designated beneficial uses must be protected. However, the two beneficial uses most pertinent to coliform bacteria are REC-1 and REC-2. Table 2 identifies for each of the listed water bodies the uses (existing or intermittent) that are affected by high bacterial indicator levels.

Table 2 - Malibu Creek Watershed Beneficial Uses - Not Supported

Watershed	REC-1	REC-2
Malibu Lagoon	E	E
Malibu Creek	E	E
Las Virgenes Creek	E	E
Stokes Creek	E	E
Upper Medea Creek	I	I
Lower Medea Creek	E	E
Lindero Creek	I	I
Palo Comado Creek	E	E

Recreational uses for body contact (REC-1) and secondary contact (REC-2) apply to all the listed water bodies as either existing, potential or intermittent. These uses apply even if access is prohibited to portions of the water body. Objectives designed to protect human health (e.g., bacterial objectives) are appropriate to protect recreational uses of the creek. The REC-1 standard protects uses where ingestion of water is reasonably possible. The REC-2 standard protects uses, which occur in proximity to water (such as picnicking, sunbathing, hiking, or boating) where ingestion of water is reasonably possible.

The Wildlife use designation (WILD) is for the protection of wildlife. This use applies to all impaired water bodies within the Malibu Creek Watershed. This is pertinent to the coliform TMDL because wildlife can contribute bacterial loading to the watershed. Issues related to the effect of wildlife population on water quality and the potential for competing beneficial uses (REC-1 vs. WILD) are discussed in more detail in Section 3 (Numeric Targets).

Specified reaches of Malibu Creek were determined to be impaired for recreational beneficial uses due to exceedance of bacterial water quality objectives during the 1996, 1998, and 2002 water quality assessment. The applicable bacterial objectives at that time were specified in the Basin Plan as follows:

In waters designated for water contact recreation (REC-1), the fecal coliform concentration shall not exceed a log mean of 200/100 ml (based on a minimum of no less than four samples for any 30-day period), nor shall more than 10 percent of total samples during any 30-day period exceed 400/100 ml.

The Regional Board recently updated the bacteria objectives for waters designated as REC-1 to be consistent with EPA criteria guidance which recommends the use of E. coli criteria for freshwater and the enterococcus criteria for marine waters (See Regional Board Resolution R01-018 and State Board Resolution 2002-0142). The updated revisions have subsequently been approved by the Office of Administrative Law and EPA, and became effective on August 19, 2002. The revisions create objectives for these two new indicators and revise the way in which the objectives for fecal and total coliform bacteria are implemented in freshwater and marine waters, respectively. The revised objectives are summarized in Table 3.

Table 3 - Summary of bacteria standard revisions

	Parameter	**30-Day Geometric Mean**	**Single Sample**
Streams (freshwater)	Fecal	200	400
	E.coli	126	235
Lagoon (marine water)	Total	1,000	10,000 or 1,000 if FC/TC > 0.1
	Fecal	200	400
	Enterococcus	35	104

The implementation provisions for the water contact recreation bacteria objectives defined in these resolutions are as follows:

The geometric mean values should be calculated based on a statistically sufficient number of samples (generally not less than 5 samples equally spaced over a 30-day period).

If any of the single sample limits are exceeded, the Regional Board may require repeat sampling on a daily basis until the sample falls below the single sample limit or for five days, which ever is less, in order to determine the persistence of the exceedance.

When repeat sampling is required because of an exceedance of any one single sample limit, values from all samples collected during that 30-day period will be used to calculate the geometric mean.

In this TMDL we recognize that there are natural sources of coliform bacteria (e.g., birds in lagoon) and that in some instances these sources may contribute bacterial loading sufficient to cause exceedance of the single sample and /or 30-day geometric mean water quality objective. Therefore, a reference system/antidegradation approach is used to establish the acceptable frequency of exceedance of the single sample objectives for the Malibu Creek TMDL.

The reference system/anti-degradation approach ensures that bacteriological water quality is at least as good as that of a reference system and that no degradation of existing bacteriological water quality is permitted where existing bacteriological water quality is better than that of the selected reference system.
The reference watershed approach is used to set a numeric target expressed in terms of allowable exceedance days for the single sample standard. This is consistent with the intent of the Regional Board's prior actions on the Santa Monica Bay TMDLs. The Basin Plan was recently amended to incorporate the following language:

The single sample bacteriological objectives shall be strictly applied except when provided for in a Total Maximum Daily Load (TMDL). In all circumstances, including in the context of a TMDL, the geometric mean objectives shall be strictly applied. In the context of a TMDL, and at the discretion of the Regional Board, implementation of the single sample objectives in fresh and marine waters may be accomplished by using a 'reference system/antidegradation approach' or 'natural sources exclusion approach.' A reference system is defined as an area and associated monitoring point that is not impacted by human activities that potentially affect bacteria densities in the receiving water body.

These approaches recognize that there are natural sources of bacteria, which may cause or contribute to exceedances of the single sample objectives for bacterial indicators. They also acknowledge that it is not the intent of the Regional Board to require treatment or diversion of natural water bodies or to require treatment of natural sources of bacteria from undeveloped areas. Such requirements, if imposed by the Regional Board, could adversely affect valuable aquatic life and wildlife beneficial uses supported by natural water bodies in the Region.

Under the reference system/antidegradation implementation procedure, a certain frequency of exceedance of the single sample objectives above shall be permitted on the basis of the observed exceedance frequency in the selected reference system or the targeted water body, whichever is less. The reference system/anti-degradation approach ensures that bacteriological water quality is at least as good as that of a reference system and that no degradation of existing bacteriological water quality is permitted where existing bacteriological water quality is better than that of the selected reference system.

Under the natural sources exclusion implementation procedure, after all anthropogenic sources of bacteria have been controlled such that they do not cause an exceedance of the single sample objectives, a certain frequency of exceedance of the single sample objectives shall be permitted based on the residual exceedance frequency in the specific water body. The residual exceedance frequency shall define the background level of exceedance due to natural sources. The 'natural sources exclusion' approach may be used if an appropriate reference system cannot be identified due unique characteristics of the target water body. These approaches are consistent with the State Antidegradation Policy (State Board Resolution No. 68-16) and with federal antidegradation requirements (40 CFR 131.12).

The appropriateness of these approaches and the specific exceedance frequencies to be permitted under each will be evaluated within the context of TMDL development for a specific water body, at which time the Regional Board may select one of these approaches, if appropriate.

Arroyo Sequit, located about 10 miles north of Malibu, was chosen as the reference watershed for this TMDL in part for its proximity and similarity to the Malibu Creek Watershed. Arroyo Sequit is the least developed watershed in the area (98% open space), like Malibu Creek it has a freshwater outlet to the beach (Leo Carillo Beach), and there is an existing shoreline monitoring station at the beach. Equally important, Arroyo Sequit is also the reference watershed being used in the Regional Board's Santa Monica Bay Beaches Bacteria TMDLs (LARWQCB, 2002b, 2002c) and the Regional Board has established a procedure for setting the acceptable allowable days of exceedances based on the historic exceedance rate at the mouth of this watershed.[2]

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[2] While Arroyo Sequit is similar in many ways to Malibu Creek, it does not have a terminus lagoon and the bird population associated with such a lagoon. Therefore, this TMDL makes provision for further evaluation of the contribution from birds and consideration of a Natural Source Exclusion.

3.2 Numeric Target

The Santa Monica Bay TMDLs allow for 17 exceedance days per year during wet weather, three exceedance days during winter dry weather, and zero exceedance days during summer dry weather.[3] An exceedance day is any day when any of the applicable bacteria single sample limits are exceeded. No exceedances of the 30-day geometric mean are allowed. Wet days are defined as days 0.1 inch or more of rainfall and the following 3 days to account for residual rainfall effects. This applies to all the beaches within Santa Monica Bay including Surfrider Beach, except where historical data indicates better water quality. Pursuant to the antidegradation policy (State Board Resolution 68-16), where existing water quality is better than the allowable exceedances, then the historical exceedance rate will apply. We propose the same allowances for the Malibu Lagoon, Malibu Creek and all the tributaries within the Malibu Creek Watershed.

3.3 Assessment of existing conditions relative to bacteria standards and numeric targets

This section describes conditions in the Malibu Creek Watershed which resulted in the inclusion of water bodies as impaired on the 1998 and 2002 Section 303(d) Lists. In performing the assessment of inland waters, the Regional Board compared the data to the fecal coliform standard in effect at the time of the assessment and the allowable exceedance days as established under the Santa Monica Bay Beaches TMDL. Because the data were too limited to directly assess compliance with 30-day geometric mean standard of 200/100 ml, the evaluation was based on greater than 10% of the samples exceeding the single sample standard of 400 /100 ml and the median using the entire data set. The Malibu Lagoon listing was based on data from Las Virgenes Municipal Water District (Ambrose *et al.*, 1995). Although the Regional Board did not include Triunfo Creek and Cold Creek on the 303(d) list, they are included in Table 4 since they were part of the Regional Board's assessment of conditions in the Malibu Creek Watershed. It is also likely that sources discharging in these water bodies contribute fecal coliform loading to the listed segments downstream and therefore need to be considered as part of our source analysis.

Bacterial water quality data from four organizations (see Table 4) were reviewed during the development of this TMDL.Enterococcus dataset were not used during this assessment because the Basin Plan does not specify objectives for enterococcus in fresh waters. Furthermore, Regional Board staff were unable to define a statistically significant correlation between enterococcus and fecal or E.coli counts. Heal the Bay has been collecting monthly E. coli samples from seven locations within the watershed since December 2001 (Table 5). Analysis of this monthly monitoring data is included in Appendix A. Analysis of this data show few exceedances of the E. coli health standards occur during dry weather at these locations.

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[3] The allowable exceedance days are based on a daily sampling schedule. If weekly sampling is performed the allowable exceedance days are reduced accordingly.

The Basin Plan does not include enterococcus standards for non-marine water bodies. A summary of the fecal coliform data used in the 1998 listing process is included in Table 5.

Table 4 - Sources of updated water quality monitoring data

Agency	Water bodies	Time Period	Parameters	Comment
Los Angeles County Department of Public Works	Malibu Creek	January 1995 to January 2002	total coliform, fecal coliform	Wet-weather only
City of Calabasas	Las Virgenes Creek, Malibu Creek	November 1999 to September 2002	total coliform, fecal coliform	dry-weather
Las Virgenes Municipal Water District	Malibu Creek, Malibu Lagoon	January 1998 to October 2002	total coliform, fecal coliform, enterococcus	dry-weather
Heal the Bay	Malibu Creek	November 1998 to March 2003	enterococcus	dry-weather
	Palo Comado, Malibu, West Carlysle Chesebro Las Virgenes, and Cold Creeks	December 2001 to December 2002	E. coli	dry-weather

Table 5 - Summary of fecal coliform data (counts/100 ml) used in the 1998 listing process (LARWQCB, 1996, 1998, 2002a).

Water Body Name	Number of Samples	Range*
Triunfo Creek	4	ND-2,300
Lindero Creek Reach 1	9	1,700-90,000
Palo Comado	4	220-30,000
Medea Creek Reach 1	8	23-50,000
Medea Creek Reach 2	4	300-90,000
Las Virgenes	10	40-17,000
Stokes Creek	4	80-14,000
Cold Creek	7	ND-90,000
Malibu Creek	83	ND-14,000

* Basin Plan single sample standard is 400 counts/100 ml.

Discussion

Recent (post-1998) bacterial water quality monitoring data were available for the streams listed in Table 4 only. Therefore, the following discussion of results will not include water bodies other than Malibu Creek, Las Virgenes Creek, and Malibu Lagoon. In addition, data were not assessed against the Basin Plan geometric mean standards because the standard requires at least five samples during a 30-day period. To give an indication of whether the dataset might have exceeded the Basin Plan geometric mean, the median of the dataset was assessed against the geometric mean standard[4]. Finally, existing data were compared

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[4] For positively skewed data the median is usually quite close to the geometric mean (Hesel and Hirsh, 1999)

with the allowable exceedance days for single sample limits, recognizing that this analysis likely underestimates the actual number of exceedances, since none of the datasets include daily sampling.

Las Virgenes Creek - Dry -Weather Sampling

The City of Calabasas submitted updated bacterial indicator data collected for this watershed. These data were collected as part of their volunteer monitoring program. Monitoring locations are shown in Figure 2. As indicated in Table 5, the data were reviewed for the period of November 1999 to September 2002. The database consisted of dry-weather monitoring data only. The indicators tested were total coliform and fecal coliform. The total coliform data were not assessed because the Basin Plan standard for total coliform is applicable for marine waters only.

A total of 198 fecal samples were assessed for compliance with Basin Plan single sample limit of 400 MPN/100 ml. Approximately 28% of the 198 samples exceeded the Basin Plans standard. The median concentration of the samples was 500 MPN/100 ml, and the range of fecal coliform counts was 0 to 160,000 MPN/100 ml. The data did not appear to indicate a trend when the data were analyzed over time. Based on the review of the most recent data for this watershed, the impairment of the REC-1 and REC-2 beneficial uses for fecal coliform based on the single sample standard is confirmed. Also, the review of the data indicates that the 30-day geometric mean standard (200 MPN/100 ml) may have been exceeded based on the median of the database. A comparison of the data with the allowable exceedance days proposed for this TMDL shows that both summer and winter dry-weather as proposed in this TMDL targets were exceeded (see Table 6).

Figure 2 - City of Calabasas Las Virgenes Creek Monitoring Stations

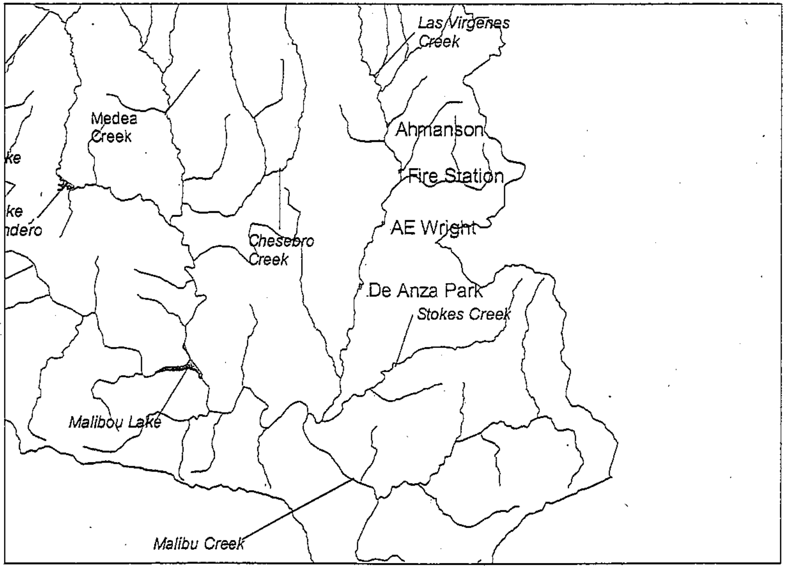


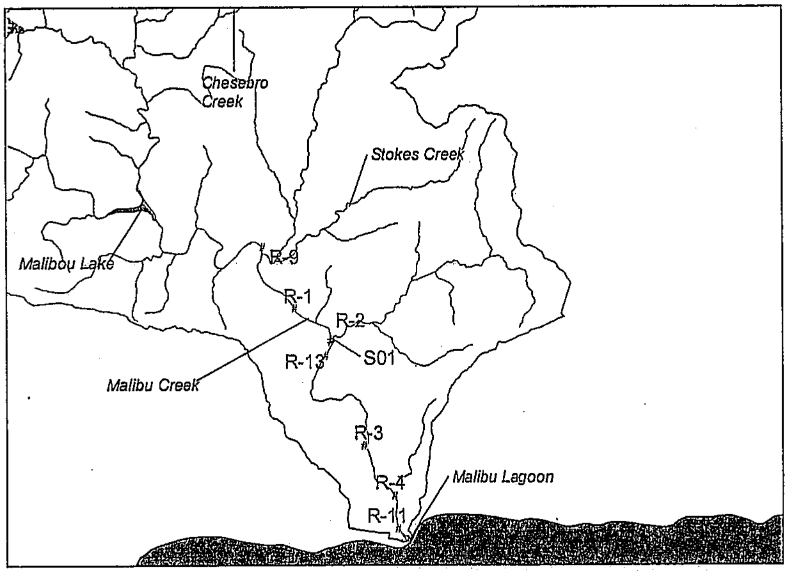
Table 6 - Las Virgenes Creek Comparison with Dry-Weather Target

Season	Dry Season Target	Exceedance Days			
		1999	2000	2001	2002
Summer	0	2	26	16	15
Winter	3	1	14	25	3

Malibu Creek - Dry Weather

The Las Virgenes Municipal Water District submits in-stream water quality data as required by their NPDES discharge monitoring reports. The data for Malibu Creek was collected at stations R-1, R-2, R-3, R-9, and R-13 (see Figure 3). The data were reviewed for the period of January 1998 to October 2002. The database consists of dry-weather monitoring data only for following bacterial indicators: fecal coliform, total coliform, and enterococcus. The total coliform and enterococcus data were not assessed, since there are no applicable fresh water objectives for these parameters.

Figure 3- LVMWD and LACDPW Malibu Creek and Lagoon Monitoring Stations



A total of 340 fecal coliform samples were assessed for compliance with Basin Plan standard of 400 MPN/100 ml, and reference/antidegradation approach. Approximately 8.5% of the 340 samples exceeded the Basin Plan standard. The median concentration of the samples was 70, and the range of the fecal coliform counts was 17 to 5,000 MPN/100 ml. The data demonstrated a decreasing trend when the data were analyzed over time. Review of the data indicates that the 30-day geometric mean standard (200 MPN/100 ml) does not exceed the Basin Plan standard based on the median of the database. A comparison of the data with the proposed allowable exceedance days shows that both summer and winter dry-weather targets were exceeded (see Table 7). Actual exceedance days may have been higher.

Table 7 - Malibu Creek Comparison with Dry-Weather Numeric Target

Season	Dry Season Target	Exceedance Days				
		1998	1999	2000	2001	2002
Summer	0	1	1	2	2	4
Winter	3	3	0	3	12	1

Malibu Creek - Wet Weather

The Los Angeles Department of Public Works submits stormwater monitoring data as required by their NPDES discharge monitoring reports. The data for Malibu Creek was collected at station S01(see Figure 3) located below the confluence of Cold Creek and Middle Malibu Creek. The data were reviewed for the period of January 1995 to January 2002. The database consists of wet-weather monitoring data only for following bacterial indicators: fecal coliform and total coliform. The total coliform data were not assessed.

A total of 52 fecal coliform samples were assessed for compliance with Basin Plan standard of 400 MPN/100 ml. Approximately 86.5% of the 52 samples exceeded the Basin Plan standard. This database was not assessed against the reference/antidegradation target. The median concentration of the samples was 50,000 and the range of the fecal-coliform counts was 0 to 1,600,000 MPN/100 ml. The data demonstrated a decreasing trend when the data were analyzed over time. Based on the review of the most recent data for this watershed, the impairment of the REC-1 and REC-2 beneficial uses for fecal coliform based on the single sample standard is confirmed. In addition, review of the data indicates that the 30-day geometric mean standard (200 MPN/100 ml) may have been exceeded based on the median of the database.

Cold Creek - Dry Weather

Heal the Bay collects E.coli data in Cold Creek as part of the Stream Team monitoring program. The data for Cold Creek was collected at station HTB3 (at Stunt Road) and HTB11 (at Piuma Road). The data were reviewed for the period of December 2001 to December 2002. The database consists of dry-weather monitoring data for the following bacterial indicators: E. coli and total coliform. The total coliform data were not assessed.

A total of 33 E. coli samples from HTB3 and HTB11were assessed for compliance with Basin Plan standard of 235 MPN/100 ml. Approximately 3% (1of 33) samples exceeded the Basin Plan standard. The geomean concentration of the samples at HTB3 and HTB11 were 9 and 15 cfu/100, respectively. The range of the E. coli counts at the sites was 5 to 272 cfu/100ml for HTB3, and 5 to 86 cfu/100mL at HTB11. Review of this data indicates that E. coli standard in upper and middle Cold Creek is in compliance with Basin Plan objectives for the single sample and geomean standard during dry weather.

Malibu Lagoon

The Las Virgenes Municipal Water District collected data for the Malibu Lagoon at stations R-4 and R-11 (see Figure 3). The data were reviewed for the period of January 1998 to October 2002. These data were assessed based on the bacterial water quality objectives for marine waters. The database consists of dry-weather monitoring data only for fecal coliform and total coliform.

Above Pacific Coast Highway – Dry Weather

A total of 57 fecal coliform and 63 total coliform samples from monitoring station R-4 were assessed for compliance with Basin Plan fecal coliform standard of 400 MPN/100 ml and total coliform standard of 1,000 MPN/100ml or 10,000 MPN/100ml, which ever applied. Approximately 8.7% of the 57 fecal coliform samples and 30% (20 of 57) of the total coliform samples exceeded the Basin Plan standard. The median concentration of the samples was 80 MPN/100 ml for fecal coliform and 800 MPN/100 ml for total coliform. The range of the fecal coliform counts was 20 to 1,700 MPN/100 ml, while the total coliform range was 70 to 9,000 MPN/100 ml. The data demonstrated an increasing fecal coliform trend and gradual decreasing total coliform trend, when the data were analyzed over time. Based on the review of the most recent data for this watershed, impairment is confirmed of the REC-1 and REC-2 beneficial uses for total coliform based on the single sample standard. On the other hand, review of the data indicates that the 30-day geometric mean standard (200 MPN/100 ml) does not exceed the Basin Plan standard for fecal or total coliforms based on the median of the database.

A comparison of the data with the allowable exceedance days shows that the summer dry-weather target was exceeded, but winter dry-weather target was not (see Table 8.) However, this analysis likely underestimates the actual exceedances since it is based on a very small number of samples.

Table 8 - Malibu Lagoon (R4) Data Comparison with Dry Weather Target

Season	Dry Season Target	Exceedance Days		
		2000	2001	2002
summer	0	0	0	2
winter	3	1	2	0

Below Pacific Coast Highway – Dry Weather

A total of 71 fecal coliform and 77 total coliform samples from monitoring station R-11 were assessed for compliance with Basin Plan fecal coliform standard of 400 MPN/100 ml and total coliform standard of 1,000 MPN or 10,000 MPN, whichever applied. Approximately 28.5% of the 71 fecal coliform samples and 7% (6 of 77) of the total coliform samples exceeded the Basin Plan standards. The median concentration of the samples was 220 MPN/100 ml for fecal coliform and 1,100 MPN/100 ml for total coliform. The range of the fecal coliform counts was 20 to 5,000 MPN/100 ml, while the total coliform range was 20 to 16,000 MPN/100 ml. The data demonstrated a decreasing trend for fecal and total coliform, when the data were analyzed over time. Based on the review of the most recent data for this watershed, the impairment of the REC-1 and REC-2 beneficial uses is confirmed for fecal coliform based on the single sample standard. In addition, review of the data indicates that the 30-day geometric mean standard (200 MPN/100 ml) exceeds the Basin Plan standard for fecal or total coliforms based on the median of the database.

A comparison of the data with the proposed allowable exceedance days shows that the summer and winter dry-weather target were exceeded (see Table 9.) However, this analysis likely underestimates the actual exceedances since it is based on a very small number of samples.

Table 9 - Malibu Lagoon (R-11) Data Comparison with Dry-Weather Numeric Target

Season	Dry Season Target	Exceedance Days		
		2000	2001	2002
summer	0	2	6	3
winter	3	8	3	1

In summary, the most recent monitoring data were reassessed against the newly revised bacteria water quality objectives and the numeric targets proposed for this TMDL and the 303(d) listed impairments were confirmed.

3.4 Fecal to E. Coli Coliform Relationship

The freshwater standards for E. coli and fecal coliform apply to all the creeks in the watershed. The marine standards for total coliform, fecal coliform and enterococcus apply to the lagoon. Recognizing that these multiple standards apply, the modeling for the linkage analysis in this TMDL was based solely on fecal coliform objectives, which are the same for fresh and marine waters. This decision was made in part because the 303(d) listings were based solely on the exceedances on the fecal coliform standard. There is almost no data on E. coli data to assess compliance with the E. coli freshwater standard and very little enterococcus data to assess conditions in the lagoon. While there is a substantial dataset for total coliform, the total coliform standard only applies to the lagoon. We anticipate that actions targeted toward the reduction of fecal coliform in the watershed will also reduce concentrations of total coliform in the lagoon.

Given the limited data for bacteria indicators in the watershed, the TMDL developed and established by USEPA in March 2003 was based solely on fecal coliform as an indicator target. Fecal coliform waste load and load allocations were developed for bacteria sources to ensure attainment with water quality standards. During the public comment period USEPA received comments that questioned whether water quality could be attained in the streams, since allocations were not developed for E. coli. In order to address these comments, the Regional Board staff conducted a data analysis to determine whether a statistical relationship between E. coli and fecal coliform existed based on a linear regression analysis of historical data from the Malibu Creek Watershed. The results of this analysis indicated that the E. coli and fecal coliform concentrations were highly correlated (r-value = 0.994). Linear regression analysis demonstrated that the concentration of E. coli could be predicted from fecal coliform concentrations (coefficients of determination [R^2] =98.7%). Therefore compliance with the fecal coliform geometric mean concentrations of 200 org/100 ml, should ensure compliance with the E. coli single sample standard numeric target of 235 org/ 100 ml, based on the relationship demonstrated in Table 10.

Equation (1) *E. coli = (1.00409 fecal coliform) - 10.6*

Table 10 - Fecal Coliform Relationship

Fecal Coliform	Fecal/E. coli Relationship	Predicted E. coli
200 org/100 ml	1.00409 (200)-10.6	190.28

Equation 1 was not used to predict the geometric mean concentrations for E. coli, since the fecal coliform data set evaluated did not have a minimum number of samples (5 samples over a 30-day period) to assess a geometric mean relationship.

4. SOURCE ASSESSMENT

Fecal coliform bacteria may be introduced from a variety of sources including onsite wastewater treatment systems, animal wastes, and runoff from both developed and undeveloped areas. An inventory of possible point and nonpoint sources of fecal coliform bacteria to the water body was compiled, and both simple methods and computer modeling were used to estimate bacteria loads for those sources. Source inventories were used in the analysis to identify all potential sources within the Malibu Creek Watershed, modeling was used to identify the potential delivery of pathogens into the creeks and the lagoon.

Fecal coliform loads from the watershed were estimated by using a computer model (Hydrologic Simulation Program – FORTRAN) and supplemental estimates of selected sources (Tetra Tech, 2002). Fecal coliform loading deposited on land surfaces or in the soil, may be attenuated through sunlight, heat, and decay over time. Transport of coliform bacteria is a result of periodic rainfall and groundwater seepage into the creek system. This source assessment chapter discusses the gross loading potential of various identified sources. While gross loading are applicable to direct discharges, adjustments were made for indirect discharges resulting from surface runoff or groundwater discharge. Gross loading was adjusted for indirect discharges and is referred to herein as "net" loading. The gross and adjusted net loading was further refined based upon calibration of the model with actual in-stream monitoring data (calibrated loading). In most cases, the calibrated loading was less than the gross and net loading. It is important to note that multivariate models were used. The multiple sources of bacteria loading (quantity of each variable) in the models were adjusted to reasonably match historical creek water quality data. Since the inputs were indirectly estimated, the data was not sufficient to confirm that the models would be able to predict the bacteria concentrations in the creek or lagoon if one or more assumed inputs of bacteria are changed. For more detailed information on the source assessment, please refer to the modeling report (Tetra Tech, 2002).

Tapia Waste Water Reclamation Facility. The Tapia WWRF has the capacity to treat and discharge up to 16.1 mgd of tertiary- treated sewage. The treated effluent from Tapia has one of two end destinations. The effluent is either reclaimed for irrigation and industrial uses, or is discharged to streams. Effluent is discharged to Malibu Creek or Las Virgenes Creek through discharge points 001, 002, and 004 (Figure 4). The primary outfall into Malibu Creek is Discharge No. 001, which is located about 0.3 mile upstream of the confluence with Cold Creek. Discharge No. 002 flows into lower Las Virgenes Creek, and is used to release surplus effluent from Las Virgenes Reservoir No. 2, which is used for distribution of the reclaimed water system. Discharge No. 004 is the discharge from the percolation ponds. Currently, discharge to Malibu Creek is not allowed from April 15 to November 15 (Regional Board Order No. 97-135). On average during the winter months the plant dischargers between 8 to 10 mgd (LVMWD, 1996-2000).

Tapia's permit requires that all the wastewater be chlorinated to at least 2.2 MPN/100 ml for fecal coliform. Although fecal coliforms have not been detected in the effluent, an upper bound on the estimated loading can be made by multiplying the reported detection limits for fecal coliforms by the average flows. The fecal coliform loads discharged to Malibu Creek from Tapia were estimated from the monthly flow and concentration measurements collected by the Las Virgenes Municipal Water District for their NPDES monitoring reports (LVMWD, 1993-2000). Based on this analysis the annual fecal coliform loading from the Tapia plant are on the order of 30 to 60 billion counts per year (Table 11).

Figure 4 - Malibu Creek Watershed Compliance Points and Tapia Discharge Points

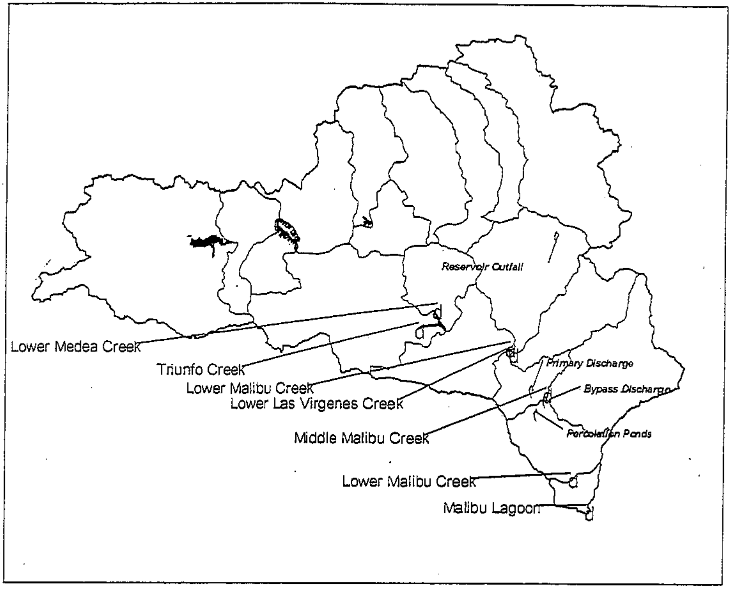


Table 11 - Annual gross fecal loading (billion counts/year) in Tapia effluent (Tetra Tech, 2002)*

	1992	1993	1994	1995	1996	1997	1998	1999
Max	<1	<1	<1	<1	<1.1	<1.1	<1.1	<1.1
Average Flow (cfs)	4.76	5.35	4.02	4.80	3.13	3.00	6.44	3.18
Load	42.2	47.3	35.7	42.8	30.5	29.3	62.9	30.8

* Fecal loads were assumed to the equal to total coliform loads. This is a conservative assumption, and it is expected that the actual fecal loads may be lower.

The Las Virgenes Municipal Water District (LVMWD) sells approximately 4,000 acre-feet per year of reclaimed wastewater from its Tapia facility that is used for irrigating open space and landscaping (Abramson et al., 1998). The use of reclaimed water is regulated under water reclamation requirements contained in Order No. 87-86 and 94-055. Table 12 summarizes the annual loading of total coliform from each effluent irrigation operation, estimated by multiplying flows times the concentration/detection limit. These are gross numbers, and do not reflect loading to receiving water. Indeed, Order No. 87-86 requires that irrigation water shall be retained on the areas of application and not be permitted to escape as surface flows, that reclaimed water shall not be applied at a rate which exceeds vegetative demand, and that special precautions shall be taken to prevent overwatering and to exclude the production of runoff.

Table 12 - Annual gross fecal loads (billion counts/year) associated with effluent irrigation in the Malibu Creek Watershed (Tetra Tech, 2002)*

Source	1992	1993	1994	1995	1996	1997	1998	1999
Triunfo Sanitation District	5.3	3.4	5.3	6.0	18.0	20.8	13.4	19.9
Western Las Virgenes Municipal Water District	30.0	28.1	24.2	27.2	29.1	37.0	27.2	34.0
Calabasas	11.7	14.7	17.1	16.7	21.3	20.0	15.6	20.7
Las Virgenes Valley	1.2	3.3	3.9	2.9	3.8	2.6	1.9	3.4
Rancho Las Virgenes	0.9	1.1	0.7	0.2	0.9	0.9	0.6	1.2
Rancho Las Virgenes Composting	0	0	0	0	0	0	0.05	0.05
Tapia Percolation Beds	11.8	8.3	21.1	27.5	23.2	26.4	0	0
Malibu Creek Park	0	0	0	0	0	0	0	0.02
Tapia Spray Fields and Wastewater Reclamation Facility	0.6	0.3	0.9	0.3	0.3	10.6	0.05	0.05
Tapia Yard	7.0	7.1	7.0	6.2	8.2	0	0	0
TOTAL	**68.5**	**66.3**	**80.2**	**87.0**	**104**	**118.3**	**58.8**	**79.3**

* Fecal loads were assumed to the equal to total coliform loads. This is a conservative assumption, and it is expected that the actual fecal loads may be lower.

Tapia is permitted to compost the solid wastes from its treatment facility into fertilizer at their Rancho Las Virgenes Compost Facility (LVMWD, 1994; LA RWQCB, 1997; Abramson et al., 1998). Another portion of the sludge from Tapia may be digested and pumped to their Rancho Las Virgenes Farm for subsurface injection. This activity is regulated under Waste Discharge Requirements contained in Order No. 79-107. Table 13 summarizes the annual loading from sludge disposal. These have decreased in recent years as composting at Rancho Las Virgenes has come on line, but injection still occurs (approx. 1 dry ton/year) according to a Las Virgenes Municipal Water District official (Colbough, 2003).

Table 13 - Annual gross fecal coliform loading associated with sludge Injection Loads at Rancho Las Virgenes Farm (Tetra Tech, 2002)

Year	Sludge Biosolids Loading (dry ton/yr.)	Fecal Coliform Loading (billion counts/year)
1997	307	53,800
1998	90	16,300
1999	1	NA

The loads from Tapia either from direct discharge or indirectly from use of reclaimed water for effluent irrigation or sludge injection are insignificant (<0.1%) of the total estimated annual loading. Both the direct discharge and reclaimed water are chlorinated so that the effective concentrations of fecal coliforms are less than 1 MPN. Given that concentrations from Tapia are less than 0.5% of the water quality objective for fecal coliform bacteria, flows from Tapia actually provide additional assimilative capacity to the system.

Onsite Wastewater Treatment Systems. Except for the City of Malibu, most of the medium to high-density residential developments in the watershed are on sewer systems. However, onsite wastewater treatment systems are still used in rural residential areas and in the City of Malibu. The term onsite wastewater treatment system is being used in this document instead of the traditional term: septic systems. Onsite wastewater treatment system describes the location and purpose of these systems. The total number of systems in the watershed was estimated at 2,300 in the mid-1990s (NRCS, 1995) and 2,420 in 2001 (Tetra Tech, 2002).

The USEPA (2003) assumed that there were about 20 commercial onsite wastewater treatment systems in shopping centers and commercial areas in the vicinity of Malibu Lagoon which discharge an estimated 70,000 to 80,000 gallons of septic effluent per day (LARWQCB, 2000). Furthermore, this refined number of commercial and multifamily systems is based on the watershed defined by surface topography and drainage along the land surface of the Malibu Lagoon Subwatershed. Since onsite wastewater treatment systems are below grade: the groundwater flow regime controls whether groundwater passing beneath a system ultimately flows into Malibu Creek, Malibu Lagoon or the surfzone. Therefore, at this time we cannot positively identify systems that contribute groundwater flow to the Creek and the Lagoon. Several hundred thousands of gallons per day are estimated to be discharged from private residences in the Malibu area of the lower watershed (LARWQCB, 2000). It is presumed that most of these systems are providing adequate treatment of bacteria. Warshall (1992) estimated that 30 single family residences with onsite systems were "short circuited" and therefore contributing elevated levels of bacteria to the Lagoon. The locations, designs, and depths to groundwater of these systems have not been inventoried to confirm this claim. Table 14 presents the total annual fecal coliform loads generated from onsite wastewater treatment systems in the Malibu Creek Watershed as used in the Tetra Tech modeling (2002).

Table 14 - Estimated gross and net annual fecal coliform loads generated from Onsite Wastewater Treatment systems

Subwatershed	**Onsite WastewaterTreatment Systems**							
	Total	Normal	Failed	Short-Circuited	Commercial	**Effluent flow (gal/day)**	**Gross Fecal Coliform Load (billion /year)**	**Net Fecal Coliform Load (billion /year)**
Hidden Valley Creek	625	500	125			171,250	1,551,250	124,100
Portereo Canyon Creek								
Westlake	60	48	12			16,440	148,920	11,914
Upper Lindero Creek								
Lower Lindero Creek								
Upper Medea Creek								
Palo Comado Creek								
Cheeseboro Creek								
Lower Medea Creek	110	88	22			30,140	273,020	21,842
Triunfo Creek	820	656	164			224,680	2,036,700	162,819
Upper Malibu Creek	95	76	19			26,030	235,790	18,863
Upper Las Virgenes Creek								
Lower Las Virgenes Creek	50	40	10			13,700	124,100	9,928
Stokes Creek	85	68	17			23,290	210,970	16,878
Middle Malibu Creek	50	40	10			13,700	124,100	9,928
Cold Creek	300	240	60			82,200	744,600	59,568
Lower Malibu Creek	5	4	1			1,370	12,410	993
Malibu Lagoon								
Above Lagoon	170	136	34			46,580	423,400	33,775
Adjacent to Lagoon	30			30		8,220	74,460	74,460
Commercial near lagoon	20				20	75,000	678,900	678,900
Total	2,420	1896	474	30	20	732,600	6,638,620	1,223,968

Source: LARWQCB, 2000; NRCS, 1995; Finney,

When properly sited and operated, it is assumed that onsite wastewater treatment systems remove nearly 100% of the fecal coliform bacteria. However, onsite wastewater treatment systems can be significant sources of bacteria when the systems provide inadequate treatment and discharge directly to groundwater in close proximity to surface waters or discharge directly to surface water via overland flow. Inadequate treatment may be due to insufficient vertical separation to the groundwater, insufficient horizontal separation or surface discharge from a failed disposal field. Onsite wastewater treatment system failure rates have been estimated to be 20 to 30% in the unincorporated parts of Los Angeles County and within the Malibu Creek Watershed. It is presumed that this estimate of system failure apparently includes a wide range of types of failures, many of which may not impact surface water quality. For example, failing systems include systems that have backed up, have surfacing effluent that does not reach a creek, or have poorly functioning leach fields. LARWQCB has historically been concerned about the bacterial loading from the residential onsite wastewater treatment systems in the Malibu Colony and Cross Creek shopping areas adjacent to the Malibu due to their close proximity to the lagoon. This concern is based on limited evidence of high pollutant concentrations measured in the shallow groundwater in this area and the potential for insufficient vertical separation between the bottom of the soil absorption systems and the high groundwater table (LARWQCB, 2000).

In estimating loads from the failing systems, a maximum failure rate of 20 percent was assumed. However to calibrate the model the failure rate was adjusted. This resulted in an average failure rate of about 8 percent for onsite wastewater treatment systems above Malibu Lagoon. Forty percent of the bacteria from these failed systems were assumed to reach surface waters (Tetra Tech 2001). For the short-circuited and commercial onsite wastewater treatment systems adjacent to the lagoon, the calibrated fecal coliform failure rate was assumed to be 20 percent throughout the year, and assuming that 100% of the bacteria from the failed systems reached the lagoon. In order to account for both lower assumed to be failure rates and bacteria die off in route to the receiving water, 20 percent of the gross bacteria loads were assumed to enter the receiving water (Tetra Tech, 2002).

The City of Malibu has undertaken a study of the impact of onsite wastewater treatment systems on groundwater quality in this area. This project, entitled *Risk Assessment of Decentralized Wastewater Management in High Priority Area, Malibu, California*, is being conducted by the City of Malibu, with a California Coastal Conservancy Grant, and is administered by the Santa Monica Bay Restoration Commission. This study is collecting groundwater quality samples in this watershed on a monthly basis for one year. This ongoing study will provide a area-wide characterization of the potential contribution of onsite systems to the Malibu Lagoon Watershed. The results of this study will be incorporated into a three dimensional computer model of groundwater flow and solute transport, and will be available to refine the assumptions of the models used to more accurately allocate the source loading from onsite systems in this subwatershed. For example, the model will enable the determination of travel times for bacteria in groundwater to determine whether adequate die-off of bacteria is likely to occur prior to reaching the lagoon. Unfortunately, data from the study have not yet been released and therefore could not be considered in the development of this TMDL. However, the study results should assist the city in implementing the TMDL._

Both estimated gross and net bacteria loads are provided in Table 14. Calibrated loads for onsite wastewater treatment systems, based on the calibration of the models, are provided in Table 18. Based on these assumptions, we estimated that onsite wastewater treatment systems may account for about 18% of the total annual fecal coliform loading to the Malibu Creek Watershed. Similarly, the onsite wastewater treatment systems in the Malibu Lagoon subwatershed may account for 12% of the total annual loading to the entire Malibu Creek Watershed.

Runoff from Residential and Commercial Areas. Runoff from residential and commercial areas can be important sources of bacteria. Most of the major residential and commercial areas are in the cities of Westlake Village, Thousand Oaks, Agoura Hills, Calabasas, and Malibu. Lower density residential areas are scattered in many areas of the watershed, and include the communities around Lake Sherwood and Malibou Lake, the Hidden Valley area, the Palo Comado Creek area east of Agoura Hills, and the community of Monte Nido. The potential sources include fertilizer used for lawns and landscaping; organic debris from gardens, landscaping, and parks; trash such as food wastes; domestic animal waste; and human waste from areas inhabited by the homeless. These pollutants build up, particularly on impervious surfaces, and are washed into the waterways through storm drains when it rains. These loads are typically highest during the first major storms after extended dry periods, when the pollutants have accumulated.

Activities such as the watering of lawns and the washing down of parking lots and driveways can contribute pollutants between storms. The bacterial loading from residential runoff were estimated to be 3,150,000 billion counts per year. The estimated bacterial loading associated with commercial and industrial were on the order of 2,550,000 billion counts per year. During wet weather, urban runoff appears to be the predominate source of bacterial loading.

Horse and Livestock. Manure produced by horses, cattle, sheep, goats, birds and other wildlife in the Malibu Creek Watershed are sources of both nutrients and coliforms. These loads can be introduced directly to the receiving waters in the case of waterfowl or cattle wading in streams, or they may occur as nonpoint sources during storm runoff.

Most of the horses are concentrated in a few areas. These are Hidden Valley, the Palo Comado Creek area east of Agoura Hills, the Triunfo Creek and Lower Medea Creek areas in the vicinity and upstream of Malibou Lake, and the Cold Creek area around the community of Monte Nido. Cattle grazing is confined primarily to the Hidden Valley area in the upper western portion of the watershed. Approximately 250 cattle are estimated to reside in this area (NRCS, 1995). Approximately 200 sheep and goats reside in the pasture area north and east from the Rancho Las Virgenes. In past years, cattle grazing have also occurred on the Rancho Las Virgenes property of the upper Las Virgenes Creek subwatershed (Orton, 2001).

Estimates of fecal loads produced by horse and livestock can be estimated by multiplying the number of animals in the watersheds by a per unit fecal production load (Tables 15 and 16).

Table 15 - Gross annual fecal loads associated with horse manure

Subwatershed	Number of Horses	Estimated Fecal coliform loads (billion counts/year)
Hidden Valley Creek	920	140,890
Portereo Canyon Creek	40	6,132
Westlake		
Upper Lindero Creek		
Lower Lindero Creek	5	767
Upper Medea Creek	20	3,066
Palo Comado Creek	100	15,330
Cheeseboro Creek		
Lower Medea Creek	140	21,462
Triunfo Creek	160	24,528
Upper Malibu Creek		
Upper Las Virgenes Creek	15	2,300
Lower Las Virgenes Creek	5	767
Stokes Creek	45	6,899
Middle Malibu Creek	30	4,599
Cold Creek	115	17,630
Lower Malibu Creek		
Malibu Lagoon	100	15,330
Total	**1695**	**259,700**

Table 16 - Gross annual fecal coliform loads associated with livestock manure

Subwatershed	Cattle	Sheep/Goats	Estimated Fecal coliform (billion counts/year)
Hidden Valley Creek	250		26,000
Upper Las Virgenes Creek	15		1,560
Upper Las Virgenes Creek		200	2,400
Total	**265**	**200**	**29,960**

The values in Tables 15 and 16 present estimated gross fecal coliform loads from horse and other livestock manure, respectively, in the Malibu Creek Watershed. They do not reflect the estimated net loading to the creeks. In our model, the gross loads from horses were reduced by forty percent for input into the model, due to collection of horse manure from stables, except for the Hidden Valley subwatershed where there are many open pastures. Additionally, loads were reduced by twenty percent for horses and thirty percent for cows and sheep because these percentages were assumed to occur as urine (ASAE, 1998). Since urine is not expected to contain fecal bacteria, the reductions were necessary. Because horse and livestock loads occur as nonpoint sources in the model, there is a buildup of the bacteria during the dry periods and thus reduced contribution of the bacteria to the stream reaches during these periods. Based on these assumptions, our best estimate of net loading to the creeks is 32,100 billion counts per year. This represents about 0.5% of the total loading to the Malibu Creek Watershed.

Wildlife. Wildlife wastes contribute to the bacterial loads from the large undeveloped portions of the watershed, and may be the only source of bacteria from these areas. Over 75 percent of the entire Malibu Creek Watershed is undeveloped wildland consisting primarily of chaparral, scrub, and woodlands, with smaller areas of grasslands and forests. The abundance of wildlife varies among the different habitat and vegetation types. Approximately 50 species of mammals and 380 species of birds occur in the watershed (NRCS, 1995). The important mammals include mule deer, hares, rabbits, squirrels, foxes, bobcats, badgers, ring-tailed cats, weasels, coyotes, raccoons, skunks, mountain lions, and a variety of small rodents (rats, mice, gophers, voles) (NRCS, 1995). We have no direct estimates of populations or the loading rates associated with these animals. However, the values for bacterial loading associated with runoff from undeveloped land provide an indirect estimate of wildlife contribution. It is estimated that runoff from chaparral/sage scrublands contributes 37,700 billion per year, runoff from grasslands contributes 2,690 billion per year, and runoff from woodlands contributes 809 billion per year. Estimates for each type of vegetation were based on literature and event mean concentrations measured by the Los Angeles County Department of Public Works (Tetra Tech, 2002).

Waterfowl are important components of the Malibu Lagoon ecosystem, and may also contribute nutrients and bacteria to the various lakes in the watershed. Waterfowl were considered as a separate loading source only for Malibu Lagoon, since birds have previously been suggested to be an important source of the elevated coliform levels in the lagoon (Warshall et al., 1992). Table 17 presents the estimated annual bacteria loads produced by waterfowl near Malibu Lagoon. The loads were reduced to 35% of the total load for use after model calibration (see Table 18). This reduction in bird loads can be explained by the fact that the birds do not spend all their time in the lagoon. It should be pointed out that waterfowl loads were not evaluated for the lakes, since bird counts were not available.

Table 17 - Estimated gross annual bacterial loads (billion counts) produced by waterfowl near Malibu

Month	**Bird Population**	**Estimated Fecal coliform (billion counts/year)**
January	1000	75,330
February	1500	102,060
March	1630	122,788
April	400	29,160
May	300	22,599
June	320	23,328
July	230	17,326
August	200	15,066
September	400	29,160
October	750	56,498
November	780	56,862
December	1100	82,863
Annual Total	8610	**633,040**

Source: Topanga-Las Virgenes Resource Conservation District; ASAE, 1998.

Golf Courses. Golf courses are a potential source of bacteria since the typical fertilization and watering rates are generally high. Golf courses also attract large numbers of waterfowl. The bacteria may be transported to waterways in storm runoff. Most of the golf courses are adjacent to waterways. Both Lake Sherwood and Lake Lindero have golf courses just upstream of the lakes, and Westlake Lake has a golf course about 0.6 mile northeast of the lake. In addition, two golf courses are located in the upper portions of the Westlake and Upper Lindero Creek watersheds near perennial or intermittent streams. There is also a small private golf course on the west side of Malibu Lagoon in the Malibu Colony area (Tetra Tech, 2002). Based on our analysis, the runoff of fecal coliform bacteria associated with golf courses appears to be negligible (less than 1%).

Tidal Inflow to Lagoon. Tidal inflow loads of bacteria were calculated from estimated tidal inflow rates from the UCLA study (Ambrose et al., 2000) and fecal coliform concentrations in coastal waters measured during the Malibu Technical investigation (LARWQCB, 2000). The average concentration for fecal coliform at beach surf zone stations was 69 counts per 100 ml. From this number, annual loading associated with tidal inflow was estimated to be 16,100 billion counts per year. This is a relatively small percentage (0.2%) of the annual loading to the lagoon.

Dry weather storm drain loads to Malibu Lagoon. Three storm drains discharge to the Malibu Lagoon. These are the Civic Center drain, the Cross Creek Road drain, and the Malibu Colony. It is estimated that the fecal loading from the Malibu Colony storm drain was 48 million per day. These high concentrations from these storm drains may result in localized exceedances of water quality standards. However in terms of annual loading, these drains appears to contribute a very small fraction (<1%) of the loads to the lagoon.

Sanitary Sewer Overflows, Leaking Sewer Pipes

Sanitary Sewer Overflows (SSOs) and exfiltration from sewer systems has been indentified by EPA as a potential cause of pathogens in surface water (USEPA 2000a and 2001). SSOs are primarily addressed through enforcement actions such as Administrative Civil Liabilities (ACL) fines, Cease and Desists Orders (CDOs), and litigation. In addition, USEPA documents indicate that although exfiltration may be possible given certain conditions, "no data or narrative information in the literature demonstrate, or even suggest, that sewer exfiltration has directly contaminated surface waters."(USEPA 2000a). Thus, these potential sources were not included in the source assessment.

Illicit Connections

Sources of elevated bacteria to marine and fresh waters may also include direct illegal discharges from malfunctioning onsite water treatment systems and illicit discharges from private drains. Data were not available at the time of TMDL development to assess the bacterial contribution from illicit connections. Based on local code and/or ordinances, illicit connections are prohibited in the following areas: unincorporated county areas of Ventura and Los Angeles and the cities of Calabasas, Westlake Village, Thousand Oaks, Simi Valley, and Malibu.

4.1 Summary of source assessment.

The values in Tables 11-17 do not by themselves provide enough information to allocate load reductions among the various sources. A model has been developed to relate loading to concentrations in the creek and lagoon system. The model integrates this information on potential loading with assumptions about the timing and delivery of these loading relative to instream flows and instream processes to predict water quality. The calibrated modeled loads to the system are summarized in Table 18.

These values represent our best estimates of potential sources from the watershed to the creeks and lagoon. Surface runoff loads from residential and commercial areas appear most likely to be the largest sources. Most of these loading are associated with storms. However dry-weather urban runoff also contributes anthropogenic loading. Based on preliminary data, inadequate onsite wastewater treatment systems may result in significant fecal contribution, especially to the lagoon. Birds are another significant potential source of fecal coliforms to the lagoon. These are the apparent major contributors to the total watershed on an annual basis. During the dry season, urban runoff appears to be the largest source of fecal coliforms, but the loads associated with birds and failing onsite wastewater treatment systems may be comparable in magnitude.

5. . LINKAGE ANALYSIS

Information on sources of pollutants provides one part of the TMDL analysis. To determine whether those pollutants impair a water body, it is also necessary to determine the assimilative capacity of the receiving water under critical conditions. This section describes the use of a hydrodynamic and water quality model to determine the loading of bacteria that are expected to achieve the compliance with the TMDL. In this section, we also describe the approaches for defining the critical conditions and developing an appropriate

Margin of Safety (MOS) to ensure that water quality standards will be met.

5.1 Model description

Receiving water quality models were used to predict fecal coliform concentrations in the 303(d) listed creeks and lagoon under various loading scenarios. The models were used to establish potential relationships between pollutant loads from the identified sources within Malibu Creek Watershed and the in-stream water quality targets for the listed reaches (Tetra Tech, 2002).

HSPF was selected since it could be linked directly with the watershed and stream modeling framework. For the purpose of analysis, the Malibu Creek Watershed was divided into 18 subwatersheds. The source loading data from each these subwatersheds were treated as inputs at the appropriate location within the network of tributaries and creeks that were modeled as part of Malibu Creek Watershed (Figure 4). The following stream reaches within the Malibu Creek Watershed were included in the model: Hidden Valley Creek, Portrero Canyon Creek, Upper Lindero Creek, Lower Lindero Creek, Upper Medea Creek, Palo Comado Creek, Cheeseboro Creek, Lower Medea Creek, Triunfo Creek, Upper Malibu Creek, Upper Las Virgenes Creek, Lower Las Virgenes Creek, Stokes Creek, Middle Malibu Creek, Cold Creek, Lower Malibu Creek and Malibu Lagoon. The following lakes were also considered as part of the stream network: Westlake Lake, Lake Sherwood, Lake Lindero and Malibou Lake.

Calibration of the model involved a comparison of historical receiving water data (baseline conditions) with predicted receiving water concentrations (simulated conditions) from the model. The model predictions were compared to actual in-stream concentrations at five locations within the watershed where there were existing data: Upper Malibu Creek (R9), Middle Malibu Creek (R2), Lower Malibu Creek (R3), Malibu Creek at the Lagoon (R4) and Malibu Lagoon (R11). As result of calibration, some pollutant source inputs were adjusted. The final calibrated sources loads are summarized in Table 18. Although the model was calibrated, the model was not validated due to insufficient instream monitoring data at the time of model development. Therefore, we cannot be sure that the model reflects all of the existing and potential bacteria sources. Furthermore, since this model has multiple variables and has not been validated, we cannot be sure that the loads are appropriately allocated among the sources. These source loads should be considered to be estimates. The nature of the calibration process and the parameters adjusted to achieve calibration are detailed in the modeling document (Tetra Tech, 2002).

Table 18 - Summary of Calibrated Source Loading

Potential Sources	Total Annual Loading (billion counts/year)
Tapia Discharge	59
Storm Water Runoff	
Commercial/Industrial	2,550,000
High/Med. Density Residential	2,700,000
Low Density Residential	344,000
Rural Residential	97,500
Agriculture/Livestock	32,100
Onsite Wastewater Treatment Systems	247,000
Effluent Irrigation	12
Dry Weather Runoff	
Entire Watershed (except lagoon)	5,210
Malibu Lagoon	18
Birds	450,000
Tidal Inflow	16,100
Natural Sources Other than Birds	
Vacant	1,950
Chaparral/Sage Scrub	37,700
Grasslands	2,690

Woodlands	809

The model results were evaluated for the critical condition (See Section 5.2) and then used to evaluate the bacterial load reductions that would be required to ensure that water quality standards are met at each of the listed reaches (See Section 5.3).

5.2 Critical Conditions and Seasonality

The linkage analysis revealed the conditions to which the impaired water bodies were most likely to exceed water quality standards: storms and summer dry weather. During summer dry weather when Tapia WWRF is prohibited from discharging to the creek and base flows in the creek system and to the lagoon are fairly low, dilution of bacterial loads is minimal. Under these conditions, small and localized loading (e.g. onsite wastewater treatment systems) can result in exceedances of water quality standards. On the other hand the largest bacterial loads are delivered during winter storm events. The effect of storm runoff is to dramatically increase the in-stream instantaneous concentration and the 30-day geometric mean.

To establish the critical condition for the wet days, we used rain data from 1993. Based on data from the Regional Board's Santa Monica Bay TMDL, this represents the 90th percentile wet-weather year based on rain data from 1947 to 2000. Use of this year provides a conservative estimate of loading from runoff. For the critical year (1993) we identified 69 wet days and 296 dry days.[5] To further evaluate the critical conditions, we modeled a representative dry year. The model was calibrated using meteorological data from 1992 to 1995. Of these years, 1994 had the greatest number of dry-weather days (310). The dry-year scenario was based on 1994, which was the 50th percentile year in terms of dry-weather days for the period of 1947-2000.

Based on the linkage analysis of in-stream response to source loading, we have determined the bacterial concentrations are most likely to exceed the single sample standard of 400 org/100mL and the geometric mean standard of 200 org/100mL during storm events. In addition, the single sample standard is likely to be exceeded during the summer dry weather in a representative dry year. Therefore, this TMDL will be based on two critical periods to ensure compliance of water quality standards.

5.3 Application of the model to link loading to water quality

The model was used to examine the relationship between loading and the numeric targets. Seven critical compliance points were identified at major tributaries and the Malibu Creek mainstem (see Table 19). These compliance points (see Figure 2) were consistent with the listed reaches, modeling output points and/or available monitoring data. Although Triunfo Creek is not listed, a compliance point was identified to address the contributions of fecal coliform loading from the western section of the watershed.

Table 19 - Compliance Points and Major Load Contributions

Compliance Point	Description	Local Watershed Loads	Upstream Creek Loads
Lower Medea Creek	upstream of confluence with Malibou Lake	Storm water Residential Onsite Wastewater Treatment Systems	Upper Lindero Creek Lake Lindero Lake Lindero Creek Lower Lindero Creek Chesebro Creek Palo Comado Creek Upper Medea Creek

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[5] The 1993 calendar year is used solely in the modeling scenarios which will lead to the recommended load reductions percentages. For purposes of calculating the allowable days of exceedances, the storm year was used, which is consistent with the Santa Monica Bay Wet-Weather Bacteria TMDL. .

Triunfo Creek	upstream of confluence with Malibou Lake	Storm water Residential Onsite Wastewater Treatment Systems	Hidden Valley Creek Lake Sherwood Potrero Creek Westlake Lake
Lower Las Virgenes Creek	upstream of confluence with Malibu Creek	Storm water	Upper Las Virgenes Creek
Upper Malibu Creek	upstream of confluence with Las Virgenes Creek	Storm water Residential Onsite Wastewater Treatment Systems	Malibou Lake
Middle Malibu Creek	downstream Tapia discharge serial 001	Storm water Residential Onsite Wastewater Treatment Systems	Lower Las Virgenes Creek Stokes Creek
Lower Malibu	downstream of Cold Creek confluence	Storm water Residential Onsite Wastewater Treatment Systems	Cold Canyon
Malibu Lagoon	Cross Creek Road and below Pacific Coast Highway	Storm water Commercial Onsite Wastewater Treatment Systems Birds	Lower Malibu Creek

Baseline Conditions – Comparison with Allowable Exceedance Days

For each of the seven compliance points the relationship between loads and water quality was determined based on examination of the model output results. The daily fecal coliform counts for the critical wet year (1993) predicted by the model were evaluated against the single sample standard of 400 org/100mL.

The model results indicated a significant number of days of exceedance during the critical years (see Appendix 1). Most of the exceedance days are associated with rain days. Indeed, the model suggests that every storm of 0.1 inch or greater has the potential to cause exceedance of the single sample standard. The predicted number of wet-day exceedances far exceeds the 17 days dry weather allowance for wet days. In comparison, there were relatively few dry-day exceedances in the creeks. The dry-day exceedance predicted by the model vary by watershed but range from 3 to 12 days. The higher numbers were associated with the Triunfo Creek and Lower Las Virgenes Creek watersheds. In contrast to the creeks, the number of exceedances dry-days predicted for the lagoon (42 days) far exceeds the 3 day allowance for dry weather days.

Baseline Conditions –Comparison with the 30 day Running Geometric Mean Standard

The 30-day geometric mean fecal coliform counts for the critical wet-year (1993) generated by the model were evaluated against the geometric standard of 200 org/100mL. The model hindcast that the 30-day geometric mean was exceeded at each compliance point more than 100 days during 1993. According to the model output the geometric mean for the estuary was exceeded 365 days for 1993. As noted in Section 2, review of dry weather data for lagoon monitoring station R-11 indicates that the median concentration from 1998-2002 was above 200 MPN/100 ml suggesting that the 30 day-geometric mean will exceeded in dry weather as well. Based on the modeling scenarios, this maybe a result of the year round fecal coliform loading from birds or onsite wastewater treatment systems (see Appendix 2).

Load Reductions

The compliance points were used during the linkage analysis to assess the relationship between water quality and source load reduction. The goal of the assessment was to reduce source loads to achieve the fecal coliform water quality standards at each compliance point. (See Appendix 3 and 4 for linkage graphs).

Various load reduction scenarios were modeled. The initial scenario was designed to meet the allowable exceedance days during the critical wet year (1993) during storm events. However, exceedance of the single sample standards were still occurring according to model output during the dry period (April 1 to October 31) of the critical wet-weather year (1993). This pattern is apparently related to the temporal influence of major loading sources: storm water (during storms) and onsite wastewater treatment systems (low-flow conditions). Compliance was finally achieved with the single sample standard by reducing a combination of dry season and wet season loads. Further reductions were required to meet the numeric targets for the critical dry year (1994).

Additional reductions were required to achieve compliance with the 30-day geometric mean standard (200-org/100 mL). In order to achieve the geometric mean standard, further reductions were required from watersheds upstream of these affected compliance points. As a result, reductions were required in watersheds, which were not listed on the 303(d) list and but were upstream of listed reaches. In the case of Triunfo, reductions were required from Hidden Valley and Westlake subwatersheds, although these watersheds are not listed as impaired. The Medea Creek geometric mean compliance was achieved by further reducing loads in Chesebro, Palo Comado, Upper Lindero, and Lower Lindero until water quality in Medea Creek meet the 30-day geometric mean. The Malibu Lagoon estuary 30-day geometric mean could not be achieved, even after anthropogenic loads within the water body were reduced by 99%. The final overall load reductions for each compliance point is included in Table 20. A map delineating the subwatershed is provided in Figure 5.

Figure 5 - Subwatershed Delineation

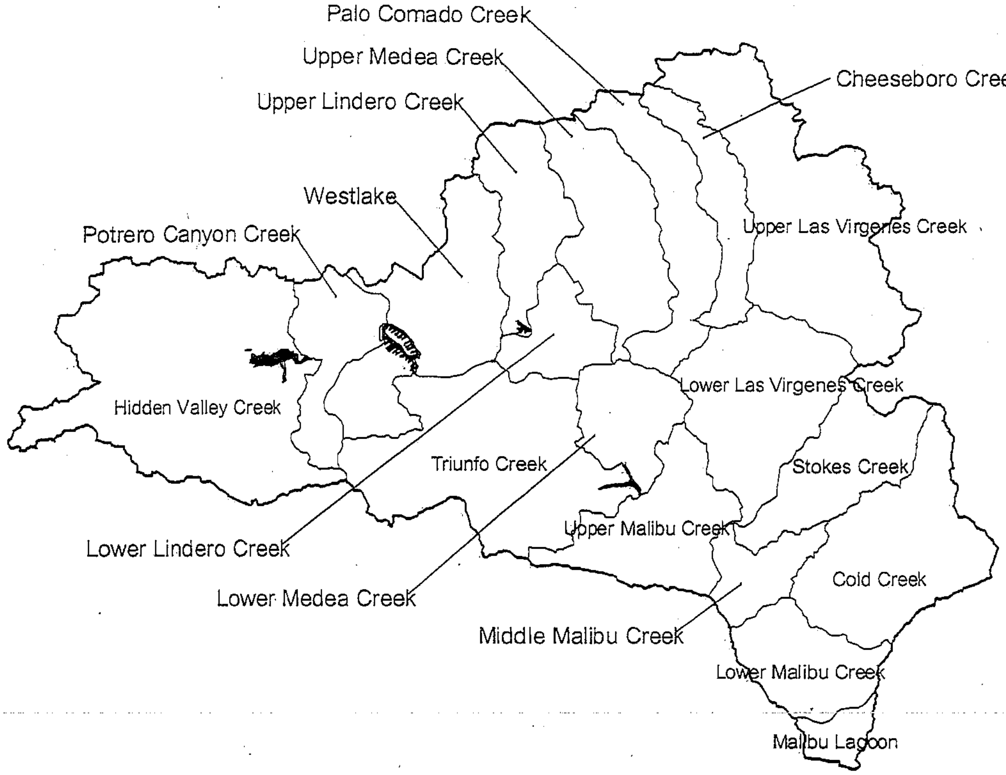

Palo Comado Creek
Upper Medea Creek
Upper Lindero Creek
Cheeseboro Creek
Westlake
Potrero Canyon Creek
Upper Las Virgenes Creek
Hidden Valley Creek
Lower Las Virgenes Creek
Triunfo Creek
Stokes Creek
Upper Malibu Creek
Lower Lindero Creek
Cold Creek
Lower Medea Creek
Middle Malibu Creek
Lower Malibu Creek
Malibu Lagoon

Table 20 - Subwatershed Estimated Source Reductions to Meet TMDL Allocation

Watershed	Estimated Load	Allocation	Estimated Percent Reduction
Triunfo	1.70×10^{14}	3.85×10^{13}	77
Hidden Valley	1.36×10^{14}	5.14×10^{13}	62
Potrero	3.22×10^{14}	2.07×10^{13}	94
Westlake	1.60×10^{15}	9.53×10^{13}	94
Lower Medea	6.47×10^{13}	4.93×10^{12}	92
Upper Medea	9.46×10^{14}	1.32×10^{13}	99
Chesebro	6.40×10^{13}	1.56×10^{12}	98
Palo Comado	2.85×10^{14}	4.86×10^{12}	98
Upper Lindero	4.66×10^{14}	6.99×10^{12}	99
Lower Lindero	5.10×10^{14}	6.97×10^{12}	99
Lower Las Virgenes	7.14×10^{14}	9.07×10^{13}	87
Upper Las Virgenes	2.34×10^{14}	4.74×10^{12}	98
Upper Malibu	1.36×10^{13}	1.14×10^{13}	16
Middle Malibu	2.24×10^{13}	6.14×10^{12}	73
Stokes Creek	6.17×10^{13}	1.25×10^{13}	80
Lower Malibu Creek	4.27×10^{12}	2.60×10^{12}	39
Cold	1.24×10^{14}	2.51×10^{13}	80
Malibu Lagoon (subwatershed)	1.36×10^{14}	9.32×10^{11}	99
Estuary	6.70×10^{14}	4.95×10^{14}	26
Total	$\mathbf{6.54 \times 10^{15}}$	$\mathbf{8.94 \times 10^{14}}$	**86**

The seven compliance points each receive load contributions from within its watershed, from upstream water bodies and/or a tributary. The lakes were not included in Table 20, because the lakes were not identified as a fecal coliform source during the source assessment (Section 4). The existing loads (or baseline) presented in Table 21 are the same loads presented in Table 20. The allocation is the load that meets the in-stream targets, and corresponds to attainment of the numeric targets. Included in the allocation load category are the natural sources of bacteria, such as wildlife. The percent reduction category is the load reduction required from the estimated existing baseline conditions to meet the instream numeric targets.

Prior to allocations of the bacteria loads, natural sources of bacteria must be subtracted from the gross loads. In this TMDL, natural sources of bacteria include birds, as well, as the following land uses: chaparral/sagebrush, grassland, and woodlands. The estimated anthropogenic loads primarily from runoff and onsite wastewater treatment systems available for allocations are presented by watershed in Table 21.

Table 21 - Estimated Watershed Anthropogenic Source Allocation

Watershed	Existing Loads	Natural Source Loads	Existing Anthropogenic Sources	Allocation Anthropogenic Sources	% Reduction Anthropogenic Sources
Triunfo	1.70×10^{14}	5.30×10^{12}	1.65×10^{14}	3.32×10^{13}	80
Hidden Valley	1.36×10^{14}	7.06×10^{12}	1.29×10^{14}	4.44×10^{13}	67
Potrero	3.22×10^{14}	1.84×10^{12}	3.20×10^{14}	1.89×10^{13}	94
Westlake	1.60×10^{15}	1.95×10^{12}	1.60×10^{15}	9.33×10^{13}	94
Lower Medea	6.47×10^{13}	1.51×10^{12}	6.32×10^{13}	3.42×10^{12}	94
Upper Medea	9.46×10^{14}	9.06×10^{11}	9.45×10^{14}	1.23×10^{13}	98
Chesebro	6.40×10^{13}	7.97×10^{11}	6.32×10^{13}	7.66×10^{11}	98
Palo Comado	2.85×10^{14}	1.07×10^{12}	2.84×10^{14}	3.08×10^{12}	98
Upper Lindero	4.66×10^{14}	7.24×10^{11}	4.65×10^{14}	6.72×10^{12}	98
Lower Lindero	5.10×10^{14}	4.90×10^{11}	5.10×10^{14}	6.48×10^{12}	98
Lower Las Virgenes	7.14×10^{14}	2.93×10^{12}	7.11×10^{14}	8.77×10^{13}	87
Upper Las Virgenes	2.34×10^{14}	2.84×10^{12}	2.31×10^{14}	1.90×10^{12}	99
Upper Malibu	1.36×10^{13}	3.45×10^{12}	9.45×10^{12}	7.95×10^{12}	16
Middle Malibu	2.24×10^{13}	1.34×10^{12}	2.11×10^{13}	4.78×10^{12}	77
Stokes	6.17×10^{13}	2.85×10^{12}	5.89×10^{13}	9.65×10^{12}	83
Lower Malibu	4.27×10^{12}	2.28×10^{12}	1.99×10^{12}	3.21×10^{11}	84
Cold	1.24×10^{14}	5.12×10^{12}	1.19×10^{14}	2.00×10^{13}	83
Malibu Lagoon	1.36×10^{14}	1.53×10^{11}	1.34×10^{14}	7.78×10^{11}	99
Estuary	6.70×10^{14}	4.95×10^{14}	1.75×10^{14}	4.07×10^{11}	100
Total	**6.54×10^{15}**	**5.38×10^{14}**	**6.00×10^{14}**	**3.56×10^{14}**	**94**

6. POLLUTANT ALLOCATIONS AND TMDLs

The Waste Load Allocations and Load Allocations for this TMDL are the same as for the Santa Monica Bay Beaches Bacteria TMDL (See Table 22).

Table 22 - Waste Load and Load Allocations for the Malibu Creek Watershed Bacteria TMDL*

Summer (April 1 to October 31) Dry-Weather Days	Zero (0) exceedance days based on the Single Sample Bacteria Water Quality Objectives Zero (0) exceedance days based on the Rolling 30-Day Geometric Mean Bacteria Water Quality Objectives
Winter (November 1-March 31) Dry-Weather Days	Three (3) exceedance days based on the Single Sample Bacteria Water Quality Objectives Zero (0) exceedance days based on the Rolling 30-Day Geometric Mean Bacteria Water Quality Objectives
Wet-Weather Days (days with 0.1 inch of rain or greater and three days following the rain event)	17 exceedance days based on the Single Sample Bacteria Water Quality Objectives Zero (0) exceedance days based on the Rolling 30-Day Geometric Mean Bacteria Water Quality Objectives

*The allowable exceedance days are based on daily sampling. If weekly sampling is performed, the allowable exceedance days are scaled accordingly.

Responsible jurisdictions, responsible agencies, and responsible entities may employ any reduction strategy they choose to meet these allocations. However, a sample strategy, based on model output is depicted in Table 23. This table is for information purposes only. However, it appears that any successful strategy must achieve major reductions in loading from runoff from urban and suburban areas in the upper watershed and in Malibu, and commercial and multi-family onsite wastewater treatment systems in the Malibu Lagoon subwatershed and estuary. The following subsections describe staff's analysis of suggested loading reductions.

Table 23 - Example Watershed Reduction Strategy by Source Category

Source	**Estimated Existing Loading**	**% of Total Existing**	**TMDL Allocation**	**%Reduction**
Tapia Discharge	5.92 x 10^{10}	0.00%	5.92 x 10^{10}	0%
Effluent Irrigation	1.16 x 10^{10}	0.00%	1.16 x 10^{10}	0%
Commercial/ Industrial Stormwater Runoff	2.55 x 10^{15}	39.03%	7.65 x10^{13}	97%
High/Med. Density Res. Stormwater Runoff	2.71 x 10^{15}	41.33%	8.13 x 10^{13}	97%
Low Density Residential Stormwater Runoff	3.44 x 10^{14}	5.27%	6.88 x 10^{13}	80%
Rural Residential Stormwater Runoff	9.75 x 10^{13}	1.49%	4.88 x 10^{13}	50%
Agriculture/ Livestock	3.21 x 10^{13}	0.49%	1.65 x 10^{13}	50%
Onsite wastewater treatment Systems	2.47 x 10^{14}	3.78%	3.71x 10^{13}	85%
Dry Weather Urban Runoff	5.21 x 10^{12}	0.00%	2.84 x 10^{9}	99%*
Lagoon Drains	1.75 x 10^{10}	0.00%	1.75 x 10^{8}	99%
Tidal Inflow	2.44 x 10^{13}	0.37%	1.83 x 10^{13}	25%
Total	**6.00 x 10^{15}**		**3.47 x 10^{14}**	

* It is assumed that measures used to control urban stormwater runoff also will effectively control urban dry-weather runoff. Suggested source load reductions by subwatershed are included in Appendix 5.

6.1 Estimated Load Reductions for Point Sources

Tapia Water Reclamation Facility and Effluent Irrigation

The Tapia WRP effectively disinfects the tertiary treated wastewater, which is either discharged to Malibu Creek or reclaimed and used for irrigation. The fecal loading is small and is not likely to increase fecal coliform concentrations. Indeed the effluent from Tapia actually provides additional dilutive capacity to the creek system. Therefore, no load reduction is warranted for this source.

Stormwater Water Discharges

Most of fecal coliform loads are discharged during storm events. Runoff from developed areas is the major source of contamination, increasing the coliform concentrations in streams by several order of magnitude (Tetra Tech, 2001). The water quality model was run repeatedly with different combinations of load scenarios in order to establish the load reductions that would be needed to meet the TMDL targets. The model analyses demonstrated that coliform loads from storm runoff would have to be reduced by more than 90 percent to meet the geometric mean criterion of 200 MPN/100 mL. These load reductions would also meet the single sample criterion of 400 MPN/100 mL.

6.2 Overview of Estimated Load Reductions for Nonpoint Sources

Septic Systems (Onsite Wastewater Treatment Systems)

Properly sited and functioning onsite wastewater treatment systems are expected to meet the load allocations without further modification. The waste being discharged from the onsite systems is being required to meet the REC-1 water quality standard of 200 CFU per 100 ml. It is anticipated that in the leach field the fecal coliform concentrations will be further reduced by more than 99%; this can be confirmed by groundwater monitoring. It has been estimated that these actions will decrease the annual loading to the watershed from 2.47×10^{14} counts per year to 1.04×10^{13} counts per year.

There is a potential for significant loading impacts from the commercial and multi-family onsite wastewater systems in the Malibu Lagoon subwatershed, and these should be a high priority. In addition, residential onsite wastewater systems upstream of the Malibu Creek Watershed have been given a load allocation..

Dry Weather Urban Runoff, Lagoon Drains and Tidal Inflow

These pollutant sources appear to contribute a relatively small percentage of the annual fecal coliform load when compared to onsite wastewater systems and stormwater. However, because creek flows are lower during dry weather discharges assimilative capacity is also low. Reduction was necessary for the loads to ensure that fecal coliform criteria are not exceeded during the low flow periods in the streams and estuary.

Natural Sources

No load reduction was given to birds since they are a natural part of the system. At the present time, we believe that the allocations described above are sufficient to meet the objectives. However, it may prove that the birds in Malibu Lagoon are sufficient alone to cause an exceedance. If this proves to be the case, the Regional Board staff will recommend that the Regional Board consider re-evaluating the TMDL, or to incorporate a natural source exclusion.

6.3 Margin of Safety

The Margin of Safety was derived from the use of several conservative assumptions during model analysis. These include:

- The watershed loading was based on the 90th percentile year for rain (1993) based on the number of wet weather days. This should provide conservatively high runoff from different land uses for sources of storm water loads

- The watershed loading was also based on a very dry rain year (1994). This ensures compliance with the numeric target during low flows when onsite wastewater treatment systems and dry urban runoff loads are the major bacterial sources.

- The TMDL was based on meeting the fecal 30-day geometric mean target of 200 MPN/ 100 ml, which for these watersheds was estimated to be more stringent level than the allowable exceedance of the single sample standard. This approach also provides assurance that the E. coli single sample standard will not be exceeded.

- The load reductions established in this TMDL were based on reduction required during the two different critical year conditions. A wet year when storm loads are high and a more typical dry year when base flows and assimilative capacity is low. This adds a margin of safety for more typical years.

6.4 Summary of pollutant reductions

The percent reduction is calculated based on estimated existing loads as determined by the model output and is provided for informational purposes only. Although localized load reductions may vary based on subwatershed, these allocations provide a watershed-wide summary of the expected load reduction needs by source type. The loads presented herein were derived from the 4-year average (1992-1995) of the simulation period, for all loads entering the Malibu Creek Watershed system. Future monitoring and assessment may result in refining these estimates.

7. IMPLEMENTATION PLAN

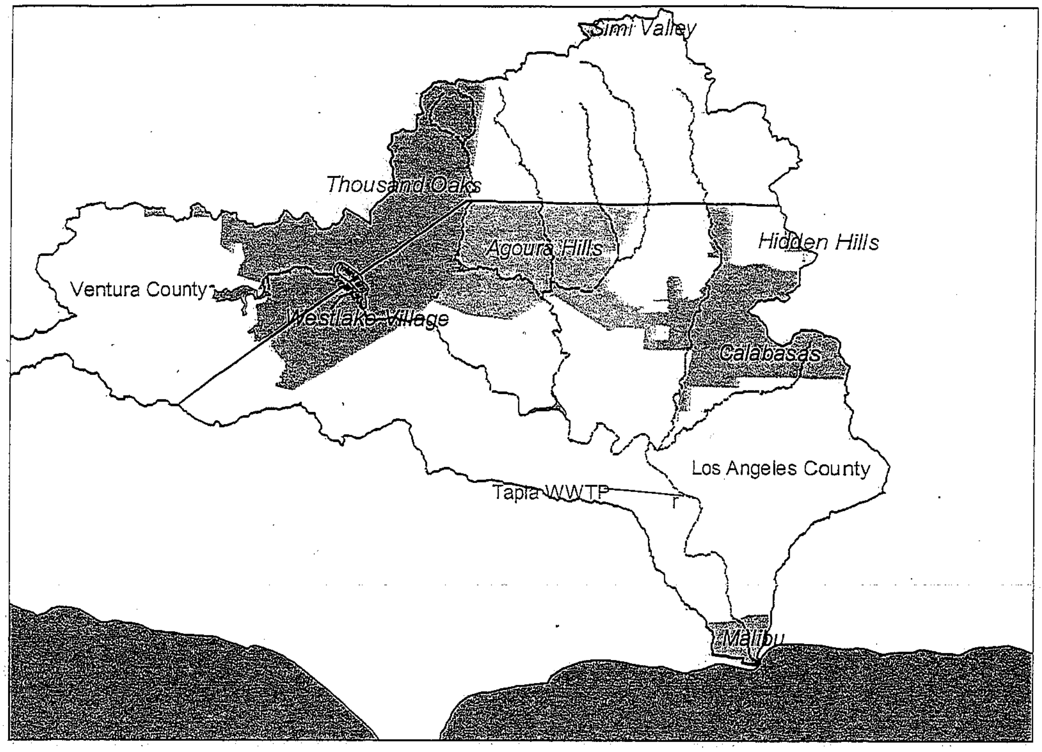
The objective of this section is to develop an implementation plan that will demonstrate a manner to which the waste load and load allocations developed for the Malibu Creek Coliform TMDL can be met. Where possible Regional Board staff considered implementation measure that have been proposed or discussed in publicly available stakeholder developed watershed management plans or Regional Board policies.

The Porter Cologne Water Quality Control Act prohibits the Regional Board from prescribing the method of achieving compliance with water quality standards, and likewise TMDLs. Below staff have identified some potential implementation strategies; however, there is no requirement to follow the particular strategies proposed herein as long as the maximum allowable exceedance days for each time period are not exceeded.

7.1 Responsible Jurisdictions, Agencies and Entities

The cities of Calabasas, Malibu, Westlake Village, Agoura Hills, Hidden Hills, Simi Valley, Thousand Oaks, the Counties of Los Angeles and Ventura, California Department of Parks and Recreation, National Park Service, and Santa Monica Mountains Conservancy, and Caltrans are jointly responsible for meeting the TMDL requirements for urban runoff in the for the Malibu Creek Watershed. Onsite, commercial and multi-family facilities served by on-site wastewater treatment systems are subject to Waste Discharge Requirements are individually responsible for their discharges and are responsible entities. To the extent that single-family on-site wastewater treatment systems continue to be regulated by local agencies, the local agency will be the responsible agency. Should the regulation of single family residential on-site wastewater treatment systems revert to the Regional Board, the owners of those systems will become the responsible entity (see following subsection on single-family systems). The cities and the counties may jointly decide how to achieve the necessary reductions in exceedance days at each compliance point by employing one or more of the implementation strategies discussed below or any other viable strategy. Since, the majority of the Malibu Creek Watershed is located in an unincorporated area of the County of Los Angeles, the County of Los Angeles is the primary jurisdiction. Staff expects that the additional monitoring and source characterization outlined in the monitoring plan in Section 8 will assist municipalities in focusing their implementation efforts on key land uses, critical sources and storm periods.

Figure 6 - Jurisdictions within the Malibu Creek Watershed



7.2 Implementing Strategies for Achieving Allocations

Municipal Stormwater Permits

As required by the federal Clean Water Act, discharges of pollutants to the Malibu Creek Watershed from municipal storm water conveyances are prohibited, unless the discharges are in compliance with a NPDES permit. The Los Angeles County Municipal NPDES Storm Water Permit (Board Order No. 01-182; NPDES No. CAS004001) and the Ventura County Municipal Storm Water Permit (Board Order No. 00-108; NPDES No. CAS004002) will be key implementation tools for this TMDL. Future storm water permits will be modified in order to address implementation and monitoring of this TMDL and to be consistent with the waste load allocations of this TMDL.

A requirement of the Los Angeles County Municipal Storm Water Permit is that a Watershed Management Area Plan (WMAP) must be developed that include actions that address water quality problems and concerns that are unique to the six watershed areas of Los Angeles County. The WMAP for the Malibu Creek Watershed was developed in 2001. A brief description of some proposed implementation measures applicable to this TMDL are cited from the WMAP are presented below:

> *Permeable Urban Landscapes*
>
> *Using the soils data on GIS, the Council of Governments will identify opportunities to increase permeability on new urban landscapes, parking lots and street parking lanes. Cities and the*

> *County will take the responsibility of implementing the identified opportunities. Technologies have been developed to safely allow storm water infiltration in parking lots and along street corridors, which provide functions of flow attenuation and water quality improvement. Extensive opportunities exist to install such features in new developments, and to retrofit existing development when upgrading is appropriate.*
>
> *Storm Drains*
>
> *Over-irrigated landscape areas that discharge to the street and enter storm drains during dry weather will be identified and minimized. Surveys could be carried out during routine clearing of catch-pits for water quality maintenance. Where there is a practicable alternative (for example using porous, pollution-filtering drainage galleries to encourage infiltration) discharges from the storm water system to streams will be blocked. To enable this, the outfall's catchments may have to be fitted with discharge control devices as well as replacing pipes with porous drainage galleries.*

The strategies described in the Malibu Creek WMAP may be used to meet the Waste Load Allocation for the MS4 permit. However, it is most likely that such strategies would need to be expanded to include both new and existing commercial and high-density residential developments. Retrofitting of existing facilities may best be achieved by providing some combination of financial incentive and local ordinances.

Alternatively, the MS4 co-permittees could pursue a centralized strategy of diverting and treating dry-weather and wet-weather urban runoff from storm drains. The County of Los Angeles and the City of Los Angeles are presently pursuing diversion and treatment strategies in urbanized watersheds of the Santa Monica Bay. However, as stated in the Basin Plan, as amended, it is not the intent of the Regional Board to require treatment or diversion of natural water bodies or to require treatment of natural sources of bacteria from undeveloped areas. Therefore, strategies involving diversion and treatment should be limited to the higher-density developed areas of the Malibu Creek Watershed.

Distributed on-site retention and treatment strategies, such as those described in the Malibu Creek WMAP, offer several advantages to centralized diversion and treatment. These advantages include providing incentives to the individual property owners to reduce dry-weather runoff from irrigation overspray and to encourage architectural designs to maximize non-permeable surfaces. On-site retention systems also reduce wet-weather flows, and the potential for downstream flooding. A distributed onsite structural control strategy is based on the premise that specific land uses, critical sources, or specific periods of a storm event can be targeted to achieve the TMDL waste load allocations. For the Malibu Creek Watershed the target land uses identified are commercial/industrial and high density residential.

Structural controls may include placement of storm water treatment devices specifically designed to reduce bacteria densities or storage and infiltration facilities at critical upstream points in the storm water conveyance system. A treatment system may be further targeted to a specific storm period such as the first 0.5-inch or 1 inch if the bacteria wash-off pattern mimics a 'first-flush' effect. The results from effluent sampling indicate removal rates of 97 percent for fecal coliform bacteria (90 percent for dissolved nitrogen and 90 percent phosphorus). A description of a potential control strategy taken from USEPA Factsheet (USEPA, 1999) on modular treatment system is provided below:

> *A modular treatment system consists of a series of sedimentation chambers and small constructed wetlands. The wetlands are contained within a modular tank. A storm water treatment system currently on the market can be applied in residential areas, as well as, industrial/commercial developments. A diagram of the such a system in located in Appendix 6. Also, a USEPA fact sheet is located in Appendix 6. The systems are suitable for the diverse settings that exist in the Malibu Creek Watershed: coastal and inland areas. These systems are protective of groundwater by removing pollutants prior to infiltration. Soil types and high water tables surrounding the modular unit will not limit the effectiveness of the system.*

> *Influent is conveyed from a catch basin through piping to sedimentation chambers and subsequently to the soil wetlands portion of the treatment system. The system has a static holding volume of 5,270 liters (1,390 gallons). The basis for the system sizing is the static holding volume plus associated detention structures. Generally, 1-2 units are required for each acre of impervious surface. The first flush volume is stored in the preliminary storage structures (tanks or underground pipes). The system captures and treats the first half-inch of all the smaller (routine) storms and treats the first flush of the large (less common) storms. A 0.5-inch storm requires 1 tank per acres, and a 1-inch storm requires 2 tanks per acres.*

Dry -Weather Urban Runoff Reduction

In order to achieve the reductions required to meet the load allocation for dry weather urban runoff, a runoff reductions program must be implemented. The Malibu Creek Watershed Urban Runoff Reduction Project is a runoff reduction program developed by the Las Virgenes Municipal Water District and cities of Westlake Village, Calabasas, and Agoura Hills. This program will identify sources of commercial and residential urban runoff by a combination of curbside observations and computer analysis of water use (LVMWD, 2003). The sources of dry weather runoff identified will be offered technical assistance by the LVMWD staff to reduce runoff. An example of a mitigation measure offered LVMWD staff is tuning of irrigation systems to address inefficient irrigation practices. Water use and runoff will be monitored to measure the effectiveness of the program at reducing urban runoff (LVMWD, 2003). Although elimination of dry-weather urban runoff is the preferred strategy, it is likely that measures employed to control wet-weather urban runoff, also will control dry-weather urban runoff.

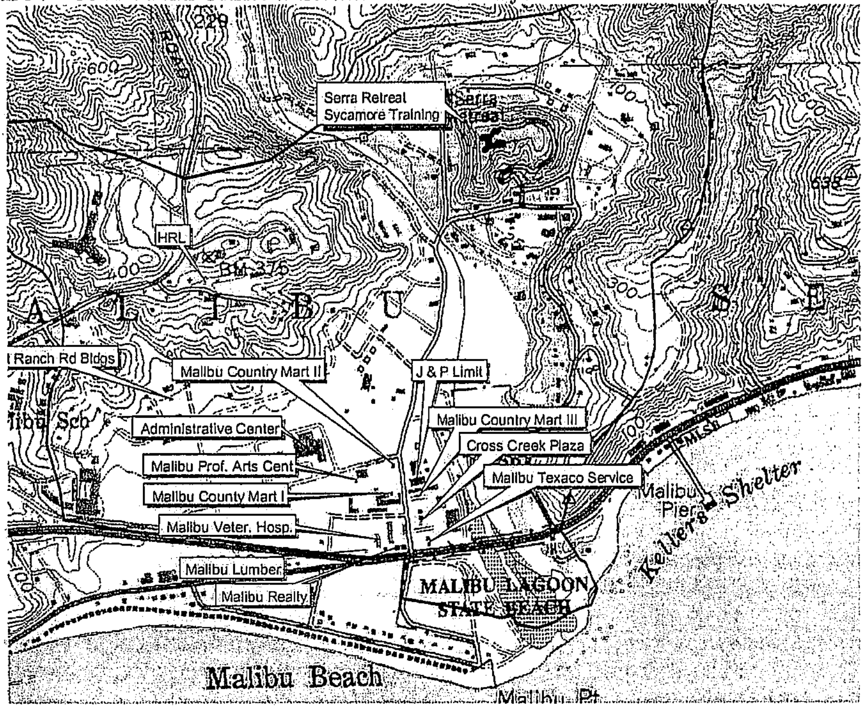
Onsite Wastewater Treatment Systems

On-site treatment systems were identified as a potential major anthropogenic source of dry-weather exceedances of the single sample and 30 day geometric limits. These systems are located within the City of Malibu and the unincorporated rural residential areas. Based on staff's analyses, commercial and multi-family systems represent the highest bacteria loading and are of highest priority. However, private residential systems may also cause exceedances of bacteria standards, especially when systems are not properly sited, designed, or operated. These situations are more likely to result in bacterial contamination of surface waters when inadequate systems, are located in areas of high groundwater tables and in close proximity to the creek or lagoon.

Commercial and Multi-Family Systems

Commercial and multi-family systems are regulated by the Regional Board (Order No. 01-031). These systems are confined to the City of Malibu, and within the Malibu Creek Watershed, are located in the Civic Center area. The commercial/multi-family systems targeted for reduction are located in the Malibu Civic Center area (see Figure 6). Some of these onsite wastewater treatment systems may be located adjacent to the lagoon, in a groundwater table with historic levels that do not allow as least 10 feet between the groundwater and the wastewater distribution system. The specific vertical separation of these systems to groundwater has not yet been determined. Commercial multi-family onsite wastewater treatment systems located within the aforementioned commercial centers were the focus of Los Angeles Regional Board Resolution 98-023. This resolution provided direction to the Executive Officer to require the submittal of Reports of Waste Discharge for all discharges from multi-family and commercial onsite wastewater treatment systems located in the Malibu Creek Watershed.

Figure 7 - Commercial Onsite wastewater treatment System in Malibu Lagoon subwatershed



Waste Discharge Requirements

WDRs will be the mechanism for implementation of the onsite wastewater treatment system Load Allocations (LAs) derived from this TMDL for commercial and multifamily occupancies. The LAs developed for this TMDL will be established as WDR permit limits for the individual onsite wastewater treatment systems. The WDRs have specific prohibitions on onsite wastewater treatment systems within 10 feet of the highest historical groundwater levels.

The *Onsite Wastewater Treatment Systems Manual* (USEPA, 2002) has been released since the General WDR requirements were released in early 2001. This manual states: "Normal operation of septic tank/infiltration systems results in retention and die-off of most, if not all, observed pathogenic bacterial indicators with 2 to 3 feet (60 to 90 centimeters) of the infiltrative surface (USEPA, 2002; page 3-33)." However, the USEPA Manual may not have considered commercial and multi-family systems with higher flow rates that have a greater potential of saturating underlying soils. Also, the study must presume 2 to 3 feet of suitable soil types for infiltration and treatment. Systems overlying fractured bedrock, which occurs within the Malibu Creek watershed, may contaminate groundwater even with 10 feet or more of separation. In short, site specific variables must be taken into account to positively identify systems that are contributing to groundwater or surface water contamination.

Within the Malibu Creek Watershed, the recently renewed WDRs require disinfection for commercial and multifamily occupancies. Three types disinfection technology are available to commercial and multifamily WTS: chlorination, ozonation, and ultraviolet (UV) disinfection. The USEPA onsite manual (USEPA, 2002, page 3-33) also lists the typical pathogen survival time as less than 70 days. Therefore, systems located with greater than a specific residence time (using an appropriate safety factor) in groundwater away from surface waters, should not require disinfection. Although each technology is capable of achieving the reductions required by this TMDL, chlorination is more cost effective, and thus more widely used (USEPA, 1999). The owners of the on-site commercial and multi-family systems are individually responsible for complying the WDRs, which will be written to comply with the load allocations for this TMDL.

Centralized Waste Water Treatment Facility

The City of Malibu has developed a conceptual plan to centralize wastewater treatment, disposal, and reuse in the Civic Center area (City of Malibu, 2003). The plan proposes connecting existing and proposed commercial properties of the Civic Center to wastewater reclamation facility (Questa, 2003). Wastewater will be treated to tertiary standards for wastewater reclamation. The facility will include disinfection and nitrogen removal. The system would provide redistribution of the reclaimed wastewater back to the commercial properties where it was generated, for use as non-potable water and irrigation. Questa Engineering Corporation provided a preliminary assessment of the feasibility of installing a community wastewater reclamation facility.

Single-Family Systems

The Regional Board issued waivers for residential systems in the early 1950's as resolutions Nos. 52-4 and 53-6. The resolutions waived reporting and permitting requirements to the Regional Board for wastewater treatment systems from single-family dwellings. The waivers allowed local agencies to approve and permit this specific group of wastewater treatment systems in accordance with local ordinances. These waivers are conditional and maybe terminated at any time by the Regional Board. Recent legislation amending sections 13269 of the CWC (senate Bill 390) requires that the Regional Board review its wastewater treatment system waivers and either renew or terminate them by June 30, 2004. In addition the legislature adopted Assembly Bill 885 in September 2000, which amended sections 13290 and 13291 of the CWC. The newly amended sections require that the State Board adopt statewide regulations or standards for permitting and operation of wastewater treatment systems by January 1, 2004. Key requirements of Section 13290 and 13291 are presented below:

- minimum operating requirements that may include siting, construction, and performance requirements
- requirements for systems adjacent to impaired waters identified pursuant to subdivision (d) of section 303 of the Clean Water Act (33 U.S.C. Sec 1313(d));
- requirements authorizing a qualified local agency to implement systems/standards/regulations within its jurisdiction, if the local agency request such authorizations;
- requirements for corrective actions when systems fail to meet requirements or standards;
- minimum requirements for monitoring to determine system performance, if applicable;
- exemption criteria to be established by regional boards; and,
- requirements for determining systems are subject to a major repair.

Pursuant to SB 390, the Board must make a finding that the waiver for residential systems does not harm water quality or public health. In order to make such a finding, staff presently are negotiating Memoranda of Understanding (MOUs) with local agencies to ensure adequate regulation of on-site systems. At a minimum, it was thought that the MOU would incorporate the AB 885 regulations. However, it now appears that the AB 885 regulations may not be finalized in time to meet the SB390 deadline. Furthermore, regardless of the status of AB 885 regulations, the Board may consider whether the MOU will ensure compliance with the TMDLs, when granting a waiver. Without an MOU, the Board may not be able to make the requisite findings to continue the waiver. In which case, the regulation of single family systems would revert to the Regional Board.

Regulation of the single family onsite systems will be regulated by local agencies subject to an MOU or in lieu of an MOU, by the Regional Board directly, via a Waste Discharge Requirement. Owners of single family systems subject to Waste Discharge Requirements will become responsible entities under this TMDL. WDRs will be written to comply with the load allocations specified in this TMDL.

Regardless of the oversight mechanism, the requirements for on-site systems should include a demonstration that the systems are meeting the load allocations under the TMDL. Such a demonstration may include a site assessment evaluating depth to groundwater during times when the groundwater table is high, presence of fractured bedrock, and proximity to surface water bodies and/or groundwater monitoring. Absent such a demonstration, or upon finding that the systems are not meeting the TMDL allocations, system upgrades may be required. These may include disinfection or alternative onsite systems. Operation of disinfection systems may be problematic for individual homeowners, who may not have the time or the knowledge to ensure proper operation. In some cases, where systems will require more active maintenance and operation, an operating permit program, such as adopted by the City of Malibu in Ordinance 242, or a benefit assessment district may be required.

Technologies, and design criteria, are currently available for single family residential systems, which could provide the necessary level of bacterial reduction required to meet load allocations. For example, systems that have disposal fields, which do not meet the minimum vertical, and/or horizontal setback requirements from surface/groundwater, may need to incorporate advanced treatment with disinfection, alternative soil absorption fields. For example, a sewage treatment mound is a potential alternative for problem locations. A mound is disposal fields elevated by sand fill to provide adequate separation between the disposal field and saturated soil conditions. Elevation of the disposal field eliminates the "short circuiting" of effluent with groundwater, and allows for bacterial degradation within the mound disposal field. Mounds treatment systems are a standard technology for single-family residences (Solomon et al., 1998). However, mounds have specific land area requirements and may not be appropriate on many existing parcels in Malibu. A mound system is a specific example of an intermittent sand/media filter (USEPA, 2002). Other types of intermittent sand/media filters can provide similar attenuation of pathogenic bacteria (USEPA, 2002).

Lagoon Drains

The City of Malibu is in the process of installing an advanced disinfection system to collect storm water "first flush" and dry weather urban runoff from the three drains (Civic Center, Malibu Colony, and Cross Creek Road) which discharge into Malibu Lagoon estuary. The system is known as the Malibu Storm Drain Treatment Facility. Preliminary testing of the effluent from the system has demonstrated the ability to meet or the REC-1 standards for bacteria indicators.

Tidal Inflow

The sources of fecal bacteria in the surfzone were not assessed during this TMDL. Potential sources of tidal inflow loads maybe foreshore washing of bird feces, subsurface exchange of contaminated lagoon or groundwater, and ebb flow from the lagoon (Grant, 2002). It is anticipated that the upstream implementation measures (e.g., OSWTS and urban runoff) as well as implementation of the Santa Monica Bay TMDL will contribute to the reduction of surfzone fecal bacteria load.

7.3 Implementation Cost Estimates

Stormwater Structural Control Strategy

This cost estimate is based on the modular treatment system described in Section 7.2. Modular treatment systems are prefabricated. The cost for one unit is $4,900 and the installation cost is approximately $1,400. The estimated total cost for purchase and installation is $6,300. Per tank cost decrease as the number of units per site increase. The estimated maintenance cost for one tank is $80 to $120 every three to five years. The impervious area requiring treatment in the Malibu Creek Watershed is approximately 5,440 acres of commercial and residential landuse (Tetra Tech, 2002). Assuming a lot size of 1-acre per discharger, the preliminary cost estimate based on 5,440 units to treat 5,440 acres of impervious surface from the watershed is approximately $34,272,000. The cost were based on the StormTreat Systems Sizing Worksheet.xls located in Appendix 6.

Commercial and Multi-family Onsite Wastewater Treatment Systems

Disinfection systems will likely be required for many commercial and multi-family systems. The cost of disinfection systems is dependent on the manufacturer, the site, the capacity of the plant, and the characteristics of the wastewater to be disinfected. In addition, the annual operation and maintenance costs for disinfection include power consumption, chemicals and supplies, miscellaneous equipment repairs, and personnel costs. The approximate capital cost of systems recently permitted within the Santa Monica Bay watershed are presented in Table 24.

Table 24 - Cost of Recently Permitted Systems

Discharger	Volume	Treatment	Cost
Malibu RV Park	18,000 gpd	FAST (biological)	0.5 million
Malibu Bay Club	59,000 gpd	Zenon (membrane)	1.4 million
Trancas WWTP	288,000 gpd	Secondary (biological) BMR	1.6 million
POTW (other area)	1.5 MGD	tertiary, with UV	4.5 million

Note: With the exception of the Malibu RV Park, the systems in Table 24 are designed to treat nutrients as well.

The conceptual plan estimates for the cost of collection, treatment, and redistribution for the core commercial facilities in the Civic Center area (see Figure 6) is approximately 12 million dollars. The estimated annual operation and maintenance cost are approximately $700,000. (Questa, 2003).

Upgrade of Residential Onsite Wastewater Treatment Systems

Single family onsite wastewater treatment systems that do not meet the requisite vertical or horizontal separation distance from groundwater and/or surface water may be upgraded to a mound type system. Design and installation of a mound system in rural parts of the country is approximately $10,000 (Solomon et al, 1998). On a national basis, the annual operation cost is approximately $150 – 200 (USEPA, 2002) An estimate of 440 failing systems was used for this TMDL (Tetra Tech, 2002). Assuming all failing system installed the mound system, and an average cost of $10, 000 per mound system, the total capital cost for the entire watershed is approximately $4,400,200.

Dry Weather Urban Runoff Reduction

The Malibu Creek Dry Urban Runoff Reduction Project is partly funded by the Proposition 13 Nonpoint Source Pollution Grant Program. The total cost to fund the program through May 2005 is $304,428 (LVMWD, 2003)

Lagoon Drains

Construction cost of the Civic Center Drain Treatment Facility is estimated at $850,000, with annual operating and maintenance cost estimated at $31,000 (City of Malibu, 2002). The cost for the three drains discharging to Malibu Lagoon is $2,500,000.

7.4 Implementation Schedule

The proposed implementation schedule shall consist of a phased approach as discussed below and outlined in Table 25. This TMDL provides an implementation schedule allowing the responsible jurisdictions and responsible agencies time to gather additional monitoring data to validate the model and to better quantify the loading from birds in the Lagoon. The Regional Board may reconsider the TMDL in three years from the effective date to consider the impact of birds in the Lagoon and to revise the allowable days of exceedance based on additional studies. At that time, the Regional Board may revise the TMDL to allow for the Natural Source Exclusion, as provided for in the Basin Plan. The Natural Source Exclusion can only be applied after all anthropogenic sources of bacteria have been controlled. The schedule would allow six years from the effective date to meet both summer and winter dry-weather load and waste load allocations. This is a longer schedule than generally provided for in the Santa Monica Bay TMDL for summer dry weather. However, it is warranted due to the disperse nature of the sources and the foreseeable implementation measures. In Santa Monica Bay, the City of Los Angeles and the County of Los Angeles already had started construction of the implementation measure, which is dry-weather diversion of major storm drains. Therefore a three year schedule for summer dry weather was feasible.

To be consistent with the SMB Beaches TMDLs, the Regional Board intends to revise this TMDL, in conjunction with the revision of the SMB Beaches TMDLs. The SMB Beaches TMDLs are scheduled to be revised in four years: to re-evaluate the allowable winter dry-weather and wet-weather exceedance days based on additional data on bacterial indicator densities in the wave wash; to re-evaluate the reference system selected to set allowable exceedance levels; and to re-evaluate the reference year used in the calculation of allowable exceedance days. This TMDL is scheduled to be re-considered in three years from the effective date which will approximately coincide with the Santa Monica Bay TMDL revision.
Until the TMDL is revised, the allowable number of winter dry-weather and wet-weather exceedance days will remain as presented in Table 22. Revising the TMDL will not create a conflict in the interim, since the TMDL does not require compliance during winter dry-weather or wet-weather until six and ten years, respectively, from the effective date of the TMDL. Therefore, the allowable exceedance days for winter dry-weather and wet-weather will be revised as necessary before the compliance deadlines.

Table 25 - Summary of Implementation Schedule

120 days after the effective date of this TMDL	Responsible jurisdictions and responsible agencies must submit a comprehensive bacteria water quality monitoring plan for the Malibu Creek Watershed to the Executive Officer of the Regional Board. The plan must be approved by the Executive Officer before the monitoring data can be considered during the implementation of the TMDL. The Executive Officer will consider cost in relation to the need for data. Monitoring cost will be considered with the benefits of protecting human health for persons swimming and wading in Malibu Creek and its tributaries, and for swimmers and surfers using downstream beaches that are impacted by the creek and lagoon. The purpose of the plan is to better characterize existing water quality as compared to water quality at the reference watershed,- and ultimately, to serve as a compliance monitoring plan. The plan must provide for analyses of all applicable bacteria indicators for which the Basin Plan has established objectives including E. coli. For fresh water and enterococcus for marine water. The plan must also include sampling locations that arespecified in Table 7-10.2, at least one location in each subwatershed, and areas where frequent REC-1 use is known to occur. However, this is not to imply that a mixing zone has been applied; water quality objectives apply throughout the watershed—not just at the sampling locations.

1 year after effective date of this TMDL	1. Responsible jurisdictions and responsible agencies shall provide a written report to the Regional Board outlining how each intends to cooperatively achieve compliance with the TMDL. The report shall include implementation methods, an implementation schedule, and proposed milestones. Specifically, the plan must include a comprehensive description of all steps to be taken to meet the 3-year summer dry weather compliance schedule, including but not limited to a detailed timeline for all category of bacteria sources under their jurisdictions including but not limited to nuisance flows, urban stormwater, on-site wastewater treatment systems, runoff from homeless encampments, horse facilities, and agricultural runoff. 2. If the responsible jurisdiction or agency is requesting an extension of the summer dry-weather compliance schedule, the plan must include a description of all local ordinances necessary to implement the detailed workplan and assurances that such ordinances have been adopted before the request for an extension is granted. 3. Local agencies regulating on-site wastewater treatment systems shall provide a written report to the Regional Board's Executive Officer detailing the rationale and criteria used to identify high-risk areas where on-site systems have a potential to impact surface waters in the Malibu Creek watershed. Local agencies may use the approaches outlined below in (a) and (b), or an alternative approach as approved by the Executive Officer. (a) Responsible agencies may screen for high-risk areas by establishing a monitoring program to determine if discharges from OWTS have impacted or are impacting water quality in Malibu Creek and/or its tributaries. A surface water monitoring program demonstration must include monitoring locations upstream and downstream of the discharge, as well as a location at mid-stream (or at the approximate point of discharge to the surface water) of single or clustered OWTS. Surface water sampling frequency will be weekly for bacteria indicators and monthly for nutrients. A successful demonstration will show no statistically significant increase in bacteria levels in the downstream sampling location(s). (b) Responsible agencies may define the boundaries of high-risk or contributing areas or identify individual OWTS that are contributing to bacteria water quality impairments through groundwater monitoring or through hydrogeologic modeling as described below: (1) Groundwater monitoring must include monitoring in a well no greater than 50-feet hydraulically downgradient from the furthermost extent of the disposal area, or property line of the discharger, whichever is less. At a minimum, sampling frequency for groundwater monitoring will be quarterly. The number, location and construction details of all monitoring wells are subject to approval of the Executive Officer.

2 years after the effective date of this TMDL	The California Department of Parks and Recreation shall provide the Regional Board Executive Officer, a report quantifying the bacteria loading from birds to the Malibu Lagoon. The Regional Board's Executive Officer shall require the responsible jurisdictions and responsible agencies to provide the Regional Board with a reference watershed study. The study shall be designed to collect sufficient information to establish a defensible reference condition for the Malibu Creek and Lagoon watershed.
3 years after effective date of this TMDL** ** May be extended to up to 6 years from the effective date of this TMDL	Achieve compliance with the applicable Load Allocations and Waste Load Allocations, as expressed in terms of allowable days of exceedances of the single sample bacteria limits and the 30-day geometric mean limit during summer dry-weather (April 1 to October 31). In response to a written request from a responsible jurisdiction or responsible agency, the Executive Officer of the Regional Board may extend the compliance date for the summer dry-weather allocations from 3 years to up to 6 years from the effective date of this TMDL. The Executive Officer's decision to extend the summer dry-weather compliance date must be based on supporting documentation to justify the extension, including a detailed work plan, budget and contractual or other commitments by the responsible jurisdiction or responsible agency.
3 years after effective date of this TMDL	The Regional Board shall reconsider this TMDL to: (1) Consider a natural source exclusion for bacteria loading from birds in the Malibu Lagoon if all anthropogenic sources to the Lagoon have been controlled. (2) Reassess the allowable winter dry-weather and wet-weather exceedances days based on additional data on bacterial indicator densities, and an evaluation of site-specific variability in exceedance levels to determine whether existing water quality is better than water quality at the reference watershed, (3) Reassess the allowable winter dry-weather and wet-weather exceedance days based on a re-evaluation of the selected reference watershed and consideration of other reference watersheds that may better represent reaches of the Malibu Creek and Lagoon. (4) Consider whether the allowable winter dry-weather and wet-weather exceedance days should be adjusted annually dependent on the rainfall conditions and an evaluation of natural variability in exceedance levels in the reference system(s), (5) Re-evaluate the reference year used in the calculation of allowable exceedance days, and (6) Re-evaluate whether there is a need for further clarification or revision of the geometric mean implementation provision.

6 years after the effective date of this TMDL	Achieve compliance with the applicable Load Allocations and Waste Load Allocations, expressed as allowable exceedance days during winter dry weather (November 1-March 31) single sample limits and the rolling 30-day geometric mean limit.
10 years after the effective date of this TMDL ** May be extended up to July 15, 2021.	Achieve compliance with the wet-weather Load Allocations and Waste Load Allocations (expressed as allowable exceedance days for wet weather and compliance with the rolling 30-day geometric mean limit.) The Regional Board may extend the wet-weather compliance date up to July 15, 2021 at the Regional Board's discretion, by adopting a subsequent Basin Plan amendment that complies with applicable law.

8. AMBIENT BACTERIA WATER QUALITY AND COMPLIANCE MONITORING PLAN

Responsible jurisdictions and responsible agencies are jointly responsible for developing and implementing a comprehensive monitoring plan to better characterize existing water quality based on applicable bacteria water quality objectives and to assess compliance with the waste load allocations and load allocations in the TMDL. The monitoring plan must include all applicable bacteria water quality objectives and sampling frequency must be adequate to assess compliance with the 30 day geometric mean limits (i.e., at least 5 samples per 30 days). Ongoing monitoring programs developed by the Malibu Creek Watershed Management Committee as described below may fulfill the need for ambient monitoring data. However, the responsible jurisdictions and responsible agencies are ultimately accountable for ensuring that the monitoring requirements specified in this TMDL are met.

8.1 Malibu Creek Watershed Monitoring Plan

The Watershed Management Committee (composed of the cities of Calabasas, Agoura Hills, Westlake Village, and Malibu, and the County of Los Angeles) and the Las Virgenes Municipal Water District has been awarded a Coastal Nonpoint Source Control Program grant for $500,000 to implement the Malibu Creek Watershed Monitoring Program. The monitoring program was developed by members from the LARWQCB, State Department of Parks and Recreation, City of Calabasas, Las Virgenes Municipal Water District, Heal the Bay, City of Malibu, and UCS California Sea Grant staff. Monitoring data from this program may be used to fulfill a portion of the monitoring requirements under this TMDL. This may include fecal coliform and E. coli in the creeks, and total coliform, fecal coliform and enterococcus in the lagoon. The program is currently funded through March 2006.

8.2 Compliance Monitoring

For purposes of compliance monitoring, responsible jurisdictions and agencies shall jointly submit a compliance monitoring plan that specifies agreed upon sampling stations that will serve as compliance points. At a minimum, at least one sampling station will be located in each subwatershed. The sampling plan must also list the sampling parameters, methods of measuring flow, and sampling frequency. Responsible jurisdictions and/or agencies shall conduct daily or systematic weekly sampling at each compliance point. If weekly sampling is performed, then the days of allowable exceedance for single sample limits will be scaled accordingly.[6] Also if weekly sampling is conducted, the weekly sampling results will be

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[6] The number of allowable exceedance days was scaled for weekly sampling by calculating the number of exceedances that would have been identified under a weekly sampling program at the reference beach during the critical year. The number of winter dry weather days that would have been sampled in 1993 under a weekly sampling regime was determined by solving for X in the following equation, where 80 days

assigned to the remaining days of the week in order to calculate the daily rolling 30-day geometric mean.

If the number of exceedance days is greater than the allowable number of exceedance days or the 30-day geometric mean is exceeded, then the responsible jurisdictions and agencies within the contributing subwatershed shall be considered out-of-compliance with the TMDL. Responsible jurisdictions or agencies shall not be deemed out of compliance with the TMDL if the investigation described in the paragraph below demonstrates that bacterial sources originating within the jurisdiction of the responsible agency have not caused or contributed to the exceedance.

If a single sample shows the discharge or contributing area to be out of compliance, the Regional Board may require, through permit requirements or the authority contained in Water Code section 13267, daily sampling at the downstream compliance point or at the existing downstream monitoring location (if it is not already) until all single sample events meet bacteria water quality objectives. Furthermore, if a creek location is out-of-compliance as determined in the previous paragraph, the Regional Board shall require responsible agencies to initiate an investigation, which at a minimum shall include daily sampling in the target receiving water body reach or at the existing monitoring location until all single sample events meet bacteria water quality objectives.

The estimated annual cost for the monitoring plan is $200,000. This is based on the cost of monitoring 24 sites on a weekly basis (one site in each of the 18 subwatersheds plus six additional sites where frequent REC-1 use is known to occur) for total coliform, fecal coliform, enterococcus, and E. coli bacteria. Monitoring cost will be considered with the benefits of protecting human health for persons swimming downstream and wading in Malibu Creek and its tributaries, and for swimmers and surfers using downstream beaches that are impacted by the Creek.

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equals the number of winter dry-weather days during the critical year 1993.

$$\frac{80 \text{ days}}{365 \text{ days}} = \frac{X}{52 \text{ weeks}}$$

Solving for the variable X yields 11.4, which was multiplied by 0.03, the historical exceedance frequency for winter dry-weather at the Leo Carrillo Beach, the reference beach in the Arroyo Sequit watershed (LARWQCB,2003). The adjusted allowable days of winter dry-weather exceedance days under a weekly sampling scenario is 1 day. Likewise, the adjusted allowable exceedance days during wet weather is 3 days when compliance points are sampled weekly. This is based on 75 wet-weather days in 1993, and a historical exceedance rate at the reference beach during wet-weather days of 0.22.

9. REFERENCES

Abramson, M.,. Padick. E.T. Schueman, G.O. Taylor, J. Olson, J. Safford, K. Starman, and J. Woodward. 1998. The Malibu Creek Watershed: A Framework for Monitoring, Enhancement and Action. Prepared for Heal the Bay and The California State Coastal Conservancy. The 606 Studio Graduate Department of Landscape Architecture, California State Polytechnic University, Pomona

Ambrose, R.F.., I.H. Suffet, and S.S. Que Hee. 1995. Enhanced environmental monitoring program at Malibu Lagoon and Malibu Creek. Prepared for the Las Virgenes Municipal Water District by the Environmental Science and Engineering Program at the University of California, Los Angeles.

Ambrose, R.F. and A. R. Orme. 2000. Lower Malibu Creek and Lagoon resource enhancement and management. Final report to the California State Coastal Conservancy. University of California, Los Angeles May 2000.

ASAE, 1998. ASAE Standards. Manure Production Characteristics. ASAE D384.1 DEC93

City of Malibu.2000. Proposition 13 Grant Application--Civic Center Stormdrain Treatment Facility

Colbough, Jim. 2003. Personal communication.

Consent Decree (Heal the Bay Inc., et al. v. Browner) C 98-4825 SBA

Entrix, 1999. Minimum Flow Recommendations for Malibu Creek. Prepared for the Las Virgenes Municipal Water District by ENTRIX, Inc, Walnut CA.

Flowers 1972. Measurement and management Aspects of Water Toxicology: The Malibu Creek Watershed, A mixed residential and Wilderness Areas

Haith, D.A., R. Mandel, and R.S. Wu. 1992. GWLF, Generalized loading functions, Version 2.0 Users Manual. Department of Agricultural and Biological Engineering, Cornell University, Ithaca, New York.

LARWQCB. 1994. Water Quality Control Plan for the Los Angeles Region. California Regional Water Quality Control Board, Los Angeles Region.

LARWQCB. 1996. 1996 Water Quality Assessment and Documentation. California Regional Water Quality Control Board, Los Angeles Region.

Los Angeles Regional Water Quality Control Board.1997. Fact Sheet: Order No. 97-135, Waste Discharge Requirements for Las Virgenes Municipal Water District (Tapia Water Reclamation Facility).

LARWQCB. 1998. Proposed 1998 list of impaired surface waters (the 303(d) List). March 24, 1998. California Regional Water Quality Control Board, Los Angeles Region.

LARWQCB, 2000. Malibu Technical Investigation. California Regional Water Quality Control Board, Los Angeles Region.

LARWQCB. 2002a. Draft 303(d) list. California Regional Water Quality Control Board, Los Angeles Region.

LARWQCB. 2002b. Total maximum daily load to reduce bacterial indicator densities at Santa Monica Bay Beaches during dry weather. California Regional Water Quality Control Board, Los Angeles Region. January 14, 2002.

LARWQCB. 2002c. Draft. Total Maximum Daily Load to Reduce Bacterial Indicator Densities at Santa Monica Bay Beaches during Wet Weather. California Regional Water Quality Control Board, Los Angeles Region. November 7, 2002.

LVMWD. 2002. Proposition 13 Grant Application--Nonpoint Pollution Program.

Lund, L.J., M.A. Anderson, and C. Amrhein. 1994. Evaluation of Water Quality for Selected Lakes in the Los Angeles Hydrological Basin. Prepared for the Los Angeles Regional Water Quality Control Board by the Department of Soil Science, University of California, Riverside, CA.

Manion, B.S. and J.H. Dillingham.1989. Malibu Lagoon: A Baseline Ecological Survey. Prepared for Los Angeles County Department of Beaches and Harbors and California State Department of Parks and Recreation. Topanga-Las Virgenes Resources Conservation District.

Orton, Randall. 2001. Personal Communications.

Tetra Tech. 2002. Nutrient and Coliform Modeling for the Malibu Creek Watershed TMDL Studies. Prepared for US Environmental Protection Agency Region 9 and the Los Angeles Regional Water Quality Control Board by Tetra Tech, Inc. Lafayette CA.

USEPA 2000. Guidance for Developing TMDLs in California

USEPA 2000a. Exfiltration in Sewer Systems, December, 2000. EPA 600-R-01-034

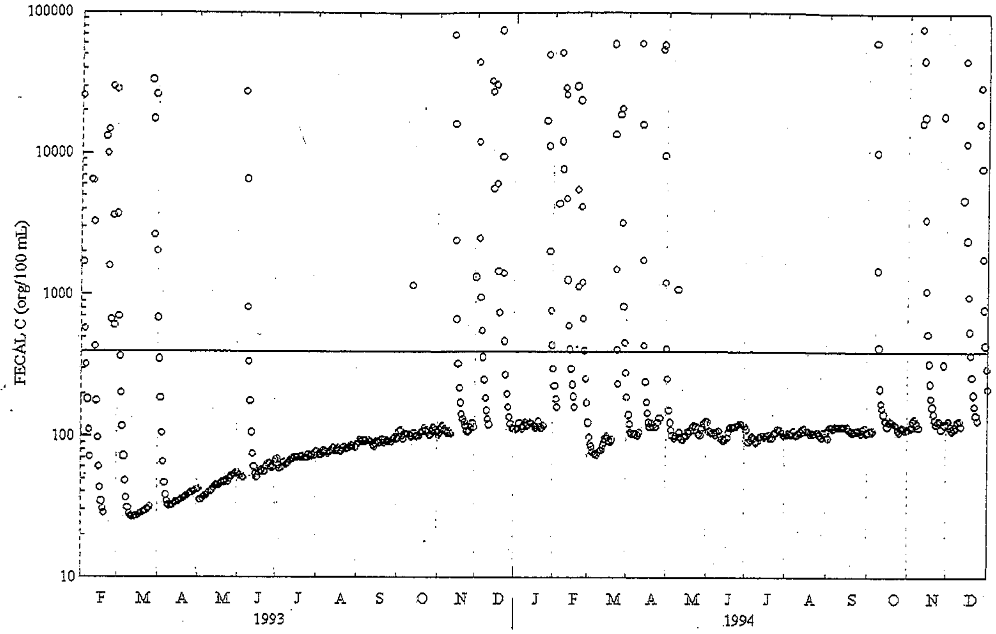
USEPA 2001. Protocol for Developing Pathogen TMDLs: First Edition Jan. 2001, EPA 841-R-00-0002

USEPA 2002. Onsite Wastewater Treatment Systems Manual. February, 2002, EPA 625-R-00-0002

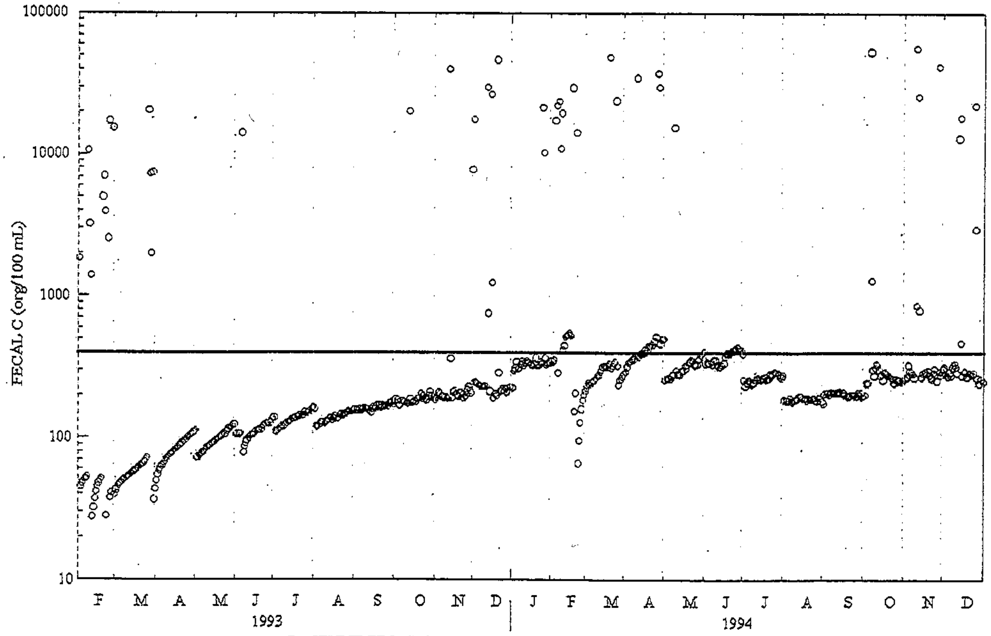
USEPA 2003. Total Maximum Daily Loads for Bacteria in the Malibu Creek Watershed. March 19, 2003

Warshall, P. and P. Williams. 1992. Malibu Wastewater Management Study: A Human Ecology of the New City. Prepared for the City of Malibu. Peter Warshall & Associates and Philip Williams & Associates, Ltd.

Appendix 1- Baseline Single Sample Model Output



BASELINE FECAL COLIFORM at LOWER MEDEA CREEK



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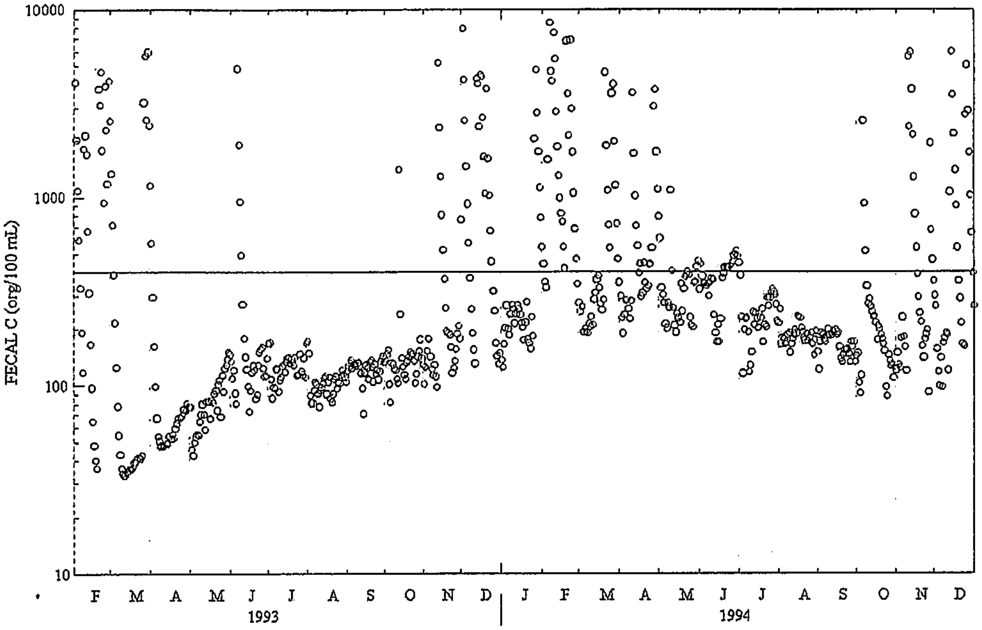

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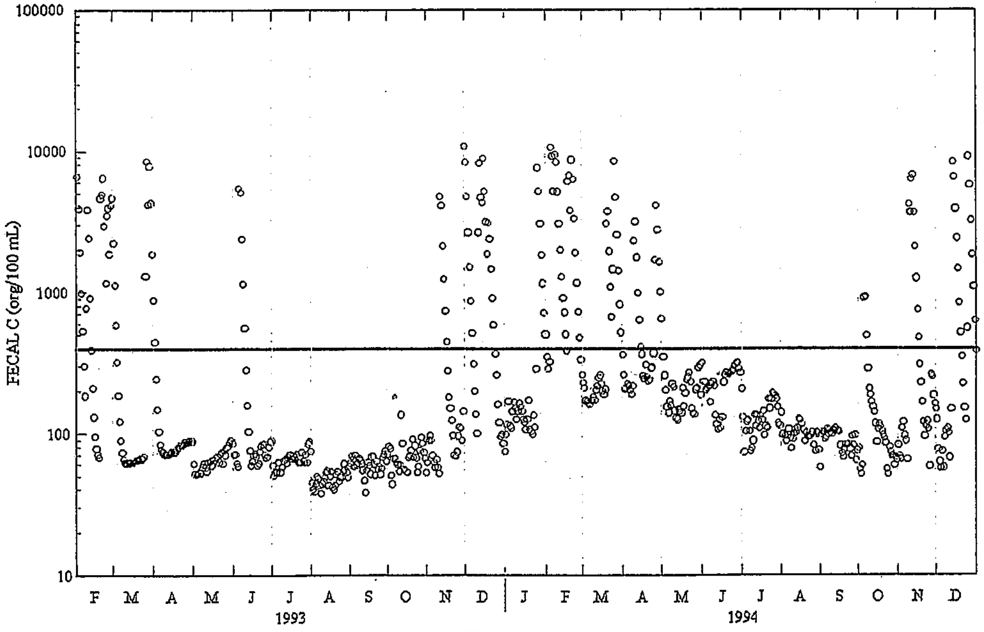

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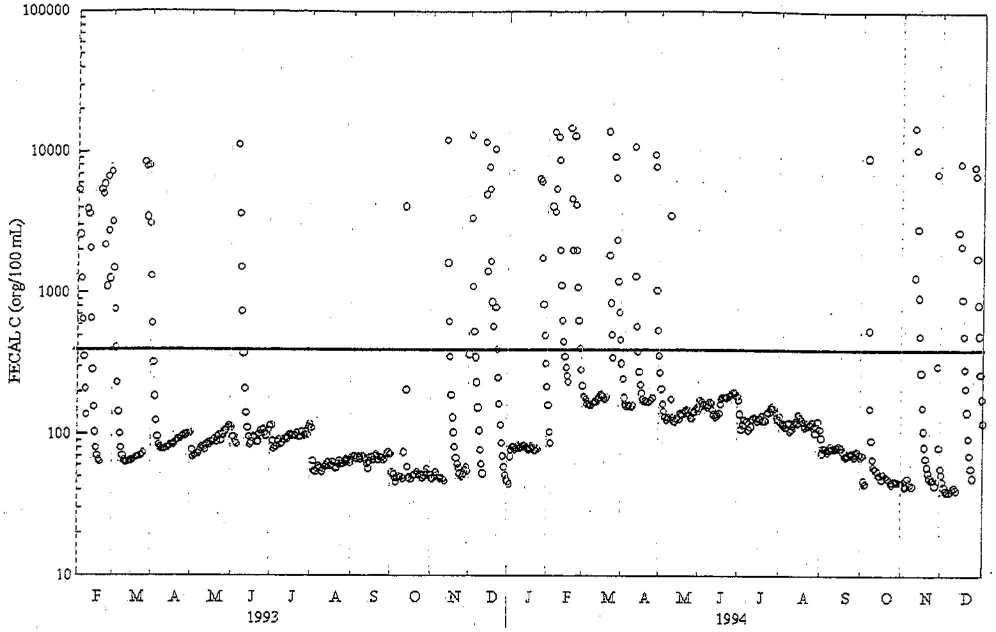

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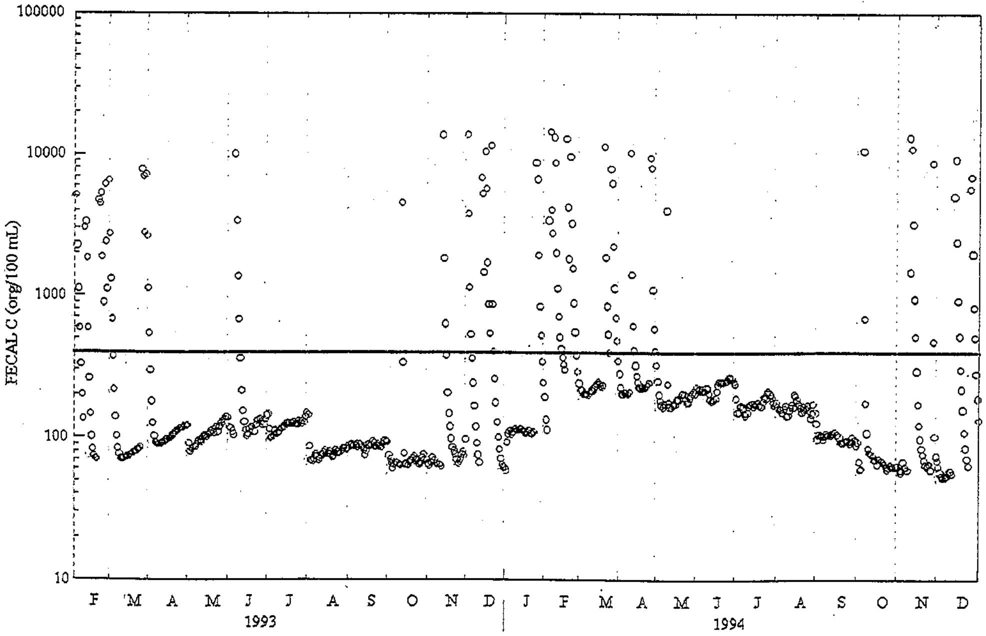

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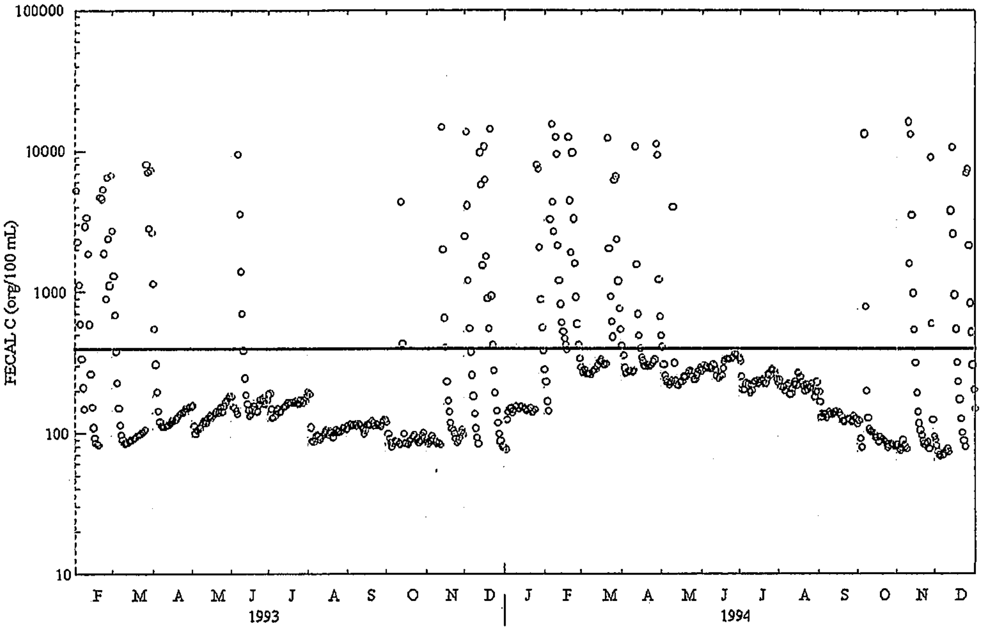
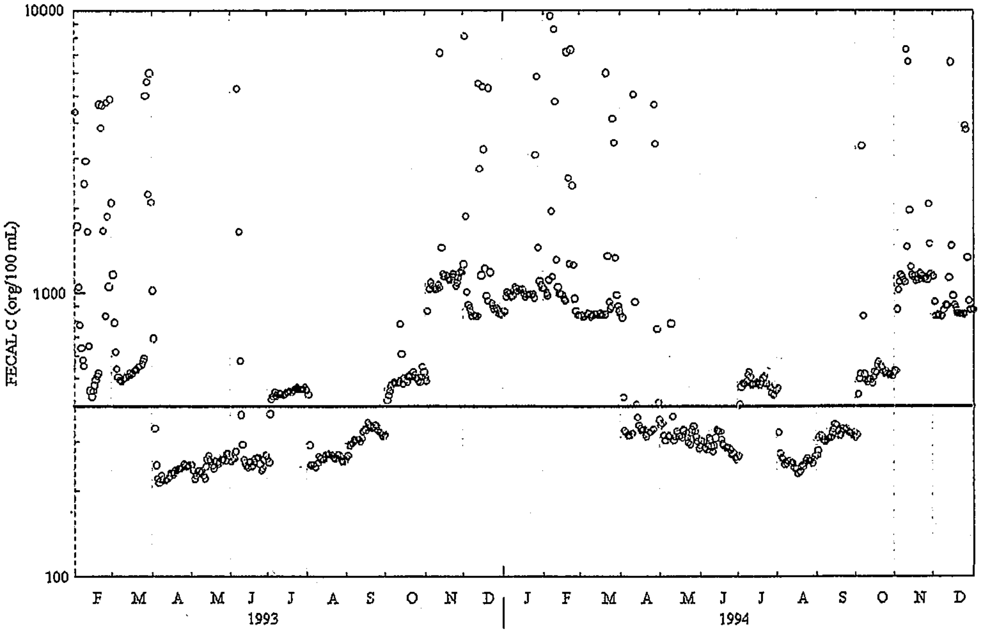
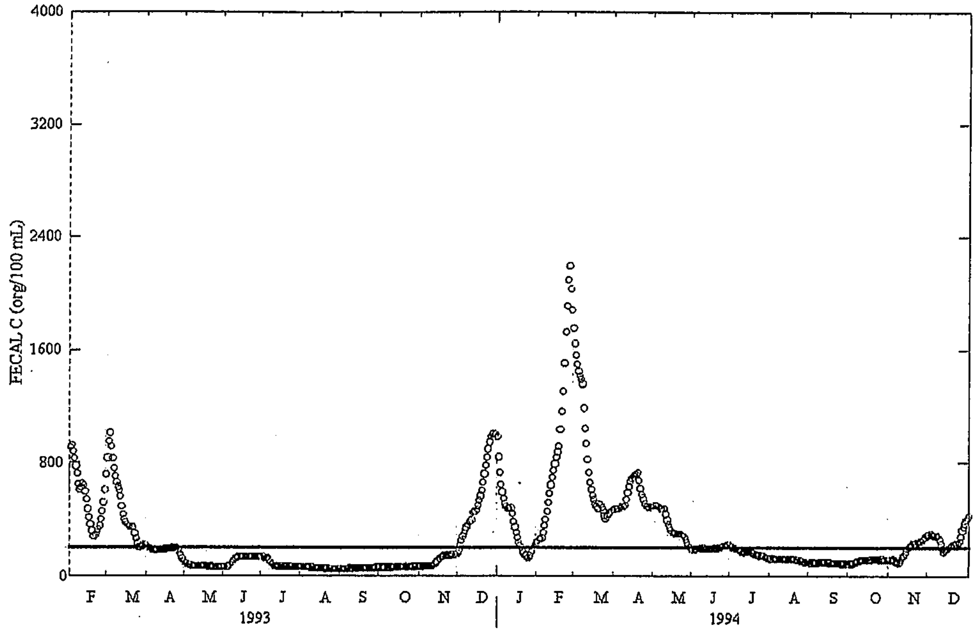


BASELINE FECAL COLIFORM at MALIBU LAGOON SUBWATERSHED

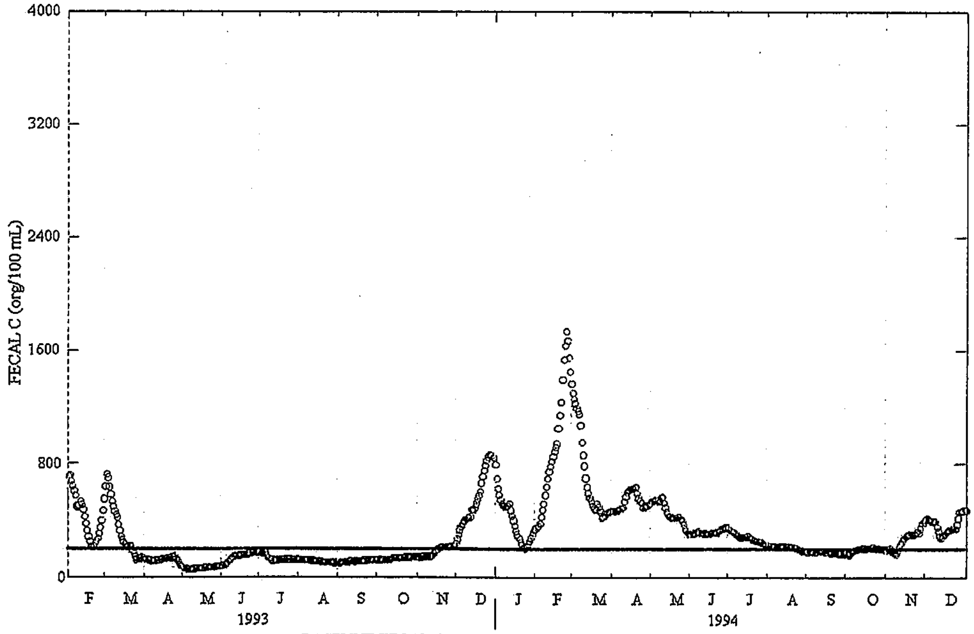


BASELINE FECAL COLIFORM at MALIBU LAGOON ESTUARY

Appendix 2 – Baseline 30-Day Running Geometric Mean Model Output



BASELINE FECAL COLIFORM at UPPER MALIBU CREEK



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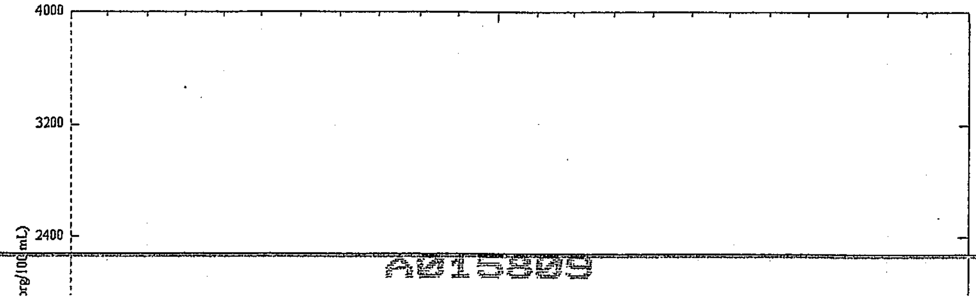
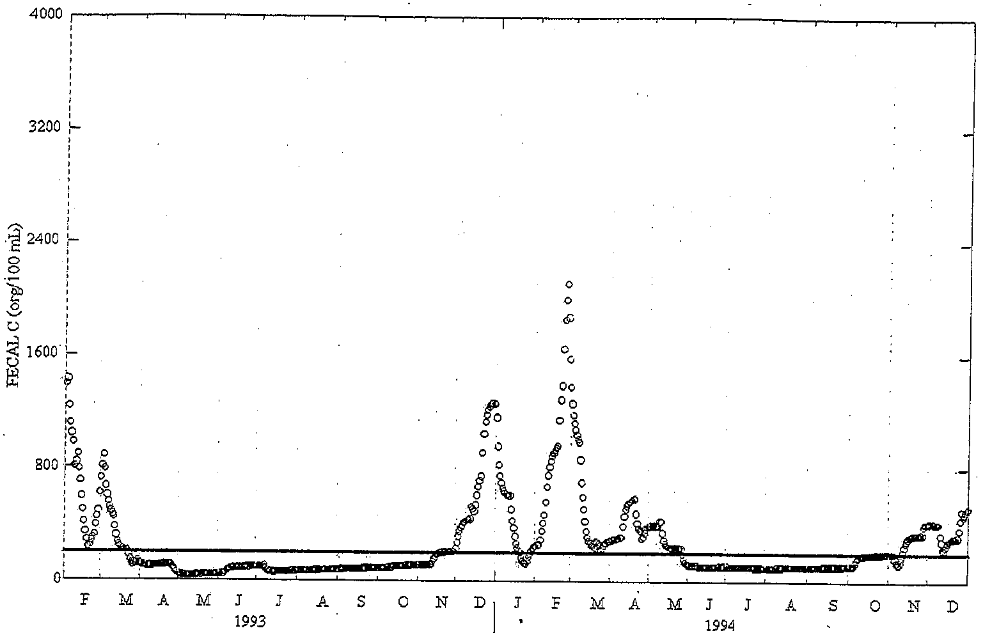
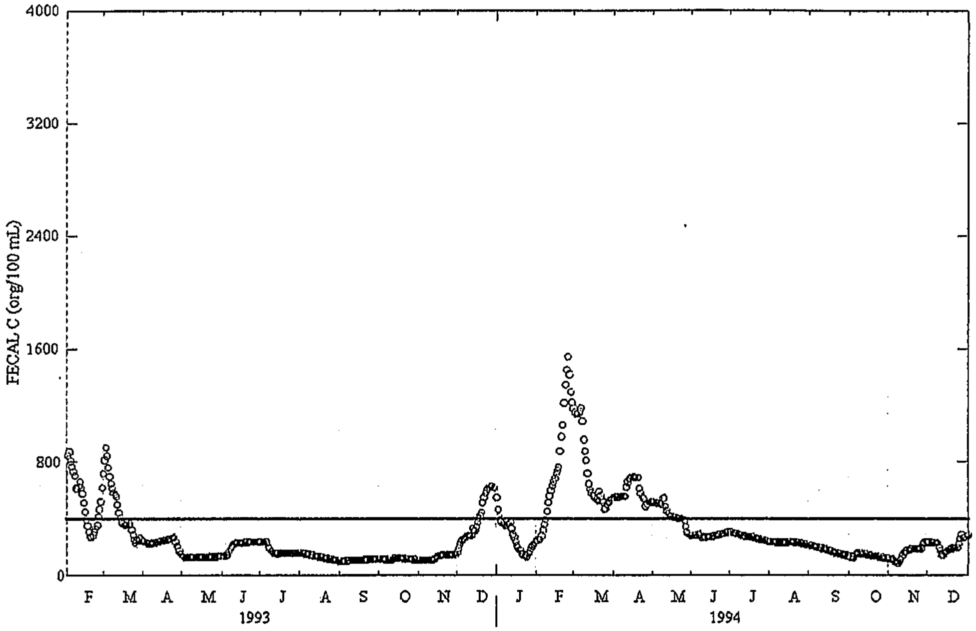
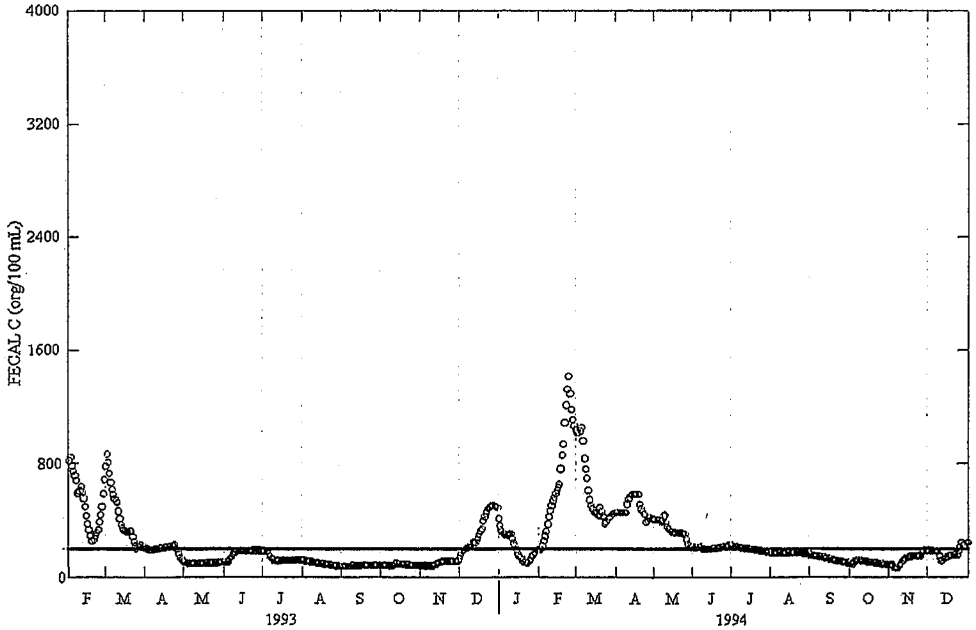




BASELINE FECAL COLIFORM at LOWER MEDEA CREEK



BASELINE FECAL COLIFORM at MALIBU LAGOON SUBWATERSHED



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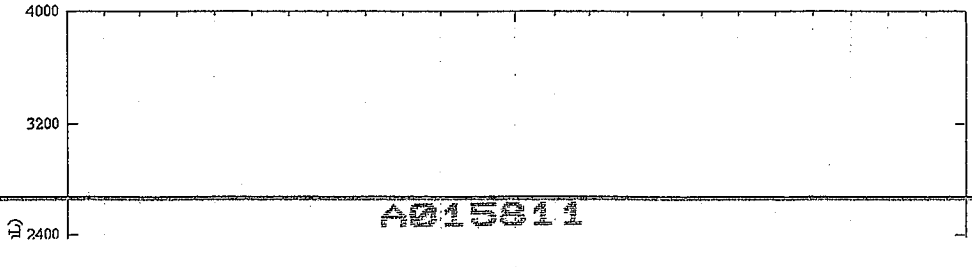
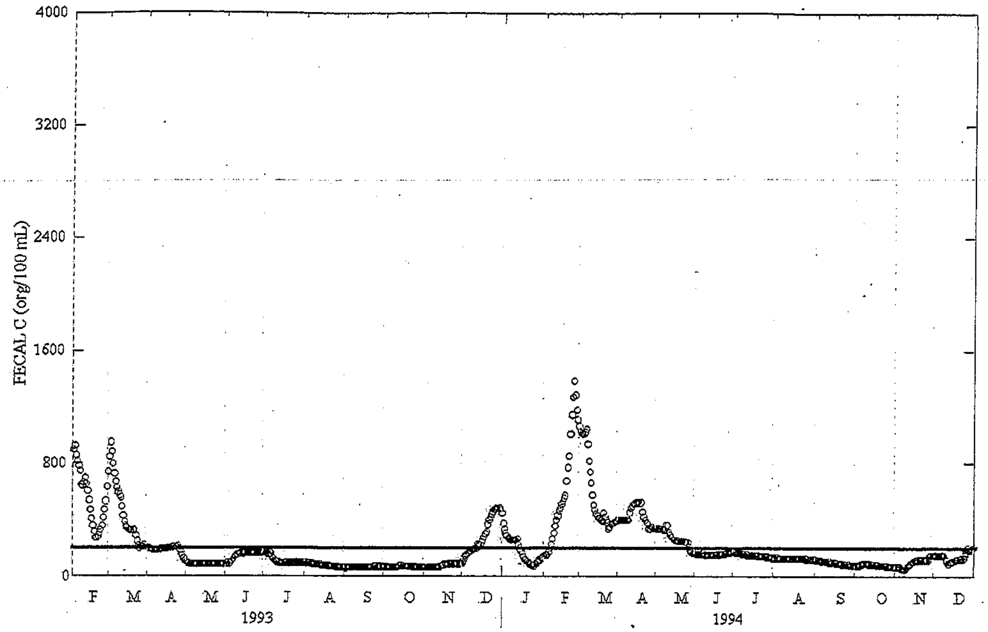
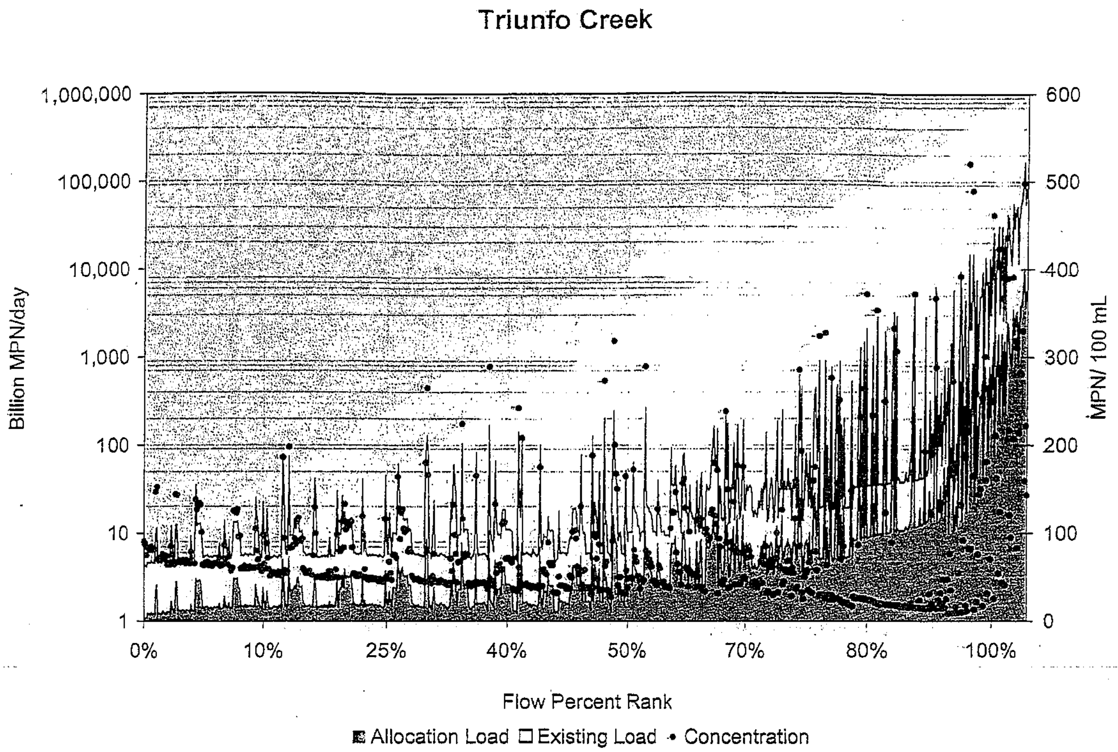




BASELINE FECAL COLIFORM at MIDDLE MALIBU CREEK

Appendix 3 - Allocations and Predicted Single Sample Compliance


Triunfo Creek
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Billion MPN/day
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200
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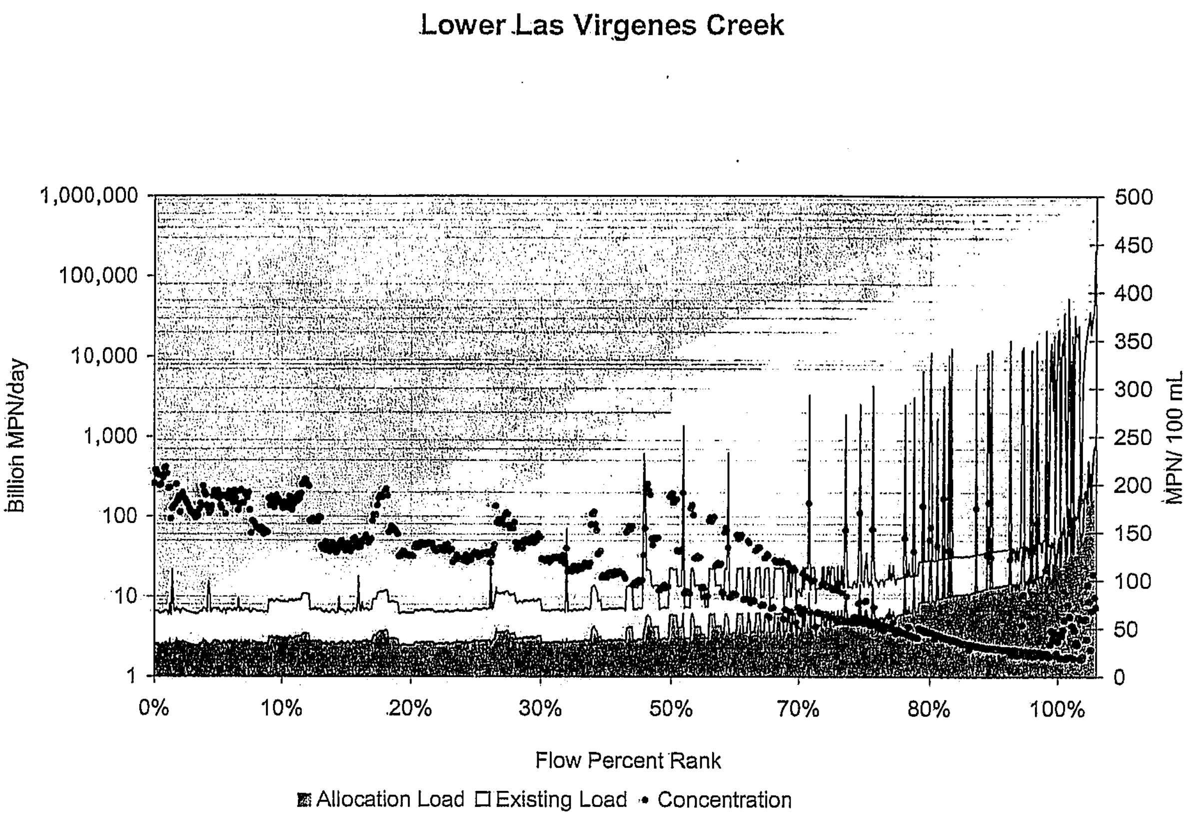
Flow Percent Rank
▨ Allocation Load ☐ Existing Load ● Concentration


Lower Las Virgenes Creek
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Billion MPN/day
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200
150
100
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MPN/ 100 mL
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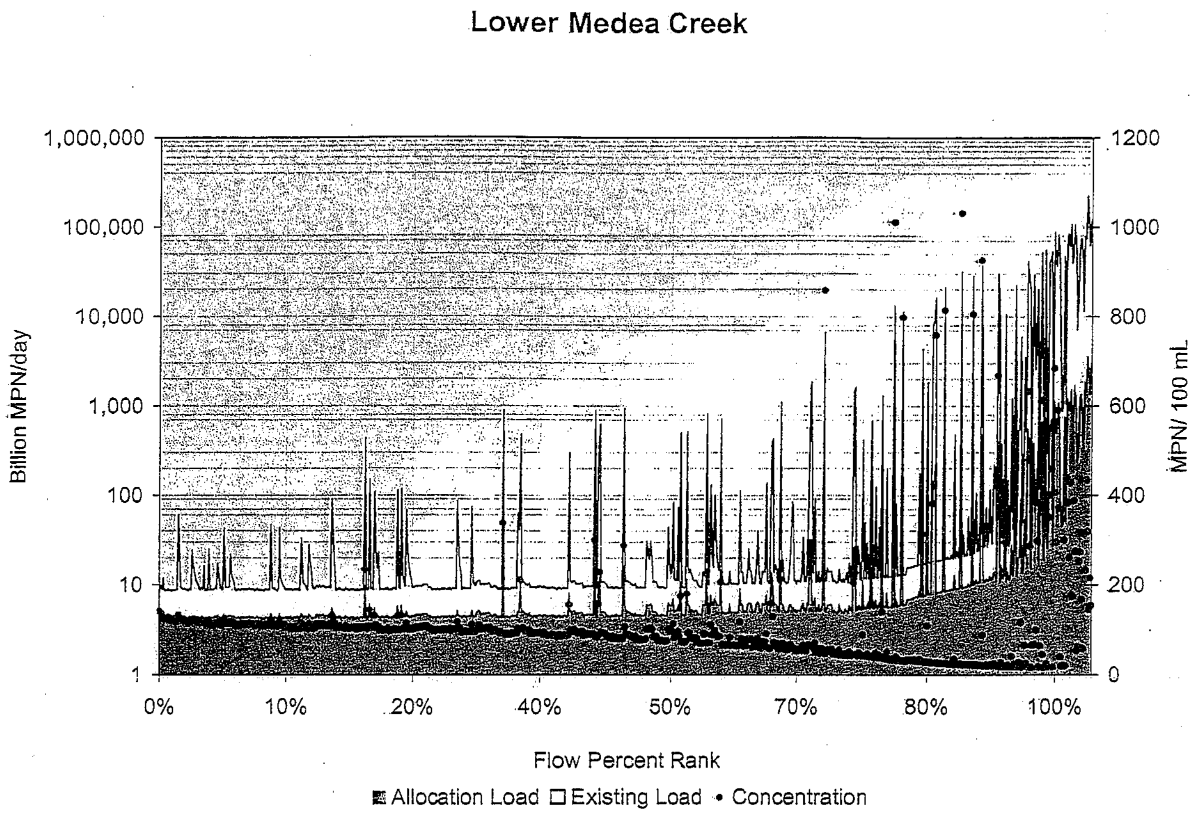
100%
Flow Percent Rank
▨ Allocation Load ☐ Existing Load • Concentration


Lower Medea Creek
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Billion MPN/day
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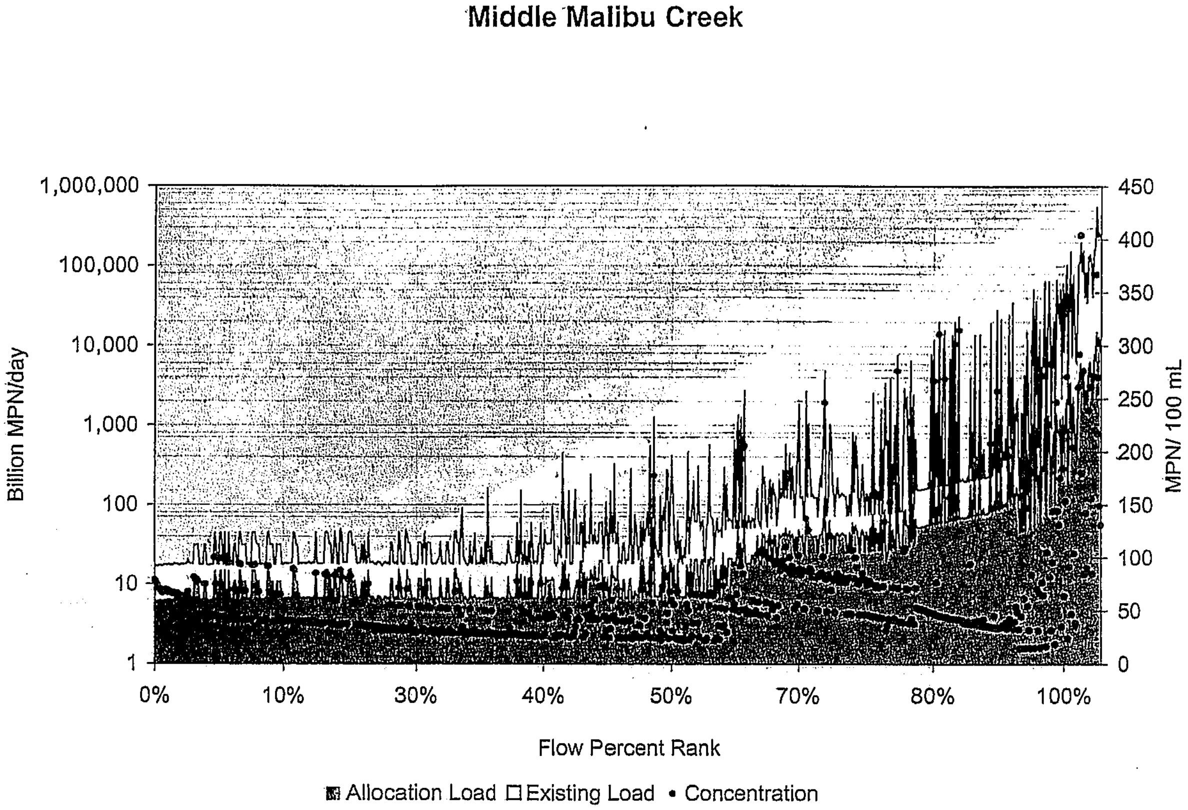
Middle Malibu Creek
Billion MPN/day
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MPN/ 100 mL
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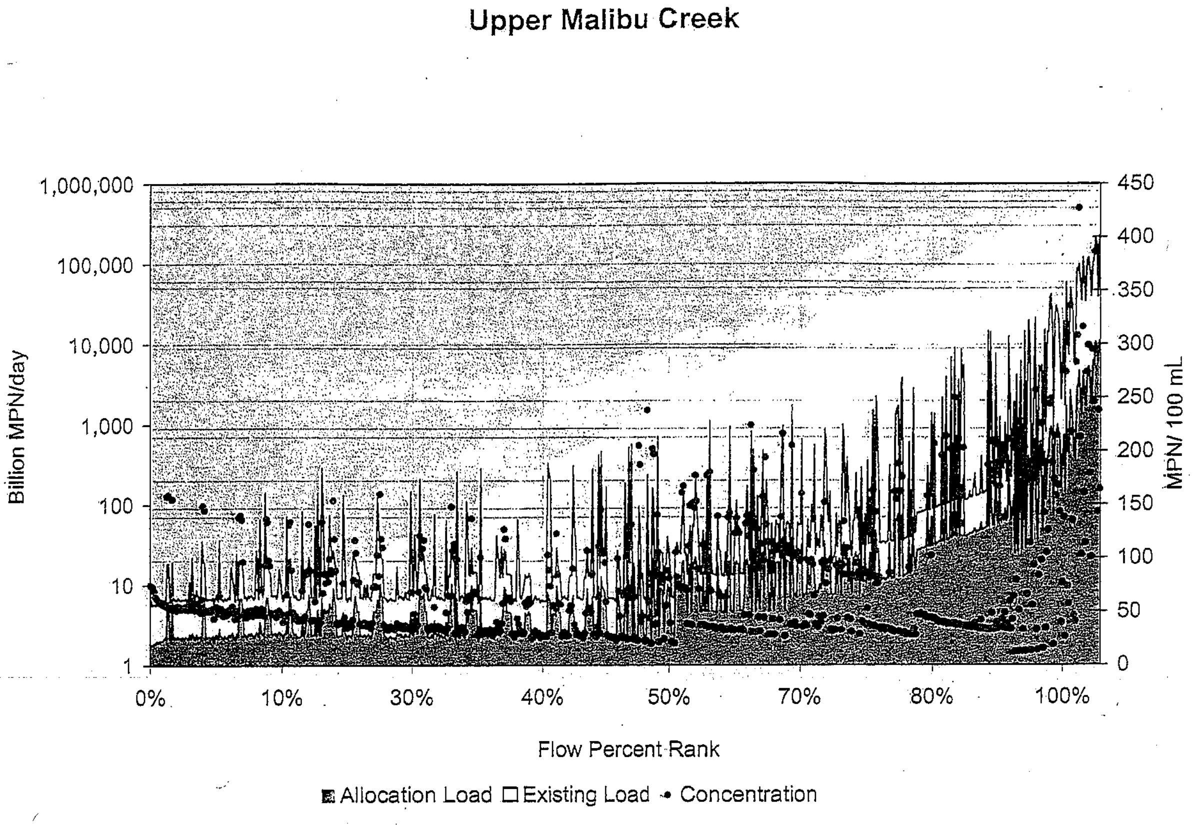
Flow Percent Rank
▨ Allocation Load ☐ Existing Load • Concentration


Upper Malibu Creek
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10,000
1,000
100
10
1
Billion MPN/day
450
400
350
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150
100
50
0
MPN/ 100 mL
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30%
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50%
70%
80%
100%
Flow Percent Rank
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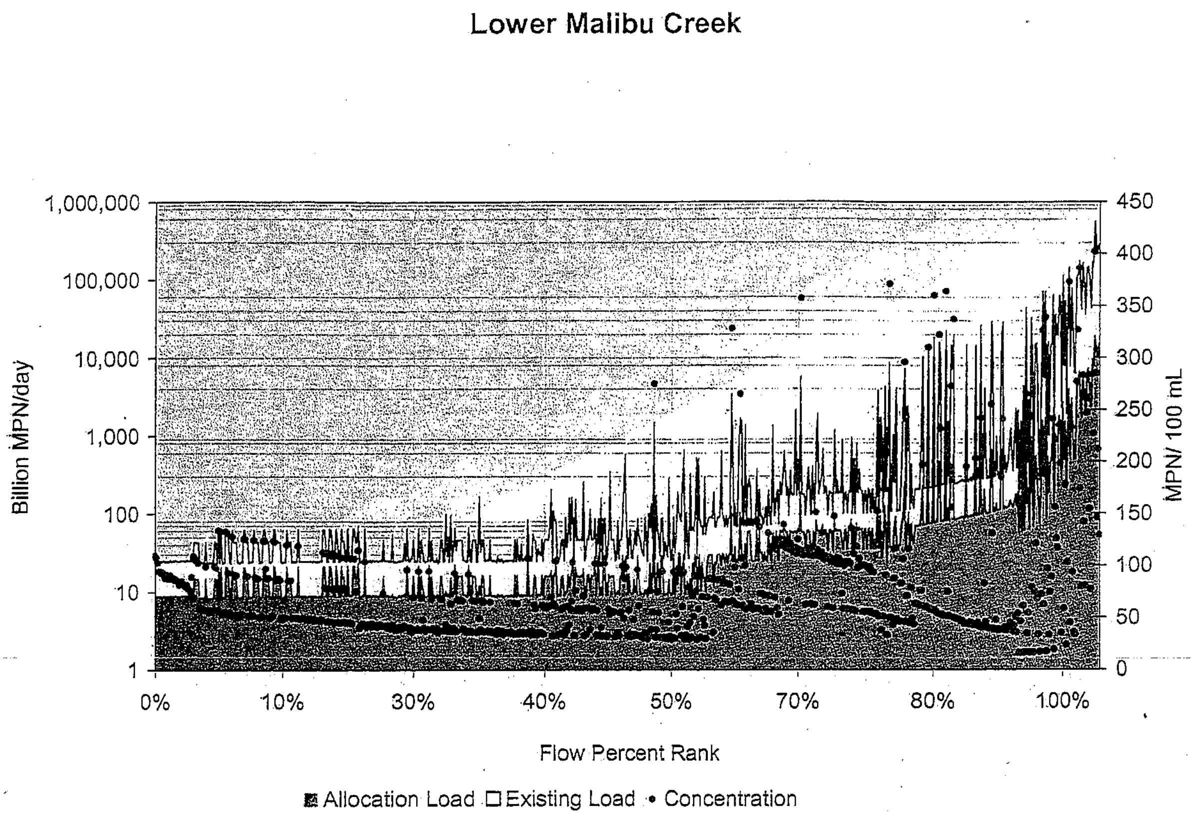
Lower Malibu Creek
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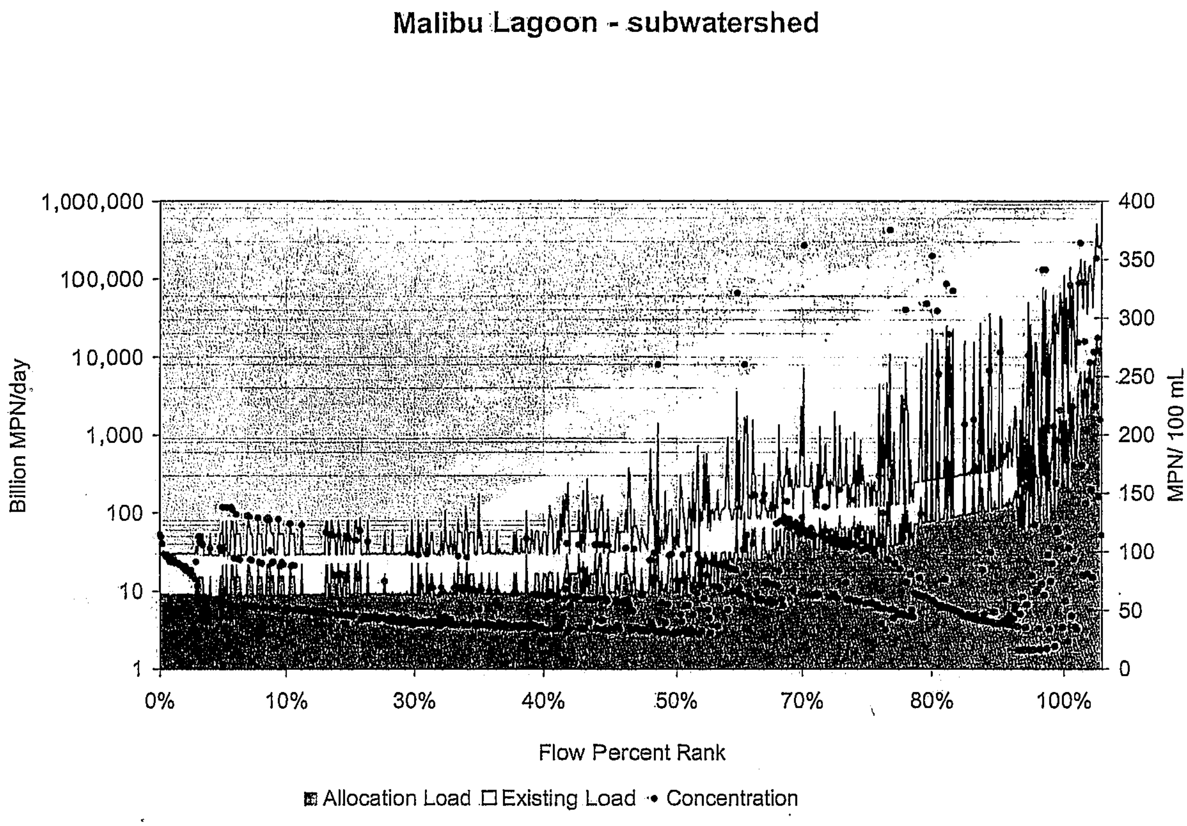
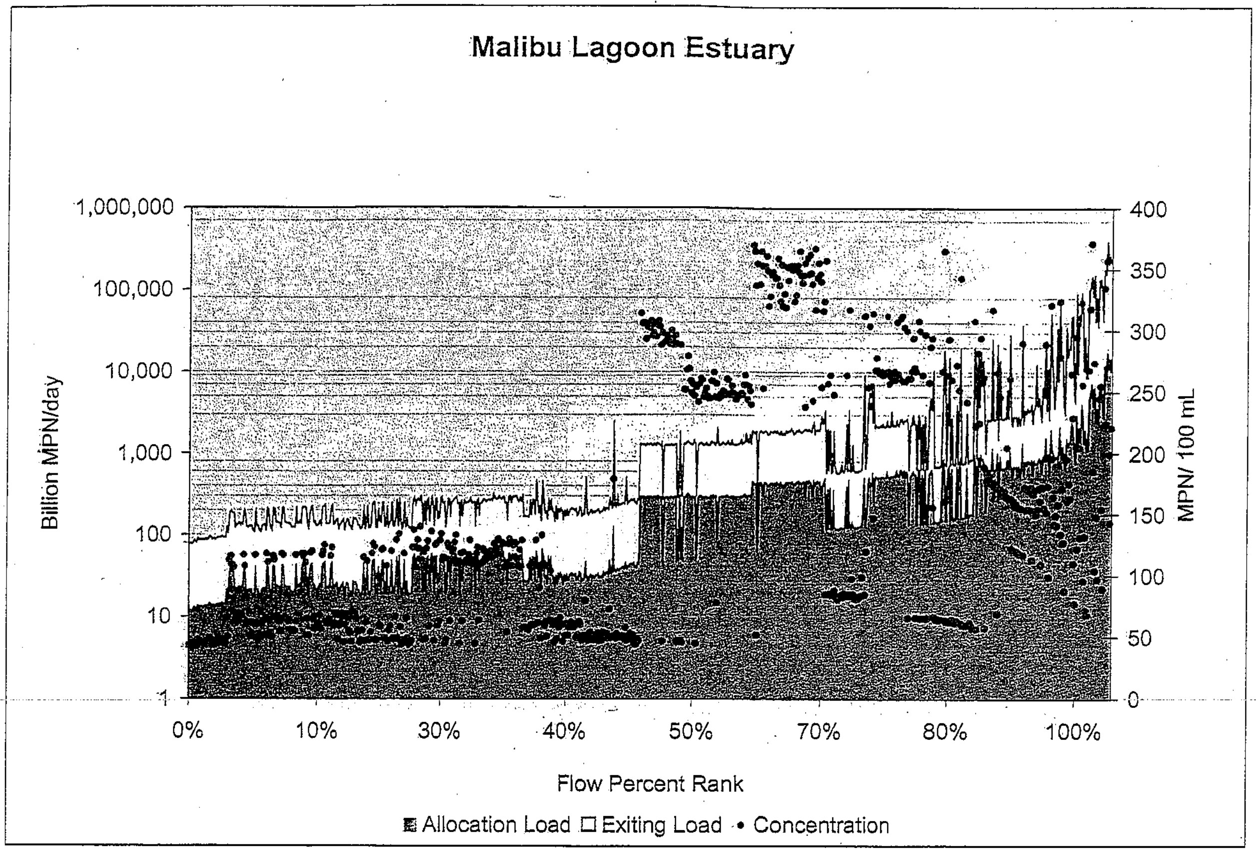
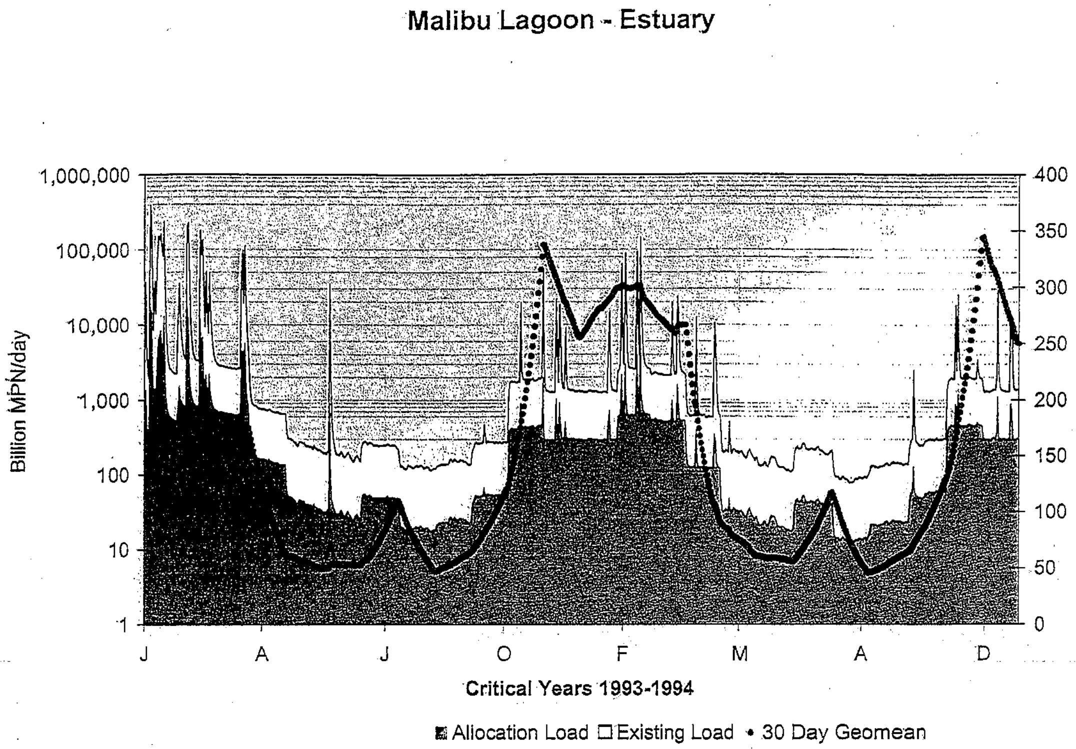
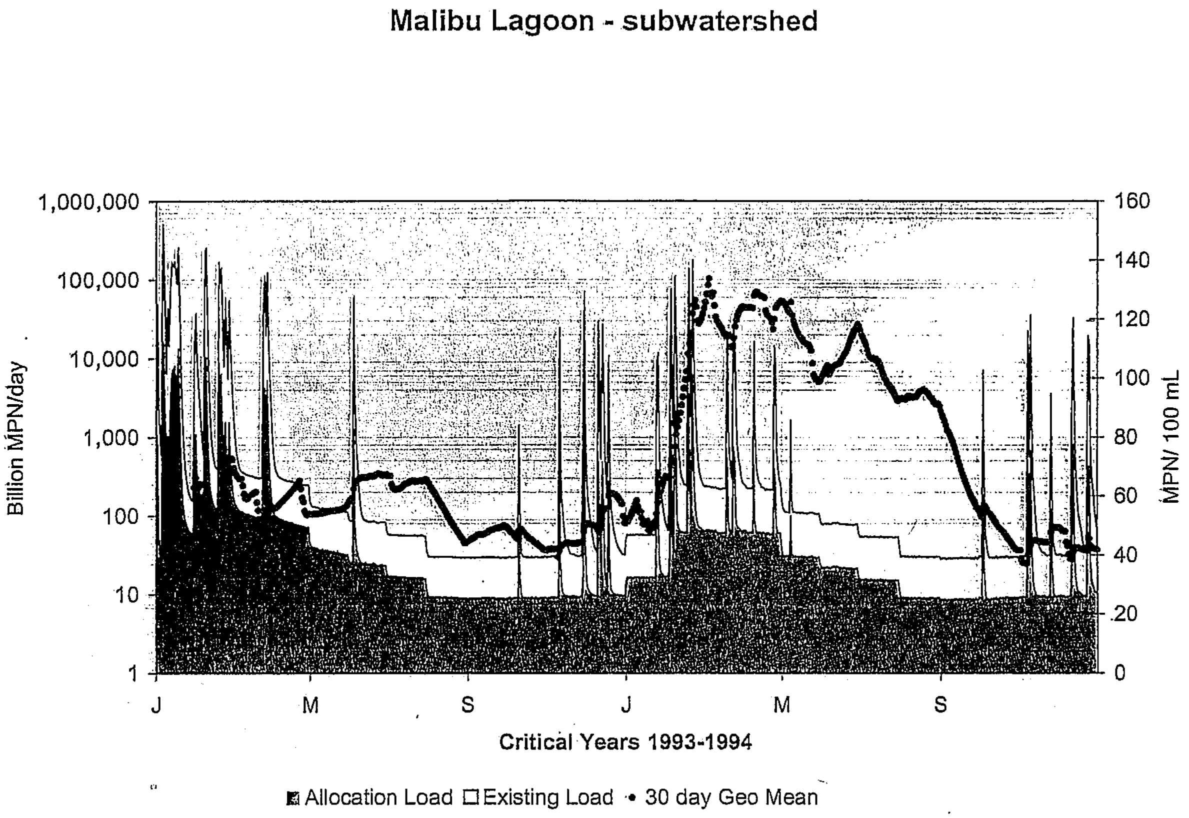
100,000
10,000
1,000
100
10
1
Billion MPN/day
450
400
350
300
250
200
150
100
50
0
MPN/ 100 mL
0%
10%
30%
40%
50%
70%
80%
100%
Flow Percent Rank
▨ Allocation Load ☐ Existing Load • Concentration

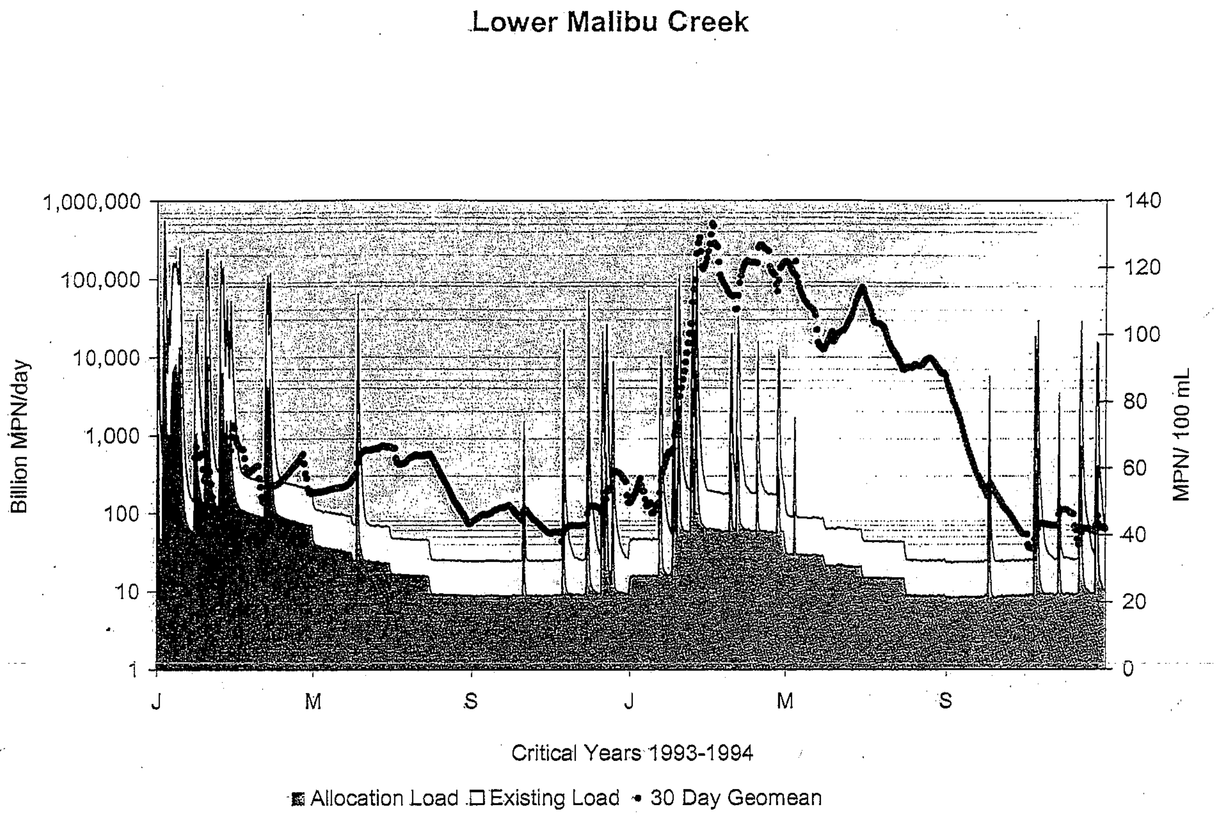

Malibu Lagoon - subwatershed
1,000,000
100,000
10,000
1,000
100
10
1
Billion MPN/day
400
350
300
250
200
150
100
50
0
MPN/ 100 mL
0%
10%
30%
40%
50%
70%
80%
100%
Flow Percent Rank
▨ Allocation Load ☐ Existing Load ·• Concentration

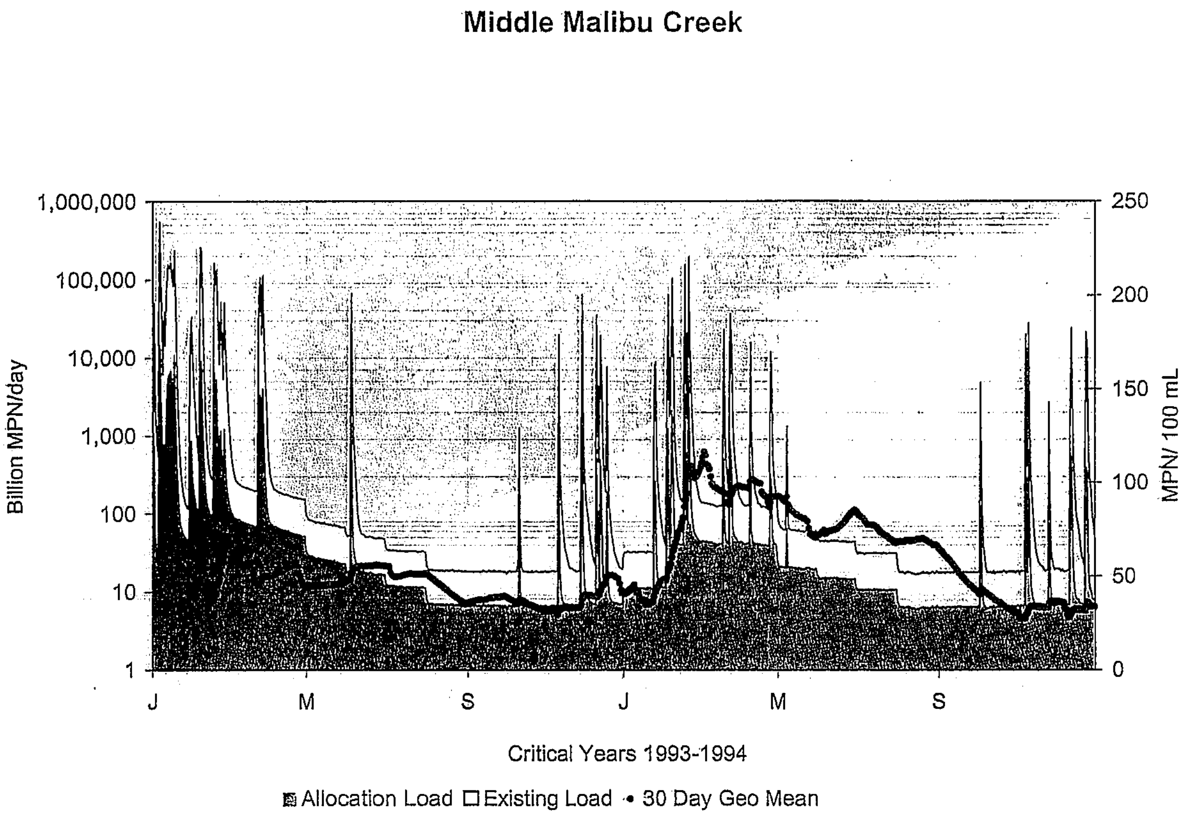

Malibu Lagoon Estuary
1,000,000
100,000
10,000
1,000
100
10
1
Billion MPN/day
400
350
300
250
200
150
100
50
0
MPN/ 100 mL
0%
10%
30%
40%
50%
70%
80%
100%
Flow Percent Rank
▨ Allocation Load ☐ Exiting Load • Concentration

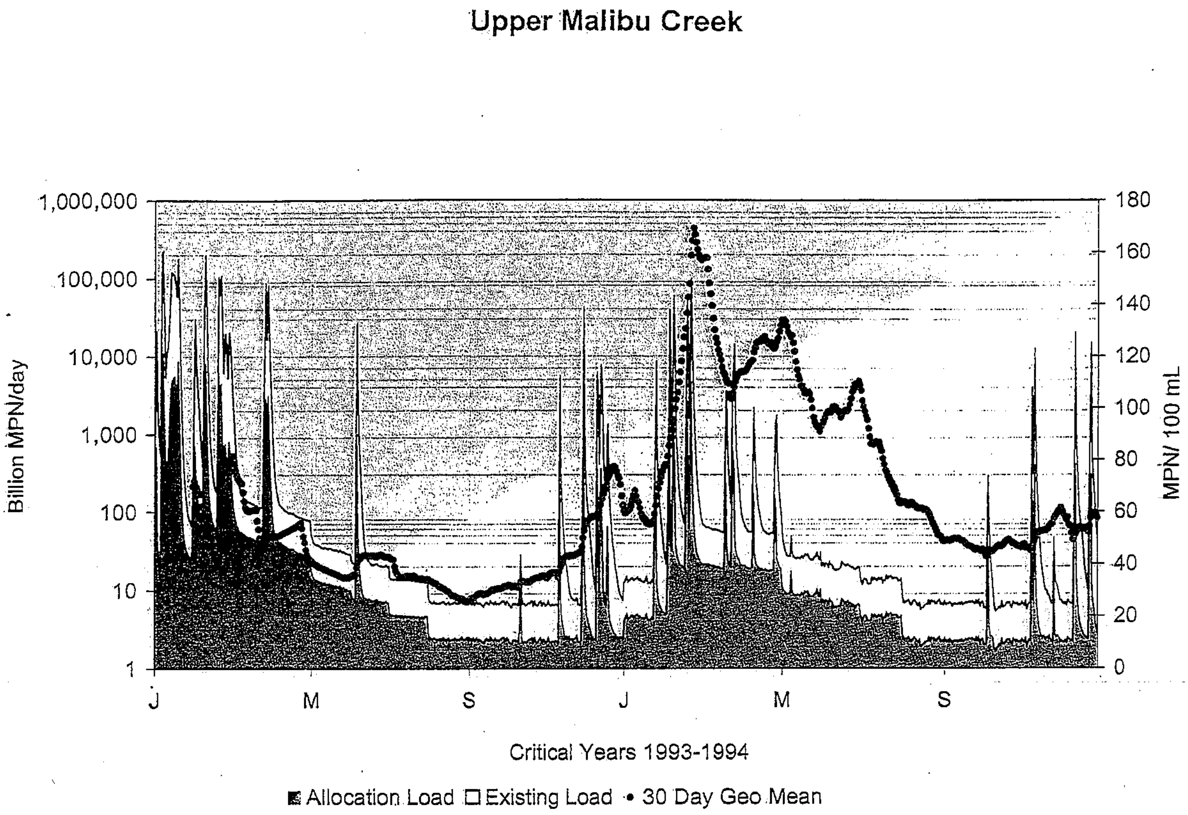
Appendix 4 - Allocations and Predicted 30-Day Running Geometric Mean Compliance


Malibu Lagoon - Estuary
1,000,000
100,000
10,000
1,000
100
10
1
Billion MPN/day
400
350
300
250
200
150
100
50
0
MPN/ 100 mL
J
A
J
O
F
M
A
D
Critical Years 1993-1994
▨ Allocation Load ☐ Existing Load • 30 Day Geomean


Malibu Lagoon - subwatershed
Billion MPN/day
1,000,000
100,000
10,000
1,000
100
10
1
MPN/ 100 mL
160
140
120
100
80
60
40
20
0
J
M
S
J
M
S
Critical Years 1993-1994
▨ Allocation Load ☐ Existing Load • 30 day Geo Mean

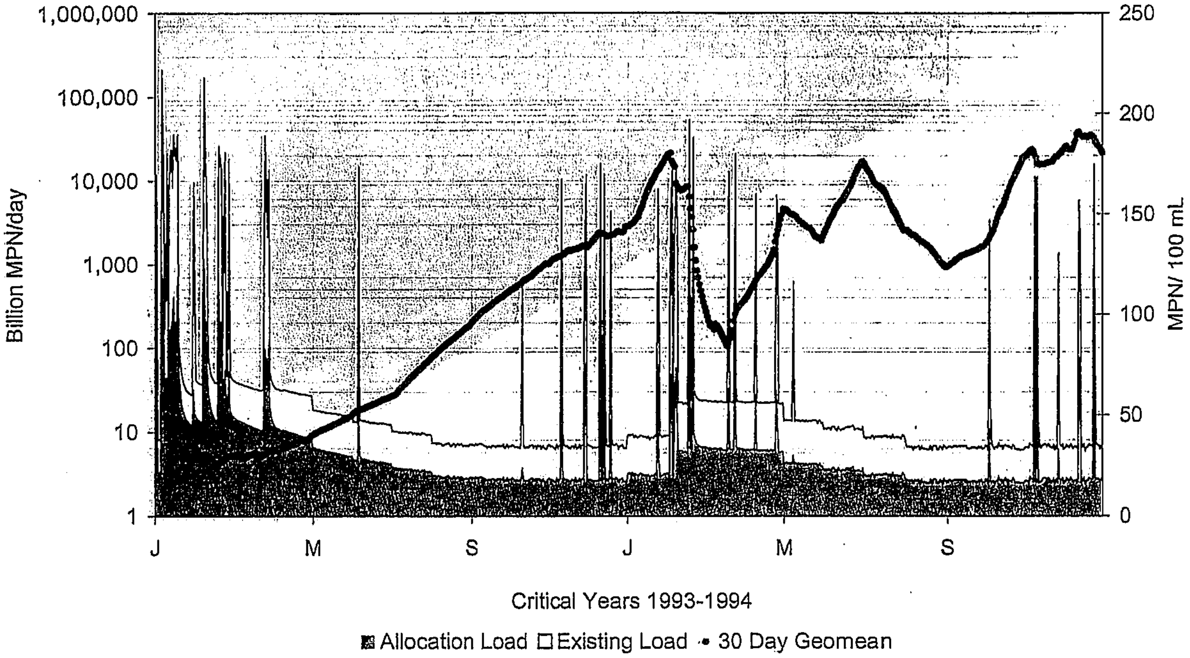

Lower Malibu Creek
1,000,000
100,000
10,000
1,000
100
10
1
Billion MPN/day
140
120
100
80
60
40
20
0
MPN/ 100 mL
J
M
S
J
M
S
Critical Years 1993-1994
▨ Allocation Load ☐ Existing Load • 30 Day Geomean


Middle Malibu Creek
1,000,000
100,000
10,000
1,000
100
10
1
Billion MPN/day
250
200
150
100
50
0
MPN/ 100 mL
J
M
S
J
M
S
Critical Years 1993-1994
▨ Allocation Load ☐ Existing Load ● 30 Day Geo Mean

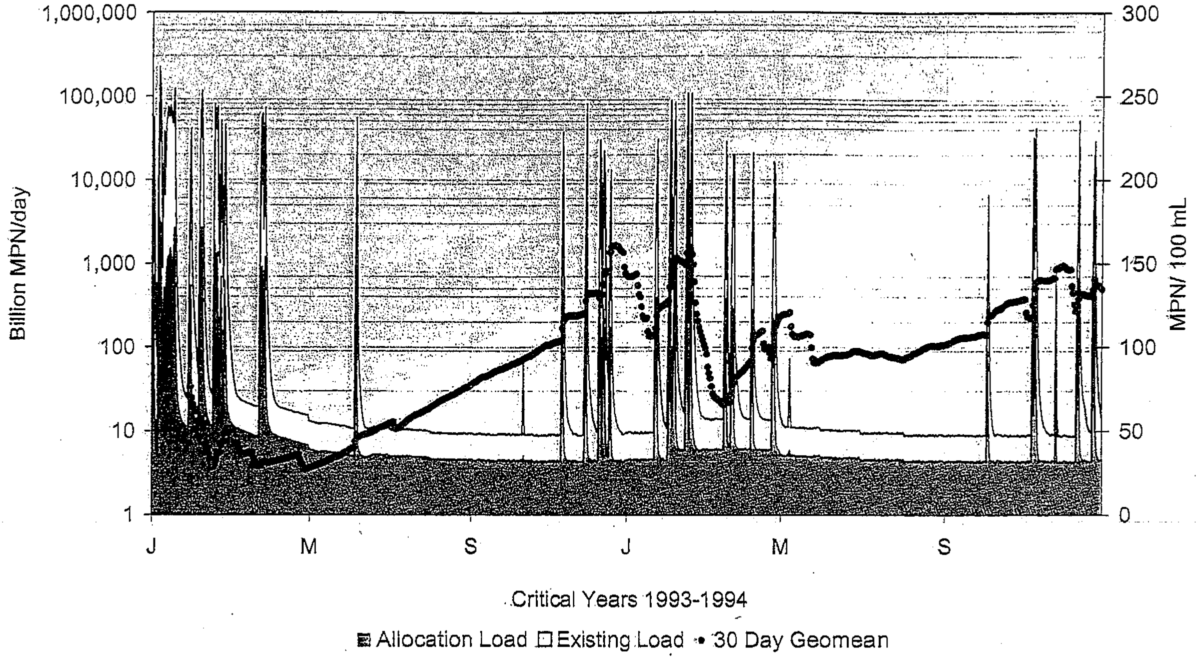


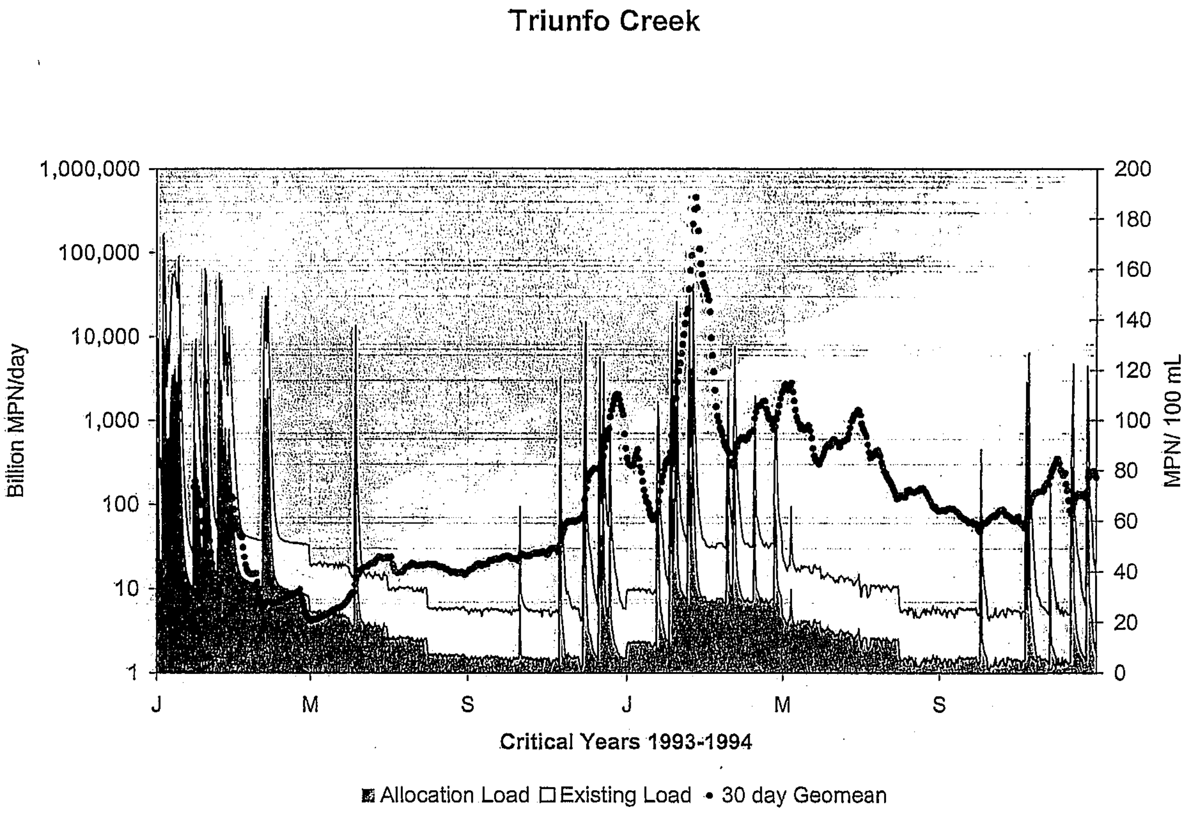
Upper Malibu Creek

Lower Las Virgenes Creek



Lower Medea Creek




Triunfo Creek
1,000,000
100,000
10,000
1,000
100
10
1
Billion MPN/day
200
180
160
140
120
100
80
60
40
20
0
MPN/ 100 mL
J
M
S
J
M
S
Critical Years 1993-1994
▨ Allocation Load ☐ Existing Load • 30 day Geomean

Appendix 5 - Allocation Loads by Subwatershed

Potrero Canyon Creek Watershed

Source Category	Existing Fecal Coliform Loads (no/yr)	Fecal Coliform Allocation (no./yr)
Commercial/Industrial	1.94E+13	1.08E+12
High/Med. Density Residential	2.98E+14	1.68E+13
Low Density Residential	2.12E+12	1.22E+11
Rural Residential	3.32E+11	1.94E+10
Agriculture/Livestock	9.50E+10	9.46E+10
Vacant	5.12E+11	5.06E+11
Chapparral/Sage Scrub	1.24E+12	1.23E+12
Grasslands	1.06E+11	1.04E+11
Woodlands	1.85E+09	1.52E+09
Imported Water	7.37E+11	7.37E+11
Total	**3.22E+14**	**2.07E+13**

Hidden Valley Watershed

Source Category	Existing Fecal Coliform Loads (no/yr)	Fecal Coliform Allocation (no./yr)
Commercial/Industrial	1.70E+13	9.44E+11
High/Med. Density Residential	4.66E+12	2.64E+11
Low Density Residential	3.73E+13	2.14E+12
Rural Residential	1.58E+13	9.22E+11
Agriculture/Livestock	2.87E+13	2.87E+13
Vacant	5.16E+11	5.11E+11
Chapparral/Sage Scrub	6.29E+12	6.22E+12
Grasslands	1.93E+11	1.89E+11
Woodlands	1.37E+11	1.13E+11
Septic Systems	2.54E+13	1.14E+13
Total	**1.36E+14**	**5.14E+13**

Upper Lindero Creek Watershed

Source Category	Existing Fecal Coliform Loads (no/yr)	Fecal Coliform Allocation (no./yr)
Commercial/Industrial	9.97E+13	1.21E+12
High/Med. Density Residential	3.54E+14	4.34E+12
Low Density Residential	1.10E+13	1.37E+11
Vacant	1.52E+11	1.50E+11
Chapparral/Sage Scrub	4.65E+11	4.58E+11
Grasslands	1.18E+11	1.15E+11
Woodlands	1.81E+09	1.29E+09
Imported Water	5.80E+11	5.80E+11
Total	**4.66E+14**	**6.99E+12**

Fecal Coliform in the Westlake Watershed

Source Category	Existing Fecal Coliform Loads (no/yr)	Fecal Coliform Allocation (no./yr)
Commercial/Industrial	9.47E+14	5.26E+13
High/Med. Density Residential	6.45E+14	3.65E+13
Low Density Residential	5.69E+12	3.28E+11
Vacant	3.86E+11	3.82E+11
Chapparral/Sage Scrub	1.27E+12	1.26E+12
Grasslands	3.03E+11	2.98E+11
Woodlands	1.35E+10	1.12E+10
Septic Systems	2.44E+12	2.44E+12
Imported Water	1.50E+12	1.50E+12
Total	**1.60E+15**	**9.53E+13**

Upper Medea Creek Watershed

Source Category	Existing Fecal Coliform Loads (no/yr)	Fecal Coliform Allocation (no./yr)
Commercial/Industrial	2.30E+14	2.79E+12
High/Med. Density Residential	7.04E+14	8.63E+12
Low Density Residential	1.01E+13	1.25E+11
Vacant	3.33E+10	3.29E+10
Chapparral/Sage Scrub	7.98E+11	7.86E+11
Grasslands	6.01E+10	5.86E+10
Woodlands	1.39E+10	9.84E+09
Effluent Irrigation	9.94E+08	9.94E+08
Imported Water	7.59E+11	7.59E+11
Total	**9.46E+14**	**1.32E+13**

Lower Lindero Creek Watershed

Source Category	Existing Fecal Coliform Loads (no/yr)	Fecal Coliform Allocation (no./yr)
Commercial/Industrial	2.50E+14	3.02E+12
High/Med. Density Residential	2.57E+14	3.15E+12
Low Density Residential	1.83E+12	2.27E+10
Rural Residential	1.19E+11	1.51E+09
Vacant	2.77E+09	2.73E+09
Chapparral/Sage Scrub	4.38E+11	4.33E+11
Grasslands	4.58E+10	4.48E+10
Woodlands	9.55E+09	7.27E+09
Imported Water	2.90E+11	2.90E+11
Total	**5.10E+14**	**6.97E+12**

Lower Medea Creek Watershed

Source Category	Existing Fecal Coliform Loads (no/yr)	Fecal Coliform Allocation (no./yr)
Commercial/Industrial	7.26E+12	8.74E+10
Low Density Residential	4.79E+13	5.96E+11
Rural Residential	3.05E+12	0.00E+00
Agriculture/Livestock	3.34E+11	3.33E+11
Vacant	1.31E+10	1.29E+10
Chapparral/Sage Scrub	1.39E+12	1.37E+12
Grasslands	1.23E+11	1.21E+11
Woodlands	7.94E+09	6.52E+09
Septic Systems	4.48E+12	2.24E+12
Effluent Irrigation	5.48E+09	5.48E+09
Imported Water	1.56E+11	1.56E+11
Total	**6.47E+13**	**4.93E+12**

Cheeseboro Creek Watershed

Source Category	Existing Fecal Coliform Loads (no/yr)	Fecal Coliform Allocation (no./yr)
Commercial/Industrial	6.32E+13	7.65E+11
Agriculture/Livestock	4.32E+08	3.95E+08
Chapparral/Sage Scrub	6.55E+11	6.45E+11
Grasslands	1.33E+11	1.29E+11
Woodlands	2.34E+10	1.68E+10
Total	**6.40E+13**	**1.56E+12**

Palo Comado Creek Watershed

Source Category	Existing Fecal Coliform Loads (no/yr)	Fecal Coliform Allocation (no./yr)
Commercial/Industrial	2.06E+14	2.50E+12
High/Med. Density Residential	2.13E+13	2.61E+11
Low Density Residential	5.67E+13	7.03E+11
Agriculture/Livestock	8.99E+10	8.94E+10
Chapparral/Sage Scrub	9.40E+11	9.26E+11
Grasslands	1.22E+11	1.19E+11
Woodlands	2.39E+10	1.71E+10
Imported Water	2.46E+11	2.46E+11
Total	**2.85E+14**	**4.86E+12**

Upper Las Virgenes Creek Watershed

Source Category	Existing Fecal Coliform Loads (no/yr)	Fecal Coliform Allocation (no./yr)
Commercial/Industrial	7.43E+13	6.92E+10
High/Med. Density Residential	1.45E+14	1.37E+11
Low Density Residential	1.02E+13	9.70E+09
Agriculture/Livestock	1.31E+12	1.31E+12
Vacant	1.97E+11	1.95E+11
Chapparral/Sage Scrub	2.07E+12	2.04E+12
Grasslands	5.62E+11	5.48E+11
Woodlands	5.84E+10	4.21E+10
Imported Water	3.80E+11	3.80E+11
Total	**2.34E+14**	**4.72E+12**

Upper Malibu Creek Watershed

Source Category	Existing Fecal Coliform Loads (no/yr)	Fecal Coliform Allocation (no./yr)
Low Density Residential	2.69E+12	2.59E+12
Rural Residential	3.52E+12	3.42E+12
Chapparral/Sage Scrub	3.28E+12	3.24E+12
Grasslands	8.75E+10	8.61E+10
Woodlands	1.22E+11	1.05E+11
Septic Systems	3.87E+12	1.93E+12
Total	**1.36E+13**	**1.14E+13**

Triunfo Creek Watershed

Source Category	Existing Fecal Coliform Loads (no/yr)	Fecal Coliform Allocation (no./yr)
Commercial/Industrial	1.70E+13	9.45E+11
High/Med. Density Residential	3.77E+13	2.13E+12
Low Density Residential	4.73E+13	2.72E+12
Rural Residential	2.88E+13	1.67E+12
Agriculture/Livestock	5.05E+11	5.03E+11
Vacant	3.27E+10	3.23E+10
Chapparral/Sage Scrub	5.20E+12	5.14E+12
Grasslands	3.15E+10	3.10E+10
Woodlands	1.00E+11	8.32E+10
Septic Systems	3.34E+13	8.34E+12
Imported Water	1.56E+11	1.56E+11
Total	**1.70E+14**	**2.18E+13**

Stokes Creek Watershed

Source Category	Existing Fecal Coliform Loads (no/yr)	Fecal Coliform Allocation (no./yr)
Commercial/Industrial	4.13E+13	5.72E+12
Low Density Residential	1.12E+13	1.62E+12
Rural Residential	2.66E+12	3.88E+11
Agriculture/Livestock	2.02E+11	2.00E+11
Vacant	5.08E+10	5.04E+10
Chapparral/Sage Scrub	2.62E+12	2.60E+12
Grasslands	1.60E+11	1.57E+11
Woodlands	4.94E+10	4.22E+10
Septic Systems	4.94E+10	1.73E+12
Total	**5.83E+13**	**1.25E+13**

Lower Las Virgenes Creek Watershed

Source Category	Existing Fecal Coliform Loads (no/yr)	Fecal Coliform Allocation (no./yr)
Commercial/Industrial	4.67E+14	5.62E+13
High/Med. Density Residential	2.34E+14	2.86E+13
Low Density Residential	6.54E+12	8.15E+11
Rural Residential	1.30E+12	1.64E+11
Agriculture/Livestock	2.69E+10	2.53E+10
Vacant	1.60E+10	1.59E+10
Chapparral/Sage Scrub	2.30E+12	2.28E+12
Grasslands	6.07E+11	5.96E+11
Woodlands	5.12E+10	4.25E+10
Septic Systems	2.04E+12	5.09E+11
Effluent Irrigation	3.73E+09	3.73E+09
Imported Water	4.02E+11	4.02E+11
Total	**7.14E+14**	**8.97E+13**

Cold Creek Watershed

Source Category	Existing Fecal Coliform Loads (no/yr)	Fecal Coliform Allocation (no./yr)
Commercial/Industrial	3.80E+12	4.56E+11
Low Density Residential	6.42E+13	8.01E+12
Rural Residential	3.80E+13	4.81E+12
Agriculture/Livestock	6.21E+11	6.20E+11
Vacant	3.32E+10	3.29E+10
Chapparral/Sage Scrub	5.09E+12	5.04E+12
Grasslands	1.87E+08	1.84E+08
Woodlands	4.98E+10	4.35E+10
Septic Systems	1.22E+13	6.11E+12
Imported Water	1.25E+10	1.25E+10
Total	**1.24E+14**	**2.51E+13**

Middle Malibu Creek Watershed

Source Category	Existing Fecal Coliform Loads (no/yr)	Fecal Coliform Allocation (no./yr)
Commercial/Industrial	1.01E+13	1.87E+12
Low Density Residential	4.97E+12	9.54E+11
Rural Residential	3.64E+12	7.08E+11
Agriculture/Livestock	1.70E+11	1.70E+11
Chapparral/Sage Scrub	1.25E+12	1.24E+12
Grasslands	3.28E+09	3.23E+09
Woodlands	1.14E+11	9.95E+10
Septic Systems	2.04E+12	1.02E+12
Effluent Irrigation	1.47E+09	1.47E+09
Tapia Discharge	5.92E+10	5.92E+10
Total	**2.24E+13**	**6.12E+12**

Lower Malibu Creek Watershed

Source Category	Existing Fecal Coliform Loads (no/yr)	Fecal Coliform Allocation (no./yr)
Commercial/Industrial	1.23E+12	1.48E+11
Low Density Residential	2.55E+11	3.20E+10
Rural Residential	2.74E+11	3.45E+10
Agriculture/Livestock	4.27E+09	4.07E+09
Chapparral/Sage Scrub	2.25E+12	2.23E+12
Grasslands	2.71E+10	2.66E+10
Woodlands	2.48E+10	2.12E+10
Septic Systems	2.04E+11	1.02E+11
Total	**4.27E+12**	**2.60E+12**

Malibu Lagoon Watershed

Source Category	Existing Fecal Coliform Loads (no/yr)	Fecal Coliform Allocation (no./yr)
Commercial/Industrial	9.70E+13	4.51E+11
High/Med. Density Residential	7.15E+12	3.34E+10
Low Density Residential	2.45E+13	1.15E+11
Agriculture/Livestock	1.10E+11	1.09E+11
Vacant	4.59E+09	4.22E+09
Chapparral/Sage Scrub	1.48E+11	1.46E+11
Grasslands	1.19E+09	1.10E+09
Woodlands	2.29E+09	1.59E+09
Septic Systems	1.58E+14	1.56E+14
Lagoon Drains	1.75E+10	8.76E+08
Birds	4.95E+14	4.95E+14
Tidal Inflow	2.44E+13	2.44E+13
Total	**8.06E+14**	**6.76E+14**

Appendix 6 - Modular Treatment Systems Cost

StormTreat Systems Sizing Worksheet

Note: Enter data in the bolded rows only (marked "Enter"); all other parameters are calculated.

Project Engineer:		
Project Location:		
Enter Impervious Area to be Treated:	**1.00**	**acres**
Enter Design or Local Mean Storm Event:	**1.00**	**inches**
Enter Design or Mean Storm Duration:	**12**	**hours**
Water Volume Requiring Treatment: (Calculated)	27225	gallons
Treated Discharge Rate (Recommended Average): (Given)*	1.00	gal/min
Water Residence Time in STS Unit: (Calculated)	0.97	days
Volume Treated During Storm per Unit: (Calculated)	720	gallons
Static Volume of Each STS Unit: (Given)	1390	gallons
Volume Entering Unit During Storm (calculated)	2110	gallons
Number of StormTreat Units Required: (Calculated)	4	units
Volume of Detention Required: (Calculated)	18785	gallons
Volume of Detention Required: (Calculated)	2505	cuft
Water Residence Time in Detention: (Calculated)	3.26	days
Total Water Residence Time in Treatment System: (Calculated)	4.73	days
If Detention Volume is Known:		
Enter Preliminary Detention Storage Volume Available:**	**30000**	**gallons**
Volume of Detention Required: (Calculated)	4000	cuft
Number of StormTreat Tanks Required (w/detention): (Calculated)	1	units
Water Residence Time in Detention: (Calculated)	0.0	days

$6,300	cost per unit
5440	acres to treat
$34,272,000	total cost

* Performance of the STS System has been verified up to a maximum flow rate of 1.00 gpm.

** Include catch/detention basins, pipe(s) between basin(s) and STS Unit(s).

Appendix 7 - Heal the Bay's Water Quality Monitoring Data

Final Staff Report

Proposed Amendments to the Water Quality Control Plan for the Los Angeles Region (Basin Plan) to Incorporate Changes to the Total Maximum Daily Load (TMDL) for Bacteria in the Malibu Creek Watershed

December 13, 2004

Prepared By
Los Angeles Regional Water Quality Control Board

TABLE OF CONTENTS

FIGURES

TABLES

1. INTRODUCTION

On March 21, 2003, the United States Environmental Protection Agency (USEPA) established a Total Maximum Daily Load (TMDL) to reduce bacteria levels in Malibu Creek and Lagoon. The USEPA TMDL describes possible implementation measures, but does not include an implementation plan or schedule. On January 29, 2004, the Los Angeles Regional Water Quality Control Board (Regional Board) adopted an amendment to the Basin Plan to incorporate a TMDL for bacteria in the Malibu Creek watershed. If approved by the State Water Resources Control Board (State Board), the Office of Administrative Law, and USEPA, the Regional Board TMDL will supercede the USEPA TMDL. The Regional Board TMDL would allow 3 to 6 years for compliance with applicable bacteria water quality standards during dry-weather conditions, and 10 years for compliance during wet-weather conditions, or up to 18 years for wet weather, if an integrated water resources approach is pursued.

In addition, the implementation plan provides minimum prescriptive criteria for identifying high-risk areas, where onsite-wastewater treatment systems (OWTS) are potentially contributing to bacteria exceedances in the Malibu Creek watershed. Local agencies (city and county health departments and/or building departments) would be required to focus their efforts to monitor and require upgrades to OWTS located in high-risk areas. In addition to the areas falling within the high-risk areas, local agencies must also use their knowledge to identify other areas, outside of the high-risk areas, that are likely to impact surface water quality due to local conditions (e.g., fractured bedrock).

2. PURPOSE OF THIS DOCUMENT

The purpose of this document is to seek clarification from the Board on the minimum prescriptive criteria for identifying high-risk areas and to offer alternative criteria for the Board's consideration.

3. COMPLIANCE WITH CEQA

States must provide notice and opportunity for public hearing in accordance with the California Environmental Quality Act (Public Resource Code Section 21000). The Regional Board must comply with the requirements of the California Environmental Quality Act (CEQA) when adopting Basin Plan Amendments for water quality control. CEQA authorizes the Secretary of the Resources Agency to certify a regulatory program of a State agency as exempt from the requirements for preparing Environmental Impact Reports, Negative Declarations and Initial Studies if certain conditions are met. The process that the Regional

Board is using to adopt the proposed policy has received certification from the Resources Agency to be "functionally equivalent" to the CEQA process (Title 22, California Code of Regulations, Section 15251(g)). Therefore, the staff report for the Malibu Creek and Lagoon Bacteria TMDL, adopted on January 29, 2004, is a Functional Equivalent Document and fulfills the requirements of CEQA for preparation of an environmental document. The environmental impacts that could occur as a result of the proposed action are discussed in the Environmental Checklist.

An Environmental Checklist was prepared for the draft Malibu Creek Bacteria TMDL released on October 10, 2003. This Environmental Checklist was certified by the Regional Board's Executive Officer on October 10, 2003. Subsequently, the draft TMDL was revised and released on December 5, 2003. The Regional Board's Executive Officer certified this second Environmental Checklist on December 5, 2003, reflecting the revisions.

The changes proposed in this action are minor and relate only to how the local agencies prioritize their assessment and upgrades of OSWTs. The final requirements and time schedule remain unchanged, and the Environmental Checklist certified on December 5, 2003 reflects the potential impacts. A summary of the environmental impacts contained in the Environmental Checklist is provided below.

- **Earth.** Soil excavation during construction of storage, diversion or treatment facilities for storm water maybe required. In addition, the construction of storm water or wastewater collection and treatment facilities have the potential to, increase erosion during excavation. The proposal may result in changes in deposition and erosion of beach sands if a portion of stormwater is stored and diverted to treatment facilities, rather than discharging directly to the creek or lagoon.

- **Water**. A change in surface water movement, drainage and infiltration patterns may occur, if compliance with the TMDL is achieved in part through diversion of storm water from open channels to treatment facilities. Also, on-site retention and treatment of stormwater may increase infiltration.

- **Noise.** The proposal may result in temporary increases in existing noise levels, particularly in the case of construction of facilities for stormwater or wastewater management.

- **Land Use.** The proposal may result in the change of land use of an area to provide land for construction of facilities for storm water or wastewater management.

- **Risk of Upset.** If used for disinfection, chlorine gas could pose a significant health risk in the event of an accidental release. However, many alternative disinfection processes are available including treatments with sodium hypochlorite, ultra violet light and ozone treatment.

- **Housing.** Existing housing served by onsite wastewater treatment systems maybe subject to system upgrades.

- **Transportation/Circulation.** Depending on the implementation strategy chosen, the proposal may result in temporary alterations to present traffic patterns during construction of storm water diversion or wastewater treatment facilities.

- **Public Service.** The proposal may result in the need for increased maintenance of public facilities and, specifically, storm water diversion facilities or structural best management practices (BMPs) or a centralized wastewater treatment system. The proposal will result in the need for increased bacteriological monitoring at Malibu Creek and Lagoon to track compliance with the TMDL and increased regulation of onsite sewage treatment systems.

- **Utilities and Service Systems.** Depending on the method used to implement the TMDL, upgraded wastewater treatment systems or the construction and operation of a centralized wastewater treatment system may require additional power to operate pumps, treatment equipment and/or ancillary facilities. In order to achieve compliance with the TMDL, onsite sewage treatment systems that affect water quality in Malibu Creek and Lagoon may need to be repaired, upgraded, replaced and/or adequately maintained. In order to achieve compliance with the TMDL, storm water drainage systems may need to be upgraded or re-configured to divert and/or capture and treat a portion of storm water that affects water quality in Malibu Creek and Lagoon.

- **Recreation.** Implementation of the TMDL will have a positive impact on the quality and quantity of recreational opportunities by reducing the number of days that exceed bacteriological water quality objectives in Malibu Creek and Lagoon.

Many of the environmental adverse impacts listed above are short-term construction related impacts, which may be necessary to achieve the long-term environmental benefits of implementing the Region's bacteria objectives and the TMDL for Bacteria and thereby protecting the health of swimmers, surfers, and others who contact the water in, and adjacent to at Malibu Creek and Lagoon.

4. BACKGROUND

The initial draft of the Malibu Creek and Lagoon Bacteria TMDL was released for public comment on October 10, 2003. The Notice of Public Hearing was mailed to all interested persons on the Malibu Creek watershed mailing list, totaling 92 individuals and organizations. Copies of the proposed resolution, Basin Plan amendment, draft staff report with attachments, California Environmental Quality Act (CEQA) checklist, and Notice of Filing were posted on the Regional Board website. Furthermore, Notice of Public Hearing was published in the Los Angeles Times, a newspaper of general circulation, on October 10, 2003. Regional Board staff conducted a workshop and CEQA Scoping meeting to solicit comments on the October 10, 2003 draft TMDL. The meeting and workshop were held at the City of Malibu City Council Chambers on October 22, 2003. A second workshop was conducted at the regularly scheduled Regional Board meeting on November 6, 2003. All interested persons were given until November 26, 2003, to submit written comments to the Regional Board on the proposed TMDL.

The October 2003 draft TMDL and the CEQA checklist were revised in response to comments received and direction from the Board. The revised documents were released for public comment on December 5, 2003. The Notice of Public Hearing was mailed to all interested persons and organizations on the Malibu Creek watershed mailing list. Copies of the proposed resolution, Basin Plan amendment, draft staff report with attachments, California Environmental Quality Act (CEQA) checklist, and Notice of Filing were posted on the Regional Board website. Furthermore, Notice of Public Hearing was published in the Los Angeles Times, a newspaper of general circulation, on December 6, 2003. All interested persons were given until January 20, 2004 to submit written comments to the Regional Board on the proposed TMDL.

In response to comments, staff proposed additional clarifying language in the TMDL implementation plan presented to the Board on January 29, 2004. These changes added language to the basin plan amendment Table 7-10.3 to provide guidance to responsible jurisdictions and agencies on the elements to be included in the implementation workplan to be submitted to the Regional Board. These changes were to:

(1) provide the responsible agencies with the option of conducting a reference watershed water quality study,
(2) encourage an integrated water resources approach by providing an option of up to 18 years for implementation of wet-weather compliance,
(3) submittal by responsible agencies of a description of all steps to be taken to meet the 3-year summer dry-weather compliance schedule within one year of the TMDL effective date,

(4) specific conditions which must be met by responsible agencies when requesting an extension to the summer dry-weather and/or a wet-weather compliance date,
(5) submittal of a written report by responsible agencies to the Regional Board staff which details the rational and criteria used to identify high-risk areas where OWSTs have the potential to impact surface water, and
(6) criteria designating OWTS located in areas where there is less than 10-ft separation between the bottom of the disposal field and historical groundwater as high risk.

On January 29, 2004, the Regional Board held a public hearing at the regularly scheduled Board meeting, conducted at the City of Simi Valley City Council Chambers, to receive comments on the draft TMDL, as revised. A strikeout copy of the TMDL, highlighting the most recent changes, a summary of comments received, and staff's responses to comments were made available to the public at the Board meeting, prior to the public hearing.

Following the public hearing, the Board made additional changes before adopting the TMDL (Resolution No. 2004-019). These changes were a logical outgrowth of the comments made and subsequent discussion by the Board members. The changes included adding additional minimum criteria for identifying high-risk areas or OWTS. The language was added to Attachment A of the Tentative Resolution, page 10, Table 7-10.3, paragraph 3. The additional criteria were:

> ". . . areas where OWTS are located less-than-250 foot from a 303(d) listed waterbody, or located in areas of a documented nitrate or human bacteria problem in the surface or groundwater."

On April 16, 2004 a draft of this staff report, revised tentative resolution and draft Basin Plan amendment were released and a Notice of Public Hearing were mailed to all interested persons on the Malibu Creek watershed mailing list. Copies of the staff report and Notice of Filing were posted on the Regional Board website. Furthermore, the Notice of Public Hearing was published in the Los Angeles Times on April 16, 2004. All interested persons were given until May 26, 2004, to submit written comments to the Regional Board on the proposed changes outlined in the draft staff report. Regional Board staff received comments for the County of Los Angeles Department of Publics Works (LADPW). The Regional Board was scheduled to consider the proposed changes at the June 10, 2004 Board Meeting. However prior to the Board meeting the City of Malibu announced the release of its draft study entitled, "Risk Assessment of Decentralized Wastewater Treatment Systems in High Priority Areas in the City of Malibu California" referred to herein as "the Malibu Study." Action on this item was postponed to allow staff time to consider the Malibu Study.

The draft Malibu Study was made available to the public in June 2004. The purpose of the study was to evaluate the environmental impacts of the current and future level of OWTS in the Malibu Creek and Lagoon subwatershed. The study delineated the contributing areas and high-risk areas. The term "contributing areas" refers to the portion of an aquifer that flows from a source of recharge to an area of discharge (Stone Environmental Inc, 2004). The source of recharge in this instance is the Malibu alluvium and the area of discharge is Malibu Creek and Lagoon. High-risk areas are areas where OWTS have the greatest potential to impact ground or surface water. Examples of such areas include high-density subdivisions, soils with high permeability or areas with shallow water tables. The extent of the high-risk area may vary depending in the mobility and the persistence of the pollutant of concern. The high-risk area for bacteria in the Malibu study was delineated as that portion of the Malibu alluvium with a groundwater time of travel of less than 6 months (see Figure 3). The study used travel time in groundwater as a criteria for bacterial (Stone Environmental Inc, 2004). Pathogenic bacteria typically survive only for a few weeks to a few months outside of their hosts. A six-month time of travel was identified as the high-risk criteria on which the City of Malibu plans to focus the OWTS management (Stone Environmental Inc, 2004). OWTS within the high-risk area will be required to upgrade their systems as necessary to demonstrate compliance with applicable effluent limits or receiving water quality objectives (RWQCB, 2004).

The Malibu Study demonstrates that the boundaries of the contributing and high-risk areas vary substantially based on site specific geology, pollutant fate and transport and depending on whether the lagoon is breached or open. As shown in Figure 3 and 4, the setback for the stream may range from 50 to 500 ft. for bacteria and 300 ft. to 2600 ft. for nitrogen. The differences in the setback distances are also related to the differences between the fate and transport of bacteria and nitrogen in the groundwater. Bacteria concentrations are reduced primary by die-off, while nitrogen concentrations are reduced primarily by denitrification.

Although the Regional Board staffs views this study as an excellent initial step, staff recommends that work continue to refine the estimated contributing areas for bacteria and nutrients. Specifically, the Regional Board staff recommended including site-specific conductivity and nitrogen transformation data, as well as, an extended calibration period for the model used to estimate the contributing and high-risk areas (RWQCB, 2004a).

5. CLARIFICATION

Staff is seeking clarification on two sections of Resolution 2004-019, Attachment A as adopted by the Regional Board on January 29, 2004.

Table 7-10.3, "1 year after the effective date of this TMDL"; paragraph 3.

- Staff assumes that the "250-foot setback from a 303(d) listed waterbody" means a waterbody listed on the 303(d) list due to exceedances of bacteria. Waterbodies within the Malibu Creek watershed are listed on the 303(d) list for a variety of pollutants including bacteria, nutrients, algae, heavy metals, and pesticides. Since this TMDL only addresses bacteria impairments, staff assumes that the reference to a 303(d)listed waterbody is a reference to waterbodies listed due to exceedances of bacteria water quality objectives. For informational purposes Figures 1 and 2 depict the Malibu Creek water bodies listed on the 303(d) list for bacteria and for nutrient related impairments, respectively. [Note: If the Regional Board decides that prescriptive criteria are no longer preferred, then clarification is not needed].

- Regional Board staff recommends a clarification in the requirement for OWTS in high-risk areas. The amendment as adopted by the regional Board in January (Table 7-10.3, row 2, paragraph 3) would appear to require OWTS in high-risk areas to install disinfection systems. However, staff recognizes that alternative systems (e.g., expanded leach fields, mound systems, etc.) may also be used to meet bacteria water quality objectives. Staff offers the following language for the Board's consideration:

  > "...OWTS located in high-risk areas are subject to upgrades as necessary to demonstrate compliance with applicable effluent limits and/or receiving water quality objectives."

6. ALTERNATIVES ANALYSIS:

Reconsideration of Prescriptive Criteria for Identifying High Risk Areas

Staff is requesting the Board to re-consider the minimum prescriptive criteria for identifying high-risk areas or OWTS. Staff acknowledges that local agencies will need to assess which of the approximate 2,400 OWTS within the watershed are most likely contributing to bacteria impairment. However, establishing prescriptive minimum criteria may divert local agency resources from other areas that may in fact be of greater risk due to local, site-specific conditions. If minimum prescriptive criteria are preferred, staff offers alternative criteria that are founded in existing codes and regulations. Staff notes that a 600-foot setback from a 303(d) listed waterbody is being considered by State Board staff involved in developing management / risk levels to be incorporated into the statewide regulation of OWTS. However, these regulations are in the development stage, and final adoption is not expected for several months. Staff has also provided non-prescriptive alternative criteria for the Board's consideration. These alternatives are either codified in other state and local regulations or are consistent with the Draft General WDRs prepared by Regional Board staff.

Staff identified four alternatives for establishing minimum criteria for identifying high-risk areas for the Malibu Creek Watershed. These options and a brief discussion of the potential consequences of each are provided as follows:

Watershed-wide High Risk Criteria

1) No action –The amendment will be forwarded as is to the State Water Resources Control Board for approval. The public will have another opportunity to comment on the draft TMDL at a workshop, prior to the State Board's action.

2) No minimum prescriptive criteria – This alternative would give the responsible agencies the opportunity to identify the high-risk areas based on local knowledge and site specific studies. As an initial step, staff suggests that the responsible jurisdiction screen for high-risk areas by conducting weekly surface water monitoring upstream and downstream of OWTS clusters. Areas where bacteria and/or nitrogen levels are statistically higher in downstream samples versus upstream samples would be considered high-risk. A groundwater monitoring study, similar to the Malibu Study, could be performed to identify the boundaries of the contributing and high-risk areas. The Regional Board staff would expect any groundwater risk assessments to contain similar elements (e.g., scope of work) as the risk assessment conducted by the Malibu Study.

   The benefit of such a study is that it provides the Regional Board with a scientifically based assessment that considers the site-specific characteristics of the study area and the receiving waterbody. It protects homeowners from being required to install potentially expensive upgrades in cases where they are not warranted and ensures that upgrades will result in water quality improvements. However, this alternative may, especially where groundwater monitoring is performed, require the responsible jurisdictions undertake a potentially costly study, which may take in excess of one year to complete.

3) Revised Prescriptive Criteria based on California Plumbing Code- Replace the existing minimum prescriptive criteria with 100 feet from Malibu Creek, Malibu Lagoon, or any surface water tributary thereto[1]. This alternative would

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[1] Staff would recommend that any setback be applied to all waterbodies because many waterbodies in the watershed have not been adequately monitored for bacteria. Local agencies are encouraged to monitor to confirm impairment before requiring system upgrades.

identify "high risk OWTS" as systems in the Malibu Creek watershed that do not meet the minimum siting criteria for seepage pits or cesspools. (horizontal distances from a streams) as contained in the California Plumbing Code and the local plumbing codes (see Table 1 on page 9). The criteria for seepage pits was selected as it provides the most stringent set-back criteria of all systems (e.g., setback criteria for septic tanks and leach fields is 50 feet from a surface water as compared to 100 feet for seepage pits). This alternative adopts a number that represents widespread consensus among health department officials and incorporates a margin of safety, by applying the most stringent setback to all types of systems. Under this alternative, this setback would be applied to all surface water bodies that are tributary to Malibu Creek or Lagoon, and would not be limited to waterbodies specifically listed on the 303(d) list. However, it should be noted that a 100 foot setback may not be protective in all areas. As demonstrated by the groundwater risk assessment conducted by the City of Malibu, OWTS areas contributing bacteria to a stream are dependent on site specific conditions. For example, the bacteria contributing area for the Malibu Lagoon changes based on whether the lagoon is closed or breached. In addition, when the lagoon is closed, the contributing areas in some stream segments are farther than 100 feet. Although the lagoon is a special case because of the tidal dynamics, it does illustrate that a "one size fits all" approach may not be appropriate for some waterbodies.

4) Revised Prescriptive Criteria based on Tentative General Waste Discharge Requirements for Residential Onsite Wastewater Treatment Systems

Replace the existing minimum prescriptive criteria with those contained in the most recent draft of the tentative WDRs for residential OWTS: High Risk Discharges are defined in the tentative WDRs as discharges from residential onsite wastewater treatment system:

- having less than a five foot vertical separation to groundwater, or
- having less than a 600 foot setback from a water body identified as impaired under section 303(d) of the Clean Water Act, or
- having less than 600 foot setback from a water supply well where the subsurface consists of alluvial material, or
- having less than 900 foot setback from a water supply well where subsurface geology consist of fractured bedrock, or
- located in an area with documented nitrate or bacterial contamination of the surface or groundwater, or
- located in an area designated as a significant aquatic, ecological area in the Basin Plan.

This definition of high-risk discharges contained in the tentative WDR is based on the latest informal draft of the State OWTS regulations. The informal draft State OWTS regulations are still in the formative stages and have not been released for public comment. The criteria contained in the informal draft are likely to change prior to final adoption.

7. STAFF RECOMMENDATION

Staff recommends Alternative 2 with the clarifying language provided in Section 5. Alternative 2 is the recommended alternative for providing a minimum standard for identifying high-risk areas where OWTS have a potential to impact surface waters in the Malibu Creek watershed. Alternative 2 should provide a higher assurance that systems contributing to water quality impairments will be upgraded and unnecessary upgrades will be avoided. Using a prescriptive requirement such as a 250 or 100-foot setback assumes that the site conditions are uniform throughout a given jurisdiction; which is not the case. A groundwater risk assessment that considers the site-specific conditions such as subsurface geology and OWTS density can more accurately assess impacts from OWTS. Therefore staff recommends the following change to Table 7-10.3, paragraph 3 of the adopted basin plan amendment:

Delete the following language:

~~3. Local agencies regulating on-site wastewater treatment systems shall provide a written report to the Regional Board detailing the rationale and criteria used to identify high-risk areas where on-site systems have a potential to impact surface waters in the Malibu Creek watershed. On-site wastewater treatment systems located in areas where there is (1) less than 10 ft separation between the bottom of the disposal field and historical groundwater, or (2) located less than 250 foot setback from a 303(d) listed waterbody, or (3) located in areas of a documented nitrate or human bacterial problem in the surface or groundwater are considered high risk and are subject to disinfection requirements unless further assessment demonstrates that the systems are not impacting surface waters in the Malibu Creek watershed. Such demonstrations may include regional or site-specific groundwater monitoring or weekly upstream/downstream surface water monitoring,~~

Insert the following language:

3. Local agencies regulating on-site wastewater treatment systems shall provide a written report to the Regional Board's Executive Officer detailing the rationale and criteria used to identify high-risk areas where on-site systems have a potential to impact surface waters in the Malibu Creek watershed. Local agencies may use the approaches outline in (a) and (b), or an alternative approach as approved by the Executive Officer.

(a) Responsible agencies may screen for high-risk areas by establishing a monitoring program to determine if discharges from OWTS have impacted or are impacting water quality in Malibu Creek and/or its tributaries. A surface water monitoring program demonstration must include monitoring locations upstream and downstream of the discharge, as well as a location at mid-stream (or at the approximate point of discharge to the surface water) of single or clustered OWTS. Surface water sampling frequency will be weekly for bacteria indicators and monthly for nutrients.

(b) Responsible agencies may define the boundaries of high-risk or contributing areas or identify individual OWTS that are contributing to bacteria water quality impairments through groundwater monitoring or through hydrogeologic modeling as described below:

(1) Groundwater monitoring must include monitoring in a well no greater than 50-feet hydraulically downgradient from the furthermost extent of the disposal area, or property line of the discharger, whichever is less. At a minimum, sampling frequency for groundwater monitoring will be quarterly. The number, location and construction details of all monitoring wells are subject to approval of the Executive Officer.

(2) Responsible agencies may use a risk assessment approach, which uses hydrogeologic modeling to define the boundaries of the high-risk and contributing areas. A workplan for the risk assessment study must be approved by the Executive Officer of the Regional Board.

4. OWTS located in high-risk areas are subject to system upgrades as necessary to demonstrate compliance with applicable effluent limits and/or receiving water objectives.

Figure 1 - Bacteria Impaired Streams

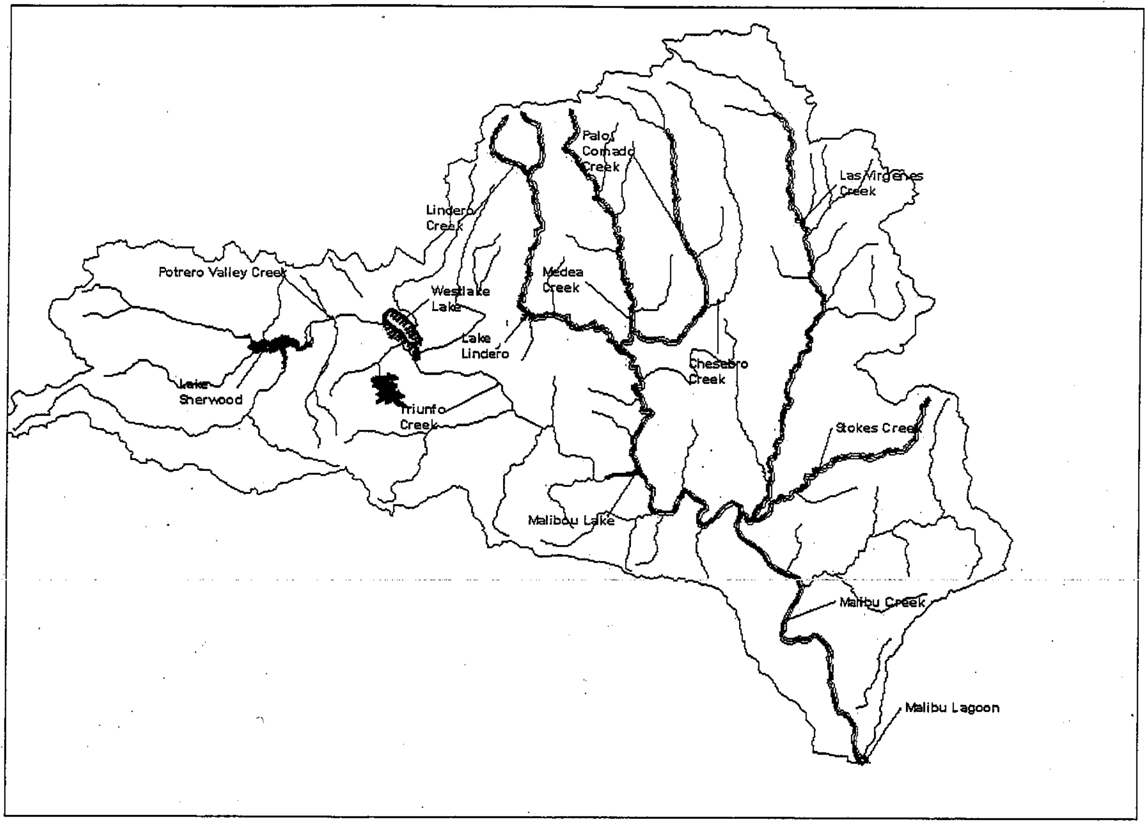

Figure 2 - Nutrient Impaired Waterbodies

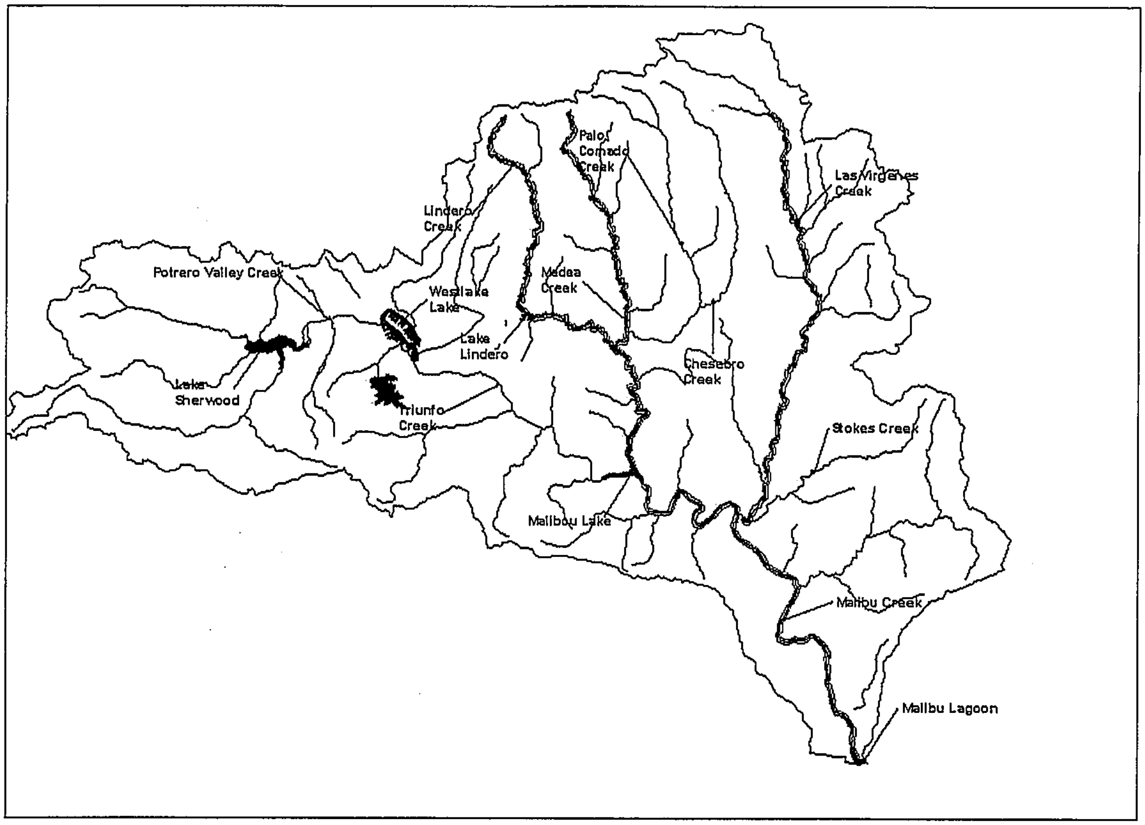

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Figure 3 - City of Malibu High-Risk Area for Bacteria

Figure 4 - City of Malibu High-Risk Area for Nitrogen

Table 1 - Location Distance Criteria for OWTS

Plumbing Code	Required Distance (feet)[2]		
	Streams	Water Supply wells	Groundwater
State of California[3]	100	150	10
City of Los Angeles[4]	100	150	10
County of Los Angeles[5]	100	150	10

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[2] The criteria used is for seepage pits or cesspools is used for the minimum distances in this table.

[3] California Plumbing Code, California Code of Regulations Title 24, Part 5

[4] City of Los Angeles Municipal Code, Section 94.1600.1, Appendix K.1 Private Sewage Disposal

[5] Los Angeles County Code, Title 28 Plumbing Code, Appendix K1 Private Sewage Disposal - General

8. REFERENCES

Stone Environmental Inc., 2004, Draft Risk Assessment of Decentralized Wastewater Treatment Systems in High Priority Areas in the City of Malibu California.

Los Angeles Regional Water Quality Control Board, 2004a, Memorandum of Understanding between LARWQCB and the City of Malibu regarding Onsite Wastewater Treatment Systems.

Los Angeles Regional Water Quality Control Board, 2004b, Letter to the City of Malibu entitled, Review of the Final draft Report Risk Assessment of Decentralized Waste Water Treatment Systems in high Priority Areas in the City of Malibu, dated July 14, 2004.

CALIFORNIA DEPARTMENT OF FISH AND GAME

CERTIFICATE OF FEE EXEMPTION

De Minimus Impact Finding

Project Title:	Amendment to the Water Quality Control Plan for the Los Angeles Region to incorporate a Total Maximum Daily Load (TMDL) for Bacteria in Malibu Creek and Lagoon
Project Location:	Malibu Creek Watershed spanning portions of the County of Los Angeles, County of Ventura, and the cities of Malibu, Thousand Oaks, Westlake Village, Agoura Hills, Calabasas and Hidden Hills.
Project Proponent:	California Regional Water Quality Control Board, Los Angeles Region 340 W. 4th Street, Suite 200, Los Angeles, CA 90013.

Project Description:

The amendment incorporates into the *Water Quality Control Plan for the Los Angeles Region* (Basin Plan) a TMDL to reduce bacteria in Malibu Creek and Lagoon. The Regional Board's goal in incorporating the above-mentioned TMDL is to reduce the risk of illness associated with swimming in waters contaminated with human sewage and other sources of bacteria. Swimming in waters with elevated bacteria densities has long been associated with adverse health effects. Local and national epidemiological studies compel the conclusion that there is a causal relationship between adverse health effects, such as gastroenteritis, and recreational water quality, as measured by bacteria indicator densities.

Elevated bacterial indicator densities are causing impairment of the water contact recreation (REC-1) beneficial use in the Malibu Creek watershed. The Regional Board has prepared this TMDL to address the documented bacteriological water quality impairments.

The TMDL establishes a phased 10-year plan for reducing the number of days that exceed REC-1 bacteriological objectives in Malibu Creek and Lagoon such that (1) bacteriological water quality is as good as that of a "reference" beach (i.e., a beach with a largely natural drainage area) and (2) no degradation of existing water quality occurs. The purpose of this project is to remove the bacteriological water quality impairments that prevent several streams in the Malibu Creek Watershed from supporting the REC-1 beneficial use. It involves holding jurisdictions within the watershed jointly accountable for storm water discharges from their storm drains and onsite sewage treatment systems, and encourages the use of a variety of methods to prevent these discharges. The Regional Board may extend the wet-weather compliance date up to July 15, 2021 at the Regional Board discretion, by adopting a subsequent Basin Plan amendment that complies with applicable law.

The TMDL includes a "reference system/antidegradation approach" in recognition that natural sources of bacteria may cause or contribute to exceedances of the single sample objectives. The intent of the proposed action is to ensure that bacteriological water quality is at least as good as that of a reference site.

Findings of Exemption: (See attached CEQA Checklist).

This project will improve bacteriological water quality in the Malibu Creek Watershed and will have no negative impact on the environment.

Certification;

I hereby certify that the California Regional Water Quality Control Board, Los Angeles Region, has made the above findings of fact and that based upon the Environmental Checklist and written report and hearing record, the project will not individually or cumulatively have an adverse effect on wildlife resources as detailed in Section 711.2 of the Fish and Game Code.

Jonathan Bishop
Executive Officer
California Regional Water Quality Control Board
Los Angeles Region

1/24/06
Date

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LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD

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LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD

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		➢ Abrol, S., Augustenborg, C., Madden, C., Suffet, M. 2003. Development of a TMDL for Organochlorine Pesticides for the Calleguas Creek Watershed. Prepared for the Los Angeles Regional Water Quality Control Board. Contract No. 01-172-140-0. September 2003.	13-1 to 13-56

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		➢ Anderson, B.S., Vlaming, V. DE, Larsen, K., Deanovic, L.S., Birosik, S., Smith, D.J., Hunt J.W., Phillips B.M., Tjeerdema R.S. 2002. Causes of Ambient Toxicity in the Calleguas Creek Watershed of Southern California. *Environmental Monitoring and Assessment*. 78, 131-151.	13-115 to 13-156
		➢ Anderson, B.S. 2004. Moss Landing Marine Laboratory. Personal communication with C. Minton, November 30, 2004.	13-137 to 13-138
		➢ Anderson, T. D. and Lydy, M. J. 2002. Increased toxicity to invertebrates associated with a mixture of atrazine and organophosphate insecticides. Environ. Tox. and Chem. V21, No. 7, 1507–1514.	13-139 to 13-146
		➢ Bailey, H.C., DiGiorgio, C., Kroll, K., Miller, J.L., Hinton, D.E., Starrett, G. 1996. Development of Procedures for Identifying Pesticide Toxicity in Ambient Waters: Carbofuran, Diazinon, Chlorpyrifos. Environ. Tox. and Chem. V15, No. 6, 837–845.	13-147 to 13-156
		➢ Bailey, H. C., Elphick, J. R., Krassoi, R., Lovell, A. 2001: Joint Acute Toxicity of Diazinon and Ammonia to Ceriodaphnia dubia. Environ. Tox. and Chem. V20, No. 12, 2877–2882.	13-157 to 13-162
		➢ Callaghan, A., G. Hirthe, et al. 2001. "Effect of Short-Term Exposure to Chlorpyrifos on Developmental parameters and Biochemical Biomarkers in Chironomus riparius Meigen. " Ecotoxicology and Environmental Safety 50(1): 19-24.	13-163 to 13-164
		➢ California Department of Fish and Game (CDFG). 2000. Water Quality Criteria for Diazinon and Chlorpyrifos. California Department of Fish and Game Administrative Report 00-3. 65pp.	13-165 to 13-246

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		➢ California Resources Agency. 1997. CWIS Mugu Lagoon. California Environmental Resources Evaluation System (CERES). Website visited January 2001: http://ceres.ca.gov/wetlands/geo_info/so_cal/mugu_lagoon.html	13-249 to 13-262
		➢ Central Valley Regional Water Quality Control Board (CVRWQCB). 2001. Diazinon and Chlorpyrifos Target Analysis – Draft.	13-263 to 13-332
		➢ Central Valley Regional Water Quality Control Board (CVRWQCB). 2004. Total Maximum Daily Load (TMDL) Report for the Pesticides Diazinon and Chlorpyrifos in: Arcade Creek, Elder Creek, Elk Grove Creek, Morrison Creek, and Chicken Ranch and Strong Ranch Sloughs Sacramento County, California –Final Staff Report.	13-333 to 13-402
		➢ City of Camarillo. 1997 – 2000. Camarillo Wastewater Treatment Plant NPDES Annual Reports.	13-483
		➢ City of Thousand Oaks. 1997 – 2001. Olsen Road and Hill Canyon Wastewater Treatment Facility NPDES Annual Reports.	13-484
		➢ Code of Federal Regulations (CFR). 2000. 40 Code of Federal Regulations Part 130 (TMDL Rule).	13-485 to 13-494
		➢ Granade, Steve. 2003. Environmental Engineer, Naval Base Ventura County. steve.granade@navy.mil. Personal communication with C. Minton, August 4, 2003.	13-495 to 13-498
		➢ Grigorian, Grigor. 2001. Personal communication with A. Cooper. January 18, 2001.	13-499 to 13-502
		➢ Helsel, D.R. and T.A. Cohn. 1988. Estimation of Descriptive Statistics for Multiply Censored Water Quality Data, Water Resour. Res. Vol. 24, No. 12, pp. 1997-2004.	13-503 to 13-510

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		➢ Helsel, D.R. 1990. Less than obvious: Statistical treatment of data below the detection limit. Environ. Sci. Technol., Vol. 24, No. 12., pp. 1766-1774.	13-511 to 13-520
		➢ Helsel D.R. and R.M. Hirsch. 1992. Statistical Methods in Water Resources, Elsevier Science B.V., Amsterdam.	13-521 to 13-550
		➢ Landis, J. D. PhD, Chair of the City and Regional Planning at the University of California, Berkeley (with Juan Pablo Monzon, Michael Reilly, and Chris Cogan). 1998. Development and Pilot Application of the California Urban and Biodiversity Analysis Model, forthcoming in Computers, Environment, and Urban Systems, http://gis.esri.com/library/userconf/proc98/PROCEED/TO600/PAP571/P571.htm	13-551 to 13-562
		➢ Keller, A.A., Y. Zheng, and T.H. Robinson.2004. Determining Critical Water Chemistry Conditions for Inorganic Nitrogen in Dry, Semi-Urbanized Watersheds. J. American Water Res. Assoc., V 40, n 3, pp, 721-735.	13-563 to 13-578
		➢ Larry Walker Associates (LWA). 2000. Calleguas Creek Characterization Study. Results of the Coordinated Water Quality Monitoring Program, Surface Water Element.	13-579 to 13-770
		➢ Larry Walker Associates (LWA). 2004a. Calleguas Creek Watershed Database. Accessed December 6, 2004.	13-771 to 13-772
		➢ Larry Walker Associates (LWA). 2004b. Progress Report on Efforts to Address Salts on the Calleguas Creek Watershed, submitted to Calleguas Creek Watershed Management Plan, pp. 105, June 30, 2004.	13-773 to 13-1214
		➢ Los Angeles Regional Water Quality Control Board (LARWQCB). 1996 Water Quality Assessment and Documentation. 1996.	13-1215 to 13-1298
		➢ Los Angeles Regional Water Quality Control Board (LARWQCB). 1998. Public Notice – Biennial Listing of Impaired Surface Waters – Pursuant to the Clean Water Act Section, Section 303(d). March 24, 1998.	13-1299 to 13-1346
		➢ Los Angeles Regional Water Quality Control Board (LARWQCB). 2002a. Draft Staff Report – 2002 Update: Clean Water Act Section 305(b) Report and Section	13-1347 to 13-1372

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		303(d) List of Impaired Waters – LA Region. January 29, 2002.	
		➢ Los Angeles Regional Water Quality Control Board (LARWQCB). 2002b. Total Maximum Daily Loads for Nitrogen Compounds and Related Effects Calleguas Creek, Tributaries, and Mugu Lagoon – Staff Report.	13-1373 to 13-1476
		➢ Los Angeles Regional Water Quality Control Board (LARWQCB). 2003. 2002 Clean Water Act Section 303(d) List of Water Quality Limited Segments.	13-1477 to 13-1530
		➢ McIntyre, Sam. 2004. Pesticide Advisor, Somis Ag Management Inc. sompacag@aol.com . Personal communication with M. Casterline, May 2004.	13-1531 to 13-1532
		➢ Mackay, D., W.Y. Shiu, K.C. Ma.1997. Illustrated handbook of physical-chemical properties and environment fate for organic chemicals, CRC Press, Lewis Publishers, Boca Raton, FL	13-1533 to 13-1560
		➢ Majewski, M.S., D.S. Baston. 2002. Atmospheric Transport of Pesticides in the Sacramento, California, Metropolitan Area, 1996-1997. USGS Report 02-4100.	13-1561 to 13-1624
		➢ Javier Minjares, Southern California Association of Governments, Population Growth by City for SCAG Region for 2000-2030 (pre-website release of population projections), minjares@scag.ca.gov.	13-1625 to 13-1626
		➢ National Research Council (NRC). 2001. Assessing the TMDL Approach to Water Quality Management. Committee to Assess the Scientific Basis of the Total Maximum Daily Load Approach to Water Pollution Reduction. Water Science and Technology Board, Division on Earth and Life Studies. National Academy Press, Washington, DC.	13-1627 to 13-1644
		➢ Natural Resources Conservation Service (NRCS). 1995. Calleguas Creek Watershed Erosion and Sediment Control Plan for Mugu Lagoon.	13-1645 to 13-1804
		➢ Neter, J., W. Wasserman, and M.H. Kutner. 1990. Applied Linear Statistical Models Regression, Analysis of Variance, and Experimental Design, 3rd Ed., Irwin, Homewood, IL.	13-1805 to 13-1820

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		➢ Ross, L. 2002. Department of Pesticide Regulation, personal communication.	13-1821 to 13-1822
		➢ San Francisco Bay Regional Water Quality Control Board (SFBRWQCB). 2004. Diazinon and Pesticide-Related Toxicity in Bay Area Urban Creeks Water Quality Attainment Strategy and Total Maximum Daily Load – Final Project Report.	13-1823 to 13-1944
		➢ Schimmel, S.C., B.D. Melzian, D.E. Campbell, C.J. Strobel, S.J. Benyi, J.S. Rosen, H.W. Buffum, and N.I. Rubinstein. 1994. Statistical Summary EMAP-Estuaries Virginian Province - 1991. EPA /620/R-94/005.	13-1945 to 13-2034
		➢ Southern California Association of Governments (SCAG). 2004. Urban land use GIS data. Website visited June 2004: http://rtmisweb.scag.ca.gov/data_gis/ .	13-2035 to 13-2036
		➢ State Water Resources Control Board (SWRCB). 1996. Marine Bioassay Project-Eighth Report-Refinement and Implementation of Four Effluent Toxicity Testing methods Using Indigenous marine Species. July 1996.	13-2037 to 13-2186
		➢ State Water Resources Control Board (SWRCB). 1997. Proposed Decision Regarding Application 29408 and Wastewater Change Petition No. 6 of the City of Thousand Oaks and Availability of Unappropriated Water for Applications 29816, 29819, 29581, 29959, 300317, 30092, and 30194--Arroyo Conejo, Conejo Creek, and Calleguas Creek in Ventura County. Sacramento, California. August 1997.	13-2187 to 13-2250
		➢ State Water Resources Control Board (SWRCB). 1998. Sediment Chemistry, Toxicity, and Benthic Community Conditions in Selected Water Bodies of the Load Angeles Region. August 1998.	13-2251 to 13-2500
		➢ State Water Resources Control Board (SWRCB). 2000. Policy for Implementation of Toxics Standards for Inland Surface Waters, Enclosed Bays, and Estuaries of California (SIP). May 2000.	13-2501 to 13-2570
		➢ State Water Resources Control Board (SWRCB). 2004a. State Mussel Watch Program (SMWP) website visited August 2004:	13-2571

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		http://www.swrcb.ca.gov/programs/smw/index.html.	
		➢ State Water Resources Control Board (SWRCB). 2004b. Toxic Substances Monitoring Program (TSMP) website visited August 2004: http://www.swrcb.ca.gov/programs/smw/index.html.	13-2572
		➢ State Water Resources Control Board (SWRCB). 2004c. Water Quality Control Policy For Developing California's Clean Water Act Section 303(D) List. September 30th, 2004.	13-2573 to 13-2610
		➢ Stow, C.A. and M.E. Borsuk. 2003. Assessing TMDL Effectiveness Using Flow-Adjusted Concentrations: A Case Study of the Neuse River, North Carolina, Environ Sci. Technol., V 37, 2043-2050.	13-2611 to 13-2618
		➢ Tchobanoglous, G. and Schroeder, E. 1985. Water Quality: Characteristics, Modeling, Modification, Addison-Wesley Publishing Company, Reading, MA.	13-2619 to 13-2636
		➢ Tetra Tech. 2000. Final Phase 1 Remedial Investigation Technical Memorandum. Naval Air Weapons Station, Point Mugu, California.	13-2637 to 13-2638
		➢ Tetra Tech. 2003. Draft Ecological Risk Assessment Addendum for Installation Restoration Program Sites 5 and 11. Naval Base Ventura County, Point Mugu Site, California.	13-2639 to 13-2874
		➢ Thursby, G.B. and C.E. Schlekat. 1993. Statistical analysis of 10-day solid phase toxicity data for amphipods. Abstract, 14th Annual Meeting, Society of Environmental Toxicology and Chemistry.	13-2875 to 13-2880
		➢ Thompson, B., Anderson, B., Hunt, J., Taberski, K., Phillips, B. 1997. Relationship Between Sediment Toxicity and Contamination in San Francisco Bay. Prepared for the San Francisco Estuary Institute.	13-2881 to 13-2904
		➢ United States Census Bureau (USCB). Website visited May 2004: http://www.census.gov/population/projections/state/stpjpop.txt	13-2905 to 13-2906
		➢ United States Geological Survey (USGS). 2004. Letter from Chris Ingersoll (USGS) to Lenwood Hall (University	13-2907 to 13-2910

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		of Maryland). Subject line: Diazinon toxicity data for Gammarus fasciatus reported in Johnson and Finley (1980) and in Mayer and Ellersieck (1986).	
		➢ United States Department of Health and Human Services (USDHHS). 1996. Toxicological Profile for Diazinon.	13-2911 to 13-3156
		➢ United States Environmental Protection Agency (USEPA). 1980. Ambient Water Quality Criteria for DDT. Office of Water Regulations and Standards. EPA 440/5-80-038.	13-3157 to 13-3332
		➢ United States Environmental Protection Agency (USEPA). 1985. Guidelines for Deriving Numeric National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses. Office of Research and Development PB85-227049.	13-3333 to 13-3438
		➢ United States Environmental Protection Agency (USEPA). 1986. Ambient Water Quality Criteria for Chlorpyrifos – 1986. Office of Water 440/5-005.	13-3439 to 13-3510
		➢ United States Environmental Protection Agency (USEPA). 1991. Technical Support Document for Water Quality Based Toxics Control. EPA/505/2-90-001	13-3511 to 13-3536
		➢ United States Environmental Protection Agency (USEPA). 1999. Reregistration Eligibility Science Chapter for Chlorpyrifos, Fate and Environmental Risk Assessment Chapter. US Environmental Protection Agency, Washington, D.C. October, 1999; revised June 2000	13-3537 to 13-3630
		➢ United States Environmental Protection Agency (USEPA). 2000a. Draft Ambient Aquatic Life Water Quality Criteria for Diazinon. Office of Water Draft.	13-3631 to 13-3720
		➢ United States Environmental Protection Agency (USEPA). 2000b. Chlorpyrifos Revised Risk Assessment and Agreement with Registrants. US Environmental Protection Agency, Washington, D.C.	13-3721 to 13-3724
		➢ United States Environmental Protection Agency (USEPA). 2001a. Diazinon Revised Risk Assessment and Agreement with Registrants. US Environmental Protection Agency, Washington, D.C.	13-3725 to 13-3728

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		➢ United States Environmental Protection Agency (USEPA). 2002a. Methods for Measuring the Acute Toxicity of Effluents and Receiving Waters to Freshwater Marine Organisms. Fifth Edition. October.	13-3729 to 13-4094
		➢ United States Environmental Protection Agency (USEPA). 2002b. Total Maximum Daily Loads for Toxic Pollutants – San Diego Creek and Newport Bay, California. US Environmental Protection Agency, Region 9. Established June 14, 2002.	13-4095 to 13-4098
		➢ Ventura County. Website visited May 2004: http://www.countyofventura.org/visitor/visitor.asp	13-4099 to 13-4100
		➢ Ventura County Flood Control District. 1998. Ventura Countywide Stormwater Quality Management Program. Annual Report.	13-4099 to 13-4100
		➢ Ventura County Flood Control District. 1999. Ventura Countywide Stormwater Quality Management Program. Annual Report.	13-4099 to 13-410
		➢ Ventura County Flood Control District. 2000. Ventura Countywide Stormwater Quality Management Program. Annual Report.	13-4099 to 13-4100
		➢ Ventura County Flood Control District. 2001. Ventura Countywide Stormwater Quality Management Program. Annual Report.	13-4099 to 13-4100
		➢ Ventura County Flood Control District. 2002. Ventura Countywide Stormwater Quality Management Program. Annual Report	13-4099 to 13-4100
		➢ Ventura County Flood Control District. 2003. Ventura Countywide Stormwater Quality Management Program. Annual Report.	13-4099 to 13-4100
		➢ Wilen, C.A. 2001. Survey of Residential Pesticide Use and Sales in the San Diego Creek Watershed of Orange County, California. University of California Statewide Integrated Pest Management Project, University Cooperative Extension.	13-4101 to 13-4206
		➢ Wu, Jigang; Laird David. 2004. Interaction of Chlorpyrifos with Colloidal Material in Aqueous Systems. Journal of Environmental Quality	13-4207 to 13-4208

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		➢ Young, T. 2002, Department of Civil and Environmental Engineering, University of California, Davis, personal communication with M. Mysliwiec.	13-4209 to 13-4210
		➢ Zabik, J.M., Seiber, J.N. 1993. Atmospheric transport of organophosphate pesticides from California's Central Valley to the Sierra Nevada mountains. J Environ Qual 22(1):80-90.	13-4211 to 13-4212

State of California
California Regional Water Quality Control Board, Los Angeles Region

RESOLUTION NO. R4-2005-009
July 7, 2005

Amendment to the *Water Quality Control Plan for the Los Angeles Region* to Incorporate a Total Maximum Daily Load for Toxicity, Chlorpyrifos, and Diazinon in Calleguas Creek its Tributaries and Mugu Lagoon

WHEREAS, the California Regional Water Quality Control Board, Los Angeles Region, finds that:

1. The Federal Clean Water Act (CWA) requires the California Regional Water Quality Control Board, Los Angles Region (Regional Board) to develop water quality objectives, which are sufficient to protect beneficial uses for each water body found within its region.

2. A consent decree between the U.S. Environmental Protection Agency (USEPA), Heal the Bay, Inc. and BayKeeper, Inc. was approved on March 22, 1999. This court order directs the USEPA to complete Total Maximum Daily Loads (TMDLs) for all impaired waters within 13 years. A schedule was established in the consent decree for the completion of the first 29 TMDLs within 7 years, including completion of a TMDL to reduce toxicity, chlorpyrifos, and diazinon in the Calleguas Creek Watershed by March 22, 2006. The remaining TMDLs will be scheduled by Regional Board staff within the 13-year period.

3. The elements of a TMDL are described in 40 CFR 130.2 and 130.7 and section 303(d) of the CWA, as well as in USEPA guidance documents (Report No. EPA/440/4-91/001). A TMDL is defined as the sum of the individual waste load allocations for point sources, load allocations for nonpoint sources and natural background (40 CFR 130.2). Regulations further stipulate that TMDLs must be set at levels necessary to attain and maintain the applicable narrative and numeric water quality standards with seasonal variations and a margin of safety that takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality (40 CFR 130.7(c)(1)). The regulations in 40 CFR 130.7 also state that TMDLs shall take into account critical conditions for stream flow, loading and water quality parameters.

4. The numeric targets in this TMDL are not water quality objectives and do not create new bases for enforcement against dischargers apart from the water quality objectives they translate. The targets merely establish the bases through which load allocations (LAs) and waste load allocations (WLAs) are calculated. WLAs are only enforced for a discharger's own discharges, and then only in the context of its National Pollutant Discharge Elimination System (NPDES) permit, which must be consistent with the assumptions and requirements of the WLA. The Regional Board will develop permit requirements through a subsequent permit action that will allow all interested persons, including but not limited to municipal storm water dischargers, to provide comments on how the WLA will be translated into permit requirements.

5. Upon establishment of TMDLs by the State or USEPA, the State is required to incorporate the TMDLs along with appropriate implementation measures into the State Water Quality

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Management Plan (40 CFR 130.6(c)(1), 130.7). This Water Quality Control Plan for the Los Angeles Region (Basin Plan), and applicable statewide plans, serves as the State Water Quality Management Plans governing the watersheds under the jurisdiction of the Regional Board.

6. The SWRCB adopted Policy for Implementation of Toxics Standards for Inland Surface Waters, Enclosed Bays, and Estuaries of California (also known as the State Implementation Plan or SIP) on March 2, 2000. The SIP was amended by Resolution No. 2000-30, on April 26, 2000, and the Office of Administrative Law approved the SIP on April 28, 2000. The SIP applies to discharges of toxic pollutants in the inland surface waters, enclosed bays and estuaries of California which are subject to regulation under the State's Porter-Cologne Water Quality Control Act (Division 7 of the Water Code) and the Federal Clean Water Act. This policy also establishes the following: implementation provisions for priority pollutant criteria promulgated by USEPA through the CTR and for priority pollutant objectives established by Regional Water Quality Control Boards in their water quality control plans (Basin Plans) and chronic toxicity control provisions.

7. On May 18, 2000, the U.S. EPA promulgated the numeric criteria for priority pollutants for the State of California, known as the California Toxics Rule (CTR) and as codified as 40 CFR section 131.38.

8. The Calleguas Creek Watershed is located in southeast Ventura County, California, and in a small portion of western Los Angeles County, and drains an area of approximately 343 square miles from the Santa Susana Pass in the east, to Mugu Lagoon in the southwest. Current land use is approximately 26 percent agriculture, 24 percent urban, and 50 percent open space. The tributaries and the streams of the Calleguas Creek Watershed are divided into fourteen segments, or reaches. The 2002 Clean Water Act 303(d) list identified six reaches as impaired for water column toxicity, two for sediment toxicity, two for chlorpyrifos in fish tissue, and one for organophosphate pesticides in water. These listings were approved by the State Water Resources Control Board on February 4, 2003.

9. The Regional Board's goal in establishing the Calleguas Creek Toxicity TMDL is to determine and set forth measures needed to prevent impairment of water quality due to water column toxicity in all impaired reaches by requiring reductions in diazinon and chlorpyrifos from both point and non-point sources, and by developing a numeric target for unknown causes of toxicity.

10. Calleguas Creek stakeholders have been actively engaged with US EPA and the Regional Board on a variety of watershed planning initiatives in the Calleguas Creek Watershed. Key stakeholders have formed the Calleguas Creek Watershed Management Plan (CCWMP), an established, stakeholder-led watershed management group that has been continually operating since 1996. The Calleguas Creek Watershed Management Plan has broad participation from Federal, State and County agencies, municipalities, POTWs, water purveyors, groundwater management agencies, and agricultural and environmental groups. As part of its mission to address issues of long-range comprehensive water resources; land use; economic development; open space preservation, enhancement and management, the CCWMP proposed to US EPA and Regional Board to take the lead on development of the TMDLs.

11. Regional Board staff have participated in the development of a detailed technical document that analyzes and describes the specific necessity and rationale for the development of this TMDL. The technical document entitled "Calleguas Creek Watershed Toxicity TMDL"

prepared by Larry Walker Associates and is an integral part of this Regional Board action and was reviewed, considered, and accepted by the Regional Board as a supporting background report before acting. Further, the technical document provides the detailed factual basis and analysis supporting the problem statement, numeric targets (interpretation of the narrative and numeric water quality objectives used to calculate the pollutant allocations), source analysis, linkage analysis, waste load allocations (for point sources), load allocation (for nonpoint sources), margin of safety, and seasonal variations and critical conditions of this TMDL.

12. On May 5, 2005, prior to the Board's action on this resolution, public hearings were conducted on the Calleguas Creek Watershed Toxicity, Chlorpyrifos and Diazinon TMDL. Notice of the hearing for the Calleguas Creek Watershed Toxicity, Chlorpyrifos and Diazinon TMDL was published in accordance with the requirements of Water Code Section 13244. This notice was published in the Ventura County Star on April 26, the Daily News Los Angeles on April 26, and the Signal Newspaper on April 27, 2005

13. The public has had reasonable opportunity to participate in the review of the amendment to the Basin Plan. A draft of the Calleguas Creek Watershed Toxicity TMDL was released for public comment on April 26, 2005; a Notice of Hearing was published and circulated 45 days preceding Board action; Regional Board staff responded to oral and written comments received from the public; and the Regional Board held a public hearing on July 7, 2005 to consider adoption of the TMDL.

14. In amending the Basin Plan, the Regional Board considered the factors set forth in Sections 13240 and 13242 of the California Water Code.

15. The amendment is consistent with the State Antidegradation Policy (State Board Resolution No. 68-16), in that it does not authorize any lowering of water quality and is designed to implement existing water quality objectives. Likewise, the amendment is consistent with the federal Antidegradation Policy (40 CFR 131.12).

16. The basin planning process has been certified as functionally equivalent to the California Environmental Quality Act requirements for preparing environmental documents (Public Resources Code, Section 21000 et seq.) and as such, the required environmental documentation and CEQA environmental checklist have been prepared. A CEQA Scoping hearing was conducted on May 31, 2005 in the City of Thousand Oaks, 2100 E. Thousand Oaks Blvd., Thousand Oaks, California. A notice of the CEQA Scoping hearing was sent to interested parties including cities and/or counties with jurisdiction in or bordering the Calleguas Creek watershed.

17. The proposed amendment could have a significant adverse effect on the environment. However, there are feasible alternatives and/or feasible mitigation measures that would substantially lessen any significant adverse impact.

18. The regulatory action meets the "Necessity" standard of the Administrative Procedures Act, Government Code, Section 11353, Subdivision (b).

19. The Basin Plan amendment incorporating a TMDL for Toxic Pollutants in Calleguas Creek watershed must be submitted for review and approval by the State Water Resources Control Board (State Board), the State Office of Administrative Law (OAL), and the USEPA. The Basin Plan amendment will become effective upon approval by USEPA. A Notice of Decision will be filed State of California Secretary of Resources.

THEREFORE, be it resolved that pursuant to sections 13240 and 13242 of the Water Code, the Regional Board hereby amends the Basin Plan as follows:

1. Pursuant to Sections 13240 and 13242 of the California Water Code, the Regional Board, after considering the entire record, including oral testimony at the hearing, hereby adopts the amendments to Chapter 7 of the Water Quality Control Plan for the Los Angeles Region, as set forth in Attachment A hereto, to incorporate the elements of the Calleguas Creek Watershed Toxicity TMDL.
2. The Executive Officer is directed to forward copies of the Basin Plan amendment to the State Board in accordance with the requirements of section 13245 of the California Water Code.
3. The Regional Board requests that the State Board approve the Basin Plan amendment in accordance with the requirements of sections 13245 and 13246 of the California Water Code and forward it to OAL and the USEPA.
4. If during its approval process Regional Board staff, the State Board or OAL determines that minor, non-substantive corrections to the language of the amendment are needed for clarity or consistency, the Executive Officer may make such changes, and shall inform the Board of any such changes.
5. The Executive Officer is authorized to sign a Certificate of Fee Exemption.

I, Jonathan S. Bishop, Executive Officer, do hereby certify that the foregoing is a full, true, and correct copy of a resolution adopted by the California Regional Water Quality Control Board, Los Angeles Region, on July 7, 2005.

Jonathan S. Bishop
Executive Officer

7/15/05
Date

Attachment A to Resolution No. R4-2005-009

Amendment to the Water Quality Control Plan – Los Angeles Region

to Incorporate the

Total Maximum Daily Load for Toxicity, Chlorpyrifos, and Diazinon in the Calleguas Creek, its Tributaries and Mugu Lagoon

Adopted by the California Regional Water Quality Control Board, Los Angeles Region on 7 July, 2005.

Amendments

Table of Contents

Add:

Chapter 7. Total Maximum Daily Loads (TMDLs)

List of Figures, Tables, and Inserts

Add:

Chapter 7. Total Maximum Daily Loads (TMDLs)
Tables

Chapter 7. Total Maximum Daily Loads (TMDLs)
Calleguas Creek Watershed Toxicity TMDL

This TMDL was adopted by:

The Regional Water Quality Control Board on July 7, 2005.

This TMDL was approved by:

The State Water Resources Control Board on September 22, 2005.
The Office of Administrative Law on December 22, 2005.
The U.S. Environmental Protection Agency on March 14, 2006.

Table 7-16.1. Calleguas Creek Watershed Toxicity TMDL: Elements

TMDL Element	Calleguas Creek Watershed Toxicity TMDL
Problem Statement	Discharge of wastes containing chlorpyrifos, diazinon, other pesticides and/or other toxicants to Calleguas Creek, its tributaries and Mugu Lagoon cause exceedances of water quality objectives for toxicity established in the Basin Plan. Elevated levels of chlorpyrifos have been found in fish tissue samples collected from a segment of Calleguas Creek. Chlorpyrifos and diazinon are organophosphate pesticides used in both agricultural and urban settings. Excessive chlorpyrifos and diazinon can cause aquatic life toxicity in inland surface and estuarine waters such as Calleguas Creek and Mugu Lagoon. The California 2002 303(d) list of impaired waterbodies includes listings for "water column toxicity," "sediment toxicity," chlorpyrifos in fish tissue," and "organophosphate pesticides in water" for various reaches of Calleguas Creek, its tributaries and Mugu Lagoon.
Numeric Targets	This TMDL establishes a numeric toxicity target of 1.0 toxicity unit – chronic (1.0 TUc) to address toxicity in reaches where the toxicant has not been identified through a Toxicity Identification Evaluation (TIE) (unknown toxicity). TU_C = Toxicity Unit Chronic = 100/NOEC (no observable effects concentration) A sediment toxicity target was defined in the technical report for reaches where the sediment toxicant has not been identified through a TIE. The target is based on the definition of a toxic sediment sample as defined by the September 2004 Water Quality Control Policy For Developing California's Clean Water Act Section 303(d) List (SWRCB). Chlorpyrifos Numeric Targets (ug/L) Chronic (4 day average) / Acute (1 hour average) Freshwater: 0.014 / 0.025 Saltwater (Mugu Lagoon): 0.009 / 0.02 Diazinon Numeric Targets (ug/L) Chronic (4 day average) / Acute (1 hour average) Freshwater: 0.10 / 0.10 Saltwater (Mugu Lagoon): 0.40 / 0.82

<table>
<tr><th>TMDL Element</th><th>Calleguas Creek Watershed Toxicity TMDL</th></tr>
<tr><td></td><td>Additionally, the diazinon criteria selected as numeric targets are currently under review by the USEPA. If water quality objectives become available, the Regional Board may reconsider this TMDL and revise the water toxicity numeric target.</td></tr>
<tr><td>Source Analysis</td><td>Source analysis determined that agricultural and urban uses are the largest sources of chlorpyrifos and diazinon in the watershed. Urban use of diazinon and chlorpyrifos is unlikely to be a long-term source to the Calleguas Creek Watershed (CCW) as both of these pesticides have been banned for sale for non-agricultural uses on December 31, 2005 by federal regulation. As a result, the proportion of the loading from urban sources will likely decrease after December 2005.

Chlorpyrifos – Sources by Use
<table>
<tr><th></th><th>Dry Weather</th><th>Wet Weather</th></tr>
<tr><td>Agriculture</td><td>66%</td><td>80%</td></tr>
<tr><td>Urban</td><td>23%</td><td>20%</td></tr>
<tr><td>POTW</td><td>11%</td><td><1%</td></tr>
<tr><td>Other</td><td><1%</td><td><1%</td></tr>
</table>

Diazinon – Sources by Use
<table>
<tr><th></th><th>Dry Weather</th><th>Wet Weather</th></tr>
<tr><td>Agriculture</td><td>30%</td><td>1%</td></tr>
<tr><td>Urban</td><td>13%</td><td>62%</td></tr>
<tr><td>POTW</td><td>57%</td><td>37%</td></tr>
<tr><td>Other</td><td><1%</td><td><1%</td></tr>
</table>
</td></tr>
<tr><td>Linkage Analysis</td><td>Water quality modeling established the linkage of sources of chlorpyrifos and diazinon in the CCW to observed water quality data. The linkage analysis qualitatively describes the connection between water column concentrations and sediment and fish tissue concentrations. The qualitative analysis demonstrates that the water column analysis conducted by laboratories implicitly includes sediment associated diazinon and chlorpyrifos loads transported to receiving waters as almost all water quality data do not differentiate between dissolved and particulate fractions. The linkage analysis assumes a reduction in water column concentrations will result in a reduction in fish tissue as chlorpyrifos in freshwater fish tissue rapidly depurate within several days of removal from exposure. Additionally, as chlorpyrifos preferentially binds to sediment the linkage analysis suggests that sediment concentrations of</td></tr>
</table>

<table>
<tr><th>TMDL Element</th><th>Calleguas Creek Watershed Toxicity TMDL</th></tr>
<tr><td></td><td>chlorpyrifos will need to decrease to achieve water quality numeric targets. The modeling approach reflects the uncertainty in current conditions and the potential impacts of watershed planning actions that may affect those conditions. A detailed description of the model is provided in an Attachment to the TMDL Technical Report.</td></tr>
<tr><td>Wasteload Allocations (WLA)</td><td>
<p><u>Major point sources:</u></p>
<p>A wasteload of 1.0 TU_c is allocated to the major point sources (POTWs) discharging to the Calleguas Creek Watershed.</p>
<p>Additionally, the following wasteloads for chlorpyrifos and diazinon are established for POTWs. A margin of safety of 5% was included in the targets for chlorpyrifos for discharges to the Calleguas and Revolon subwatersheds.</p>
<p><u>Chlorpyrifos WLAs, ug/L</u></p>
<table>
<tr><th>POTW</th><th>Interim WLA
(4 day)</th><th>Final WLA
(4 day)</th></tr>
<tr><td>Hill Canyon WWTP</td><td>0.030</td><td>0.014</td></tr>
<tr><td>Simi Valley WQCP</td><td>0.030</td><td>0.014</td></tr>
<tr><td>Ventura County (Moorpark) WTP</td><td>0.030</td><td>0.014</td></tr>
<tr><td>Camarillo WRP</td><td>0.030</td><td>0.0133</td></tr>
<tr><td>Camrosa WRP</td><td>0.030</td><td>0.0133</td></tr>
</table>
<p><u>Diazinon WLAs, ug/L</u></p>
<table>
<tr><th>POTW</th><th>Interim
Acute
(1 hour)</th><th>Interim
Chronic
(4 day)</th><th>Final WLA
(Acute or Chronic)</th></tr>
<tr><td>Hill Canyon WWTP</td><td>0.567</td><td>0.312</td><td>0.10</td></tr>
<tr><td>Simi Valley WQCP</td><td>0.567</td><td>0.312</td><td>0.10</td></tr>
<tr><td>Ventura County (Morepark) WTP</td><td>0.567</td><td>0.312</td><td>0.10</td></tr>
<tr><td>Camarillo WRP</td><td>0.567</td><td>0.312</td><td>0.10</td></tr>
<tr><td>Camrosa WRP</td><td>0.567</td><td>0.312</td><td>0.10</td></tr>
</table>
<p>A wasteload of 1.0 TU_c is allocated to Urban Stormwater Co-Permittees (MS4) discharges to the Calleguas Creek Watershed.</p>
</td></tr>
</table>

<table>
<tr><th>TMDL Element</th><th>Calleguas Creek Watershed Toxicity TMDL</th></tr>
<tr><td></td><td>
<p>Additionally, the following wasteloads for chlorpyrifos and diazinon are established for MS4 discharges.</p>
<p><u>Chlorpyrifos WLAs, ug/L</u></p>
<table>
<tr><th>Interim WLA
(4 day)</th><th>Final WLA
(4 day)</th></tr>
<tr><td>0.45</td><td>0.014</td></tr>
</table>
<p><u>Diazinon WLAs, ug/L</u></p>
<table>
<tr><th>Interim WLA
Acute (1 hour)</th><th>Interim WLA
Chronic (4 day)</th><th>Final WLA
Acute and Chronic</th></tr>
<tr><td>1.73</td><td>0.556</td><td>0.10</td></tr>
</table>
<p><u>Minor point sources:</u></p>
<p>Minor sources include NPDES permittees other than POTWs and MS4s, discharging to the Calleguas Creek Watershed.</p>
<p>A wasteload of 1.0 TU_c is allocated to the minor point sources discharging to the Calleguas Creek Watershed.</p>
<p>Additionally, the following wasteloads for chlorpyrifos and diazinon are established.</p>
<p><u>Chlorpyrifos WLAs, ug/L</u></p>
<table>
<tr><th>Interim WLA
(4 day)</th><th>Final WLA
(4 day)</th></tr>
<tr><td>0.45</td><td>0.014</td></tr>
</table>
<p><u>Diazinon WLAs, ug/L</u></p>
<table>
<tr><th>Interim WLA
Acute (1 hour)</th><th>Interim WLA
Chronic (4 day)</th><th>Final WLA
Acute and Chronic</th></tr>
<tr><td>1.73</td><td>0.556</td><td>0.10</td></tr>
</table>
</td></tr>
<tr><td>Load Allocations</td><td>
<p><u>Non Point Source Dischargers:</u></p>
<p>A load of 1.0 TU_c is allocated to nonpoint sources discharging to the Calleguas Creek Watershed.</p>
</td></tr>
</table>

<table>
<tr><th>TMDL Element</th><th>Calleguas Creek Watershed Toxicity TMDL</th></tr>
<tr><td></td><td>
<p>Additionally, the following loads for chlorpyrifos and diazinon are established. These loads apply to dischargers in accordance with the subwatershed into which the dischargers discharge. A margin of safety of 5% was included for chlorpyrifos for discharges to the Calleguas and Revolon subwatersheds.</p>
<p><u>Chlorpyrifos Load Allocations, ug/L</u></p>
<table>
<tr><th></th><th>Interim</th><th>Interim</th><th>Final</th></tr>
<tr><th>Subwatershed</th><th>Acute (1hour)</th><th>Chronic(4 day)</th><th>Acute and Chronic</th></tr>
<tr><td>Arroyo Simi</td><td>2.57</td><td>0.810</td><td>0.014</td></tr>
<tr><td>Las Posas</td><td>2.57</td><td>0.810</td><td>0.014</td></tr>
<tr><td>Conejo</td><td>2.57</td><td>0.810</td><td>0.014</td></tr>
<tr><td>Calleguas</td><td>2.57</td><td>0.810</td><td>0.0133</td></tr>
<tr><td>Revolon</td><td>2.57</td><td>0.810</td><td>0.0133</td></tr>
<tr><td>Mugu Lagoon</td><td>2.57</td><td>0.810</td><td>0.014</td></tr>
</table>
<p><u>Diazinon Load Allocations, ug/L</u></p>
<table>
<tr><th>Interim LA
Acute</th><th>Interim LA
Chronic</th><th>Final LA
Acute and Chronic</th></tr>
<tr><td>0.278</td><td>0.138</td><td>0.10</td></tr>
</table>
</td></tr>
<tr><td>Margin of Safety</td><td>In addition to the implicit margin of safety achieved by conservative assumptions and by using a concentration based TMDL, an explicit margin of safety of 5% has been added to the targets for chlorpyrifos in the Calleguas and Revolon subwatersheds to address uncertainty in the linkages between the water column criteria and fish tissue and sediment concentrations. The Calleguas and Revolon subwatersheds include those reaches listed for sediment toxicity and chlorpyrifos in fish tissue.</td></tr>
<tr><td>Future Growth</td><td>Ventura County accounts for slightly more than 2% of the state's residents with a population of 753,197 (US Census Bureau, 2000). GIS analysis of the 2000 census data yields a population estimate of 334,000 for the CCW, which equals about 44% of the county population. According to the Southern California Association of Governments (SCAG), growth in Ventura County averaged about 51% per decade from 1900-2000; with growth exceeding 70% in the 1920s, 1950s, and 1960s. The phase-out of chlorpyrifos and diazinon is expected to reduce loads from urban and POTWs significantly by 2007. Use of diazinon in agriculture has declined considerably between 1998 and 2003. Conversely, chlorpyrifos use</td></tr>
</table>

TMDL Element	Calleguas Creek Watershed Toxicity TMDL
	in agriculture has remained relatively stable over the same period. The phase out of chlorpyrifos and diazinon as well as population growth will cause an increase in the use of replacement pesticides (e.g. pyrethroids) in the urban environment and may have an impact on water and/or sediment toxicity. Additionally, population growth may affect an increase in the levels of chlorpyrifos and diazinon loading in the CCW from imported products which contain residues of these pesticides.
Critical Conditions	The critical condition in this TMDL is defined as the flowrate at which the model calculated the greatest in-stream diazinon or chlorpyrifos concentration in comparison to the appropriate criterion. The critical condition for chlorpyrifos was in dry weather based on a chronic numeric target; the critical condition for diazinon was in wet weather based on an acute numeric target except in Mugu Lagoon where it was in dry weather based on the chronic numeric target.
Implementation Plan	WLAs established for the major points sources, including POTWs in the CCW will be implemented through NPDES permit effluent limits. The final WLAs will be included in NPDES permits in accordance with the compliance schedules provided. The Regional Board may revise these WLAs based on additional information as described in the Special Studies and Monitoring Section of the Technical Report. The toxicity WLAs will be implemented in accordance with US EPA, State Board and Regional Board resolutions, guidance and policy at the time of permit issuance or renewal. Currently, these WLAs would be implemented as a trigger for initiation of the TRE/TIE process as outlined in USEPA's 'Understanding and Accounting for Method Variability in Whole Effluent Toxicity Applications Under the National Pollutant Discharge Elimination System Program" (2000) and current NPDES permits held by dischargers to the CCW. Stormwater WLAs will be incorporated into the NPDES permit as receiving water limits measured in-stream at the base of each subwatershed and will be achieved through the implementation of BMPs as outlined below. Evaluation of progress of the TMDL will be determined through the measurement of in-stream water quality and sediment at the base of each of the CCW subwatersheds. The Regional Board may revise these WLAs based on additional information developed through special studies and/or monitoring conducted as part of the TMDL.

TMDL Element	Calleguas Creek Watershed Toxicity TMDL
	As shown in the attached table the following implementation actions will be taken by the MS4s discharging to the CCW and POTWs located in the CCW: ♣ Plan, develop, and implement an urban pesticides public education program; ♣ Plan, develop, and implement urban pesticide education and chlorpyrifos and diazinon collection program; ♣ Study diazinon and chlorpyrifos replacement pesticides for use in the urban environment; and, ♣ Conduct environmental monitoring as outlined in the Monitoring Plan and NPDES Permits. LAs for chlorpyrifos and diazinon will be implemented through the State's Nonpoint Source Pollution Control Program (NPSPCP), nonpoint source pollution (i.e. Load Allocations). The LARWQCB is currently developing a Conditional Waiver for Irrigated Lands. Once adopted, the Conditional Waiver Program will implement allocations and attain numeric targets of this TMDL. Compliance with LAs will be measured at the monitoring sites approved by the Executive Officer of the Regional Board through the monitoring program developed as part of the Conditional Waiver, or through a monitoring program that is required by this TMDL. The toxicity LAs will be implemented in accordance with US EPA, State Board and Regional Board resolutions, guidance and policy at the time of permit or waiver issuance or renewal. The following implementation actions will be taken by agriculture dischargers located in the CCW: ♣ Enroll for coverage under a waiver of waste discharge requirements for irrigated lands; ♣ Implement monitoring required by this TMDL and the Conditional Waiver program; ♣ Complete studies to determine the most appropriate BMPs given crop type, pesticide, site specific conditions, as well as the critical condition defined in the development of the LAs; and, ♣ Implement appropriate BMPs and monitor to evaluate effectiveness on in-stream water and sediment quality. The Regional Board may revise this TMDL based on monitoring data and special studies of this TMDL. If the Regional Board revises NPDES permits or the Basin Plan to use other methods of

TMDL Element	Calleguas Creek Watershed Toxicity TMDL
	evaluating toxicity or if other information supporting other methods becomes available, the Regional Board may reconsider this TMDL and revise the water toxicity numeric target. Additionally, the development of sediment quality guidelines or criteria and other water quality criteria revisions may call for the reevaluation of the TMDL. The Implementation Plan includes this provision for reevaluating the TMDL to consider sediment quality guidelines or criteria and revised water quality objectives and the results of implementation studies, if appropriate.

Table 7-16.2. Overall Implementation Schedule for Calleguas Creek Watershed Toxicity TMDL

	Implementation Action	Responsible Party	Date
1	Interim chlorpyrifos and diazinon waste-load allocations apply.[1]	POTW permittees and MS4 Copermittees	Effective date[2]
2	Interim chlorpyrifos and diazinon load allocations apply.[1]	Agricultural Dischargers	Effective date[2]
3	Finalize and submit workplan for integrated Calleguas Creek Watershed Monitoring Program for approval by the Regional Board Executive Officer.[3]	POTW permittees, MS4 Copermittees, and Agricultural Dischargers	6 months after effective date of amendment[2]
4	Initiate Calleguas Creek Watershed Toxicity TMDL Monitoring Program developed under Task 3 workplan.	POTW permittees, MS4 Copermittees, and Agricultural Dischargers	6 months after E.O. approval of Monitoring Program (task 3) workplan.
5	Special Study #1 - Investigate the pesticides that will replace diazinon and chlorpyrifos in the urban environment, their potential impact on receiving waters, and potential control measures.	POTW permittees and MS4 Copermittees	2 years after effective date[2]
6	Special Study #2 – Consider results of monitoring of sediment concentrations by source/land use type through special study required in the OC Pesticide, PCB and siltation TMDL Implementation Plan. If the special study is not completed through the OC Pesticides, PCBs and Siltation TMDL no consideration is necessary[3]	Agricultural Dischargers[3] and MS4 Copermittees	6 months after completion of CCW OC Pesticides, PCBs and Siltation TMDL sediment concentrations special study.[2]
7	Develop and implement collection program for diazinon and chlorpyrifos and an educational program. Collection and education could occur through existing programs such as household hazardous waste collection events	POTW permittees and MS4 Copermittees	3 years after effective date[2]
8	Develop an Agricultural Water Quality Management Plan in conjunction with the Conditional Waiver for Irrigated Lands, or (if the Conditional Waiver is not adopted in a timely manner) develop an Agricultural Water Quality Management Plan as part of the Calleguas Creek WMP.	Agricultural Dischargers[3]	3 years after effective date[2]
9	Identify the most appropriate BMPs given crop type, pesticide, site specific conditions, as well as the critical condition defined in the development of the LAs.	Agricultural Dischargers[3]	3 years after effective date[2]
10	Implement educational program on BMPs identified in the Agricultural Water Quality Management Plan.	Agricultural Dischargers	1 year after E.O. approval of Plan (Task 7)[2]
11	Special Study #3 Calculation of sediment transport rates in CCW. Consider findings of transport rates developed through the OC Pesticide, PCB and siltation TMDL	Agricultural Dischargers[3] and MS4 Copermittees	6 months after completion of CCW OC Pesticides, PCBa and Siltation TMDL

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[1] Interim WLAs and LAs are effective immediately upon TMDL adoption. WLAs will be placed in POTW NPDES permits as effluent limits. WLAs will be placed in stormwater NPDES permits as in-stream limits. LAs will be implemented using applicable regulatory mechanisms.

[2] Effective date of this TMDL.

[3] The Regional Board regulatory programs addressing all discharges in effect at the time an implementation task is due may contain requirements substantially similar to the requirements of an implementation task. If such a requirement is in place in another regulatory program including other TMDLs, the Executive Officer may determine that such other requirements satisfy the requirements of an implementation task of the TMDL and thereby coordinate this TMDL implementation plan with other regulatory programs.

Implementation Action		Responsible Party	Date
	Implementation Plan. If the special study is not completed through the OCsTMDL, no consideration is necessary.[3]		sediment transport special study.[2]
12	Begin implementation of BMPs.	Agricultural Dischargers[3]	1 year after E.O. approval of Plan (Task 8)[2]
13	Evaluate effectiveness of BMPs.	Agricultural Dischargers[3]	3 years after E.O. approval of Plan (Task 8)[2]
14	Based on monitoring data and on the results of Implementation Actions 1-13 and if sediment guidelines are promulgated, or water quality criteria are revised, and/or if targets are achieved without attainment of WLAs or LAs reevaluate the TMDLs, interim or final WLAs and LAs and implementation schedule, if necessary.	Stakeholders and Regional Board	2 years after the submittal of information necessary to reevaluate the TMDL
15	Achievement of Final WLAs	POTW permittees and MS4 Copermittees	2 years after the effective date of the TMDL[2]
16	Achievement of Final LAs	Agricultural Dischargers	10 years after the effective date of the TMDL[2]

STATE WATER BOARD
RESOLUTION NO. 2005-0067

APPROVING AN AMENDMENT TO THE WATER QUALITY CONTROL PLAN FOR THE LOS ANGELES REGION TO INCORPORATE A TOTAL MAXIMUM DAILY LOAD FOR TOXICITY, CHLORPYRIFOS, AND DIAZINON IN THE CALLEGUAS CREEK WATERSHED AND MUGU LAGOON

WHEREAS:

1. The Los Angeles Regional Water Quality Control Board (Los Angeles Water Board) adopted the revised Water Quality Control Plan for the Los Angeles Region (Basin Plan) under Resolution No. 94-07 on June 13, 1994. The State Water Resources Control Board (State Water Board) approved the revised Basin Plan on November 17, 1994 and by the Office of Administrative Law (OAL) on February 23, 1995.

2. A consent decree between the U.S. Environmental Protection Agency (USEPA), Heal the Bay, Incorporated and Baykeeper, Incorporated was approved on March 22, 1999. This court order establishes a requirement to establish a Total Maximum Daily Load (TMDL) to reduce toxicity, chlorpyrifos, and diazinon in the CCW by March 22, 2006.

3. On July 7, 2005, the Los Angeles Water Board adopted Resolution No. R4-2005-009 (Attachment) to incorporate a TMDL for toxicity, chlorpyrifos, and diazinon in Calleguas Creek, its tributaries, and Mugu Lagoon.

4. Los Angeles Water Board Resolution No. R4-2005-009 delegated to its Executive Officer authority to make minor, non-substantive corrections to the adopted amendment if needed for clarity or consistency. The State Water Board staff finds that provisions of the amendment, as adopted, warranted minor, non-substantive clarification of the language of various provisions. The Los Angeles Water Board Executive Officer has made the necessary corrections to the amendment.

5. The State Water Board finds that the amendment is in conformance with the requirements for TMDL development specified in section 303(d) of the federal Clean Water Act and State Water Board Resolution No. 68-16, and is an appropriate program of implementation pursuant to Water Code section 13242.

6. The State Water Board finds that the Basin Plan amendment is in conformance with the requirements of Water Code section 13240, which specifies that Regional Water Quality Control Boards shall periodically review and may revise the Basin Plans.

7. The Basin Plan amendments do not become effective until approved by the State Water Board and until the regulatory provisions are approved by OAL. In addition, TMDLs must be approved by the USEPA.

THEREFORE BE IT RESOLVED THAT:

The State Water Board:

1. Approves the amendment to the Basin Plan as adopted under the Los Angeles Water Board Resolution No. R4-2005-009 as corrected by the Regional Board Executive Officer.
2. Authorizes the Executive Director to submit the amendment adopted under Los Angeles Water Board Resolution R4-2005-009, as approved, and the administrative record for this action to OAL and the TMDL to USEPA for approval.

CERTIFICATION

The undersigned, Clerk to the Board, does hereby certify that the foregoing is a full, true, and correct copy of a resolution duly and regularly adopted at a meeting of the State Water Resources Control Board held on September 22, 2005.

Debbie Irvin
Clerk to the Board

RECEIVED
DEC 29 2005
EXECUTIVE OFFICE

STATE OF CALIFORNIA
OFFICE OF ADMINISTRATIVE LAW

In re:

STATE WATER RESOURCES CONTROL BOARD

REGULATORY ACTION:

Title 23, California Code of Regulations

Adopt sections **3939.16**

NOTICE OF APPROVAL OF REGULATORY ACTION

Government Code Section **11353**

OAL File No. **05-1110-02 S**

This amendment to the Water Quality Control Plan for the Los Angeles Region (Basin Plan) establishes a Total Maximum Daily Load (TMDL) for toxicity, chlorpyrifos, and diazinon in Calleguas Creek, its Tributaries, and Mugu Lagoon. The amendment also revises the table of contents and adds introductory text for Chapter 7 (Total Maximum Daily Loads). Additionally, the Basin Plan amendment specifies final waste allocations (WLAs) for point source discharges and load allocations (LAs) for nonpoint source discharges of chlorpyrifos and diazinon. The Basin Plan also specifies WLAs and LAs for toxicity. The TMDL establishes an implementation plan for reducing toxicity, chlorpyrifos, and diazinon loads from point-sources and nonpoint-sources which includes a monitoring program, special studies, and a compliance schedule to meet final WLAs in 2 years after the effective date of the TMDL for point sources and final LAs in 10 years after the effective date of the TMDL for nonpoint sources.

OAL approves this regulatory action pursuant to section 11353 of the Government Code.

DATE: 12/27/05

Debra M Cornez

DEBRA M. CORNEZ
Assistant Chief Counsel

for: WILLIAM L. GAUSEWITZ
Director

Original : Celeste Cantu, Executive Director
cc : Glenda Marsh

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, CA 94105-3901

MAR 14 2006

Ms. Celeste Cantú
Executive Director
State Water Resources Control Board
P.O. Box 100
Sacramento, CA 95812-0100

Dear Ms. Cantú:

Thank you for submitting the Basin Plan amendments containing total maximum daily loads (TMDLs) for Calleguas Creek watershed. The organophosphate pesticides and toxicity TMDL submittal was dated January 12, 2006 and the organochlorine pesticides and siltation TMDL submittal was dated February 6, 2006. The State adopted TMDLs to address the following water body-pollutant combinations on California's 2002 Clean Water Act Section 303(d) list:

- Calleguas Creek Reach 1 [Mugu Lagoon] for sediment toxicity, chlordane, DDT, dieldrin, PCBs, toxaphene, sedimentation/siltation
- Duck Pond drain/Mugu Drain/Oxnard Drain #2 for ambient and sediment toxicity, chlordane, DDT, dieldrin, PCBs, toxaphene
- Calleguas Ck. R2 [estuary] for sediment toxicity, chlordane, DDT, dieldrin, PCBs, toxaphene
- Calleguas Ck. R4 [Revolon Slough] for ambient toxicity, chlorpyrifos, chlordane, DDT, dieldrin, PCBs, toxaphene
- Calleguas Ck. R5 [Beardsley Channel] for ambient toxicity, chlorpyrifos, chlordane, DDT, dieldrin, PCBs, toxaphene
- Calleguas Ck. R6 [Arroyo Las Posas] for chlordane, DDT, dieldrin, PCBs, toxaphene
- Calleguas Ck. R7 [Arroyo Simi] for chlorpyrifos, diazinon
- Calleguas Ck. R9A [Conejo Ck.] for chlordane, DDT, dieldrin, PCBs, toxaphene
- Calleguas Ck. R9B [Conejo Ck. mainstem] for ambient toxicity, chlordane, DDT, dieldrin, PCBs, toxaphene
- Calleguas Ck. R10 [Conejo Ck., Hill Canyon] for ambient toxicity, chlordane, DDT, dieldrin, PCBs, toxaphene
- Calleguas Ck. R11 [Arroyo Santa Rosa] for ambient toxicity, chlordane, DDT, dieldrin, PCBs, toxaphene
- Calleguas Ck. R12 [Conejo Ck, north fork] for chlordane, DDT, dieldrin, PCBs, toxaphene
- Calleguas Ck. R13 [Conejo Ck., south fork] for ambient toxicity, chlordane, DDT, dieldrin, PCBs, toxaphene.

During the TMDL development process, the State determined the following additional water body-pollutant combinations need TMDLs pursuant to the requirements of Section 303(d)(1), and adopted TMDLs to address these additional combinations:

- Calleguas Ck. R2 [estuary] for chlorpyrifos, diazinon
- Calleguas Ck. R3 [Potrero Rd., upstream] for ambient toxicity, chlorpyrifos, diazinon, chlordane, DDT, dieldrin, PCBs, toxaphene
- Calleguas Ck. R4 [Revolon Slough] for diazinon
- Calleguas Ck. R5 [Beardsley Channel] for diazinon
- Calleguas Ck. R6 [Arroyo Las Posas] for ambient toxicity, chlorpyrifos, diazinon
- Calleguas Ck. R7 [Arroyo Simi R1 & R2] for ambient toxicity, chlordane, DDT, dieldrin, PCBs, toxaphene
- Calleguas Ck. R8 [Tapo Cyn. R1 & R2] for chlorpyrifos, diazinon, chlordane, DDT, dieldrin, PCBs, toxaphene
- Calleguas Ck. R9A [Conejo Ck.] for ambient toxicity, chlorpyrifos, diazinon
- Calleguas Ck. R9B [Conejo Ck. mainstem] for chlorpyrifos, diazinon
- Calleguas Ck. R10 [Conejo Ck., Hill Canyon] for chlorpyrifos, diazinon

During the decision-making process, the State identified these additional water body-pollutant combinations as water quality limited waters for which TMDLs are required. The State provided sufficient documentation to support its determination and provided opportunities for public review and comment on the additional water body-pollutant identifications. The State's decision to concurrently identify additional water quality limited segments and adopt TMDLs for those segments is consistent with the provisions of the Clean Water Act and federal regulations. As the State's decision to identify the additional water body-pollutant combinations is consistent with the requirements of Section 303(d) and federal regulations at 40 CFR 130.7, EPA hereby approves the identification of these additional combinations pursuant to Section 303(d)(2).

Based on EPA's review of the TMDL submittals under Clean Water Act Section 303(d)(2), I have concluded the TMDLs adequately address the pollutants of concern and, upon implementation, will result in attainment of the applicable water quality standards. These TMDLs include waste load and load allocations as needed, take into consideration seasonal variations and critical conditions, and provide an adequate margin of safety.

The State provided sufficient opportunities for public review and comment on the TMDLs and demonstrated how public comments were considered in the final TMDLs. All required elements are adequately addressed; therefore, the TMDLs are hereby approved pursuant to Clean Water Act Section 303(d)(2).

The State submittals also contain detailed plans for implementing these TMDLs. Current federal regulations do not define TMDLs as containing implementation plans; therefore, EPA is not taking action on the implementation plans provided with the TMDLs. However, EPA generally concurs with the State's proposed implementation approaches.

The enclosed review discusses the basis for these decisions in greater detail. I appreciate the State and Regional Boards' work to adopt these TMDLs and look forward to our continuing partnership in TMDL development. If you have questions concerning this action, please call me at (415) 972-3572 or David Smith at (415) 972-3416.

Sincerely yours,

Alexis Strauss 14 March 2006
Alexis Strauss, Director
Water Division

enclosures

cc: Jonathan Bishop, LARWQCB

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Enclosure: Staff Analysis of TMDL Submittals
Calleguas Creek Pesticides, PCBs, Toxicity and Siltation
March 2006

Introduction

The State of California adopted TMDLs to address water body impairments in Calleguas Creek, its tributaries and Mugu Lagoon. The TMDLs are contained in two Basin Plan Amendments submitted by the State. One amendment includes the toxicity and organophosphate pesticides TMDLs; a second amendment includes TMDLs for organochlorine pesticides and PCBs in several segments and a siltation TMDL for Mugu Lagoon.

EPA reviewed the submittals to ensure that all TMDL elements required by Clean Water Act Section 303(d) and associated federal regulations at 40 CFR 130.2 and 130.7 were adequately addressed. EPA Region 9 reviews of State TMDL submittals are organized in checklist form. This document includes separate checklists for the two Basin Plan Amendments that briefly discuss the State's approaches to meeting TMDL requirements. EPA has determined that the TMDLs meet all federal approval requirements.

By approving these TMDL submittals, EPA is in compliance with the TMDL completion requirements for these waters and pollutants established in a 1999 federal consent decree pursuant to the *Heal the Bay v. Browner* litigation. This consent decree requires completion of TMDLs for many watersheds in the Los Angeles region in accordance with a specific time schedule. The consent decree schedule requires completion of required pesticide, PCB, and toxicity TMDLs for Calleguas Creek watershed and a siltation TMDL for Mugu Lagoon by March 22, 2006.

As described below, the State of California determined that some waters identified in the consent decree do not require TMDL development because available data and information indicate that these waters are not water quality limited pursuant to Section 303(d) and do not require TMDL development. Pursuant to the provisions of paragraph 8 of the consent decree, TMDLs are not required to be completed for water body-pollutant combinations identified in the consent decree if the State or EPA determine, consistent with the requirements of Section 303(d), that the water body-pollutant combinations are not water quality limited. The State of California has determined that several water body-pollutant combinations in the Calleguas Creek watershed do not require TMDL development. Several of these combinations were removed from the Section 303(d) list during the 2002 revisions to California's Section 303(d) list and are not addressed in these TMDL submittals as EPA previously approved these delisting decisions.

During development of the, the State determined that several additional water-pollutant combinations included on California's 2002 Section 303(d) list are not impaired and do not require TMDL development. Consistent with the provisions of consent decree paragraph 8, the State's documentation prepared to support these TMDL submittals clearly describes the basis for the State's conclusion that TMDLs are not needed for these combinations. The public had several opportunities to review and comment on these determinations. EPA concurs in these determinations that TMDLs are not required for these additional combinations. EPA expects these combinations will be removed from the Section 303(d) list during the ongoing revisions to California's Section 303(d) list, scheduled for completion in 2006.

Some listed segments in these watersheds covered in the consent decree were listed on the Section 303(d) list due to ambient water or sediment toxicity. The State developed TMDLs for all pollutants found at levels associated with toxicity to aquatic organisms. The State also developed separate toxicity TMDLs to address unidentified toxic agents of ambient or sediment toxicity. EPA concurs with this approach to addressing the toxicity listings in these waters.

In addition to addressing the water body-pollutant combinations included in the consent decree, the State determined through its analysis that water quality standards were being violated in several additional segments in the subject watershed. The State identified these additional water body-pollutant combinations in the Technical Reports supporting the Basin Plan Amendments as waters and pollutants requiring TMDLs pursuant to Section 303(d)(1). The State also described the analytical basis for its determinations concerning these additional segments and pollutants and provided ample opportunities for public review of these additional identifications. The State concurrently developed TMDLs for these additional water body-pollutant combinations that are included with the Basin Plan Amendment submittals. The State's approach of concurrently identifying waters and pollutants needing TMDLs and adopting the required TMDLs is consistent with the provisions of the Clean Water Act and associated federal regulations. This approach is also efficient as it comprehensively addresses water quality problem associated with pesticides, PCBs, and toxicity in these waters.

The technical analyses for most of these TMDLs were developed by a third party, Larry Walker Associates, under contract with the Calleguas Creek Watershed Management Steering Committee. One technical report describes the toxicity and organophosphate pesticide TMDLs (June 21, 2005). Another technical report (June 20, 2005) describes the organochlorine pesticide and PCBs TMDLs. Both technical reports were developed with input and guidance from the Los Angeles Regional Water Quality Control Board and EPA. The Los Angeles Regional Board staff prepared a separate technical memo (Staff Memo, April 25, 2005) for the siltation TMDL, which was included in the Basin Plan Amendment for the organochlorine pesticide and PCBs TMDLs.

TMDL Checklist

State: California
Waterbodies: Calleguas Creek, tributaries and Mugu Lagoon
Pollutant(s): Toxicity and Organophosphate pesticides (chlorpyrifos and diazinon)
Date of State Submission: January 12, 2006
Date Received By EPA: January 26, 2006
EPA Reviewer: Cindy Lin

Review Criteria	Comments
1. Submittal Letter: State submittal letter indicates final TMDL(s) for specific water(s)/pollutant(s) were adopted by state and submitted to EPA for approval under 303(d).	Letter dated January 12, 2006. The Los Angeles Regional Water Quality Control Board (Regional Board) adopted the TMDLs on July 7, 2005 through Resolution No. R4-2005-009. The State Water Resources Control Board (State Board) approved the basin plan amendment through Resolution No. 2005-0067 on September 22, 2005. The State Office of Administrative Law approved the TMDLs on December 27, 2005 as file No. 05-1110-02 S. These TMDLs address water body-pollutant combinations identified in Analytical Units # 2 and 5 of the *Heal the Bay* consent decree. TMDLs were adopted for following segments and impairments as identified on the state's 2002 303d list: (June 21, 2005 Technical Report (Technical Report), p. 23) - Calleguas Ck Reach 1 = Mugu Lagoon (sediment toxicity) - Duck Pond drain/Mugu drain/ Oxnard drain #2 (ambient and sediment toxicity) - Calleguas Creek R2 = estuary (sediment toxicity) - Calleguas Ck R4 = Revolon Slough (ambient toxicity, chlorpyrifos) - Calleguas Ck R5 = Beardsley Channel (ambient toxicity, chlorpyrifos) - Calleguas Ck R7 = Arroyo Simi (organophosphate pesticides; i.e., chlorpyrifos and diazinon) - Calleguas Ck R9B = Conejo Ck mainstem (ambient toxicity) - Calleguas Ck R10 = Conejo Ck, Hill Canyon (ambient toxicity) - Calleguas Ck R11 = Arroyo Santa Rosa (ambient toxicity) - Calleguas Ck R13 = Conejo Ck, south fork (ambient toxicity) As discussed above, the State identified several additional segments in the Calleguas Creek watershed for which organophosphate pesticides and toxicity TMDLs were also adopted (Technical Report, pp. 45-46): - Calleguas Creek R2 = estuary (chlorpyrifos, diazinon) - Calleguas Ck R3 = Potrero Rd. (ambient toxicity, chlorpyrifos, diazinon) - Calleguas Ck R4 = Revolon Slough (diazinon) - Calleguas Ck R5 = Beardsley Channel (diazinon) - Calleguas Ck R6 = Arroyo Las Posas (ambient toxicity, chlorpyrifos, diazinon) - Calleguas Ck R7 = Arroyo Simi (ambient toxicity) - Calleguas Ck R8 = Tapo Cyn R1 & R2 (chlorpryifos, diazinon) - Calleguas Ck R9A = Conejo Ck (ambient toxicity, chlorpryifos, diazinon) - Calleguas Ck R9B = Conejo Ck mainstem (chlorpryifos, diazinon) - Calleguas Ck R10 = Conejo Ck, Hill Canyon (chlorpyrifos, diazinon) - Calleguas Ck R11 = Arroyo Santa Rosa (chlorpryifos, diazinon) EPA finds the State's analysis concerning water body impairment associated with toxicity, chlorpyrifos and diazinon organophosphate compounds in the Calleguas Creek watershed and Mugu Lagoon is reasonable and consistent with the requirements of Section 303(d).

2. Water Quality Standards Attainment: TMDL and associated allocations are set at levels adequate to result in attainment of applicable water quality standards.	The June 21, 2005 Technical Report, pp. 13-15. The TMDL is designed to implement the existing narrative objectives for toxicity and toxic pollutant that apply in Calleguas Creek, its tributaries and Mugu Lagoon. The Regional Board Basin Plan specifies narrative water quality objectives stating that toxic substances shall not be present at levels that will bioaccumulate in aquatic organisms to levels that are harmful to aquatic life or human health. Although there are no Basin Plan Objectives specific to sediment toxicity, the narrative ambient water toxicity objectives may be used to address sediment toxicity for the purposes of identifying targets for sediment toxicity. In addition, the Basin Plan specifies that no individual pesticide or combination of pesticides shall be present in concentrations that adversely affect beneficial uses. The Basin Plan also prohibits increases pesticide concentrations found in bottom sediments or aquatic life. (Technical Report Section 2.2.2) Currently, there are no adopted numeric water, sediment, or fish tissue objectives in the Basin Plan or California Toxics Rule for any organophosphate pesticides (i.e., chlorpyrifos and diazinon). The State reasonably concluded that implementation of the TMDLs, load allocations, and waste load allocations will result in elimination of the adverse effects associated with high toxicity and organophosphate pesticide loads and bring about attainment of the applicable standards for these toxicant compounds in water and sediments.
3. Numeric Target(s): Submission describes applicable water quality standards, including beneficial uses, applicable numeric and/or narrative criteria. Numeric water quality target(s) for TMDL identified, and adequate basis for target(s) as interpretation of water quality standards is provided.	Basin Plan Amendment Resolution, pp. 2-3. The TMDL report identifies numeric targets for chlorpyrifos, diazinon and water and sediment toxicity. The TMDL establishes a numeric toxicity target of 1.0 toxicity unit-chronic (1.0 TUc) to address toxicity in reaches where the toxicant has not been identified through a Toxicity Identification Evaluation (TIE) (unknown toxicity). A sediment toxicity target was defined for reaches for which TIEs did not identify the causes of sediment toxicity. (Technical Report, pp. 53-56) The TMDL establishes numeric targets for chlorpyrifos and diazinon based on USEPA's 1985 Guidelines for Deriving Numeric National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses. (Technical Report, pp. 50-52) Chlorpyrifos Numeric Targets (ug/L) — Chronic — Acute Freshwater — 0.014 — 0.025 Saltwater (Mugu Lagoon) — 0.009 — 0.02 Diazinon Numeric Targets (ug/L) — Chronic — Acute Freshwater — 0.10 — 0.10 Saltwater (Mugu Lagoon) — 0.40 — 0.82 The State's approach is a reasonable and environmentally protective approach for applying applicable numeric criteria to derive numeric targets.
4. Source Analysis: Point, non-point, and background sources of pollutants of concern are described, including the magnitude and location of sources. Submittal demonstrates all significant	Basin Plan Amendment Resolution, p. 3. The TMDL analysis evaluates all available data and information concerning the sources of toxicity and organophosphate pesticides into Calleguas Creek, its tributaries and Mugu Lagoon. The TMDL focuses on the potential sources of chlorpyrifos and diazinon as these two organophosphate pesticides have been identified as principal causes of water and/or sediment toxicity in the watershed.

sources have been considered.	The Calleguas Creek Watershed Nutrients TMDL (approved in 2003) addresses potential contributions to toxicity from ammonia. As the causes of toxicity in some listed reaches have not been fully identified, monitoring will continue to investigate toxicity of unknown causes (as stipulated in the Implementation Plan). Toxicity investigations to date suggest the unknown toxicity is associated with organic toxicants and, in particular, organophosphate pesticides. (Technical Report, p. 57) The largest source of chlorpyrifos and diazinon pesticides is agricultural runoff and urban runoff within the watershed. During dry weather, publicly owned treatment works (POTWs) contribute a significant load of diazinon to the water bodies. However, urban use of chlorpyrifos and diazinon are unlikely to be a long-term source to the watershed as both pesticides have been banned for most non-agricultural uses starting December 31, 2005. (Technical Report, pp. 58-85) The TMDL report adequately considered all significant sources of organophosphate compounds to Calleguas Creek watershed and other potential causes of observed toxicity.
5. Allocations: Submittal identifies appropriate waste load allocations for point sources and load allocations for non-point sources. If no point sources are present, waste load allocations are zero. If no non-point sources are present, load allocations are zero.	Basin Plan Amendment Resolution, pp. 4-6. The TMDLs include both wasteload allocations for point sources and load allocations for non point sources. A wasteload allocation of 1.0 TUc is allocated to point sources (POTWs, urban stormwater co-permittees (MS4), and minor NPDES-regulated sources). In addition, the major and minor point sources receive wasteload allocations set equal to the established numeric targets for chlorpyrifos (equal to the 4-day chronic numeric target) and diazinon (equal to the 1 hour acute target). All nonpoint sources received a load allocation of 1.0 TUc. Load allocations of chlorpyrifos and diazinon are set equal to the numeric targets for each subwatershed. (Technical Report, pp. 109-115) Since chlorpyrifos and diazinon are not naturally occurring, the background load allocation is set equal to zero. (Technical Report, pp. 118) Based on the information in the Technical Report and the Basin Plan Attachment to Resolution, EPA concludes that the TMDLs include as appropriate wasteload and load allocations that are consistent with the Clean Water Act and federal regulations.
6. Link Between Numeric Target(s) and Pollutant(s) of Concern: Submittal describes relationship between numeric target(s) and identified pollutant sources. For each pollutant, describes analytical basis for conclusion that sum of waste load allocations, load allocations, and margin of safety does not exceed the loading capacity of the receiving water(s).	Basin Plan Amendment Resolution, p. 3-4. The State used water quality modeling to establish the linkage between sources of chlorpyrifos and diazinon in the watershed to observed water quality data. A mass balance water quality model used existing data to determine loads and partitioning between dissolved and adsorbed fractions. The TMDL report presented a conceptual model describing the relationship between water column concentrations and fish tissue and sediment concentrations. The model incorporated the specific characteristics of chlorpyrifos (preferentially binds to sediment) and diazinon (preferentially partition to water phase) and reasonably calculated conservative loads and loading capacities. (Technical Report, pp. 86-108) The State's analysis sufficiently describes the link between numeric targets and the pollutant sources in Calleguas Creek watershed.

7. Margin of Safety: Submission describes explicit and/or implicit margin of safety for each pollutant.	Basin Plan Amendment Resolution, p. 7. The TMDL includes both an implicit and explicit margin of safety. The primary implicit margin of safety is provided through the adoption of concentration based TMDLs and allocations that are sensitive to temporal and spatial variability of pollutant loads, and through the adoption of toxicity based TMDLs to address unexplained toxicity causes. The TMDL also includes an explicit margin of safety of 5%. This 5% explicit margin of safety is added to the targets for chlorpyrifos in the Calleguas and Revolon subwatersheds to address the uncertainty in the linkages between water column criteria and fish tissue and sediment concentrations. (Technical Report, pp. 118) EPA considers this a permissible and appropriate way of dealing with uncertainty concerning the relationships between allocations and water quality.

8. Seasonal Variations and Critical Conditions: Submission describes method for accounting for seasonal variations and critical conditions in the TMDL(s)	Basin Plan Amendment Resolution, p. 7. The critical condition in this TMDL is defined as the flowrate at which the model calculated the greatest in-stream diazinon or chlorpyrifos concentration in comparison to the appropriate criterion. The critical condition for chlorpyrifos was in dry weather based on a chronic numeric target. For diazinon, wet weather (based on acute numeric target) is defined as the critical period, except in Mugu Lagoon where critical condition is in dry weather based on the chronic numeric target. (Technical Report, pp. 110 and 119) The State's approach adequately accounts for critical conditions by defining crucial hydrological periods in which ecological effects may occur.
9. Public Participation: Submission documents provision of public notice and public comment opportunity; and explains how public comments were considered in the final TMDL(s).	The Regional and State Boards provided public notice and opportunities for public comment to comment on the TMDLs through mailings, by holding numerous public meetings, and by receiving public comments at these meetings. Public comments were received in writing and in oral testimony. The State demonstrated how it considered these comments in its final decision by providing reasonably detailed responsiveness summaries, which include responses to each comment. The Regional Board held public meetings to discuss the Calleguas Creek Toxicity and Chlorpyrifos and Diazinon TMDLs on May 5, May 31 and July 7, 2005. (See summary of responses to public comments by Regional Board, July 2005.) The State Board also received public comment on the TMDLs on September 22, 2005.
10. Technical Analysis: Submission provides appropriate level of technical analysis supporting TMDL elements.	The TMDL analysis provides a thorough review and summary of available information concerning toxicity, chlorpyrifos and diazinon organophosphate pesticides impairing Calleguas Creek, its tributaries and Mugu Lagoon. EPA concludes the State was reasonably diligent in its technical analysis of toxicity, chlorpyrifos and diazinon in Calleguas Creek and its watershed.

TMDL Checklist

State: California
Waterbodies: Calleguas Creek, tributaries and Mugu Lagoon
Pollutant(s): Organochlorine pesticides (DDT, dieldrin, chlordane, toxaphene), PCBs and siltation
Date of State Submission: February 6, 2006
Date Received By EPA: February 8, 2006
EPA Reviewer: Peter Kozelka

Review Criteria	Comments
1. Submittal Letter: State submittal letter indicates final TMDL(s) for specific water(s)/pollutant(s) were adopted by state and submitted to EPA for approval under 303(d).	Letter dated February 6, 2006. The Los Angeles Regional Water Quality Control Board (Regional Board) adopted the TMDLs on July 7, 2005 through Resolution No. R4-2005-010. The State Water Resources Control Board (State Board) approved the basin plan amendment through Resolution No. 2005-0068 on September 22, 2005. The State Office of Administrative Law approved the TMDLs on January 20, 2006 as file No. 05-1026-03 S. These TMDLs address water body-pollutant combinations identified in Analytical Units # 5 and 7 of the *Heal the Bay* consent decree. TMDLs were adopted for following segments identified on the state's 2002 303d list: - Calleguas Ck Reach 1 = Mugu Lagoon (chlordane, DDT, dieldrin, PCBs toxaphene) - Duck Pond drain/Mugu drain/ Oxnard drain #2 (chlordane, DDT, dieldrin, PCBs toxaphene) - Calleguas Creek R2 = estuary (chlordane, DDT, dieldrin, PCBs toxaphene) - Calleguas Ck R4 = Revolon Slough (chlordane, DDT, dieldrin, PCBs toxaphene) - Calleguas Ck R5 = Beardsley Channel (chlordane, DDT, dieldrin, PCBs toxaphene) - Calleguas Ck R6 = Arroyo Las Posas (chlordane, DDT, dieldrin, PCBs toxaphene) - Calleguas Ck R9A= Conejo Ck (chlordane, DDT, dieldrin, PCBs toxaphene) - Calleguas Ck R9B = Conejo Ck mainstem (chlordane, DDT, dieldrin, PCBs toxaphene) - Calleguas Ck R10 = Conejo Ck, Hill Canyon (chlordane, DDT, dieldrin, PCBs toxaphene) - Calleguas Ck R11 = Arroyo Santa Rosa (chlordane, DDT, dieldrin, PCBs toxaphene) - Calleguas Ck R12 = Conejo Ck, north fork (chlordane, DDT, dieldrin, PCBs toxaphene) - Calleguas Ck R13 = Conejo Ck, south fork (chlordane, DDT, dieldrin, PCBs toxaphene) As discussed above, the State identified several additional segments in the Calleguas Creek watershed for which organochlorine pesticides and PCBs TMDLs were also adopted (Technical Report, pp. 23): - Calleguas Ck R3 = Potrero Rd., upstream (chlordane, DDT, dieldrin, PCBs toxaphene) - Calleguas Ck R7 = Arroyo Simi R1 & R2 (chlordane, DDT, dieldrin, PCBs toxaphene) - Calleguas Ck R8 = Tapo Cyn R1 & R2 (chlordane, DDT, dieldrin, PCBs toxaphene) As discussed above, the State concluded that several water body-pollutant combinations in the watershed that were covered by the consent decree are not water quality limited pursuant to the Clean Water Act and that TMDLs are not required. The State found the following water body segments, as identified on the 2002 303(d) list, were not impaired due to the corresponding pollutants: - Calleguas Ck Reach 1 = Mugu Lagoon (endosulfan) - Duck Pond drain/Mugu drain/ Oxnard drain #2 (Chem A group) - Calleguas Creek R2 = estuary (Chem A, endosulfan) - Calleguas Ck R4 = Revolon Slough (Chem A, endosulfan) - Calleguas Ck R5 = Beardsley Channel (Chem A, endosulfan, dacthal) - Calleguas Ck R9A= Conejo Ck (Chem A, endosulfan, hexachlorocyclohexane)

	- Calleguas Ck R9B = Conejo Ck mainstem (Chem A, endosulfan) - Calleguas Ck R10 = Conejo Ck, Hill Canyon (Chem A, endosulfan) - Calleguas Ck R11 = Arroyo Santa Rosa (Chem A, endosulfan) - Calleguas Ck R13 = Conejo Ck, south fork (Chem A, endosulfan) (TMDL report pp. 19-24 and pp. 32-33) EPA finds the State's analysis concerning water body impairment associated with organochlorine compounds in Calleguas Creek watershed and siltation in Mugu Lagoon is reasonable and consistent with the requirements of Section 303(d).
2. Water Quality Standards Attainment: TMDL and associated allocations are set at levels adequate to result in attainment of applicable water quality standards.	The June 20, 2005 Technical TMDL Report (Technical Report), pp. 14-16. The TMDL is designed to implement the existing numeric and narrative objectives for organochlorine compounds apply in Calleguas Creek, its tributaries and Mugu Lagoon. The federal California Toxics Rule (CTR) specifies numeric water quality criteria for organochlorine pesticides and PCBs that apply in these waters. The Regional Board's Basin Plan specifies narrative water quality objectives stating that toxic substances shall not be present at levels that will bioaccumulate in aquatic organisms to levels which are harmful to aquatic life or human health. (Technical Report, pp. 14-16) The TMDL also addresses narrative objectives regarding wetlands, which emphasize that existing habitat for flora and fauna shall be maintained. This objective is relevant to the protection of Mugu Lagoon. (Technical Report, p. 16) The State reasonably concluded that implementation of the TMDLs, load allocations, and waste load allocations will result in elimination of the adverse effects associated with high organochlorine pesticide, PCBs and siltation loads and bring about attainment of the applicable standards for these toxicant compounds and silt/sediment.
3. Numeric Target(s): Submission describes applicable water quality standards, including beneficial uses, applicable numeric and/or narrative criteria. Numeric water quality target(s) for TMDL identified, and adequate basis for target(s) as interpretation of water quality standards is provided.	Basin Plan Amendment Resolution, pp. 2-4. The TMDL report identifies numeric targets for several media (e.g., water, sediment, fish tissue, wildlife tissue). The TMDLs are designed to implement the numeric water quality criteria in the CTR as well as related fish tissue targets based on translation of the CTR human health criteria. Organochlorine pesticide and PCB targets in sediment are identified for freshwater and saltwater values based on sediment quality guidelines. Targets for bird eggs and seal blubber are included. (Technical Report, pp. 52-57) Two siltation targets are identified in the TMDL for silt reduction and maintenance of existing habitat. (Staff technical memo, dated April 25, 2005, p. 5) The State's approach is a reasonable and environmentally protective approach for applying applicable numeric criteria to derive numeric targets.
4. Source Analysis: Point, non-point, and background sources of pollutants of concern are described, including the magnitude and location of sources. Submittal demonstrates all	Basin Plan Amendment Resolution, p. 4. The TMDL analysis evaluates all available data and information concerning the sources of organochlorine pesticides and PCBs into Calleguas Creek, its tributaries and Mugu Lagoon. The largest source of organochlorine pesticides is agricultural runoff (regulated via waste discharge requirements) with minor inputs from urban runoff and wastewater treatment plants (regulated via NPDES permits) within the watershed. Atmospheric deposition is identified as a potential source of PCBs but not the other compounds. Groundwater and imported water are not significant sources of organochlorine pesticides, PCBs and sediment. (Technical Report, pp. 58-83)

significant sources have been considered.	The siltation TMDL also identified five sources as contributors of sediment to the lagoon basin. (Staff Memo, p. 5) The TMDL report adequately considered all significant sources of organochlorine compounds to Calleguas Creek watershed. It also adequately considered sources of sediments (silt) to Mugu Lagoon. The TMDL sufficiently described all sources of impairments.
5. Allocations: Submittal identifies appropriate waste load allocations for point sources and load allocations for non-point sources. If no point sources are present, waste load allocations are zero. If no non-point sources are present, load allocations are zero.	Basin Plan Amendment Resolution, pp. 5-8. The TMDLs include both waste load allocations for point sources and load allocations for non point sources. Allocations are categorized by sources and expressed in terms of allowable concentrations of organochlorine pesticides and PCBs. POTWs and minor point sources received daily and monthly wasteload allocations. Stormwater permittees (point source) and agricultural (non-point) sources received annual average wasteload allocations for toxicants in sediments. (Technical Report, pp. 102-105) For the separate siltation TMDL, stormwater permittees and agricultural sources each received a mass-based allocation for sediment yield to Mugu Lagoon. (Staff Memo, pp. 7-9) Based on the information in the Staff Report and the Basin Plan Attachment to Resolution, EPA concludes that the TMDLs include as appropriate wasteload and load allocations that are consistent with the Clean Water Act and federal regulations.
6. Link Between Numeric Target(s) and Pollutant(s) of Concern: Submittal describes relationship between numeric target(s) and identified pollutant sources. For each pollutant, describes analytical basis for conclusion that sum of waste load allocations, load allocations, and margin of safety does not exceed the loading capacity.	Basin Plan Amendment Resolution, pp. 4-5. The TMDL report provides a conceptual model that describes the fate, transformation and uptake of OC pesticides and PCBs and a mass balance model to connect sources of these compounds to their fate and transport in Calleguas Creek and Mugu Lagoon. Sediments serve as the primary exposure pathway and so reductions in sediment concentrations will yield in pollutant reductions in water and fish tissue. DDE is used as a surrogate indicator in the modeling analysis because it is consistently detected in water, sediment and tissue at levels above media specific numeric targets. (Technical Report, pp. 84-95) The Siltation TMDL memo cited several studies to demonstrate that increased sediment accumulation (via deposition of upstream sources) would create land elevation changes in areas that currently contain habitat and would impact estuarine marshes and tidal mudflats. (Staff Memo, pp. 5-6) The State's analysis sufficiently describes the link between numeric targets and the pollutant sources in Calleguas Creek watershed.
7. Margin of Safety: Submission describes explicit and/or implicit margin of safety for each pollutant.	Basin Plan Amendment Resolution, p. 8. The pesticides and PCBs TMDLs include an implicit margin of safety based on several conservative methods utilized during TMDL development. For example, the TMDLs are set based on the greater percent reduction required of either water or fish tissue concentrations in order to determine the percent reductions required for sediments. (Technical Report, pp. 106-107) The siltation TMDL also includes an implicit margin of safety based on conservative estimates of sediment volume reduction need to preserve and improve habitat conditions affected by silt loads. (Staff Memo, p. 7) EPA considers this a permissible and appropriate way of dealing with uncertainty concerning the relationships between allocations and water quality.

8. Seasonal Variations and Critical Conditions: Submission describes method for accounting for seasonal variations and critical conditions in the TMDL(s)	Basin Plan Amendment Resolution, p. 9-10. The TMDL report presents a direct correlation between organochlorine pollutant concentrations and suspended sediment levels, and a positive correlation between sediment loads and wet weather, to support a finding that critical conditions occur during wet weather. The report acknowledges that wet weather events may occur at any time of the year, and these events produce extensive sediment and organochlorine compound redistribution and transport downstream. For bioaccumulative pollutants such as these, which manifest effects over long time periods, the short-term load variations are not likely to create significant variations in beneficial use effects. (Technical Report, pp. 98-99) The siltation analysis recognizes that storm conditions account for the majority of sediment transport and deposition into Mugu Lagoon. However, as beneficial use effects in Mugu Lagoon are associated with the cumulative effects of sediment loads over multi-year periods, short term load variations are unlikely to cause measurable effects. (Staff Memo, pp. 6-7) The State's approach adequately accounts for critical conditions by establishing TMDLs for longer timeframes in which ecological effects may occur.
9. Public Participation: Submission documents provision of public notice and public comment opportunity; and explains how public comments were considered in the final TMDL(s).	The Regional and State Boards provided public notice and opportunities to comment on the TMDLs through mailings, by holding numerous public meetings, and by hearing public comments at these meetings. Public comments were received in writing and in oral testimony. The State demonstrated how it considered these comments in its final decision by providing reasonably detailed responsiveness summaries, which include responses to each comment. The Regional Board held public meetings to discuss the Calleguas Creek organochlorine compound and siltation TMDLs on May 5 and July 7, 2005. (See summary of responses to public comments by Regional Board, July 2005). The State Board also received public comment on the TMDLs on September 7, 2005.
10. Technical Analysis: Submission provides appropriate level of technical analysis supporting TMDL elements.	The TMDL analysis provides a thorough review and summary of available information concerning organochlorine pesticides and PCBs impairing Calleguas Creek, its tributaries and Mugu Lagoon. The analysis also provides appropriate review and summary information for siltation build up and effects in Mugu Lagoon. EPA concludes the State was reasonably diligent in its technical analysis of DDT, dieldrin, chlordane, PCBs and toxaphene in Calleguas Creek and its watershed, as well as the analysis for siltation in Mugu Lagoon.

April 25, 2005

Calleguas Creek Watershed Toxicity, Chlorpyrifos and Diazinon TMDL

Technical Report

Submitted to Los Angeles Regional Water Quality Control Board

Prepared by Larry Walker Associates on behalf of the Calleguas Creek Watershed Management Plan

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1 Introduction

The Calleguas Creek Watershed Toxicity, Chlorpyrifos, and Diazinon Total Maximum Daily Load (Toxicity TMDL) presents the required elements for addressing impairments to Calleguas Creek and its tributaries caused by water column toxicity, sediment toxicity, organophosphate (OP) pesticides in water, and chlorpyrifos in fish tissue. The organophosphate in water and chlorpyrifos in fish tissue listings are addressed is this TMDL as they have been identified as contributing to water and sediment toxicity as described in the Problem Statement and Current Conditions sections of this TMDL. This report summarizes the analyses completed to determine the causes of these impairments, loadings from various sources, and measures to remove these impairments.

Segments of Calleguas Creek and its tributaries are impaired by water column and sediment toxicity of unknown causes, organophosphate (OP) pesticides in water, and chlorpyrifos in fish tissue (Figure 1) and are included on the California 2002 303(d) list of water quality limited segments, which was approved by the California State Water Resources Control Board (State Board) on February 4, 2003. Specifically, the 2002 303(d) list identifies impairments due to water column toxicity in Reaches 4, 5, 9B, 10, 11, and 13, sediment toxicity in Reaches 1 and 2, chlorpyrifos in fish tissue in Reaches 4 and 5, and organophosphate pesticides in water in Reach 7 (Table 1).

The Clean Water Act requires TMDLs be developed to restore impaired waterbodies, and the Porter-Cologne Water Quality Act requires that an Implementation Plan be developed to achieve water quality objectives. This document fulfills these statutory requirements and serves as the basis for amending the Water Quality Control Plan for the Los Angeles Region (Basin Plan) to achieve water quality standards in Calleguas Creek for water column and sediment toxicity, OP pesticides in water, and chlorpyrifos in fish tissue. This TMDL addresses the requirements prescribed by Section 303(d) of the Clean Water Act, 40 CFR 130.2 and 130.7, and United States Environmental Protection Agency (1991).

The Calleguas Creek Watershed Toxicity TMDL (CCW Toxicity TMDL) is based on analysis provided by Larry Walker Associates under contract to the Calleguas Creek Watershed Management Plan Steering Committee (Steering Committee) with support from the California Regional Water Quality Control Board, Los Angeles Region (Regional Board), and the USEPA, Region 9.

Table 1. Calleguas Creek Watershed Reaches on the 2002 303(d) List for Toxicity and Organophosphate Pesticides

Reach		Impairment			
		Water Column Toxicity	Sediment Toxicity	Chlorpyrifos in Fish Tissue	Organophosphate Pesticides in Water
1	Mugu Lagoon		X		
	Duck Pond Agricultural Drains/Mugu Drain/Oxnard Drain No 2		X		
2	Calleguas Creek South		X		
4	Revolon Slough	X		X	
5	Beardsley Channel	X		X	
7	Arroyo Simi				X
9B	Conejo Creek Main Stem	X			
10	Hill Canyon	X			
11	Arroyo Santa Rosa	X			
13	Conejo Creek South Fork	X			

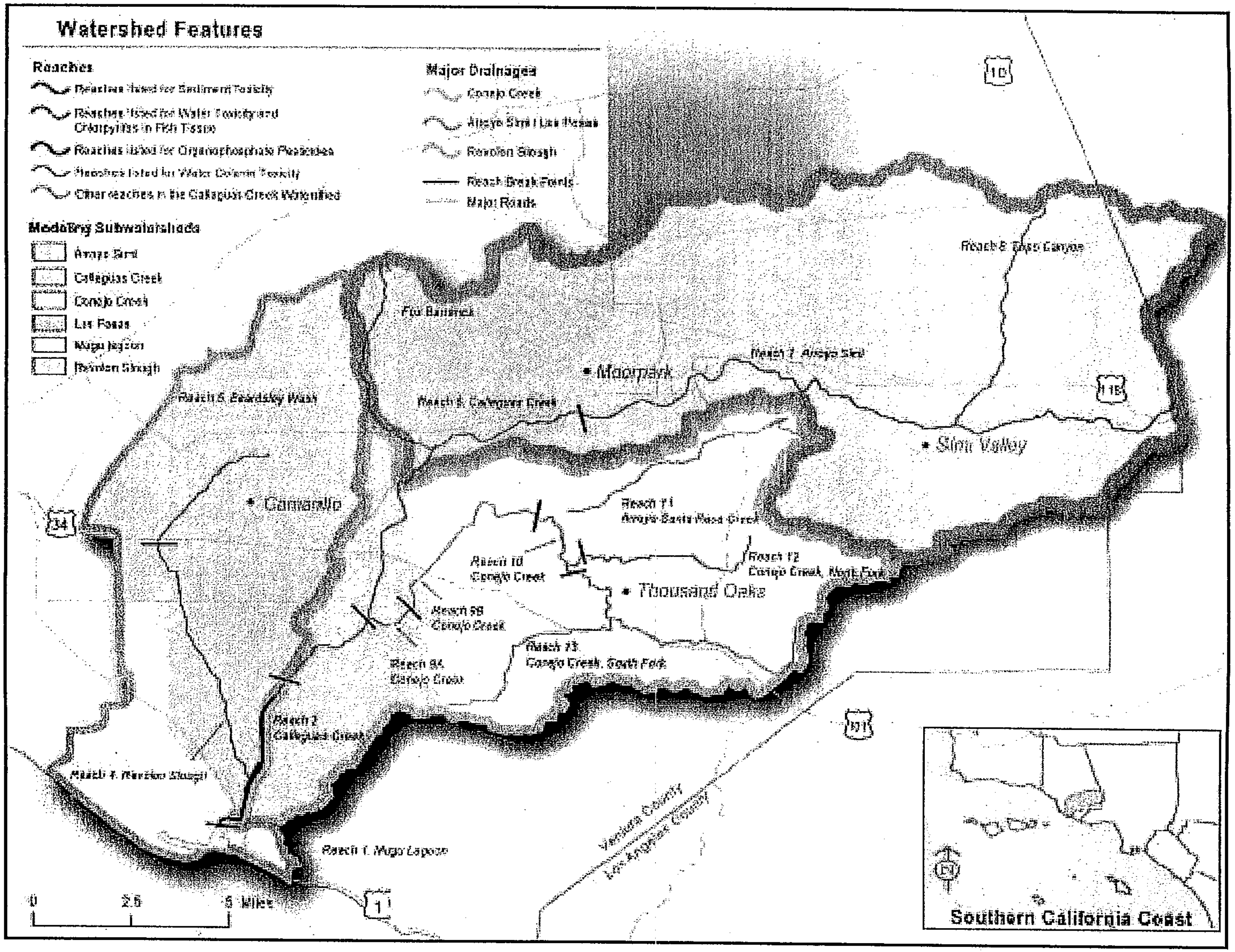

Figure 1. Reaches in the Calleguas Creek Watershed listed on the 2002 303(d) list for water or sediment toxicity, chlorpyrifos in fish tissue, and or organophosphate pesticides in water.

1.1 *Regulatory Background*

Section 303(d) of the Clean Water Act (CWA) requires that "Each State shall identify those waters within its boundaries for which the effluent limitations are not stringent enough to implement any water quality standard applicable to such waters." The CWA also requires states to establish a priority ranking for waters on the 303(d) list of impaired waters and establish TMDLs for such waters.

The elements of a TMDL are described in 40 CFR 130.2 and 130.7 and Section 303(d) of the CWA, as well as in USEPA guidance (USEPA, 1991). A TMDL is defined as the "sum of the individual waste load allocations for point sources and load allocations for nonpoint sources and natural background" (40 CFR 130.2) such that the capacity of the waterbody to assimilate pollutant loadings (the Loading Capacity) is not exceeded. TMDLs are also required to account for seasonal variations, and include a margin of safety to address uncertainty in the analysis.

States must develop water quality management plans to implement the TMDL (40 CFR 130.6). The USEPA has oversight authority for the 303(d) program and is required to review and either approve or disapprove the TMDLs submitted by states. If the USEPA disapproves a TMDL submitted by a state, USEPA is required to establish a TMDL for that waterbody. The Regional Board identified over 700 waterbody-pollutant combinations in the Los Angeles Region where TMDLs are required (LARWQCB, 2003). A schedule for development of TMDLs in the Los Angeles Region was established in a consent decree (Heal the Bay Inc., et al. v. Browner C 98-4825 SBA) approved on March 22, 1999. The consent decree combined waterbody pollutant combinations in the Los Angeles Region into 92 TMDL analytical units. In accordance with the consent decree, this document summarizes the analyses performed and presents the TMDL for addressing analytical unit 2, which contains toxicity and chlorpyrifos in fish tissue listings, and the sediment toxicity listings presented in analytical unit 5. The remaining analytical unit 5 listings for historic pesticides as well as the PCBs listings, presented in analytical unit 7, are addressed through the CCW Organochlorine and PCBs TMDL. According to the consent decree, TMDLs addressing analytical units 2, 5, and 7 must be approved or established by USEPA by March 2006.

In addition to the federal and state regulations described above, the Regional Board enacted Resolution No. 97-10, *Support for Watershed Management in the Calleguas Creek Watershed* on April 7, 1997. Resolution 97-10 recognized watershed management as an innovative, cost-effective strategy for the protection of water quality. Resolution 97-10 also recognized that the Calleguas Creek Municipal Water District and the Publicly Owned Treatment Works (POTWs) in the Calleguas Creek Watershed had worked cooperatively with the Regional Board to develop an integrated watershed-wide monitoring program. The Calleguas Watershed Management Plan has been active since 1996 in the development of a watershed management plan for the Calleguas Creek watershed and has proactively worked with the Regional Board and the USEPA to develop TMDLs in the watershed.

1.2 *Calleguas Creek TMDL Stakeholder Participation Process*

The Calleguas Creek Watershed Management Plan has been active since 1996. In 2001, the group began discussions with the Regional Board and USEPA to provide assistance in the development of the TMDLs for the watershed. In December 2002, the group developed TMDL work plans for the majority the constituents on the 2002 303(d) list. The Toxicity TMDL Work Plan, developed with input from the

LARWQCB and USEPA, forms the basis of much of the work conducted to develop this TMDL. USEPA Region 9 approved the Toxicity TMDL Work Plan in October 2003.

The purpose of the watershed group assisting with the development of this TMDL was to take full advantage of local expertise and reach a broad group of stakeholders to resolve water quality problems within the watershed. Stakeholders include representatives of cities, counties, water districts, sanitation districts, private property owners, agricultural organizations, and environmental groups with interests in the watershed.

A high level of stakeholder involvement has occurred throughout the TMDL development process. There have been no interventions from outside groups, and much of the work has been performed, or paid for, by members of local government agencies with partial USEPA grant funding.

1.3 *Elements of a TMDL*

The Calleguas Creek Watershed Toxicity TMDL contains the following elements:

- Section 2: Problem Statement – This section presents the basis for the listings addressed by this TMDL.
- Section 3: Current Conditions – Provides a summary of current conditions based on environmental data not incorporated into the listings.
- Section 4: Numeric Targets – This section presents appropriate numeric targets that will result in the attainment of water quality objectives as well as the basis for selection of targets.
- Section 5: Source Analysis – This section presents an inventory and quantification of the sources of the pollutants of concern.
- Section 6: Linkage Analysis – This section presents the analysis developed to describe the relationship between the sources of the pollutants of concern and the resulting effect on water quality.
- Section 7: TMDL and Allocations – This section identifies the TMDL allocations for point sources (waste load allocations) and nonpoint sources (load allocations) that will result in the attainment of water quality objectives.
- Section 8: Implementation Plan – This section describes the strategy for implementing the Toxicity TMDL and achieving water quality objectives as well as a brief overview of the strategy for monitoring the effects of implementation actions.

2 Problem Statement

The Problem Statement section provides context and background for the TMDL. The environmental setting provides an overview of the hydrology, climate, and anthropogenic influences in the CCW. In addition, this section includes an overview of water quality standards for the watershed and reviews water and sediment toxicity, water quality, and fish tissue data used to develop the 1996, 1998, and 2002 303(d) listings.

2.1 *Environmental Setting*

Calleguas Creek and its tributaries are located in southeast Ventura County and a small portion of western Los Angeles County. Calleguas Creek drains an area of approximately 343 square miles from the Santa Susana Pass in the east to Mugu Lagoon in the southwest. The main surface water system drains from the mountains in the northeast part of the watershed toward the southwest where it flows through the Oxnard Plain before emptying into the Pacific Ocean through Mugu Lagoon. The watershed, which is elongated along an east-west axis, is about thirty miles long and fourteen miles wide. The Santa Susana Mountains, South Mountain, and Oak Ridge form the northern boundary of the watershed; the southern boundary is formed by the Simi Hills and Santa Monica Mountains.

Land uses in the Calleguas Creek watershed include agriculture, high and low density residential, commercial, industrial, open space, and a Naval Air Base located around Mugu Lagoon. The watershed includes the cities of Simi Valley, Moorpark, Thousand Oaks, and Camarillo. Most of the agriculture is located in the middle and lower watershed with the major urban areas (Thousand Oaks and Simi Valley) located in the upper watershed. The current land use in the watershed is approximately 26% agriculture, 24% urban, and 50% open space. Patches of high quality riparian habitat are present along the length of Calleguas Creek and its tributaries.

The watershed is characterized by three major subwatersheds: the Arroyo Simi/Las Posas in the north, Conejo Creek in the south and Revolon Slough in the west. Additionally, the lower watershed is also drained by several minor agricultural drains in the Oxnard plain. The following sections describe the subwatersheds in more detail. Figure 1 depicts Calleguas Creek with reach names and designations, and six smaller subwatersheds defined for analysis and modeling in this TMDL (Mugu, Revolon, Calleguas, Conejo, Arroyo Las Posas, and Arroyo Simi).

2.1.1 Arroyo Simi/Las Posas

The northern portion of the watershed is drained by the Arroyo Las Posas and the Arroyo Simi, which is tributary to the Arroyo Las Posas. The northern part of the watershed system originates in the Simi Valley and surrounding foothills. The surface flow comes from the headwaters of the Arroyo Simi at Santa Susanna pass (upper parts of Reach 7) and Tapo Canyon (Reach 8). Arroyo Simi and Arroyo Las Posas flow through the cities of Simi Valley and Moorpark and join with Calleguas Creek near Camarillo. Upstream of Simi Valley, the creek is unlined and passes through open space and recreational areas. Through the city of Simi Valley, the Arroyo Simi flows through concrete lined or rip-rapped channels. Between Simi Valley and Moorpark, a distance of approximately seven miles, the creek is unlined and without rip-rap. From the edge of Moorpark to Hitch Boulevard, the creek is once again rip-rapped on the sides with a soft bottom throughout most of the channel, but in some areas, such as under bridges, the bottom is covered with concrete and rip rap. The Arroyo Simi flows into the Arroyo Las Posas at Hitch Blvd. Downstream of Hitch Boulevard, Arroyo Las Posas passes through agricultural fields and orchards in a primarily natural channel. Although the Arroyo Las Posas channel joins with Calleguas Creek near Camarillo, surface flow is typically not present in this portion of the channel due to evaporation and groundwater recharge upstream of Seminary Road.

Two POTWs discharge in this subwatershed. The Simi Valley Water Quality Control Plant (WQCP) discharges to the Arroyo Simi on the western edge of the City of Simi Valley. The Moorpark Wastewater Treatment Plant (WTP) discharges primarily to percolation ponds near the Arroyo Las Posas downstream of Hitch Boulevard. Direct discharges to the Arroyo Las Posas from the Moorpark WTP only occur during extremely wet periods.

2.1.2 Conejo Creek

Conejo Creek and its tributaries (Arroyo Conejo and Arroyo Santa Rosa) drain the southern portion of the watershed. Flow in the southern portion of the watershed originates in the City of Thousand Oaks and flows through the City of Camarillo before joining Calleguas Creek upstream of the California State University Channel Islands. This area supports significant residential and agricultural land uses. The following sections describe Conejo Creek and its tributaries.

2.1.2.1 Arroyo Conejo

The Arroyo Conejo runs through Thousand Oaks and has three branches, the main fork, the north fork, and the south fork. The main fork of the Arroyo Conejo runs underground for most of its length. The portions that are above ground are concrete lined until the creek enters Hill Canyon on the western side of the city and converges with the south fork. The south fork runs through the southern and western portions of Thousand Oaks. For most of its length, the south fork flows underground or through concrete lined channels. The Hill Canyon Wastewater Treatment Plant (WTP) discharges to the north fork of the Arroyo Conejo on the western edge of the City of Thousand Oaks. The north fork runs through Thousand Oaks upstream of the Hill Canyon WTP. The channel is concrete lined for the portion that runs through the city, but becomes unlined when it nears the treatment plant. The main fork and the south fork join together about a mile upstream of the treatment plant. The joined flow (usually called the south fork at this point) and the north fork converge approximately 0.4 miles downstream of the Hill Canyon WTP. The Arroyo Conejo then flows in a natural channel through a primarily open space area until it merges with the Arroyo Santa Rosa to form Conejo Creek at the base of the canyon.

2.1.2.2 Arroyo Santa Rosa

Arroyo Santa Rosa runs on the northern edge of the City of Thousand Oaks and through agricultural land in the Santa Rosa Valley. Arroyo Santa Rosa is a natural channel for most of its length with portions of riprap and concrete lining along the sides and bottom of the channel in the vicinity of homes (such as near Las Posas Road). Prior to 1999, a wastewater treatment plant (Olsen Rd.) discharged to Arroyo Santa Rosa and maintained a constant surface flow in the reach. Since 1999, the POTW has not discharged and much of the channel is dry during non-storm events.

2.1.2.3 Conejo Creek

Arroyo Conejo and Arroyo Santa Rosa converge at the base of Hill Canyon to form Conejo Creek. Conejo Creek flows downstream approximately seven and half miles, through the City of Camarillo, to its confluence with Calleguas Creek. Just downstream of the city, the Camarillo Sanitary District Water Reclamation Plant (CSDWRP) discharges to Conejo Creek. Because the Arroyo Las Posas does not generally provide surface flow to Calleguas Creek during dry periods, Conejo Creek provides the majority of the flow in Calleguas Creek. For most of the length of the Conejo and Calleguas Creeks, the sides of the channel are rip rapped and the bottom is unlined.

2.1.3 Revolon Slough

Revolon Slough drains the agricultural land in the western portion of the watershed (Oxnard Plain). The slough does not pass through any urban areas, but does receive drainage from tributaries that drain urban areas. Revolon Slough starts as Beardsley Wash in the hills north of Camarillo. The wash is a rip rapped channel for most of its length and combines with Revolon Slough at Central Avenue in Camarillo. The slough is concrete lined just upstream of Central Avenue and remains lined for approximately four miles to Wood Road. From there, the slough is soft bottomed with rip-rapped sides. The lower mile to mile and a half of the slough to above Las Posas Road appears to be tidally influenced by inflows from Mugu Lagoon. Revolon Slough flows into Mugu Lagoon in a channel that runs parallel to Calleguas Creek. The flows from Revolon Slough and Calleguas Creek only converge in the lagoon.

In addition to Revolon Slough, a number of agricultural drains (Oxnard Drain, Mugu Drain, and Duck Pond Drain) convey agricultural and industrial drainage water to Mugu Lagoon and estuary.

2.1.4 Mugu Lagoon

Mugu Lagoon, an estuary at the mouth of Calleguas Creek, supports a diverse wildlife population including migratory birds and endangered species. This area is affected by military land uses of the Point Mugu Naval Air Weapons Station and substantial agricultural activities in the Oxnard Plain. The lagoon consists of approximately 287 acres of open water, 128 acres of tidal flats, 40 acres of tidal creeks, 944 acres of tidal marsh and 77 acres of salt pan (California Resources Agency, 1997). It is comprised of a central basin into which flows from Revolon Slough and Calleguas Creek enter and two arms (eastern and western) that receive some drainage from agricultural and industrial drains. In addition, multiple drainage ditches drain into the lagoon. Two of these ditches, Oxnard drainage ditches 2 and 3, discharge urban and agricultural runoff originating beyond the Station's boundaries into the central and western portion of the lagoon. The remaining ditches discharge urban and industrial runoff originating on the Station.

The salinity in the lagoon is generally between 31 and 33 parts per thousand (ppt) (Granade, 2001). The central basin of the lagoon has a maximum tidal range of approximately -1.1 to 7 feet (as compared to mean sea level) with smaller ranges in the two arms. The western arm of the lagoon receives less tidal volume because of a bridge culvert that restricts the flows in that area. The velocity of water traveling through the mouth of the lagoon is approximately 5-6 knots, which is a high velocity for a lagoon (Grigorian, 2001). The mouth of the lagoon never closes, apparently as a result of a large canyon present at the mouth of Calleguas Creek. The canyon prevents ocean sand from building up to a high enough level to close the mouth and likely accounts for the high velocities in the lagoon (Grigorian, 2001).

2.1.5 Climate and Hydrology

The climate in the watershed is typical of the southern California coastal region. Summers are relatively warm and dry and winters are mild and wet. Eighty-five percent of the rainfall occurs between November and March with most of the precipitation occurring during just a few major storms. Annual rainfall in Ventura County averages 15 inches and varies from 13 inches on the Oxnard Plain to a maximum of 20 inches in the higher elevations (USDA, 1995). Storm events, concentrated in the wet-weather months, produce runoff of duration from one-half day to several days. Discharge during runoff from storm events is commonly 10 to 100 times greater than at other times. Storm events and the resulting high stream flows are highly seasonal, grouped heavily in the months of November through February, with an occasional major storm as early as September and as late as April. Rainfall is rare in other months, and major storm flows historically have not been observed outside the wet-weather season.

2.1.6 Surface Waters

The main surface water system drains from the mountains toward the southwest, where it flows through the Oxnard Plain before emptying to the Pacific Ocean through Mugu Lagoon. Dry weather surface water flow in the Calleguas Creek watershed is primarily composed of groundwater, municipal wastewater, urban non-storm water discharges, and agricultural runoff. In the upper reaches of the watershed, upstream of any wastewater discharges, groundwater discharge from shallow surface aquifers provides a constant base flow. Additionally, urban non-stormwater runoff and groundwater extraction for construction dewatering or remediation of contaminated aquifers contribute to the base flow. Stream flow in the upper portion of the watershed is minimal, except during and immediately after rainfall. Flow in Calleguas Creek is described as storm peaking and is typical of smaller watersheds in coastal southern California.

In the Arroyo Simi/Las Posas subwatershed, additional flow is contributed by groundwater pumped for dewatering and discharged under permit to the Arroyo Simi upstream of Madera Road. The Simi Valley WQCP discharges downstream of the City of Simi Valley and provides much of the flow in the Arroyo Simi during dry weather. During most of the year, at the point where the channel reaches Seminary Road, the surface water flow has been lost to groundwater percolation and evaporation. During and immediately following significant rains, surface flows in the Arroyo Las Posas discharge to Calleguas Creek. In the Conejo Creek subwatershed, the Hill Canyon WTP provides the majority of the surface water flow. Additionally, the Camarillo WTP provides some flow in the lower portion of Conejo Creek. Revolon Slough receives all of its flow from agricultural discharges, groundwater seepage, and some urban non-stormwater flow.

The chemical properties of surface water may influence the fate and transport of pesticides and affect toxicity of constituents to aquatic organisms. Table 2 presents the range of general water quality characteristics and summary statistics in CCW surface waters and Mugu Lagoon.

Table 2. Surface Water General Water Quality Characteristics

Water Quality Parameter	n	Mean	Std. Dev.	Maximum	Minimum	90th Percentile	10th Percentile
Freshwater Reaches							
pH	2,345	8	0.4	9.3	5	8	7
Temperature	3,911	18	5	80	5	24	12
Boron	176	5	26	183	0.1	2	0.2
Chloride	332	138	43	430	7	217	72
Hardness as CaCO3	123	658	1123	11,800	2	1347	129
Sulfate	177	410	425	2,100	5	881	88
TDS	321	1,024	730	3,930	0.8	2321	244
TSS	363	342	2112	34,800	0.1	233	1
Mugu Lagoon							
pH	60	7.8	0.5	8.8	6.2	8.4	7.1
Temperature	15	19.5	5.4	29	10	28.4	12.3
Boron	10	2	0.5	2.8	1.1	2.8	1.3
Chloride	10	7,240	3,107	14,000	4,400	11,757	3,876
Hardness as CaCO3	42	7,202	9,555	54,200	567	13,132	1,833
Sulfate	10	1,432	394	1,900	690	2,171	872
TDS	48	17,750	12,433	38,260	163	60,019	1,735
TSS	48	17.8	29	195	1	34	4

2.1.7 Groundwater

Groundwater features of the watershed are dominated by the Fox Canyon Aquifer System, which is linked to the neighboring Santa Clara River Watershed. The Fox Canyon Aquifer System is a series of deep, confined aquifers. These aquifers today receive little or no recharge from the watershed. The water quality in these aquifers is very high. However, because there is little recharge to these aquifers they suffer from overdraft. Major groundwater basins within the watershed include the Simi Basin, East Las Posas, West Las Posas, South Las Posas, Pleasant Valley, and Arroyo Santa Rosa Basins. Significant aquifers within the watershed include the Epworth Gravels, the Fox Canyon aquifer, and the Grimes Canyon aquifer in order from shallowest to deepest. In addition, the top 350 feet of sediments within the Pleasant Valley Basin are often referred to as the "Upper Zone", and are thought by some to be equivalent to the Hueneme aquifer zone that is a more well-defined and recognized layer to the west of the Pleasant Valley Basin.

Shallower, unconfined aquifers are located in the valleys of the watershed. In the upper sub-watersheds of Simi Valley and Conejo Valley, groundwater collects in the lower areas and overflows into the down-gradient valleys. The Tierra Rejada, Santa Rosa and South Las Posas valley basins are larger than the upper valley basins and are the most significant unconfined basins on the watershed. Areas of perched and unconfined groundwater are also present along the base of the Santa Monica Mountains, and overlying areas of the southeastern Oxnard Plain in the Pleasant Valley.

Water rights have not been adjudicated in many of these basins, and groundwater production is not comprehensively controlled or maintained. However, groundwater extractions are regulated in the Oxnard Plain, Pleasant Valley Basin and the Las Posas Basin by the Fox Canyon Groundwater Management Agency. In some basins, groundwater is being over-drafted and as a result Pleasant Valley has experienced subsidence. In other basins, such as the South Las Posas Basin, groundwater storage has increased significantly in the last several decades.

The chemical properties of groundwater may influence the fate and transport of pesticides and affect toxicity of constituents to aquatic organisms. The chemical solubility and sorption of these loads is largely a function of pH, redox conditions, temperature, and the presence of carbon dioxide and carbonate species. Data for many of these parameters were analyzed in groundwater samples, and the summary statistics for the results are presented in Table 3. For Calleguas Creek groundwater, temperature and Eh (redox) data were not readily available. The groundwater of the Calleguas Creek watershed is slightly alkaline, with pH typically ranging from 7.3 to 8.0, and alkalinity from 140 to 270 mg/L. Hardness also influences solubility; the analyzed Calleguas Creek groundwater samples exhibited an average hardness of 431 mg/L as $CaCO_3$. The average bicarbonate concentration was 151 mg/L. Finally, the presence of cations, often measured as electrical conductivity, can affect the sorption characteristics of infiltrating loads. As seen in Table 3, Calleguas Creek groundwater is highly heterogeneous with respect to electrical conductivity, typically ranging from 465 to 1,521 µS/cm. Consideration of these chemical properties is important when assessing the impacts of the recharge of surface waters on groundwater supplies.

Table 3. Groundwater General Water Quality Characteristics.

Water Quality Parameter	n	Mean	Std. Dev.	Maximum	Minimum	90th Percentile	10th Percentile
pH	372	7.6	0.3	10.1	7	8	7.3
Alkalinity (mg/L)	220	199	54	420	70	270	140
Hardness (mg/L, CaCO3)	76	431	136	700	132	585	235
Bicarbonate (mg/L)	79	151	99	449	7	233	8
Electrical Conductivity (µS/cm)	370	805	428	2,470	321	1,521	465

2.1.8 Anthropogenic Alterations

Historically, the Oxnard Plain served as the flood plain for Calleguas Creek. Starting in the 1850's, agriculture began to be practiced extensively in the watershed. By 1889, a straight channel from the area near the present day location of Highway 101 to the Conejo Creek confluence had been created for Calleguas Creek. In the 1920's, levees were built to channelize flow directly into Mugu Lagoon (USDA, 1995). Increased agricultural and urban land uses in the watershed resulted in continued channelization of the creek to the current channel system. Historically, Calleguas Creek was an ephemeral creek flowing only during the wet season. The cities of Simi Valley, Moorpark, Camarillo, and Thousand Oaks experienced rapid residential and commercial development beginning in the 1960s. In the early 1970s, State Water Project supplies began being delivered to the watershed. In 1957, the Camarillo Water Reclamation Plant came online, followed by the Hill Canyon WTP in Thousand Oaks in 1961. Increasing volumes of discharges from these POTWs eventually caused the Conejo/Calleguas system to become a perennial stream by 1972 (SWRCB, 1997). When the Simi Valley Water Quality Control Facility began discharging in the early 1970's, the Arroyo Simi/Arroyo Las Posas became a perennial stream that gradually flowed further downstream and currently reaches Seminary Road in Camarillo. However, surface flows from the Arroyo Simi/Arroyo Las Posas do not connect with surface flows in the Conejo Creek/Calleguas system, except during and immediately following storm events.

2.1.8.1 Sedimentation

Agricultural development and urbanization have brought about significant changes in the watershed such as increased runoff and freshwater flows, accelerated erosion and sedimentation and transport of agricultural chemicals and urban pollutants. Previous to the channelization of lower Calleguas Creek, sediment was deposited largely in a vast estuarine network that meandered across the Oxnard Plain. Numerous drop structures, channel bed stabilizers, dams, and debris basins have since been constructed to compensate for the loss of flood plain. Extensive urban development, farmland conversion, and the resulting redevelopment of orchards onto steeper slopes have changed the hydrology of the area and led to accelerated erosion rates. Accelerated erosion rates have contributed to flooding and sedimentation of the Oxnard Plain and Mugu Lagoon (NRCS, 1995).

2.1.9 Flow Diversion Project

The Conejo Creek Diversion project in the Calleguas Creek watershed diverts the majority of flow in Conejo Creek to agricultural uses in the Pleasant Valley area. The diversion project is located approximately seven miles downstream from the Hill Canyon Wastewater Treatment Plant (WTP). The water rights application allows the diversion of an amount equal to Hill Canyon's effluent minus four cubic feet per second (cfs) for in-stream uses and channel losses. An additional amount of water equal to the flow contributed by use of imported water in the region (estimated at four cfs) may be diverted when at least six cfs of water will remain in the stream downstream of the diversion point (SWRCB, 1997). Natural flows due to precipitation will not be diverted. As a result of this project, flows in the lower reach of Conejo Creek have been reduced to less than half of the previous creek flows.

Projects similar to the Conejo Creek Diversion project may be developed as part of the overall Watershed Management Plan for Calleguas Creek to address water resource, water quality, or flooding/erosion concerns. As such, TMDLs must be developed in a manner that considers the impacts of changing flows in the watershed and does not result in restrictions on the necessary use of the water for other purposes.

2.1.10 Reach Designations

Table 4 summarizes the reach descriptions of Calleguas Creek used in this TMDL and the correlation between these reaches with the 303(d) and consent decree listed reaches. These reach designations provide greater detail than the designations in the current Basin Plan, and are developed for purposes of this TMDL. The reach revisions may provide an appropriate analytical tool for future analyses in the watershed. At this time, though, the reach revisions are not regulatory and do not alter water quality objectives for the reaches in the existing Basin Plan.

Table 4. Description of CCW Reaches Based on 2002 303(d) List

Assigned Reach No.	Reach Name Reach as Listed in 303(d) List and Consent Decree	Geographic Description	Notes: Hydrology, land uses, etc.
1 Mugu Lagoon	Mugu Lagoon	Lagoon fed by Calleguas Creek	Estuarine; brackish, contiguous with Pacific Ocean
2 Calleguas Creek South	Calleguas Creek Reach 1 and Reach 2 (Estuary to Potrero Rd.)	Downstream (south) of Potrero Rd	Tidal influence; concrete lined; tile drains; Oxnard Plain
3 Calleguas Creek North	Calleguas Creek Reach 3 (Potrero to Somis Rd.)	Potrero Rd. upstream to confluence Conejo Creek	Concrete lined ; no tidal influence; Agriculture tile drains; Pleasant Valley Basin. Camrosa WRP discharges to percolation ponds.
4 Revolon Slough	Revolon Slough Main Branch	Revolon Slough from confluence with Calleguas Creek to Central Ave	Concrete lined ; tile drains; Oxnard Plain; tidal influence
5 Beardsley Channel	Beardsley Channel	Revolon Slough upstream of Central Ave.	Concrete lined ; tile drains; Oxnard Plain
6 Arroyo Las Posas	Arroyo Las Posas Reach 1 and Reach 2 (Lewis Somis Rd. to Moorpark Fwy (23))	Confluence with Calleguas Creek to Hitch Road	Ventura Co. POTW discharge at Moorpark to percolation ponds; discharges enter shallow aquifer; dry at Calleguas confluence
7 Arroyo Simi	Arroyo Simi Reach 1 and Reach 2 (Moorpark Fwy (23) to Headwaters)	End of Arroyo Las Posas (Hitch Rd) to headwaters in Simi Valley.	Simi Valley WQCP discharge; discharges from shallow aquifers; pumped GW; GW discharges from shallow aquifers.
8 Tapo Canyon	Tapo Canyon Reach 1 and Reach 2	Confluence w/ Arroyo Simi up Tapo Cyn to headwaters	Origin near gravel mine, used by nursery, ends in residences.
9A Conejo Creek	Conejo Creek Reach 1 (Confl with Calleguas Creek to Santa Rosa Rd.)	Extends from the confluence with Arroyo Santa Rosa downstream to the Camrosa Diversion	Camarillo WTP discharge; Pleasant Valley Groundwater Basin contains both confined and unconfined perched aquifers. Groundwater and surface water used for agriculture.
9B Conejo Creek	Conejo Creek Reach 1 and Reach2 (Confl with Calleguas Creek to Tho. Oaks city limit)	Extends from Camrosa Diversion to confluence with Calleguas Creek.	Pleasant Valley Groundwater Basin contains both confined and unconfined perched aquifers. Camarillo WTP discharges to percolation ponds near downstream end.
10 Hill Canyon reach of Conejo Creek	Conejo Creek Reach 2 and Reach 3 (Santa Rosa Rd. to Lynn Rd.)	Confluence w/ Arroyo Santa Rosa to confluence w/ N. Fork; and N. Fork to just above Hill Canyon WTP	Hill Canyon WTP; stream receives N. Fork Conejo Creek surface water.
11 Arroyo Santa Rosa	Arroyo Santa Rosa	Confluence w/ Conejo Creek to headwaters	Olsen Rd. WRP; dry before Calleguas Ck confluence except during storm flow.
12 North Fork Conejo Creek	Conejo Creek Reach 3 (Tho. Oaks city limit to Lynn Rd.)	Confluence w/Conejo Creek to headwaters	
13 Arroyo Conejo (South Fork Conejo Creek)	Conejo Creek Reach 4 (Above Lynn Rd.)	Confluence w/ N. Fork to headwaters —two channels	City of Thousand Oaks; pumped/treated GW

2.2 *Water Quality Standards*

Federal law requires the states to adopt water quality standards, which are defined as the designated beneficial uses of a water segment and the water quality criteria necessary to support those uses (33 U.S.C. §1313). California implements the federal water quality standard requirements by providing for the reasonable protection of designated beneficial uses through the adoption of water quality objectives (CA Water Code §13241). Water quality objectives may be numeric values or narrative statements. For inland surface waters in the Los Angeles Region, beneficial uses, numeric and narrative objectives are identified in the Basin Plan and additional numeric objectives for toxic pollutants are contained in the California Toxics Rule as adopted by the federal EPA (40 CFR 131.38). In addition, federal regulation requires states to adopt a statewide antidegradation policy that protects high quality waters and the level of water quality necessary to maintain and protect existing uses.

2.2.1 Beneficial Uses

The Basin Plan identifies 21 existing, potential and intermittent beneficial uses for waterbodies in the CCW (Table 5). The federally defined "aquatic life" beneficial use (and the Los Angeles Region Basin Plan equivalents) is the beneficial use impaired by water column and sediment toxicity and OP pesticides. The federally defined aquatic life beneficial use encompasses the following 10 beneficial uses outlined in the Basin Plan (LARWQCB, 2002a): warm (WARM) and cold (COLD) freshwater habitats; estuarine (EST), wetland (WET) and marine (MAR) habitats; wildlife habitat (WILD); biological habitats (BIOL) including Areas of Special Biological Significance; habitats that support rare, threatened, or endangered species (RARE); habitats that support migration of aquatic organisms (MIGR); and habitats that support spawning, reproduction, and/or early development of fish (SPWN).

Table 5. Beneficial Uses in the CCW as Defined in the Water Quality Control Plan – Los Angeles Region

Waterbody	Reach[1]	Hydro Unit	Aquatic Life Beneficial Use Potentially Impacted by Toxicity and OP Pesticides										Other Beneficial Uses										
			EST	MAR	WILD	BIOL	RARE	MIGR	SPWN	WET	WARM	COLD	FRSH	NAV	REC1	REC2	COMM	MUN	IND	PROC	AGR	GWR	SHELL
Mugu Lagoon	1	403.11	E	E	E	E	E	E	E	E				E	P	E	E						E
Calleguas Creek Estuary	2	403.11	E		E		E	E	E	E				P	P	E	E						
Calleguas Creek	2, 3	403.11			E		E			E	E	E	E		E	E		P*			E	E	
Calleguas Creek	3, 9A	403.12			E						E				E	E		P*	E	E	E	E	
Revolon Slough	4	403.11			E					E	E				E	E		P*	P		E	E	
Beardsley Wash	5	403.61			E						E		E		E	E		P*					
Conejo Creek	3, 9A	403.12			E						E				E	E		P*	E	E	E	E	
Conejo Creek	9B	403.63			E				E		I		I		I	I		P*				I	
Arroyo Conejo	9A, 9B,10	403.64			E		E				I		I		I	I		P*				I	
Arroyo Conejo	13	403.68			E						I		I		I	I		P*				I	
Arroyo Santa Rosa	11	403.63			E						I		I		I	I		P*				I	
Arroyo Santa Rosa	11	403.65			E						I		I		I	I		P*				I	
North Fork Arroyo Conejo	12	403.64			E				E		E				E	E		P*			E	E	
Arroyo Las Posas	6	403.12			E						E	P			E	E		P*	P	P	P	E	
Arroyo Las Posas	6	403.62			E						E	P	E		E	E		P*	P	P	P	E	
Arroyo Simi	7	403.62			E		E				I		I		I	I		P*	I			I	
Arroyo Simi	7	403.67			E						I		I		I	I		I*	I			I	
Tapo Canyon Creek	8	403.66			E						I				I	I		I*		P	P	I	
Tapo Canyon Creek	8	403.67			E						I				I	I		I*		P	P	I	
Gillibrand Canyon Creek		403.66			E						I		I		I	I		P*				I	
Gillibrand Canyon Creek		403.67			E						I		I		I	I		P*				I	
Lake Bard		403.67			E						E				P	E		E	E	E	E	P	

[1] Reach numerical designations based on 2002 303(d) list.

E Existing Beneficial Use P Potential Beneficial Use I Intermittent Beneficial Use

* Municipal designations marked with an asterisk are conditional designations and are not recognized under federal law and are not water quality standards requiring TMDL development at this time. (See Letter from Alexis Strauss [USEPA] to Celeste Cantú [State Board], Feb. 15, 2002.)

2.2.2 Water Quality Objectives

The Basin Plan contains narrative water quality objectives for toxicity and pesticides. These objectives are used in developing numeric targets and allocations for TMDLs. The following narrative objectives are the most applicable for this TMDL:

Toxicity: All waters shall be maintained free of toxic substances in concentrations that are toxic to, or that produce detrimental physiological responses in, human, plant, animal or aquatic life.

> *Effluent limits for specific toxicants can be established by the Regional Board to control toxicity identified under Toxicity Identification Evaluations (TIEs).*

There are no Basin Plan Objectives specific to sediment toxicity. However, the narrative ambient water toxicity objectives may be used to address sediment toxicity for the purposes of identifying targets for sediment toxicity.

Pesticides: No individual pesticide or combination of pesticides shall be present in concentrations that adversely affect beneficial uses. There shall be no increase in pesticide concentrations found in bottom sediments or aquatic life.

There are no adopted numeric water, sediment, or fish tissue objectives in the Basin Plan or California Toxics Rule (CTR) for any organophosphate pesticides (i.e. chlorpyrifos and diazinon).

2.2.3 Antidegradation

The state's Antidegradation Policy is contained in State Board Resolution 68-16, Statement of Policy with Respect to Maintaining High Quality Water in California. The Antidegradation Policy maintains that water quality in surface and ground waters of the state must be maintained unless it is demonstrated that a change will be consistent with the maximum benefit of the people of the state, not unreasonably affect present and anticipated beneficial use of such water, and not result in water quality less than that prescribed in water quality plans and policies. In addition to meeting state Antidegradation Policy, any actions that may result in a reduction of water quality of a water of the United States are subject to the federal Antidegradation Policy provisions contained in 40 CFR 131.12, which allows for the reduction in water quality as long as existing beneficial uses are maintained and that the lowering of water quality is necessary to accommodate economic and social development in the area.

The proposed TMDL is consistent with state and federal antidegradation policies since it does not result in a reduction of water quality.

2.3 *Basis for Listings*

The following section presents the basis for the development of the 303(d) listings related to toxicity and OP pesticides in the Watershed. The Regional Board staff conducted Water Quality Assessments (WQA) in 1996, 1998, and 2002 to identify exceedances of water quality objectives. This section discusses the data reviewed for the Water Quality Assessments and the application of the data that resulted in the 303(d) listings. For all listings except organophosphates in water, the basis of the listing was presented in the

1996 WQA. In some cases, additional data were assessed in later years, but were not used to alter the original listings. All available data used to develop listings are discussed in this section.

2.3.1 Water Column and Sediment Toxicity Listings

The following presents the available information on the development of the 303(d) listings for sediment toxicity in Reaches 1 and 2 and aquatic toxicity in Reaches 4, 5, 9B, 10, 11, and 13.

Reach: Calleguas Creek Reach 1 (Mugu Lagoon)
Formerly: Mugu Lagoon – 1996 and 1998 303(d) list
Current 303(d) listing: 2002 – Sediment Toxicity
Previous 303(d) listings: 1996 and 1998 – Sediment Toxicity
Basis: The original 1996 listing was based on information presented in the LARWQCB 1996 Water Quality Assessment Documentation (WQA). The listing of sediment toxicity in Calleguas Creek R1 on the 1996 303(d) list reads as follows: "Sed Toxicity ('93): poor survival rates[2]". The "2" references sediment data collected through the California State Water Resources Board's Bay Protection and Toxic Cleanup Program (BPTCP). Table 6 presents sediment toxicity data collected in 1993 by the BPTCP which are the basis for the 1996 listing.

Table 6. Sediment Toxicity Data Collected in Mugu Lagoon in 1993 by the BPTCP that Form the Basis for the Sediment Toxicity Listings in Calleguas Creek Reaches 1 and 2 and Duck Pond Agricultural Drains/Mugu Drain/Oxnard Drain No 2

Station	Stanum	Date	Mean % Survival *Eohaustorius estuarius* in homogenized sediment	Mean % survival for the *Rhepoxynius abronius* in homogenized sediment
Mugu Lagoon	44016	1/12/93	**66**	N/A
Mugu/Entrance	44054	1/12/93	N/A	**14**
Mugu/Main Lagoon	44051	1/12/93	N/A	**68**
Mugu/Western Arm	44052	1/12/93	N/A	**64**
Calleguas/Oxnard Ditch #3[1]	44050	1/12/93	**71**	N/A

1 BPTCP data is reported for Calleguas/Oxnard Ditch #3, however, in reviewing the summary report (SWRCB, 1998) and GIS coordinates the site labeled Calleguas/Oxnard Ditch #3 is actually located in Mugu Lagoon near the outfall of Oxnard Drain #2 not Oxnard Drain #3.
Bolded indicates results believed to be the basis for the listings
N/A = Not analyzed

Reach: Duck Pond Agricultural Drains/Mugu Drain/Oxnard Drain No 2
Formerly: Duck Pond Ag Drain/Mugu Drain/Oxnard Drain #2 – 1996 303(d) list; Duck Pond Agricultural Drain/Mugu Drain/Oxnard Drain #2 – 1998 303(d) list
Current 303(d) listing: 2002 – Sediment Toxicity
Previous 303(d) listings: 1996 and 1998 – Sediment Toxicity
Basis: The original 1996 listing was based on information presented in the LARWQCB 1996 WQA. The listing of sediment toxicity in Duck Pond Ag Drain/Mugu Drain/Oxnard Drain #2 on the 1996 303(d) list reads as follows: "Sed Toxicity ('93): poor survival rates[1]". The "1" references data collected through the California State Water Resources Board's State Mussel Watch Program (SMWP). However, no sediment toxicity data were collected through this program in the CCW. The data may not have been properly referenced in the 1996 303(d) list. The available sediment toxicity data available referenced to this site were collected by the BPTCP in 1993. The sediment toxicity samples were collected in Mugu Lagoon near the drain outfall. As the sediment toxicity samples were collected in the lagoon this listing will be

addressed as part of Mugu Lagoon. Table 6 presents sediment toxicity data collected in 1993 by the BPTCP in Mugu Lagoon which seem to be the basis for the 1996 listing in this reach.

Reach: Calleguas Creek Reach 2 (Calleguas Creek South)
Formerly: Calleguas Creek Estuary – 1996 303(d) list; Calleguas Creek R2 – Potrero Road to Broome Road – 1998 303(d) list
Current 303(d) listing: 2002 – Sediment Toxicity
Previous 303(d) listings: 1996 and 1998 – Sediment Toxicity
Basis: The original 1996 listing was based on information presented in the LARWQCB 1996 WQA. The listing of sediment toxicity in Calleguas Creek R2 on the 1996 303(d) list reads as follows: "Sed Toxicity ('93): poor survival rates[2]". The "2" references sediment data collected through the BPTCP. However, no BPTCP samples were collected in Reach 2. Table 6 presents sediment toxicity data collected in 1993 by the BPTCP in Mugu Lagoon which seem to be the basis for the 1996 listing in this reach.

Reach: Calleguas Creek Reach 4 (Revolon Slough)
Formerly: Revolon Slough and Beardsley Channel/Wash – 1996 303(d) list; Revolon Slough Main Branch: Mugu Lagoon to Central Avenue – 1998 303(d) list
Current 303(d) listing: 2002 – Toxicity
Previous 303(d) listings: 1996 and 1998 – Water Toxicity
Basis: The original 1996 listing was based on information presented in the LARWQCB 1996 WQA. The listing of water toxicity in Calleguas Creek Reach 4 on the 1996 303(d) list reads as follows: "Wat Toxicity: poor survival rates[5]". The "5" references water quality data collected for the California State Water Resources Board's 1995 draft version of the report "Final Report: Toxicity Study of the Santa Clara River, San Gabriel River, and Calleguas Creek". Table 7 presents water toxicity data collected in 1992 and 1993 by the BPTCP that are the basis for the 1996 listing. No additional data were reviewed during the water quality assessments in 1998 and 2002 for this reach. The values exceeding the narrative water quality objective for toxicity are noted in bold.

Table 7. Summary of Toxicity Test Results that Form the Basis for the Water Column Toxicity Listing on Calleguas Creek Reach 4

Parameter	Sample Date			
	7/23/92	10/23/92	1/21/93	4/2/93
Pimephales promelas				
Survival (%)	95.1	92.2	**21.7***	**27***
Growth (mg)	0.367	0.291	0.07*	0.141*
Ceriodaphnia dubia				
Survival (%)	100	0*	100	90
Reproduction	31	0*	27.8	21.5
Selenastrum capricornutum				
Cells/mL	870000*	1400000	420000*	240000*

Bolded indicates results believed to be the basis for the listing
* Indicates significance difference from control at $P \leq 0.05$; Bailey et al. 1996

Reach: Calleguas Creek Reach 5 (Beardsley Channel)
Formerly: Revolon Slough and Beardsley Channel/Wash – 1996 303(d) list; Beardsley Channel (Above Central Avenue) – 1998 303(d) list
Current 303(d) listing: 2002 – Toxicity
Previous 303(d) listings: 1996 and 1998 – Water Toxicity

Basis: The original 1996 listing was based on information presented in the LARWQCB 1996 WQA. The listing of water toxicity in Calleguas Creek Reach 5 on the 1996 303(d) list reads as follows: "Wat Toxicity: poor survival rates[5]". The "[5]" references water quality data collected for the California State Water Resources Board's 1995 draft version of the report "Final Report: Toxicity Study of the Santa Clara River, San Gabriel River, and Calleguas Creek". Table 8 presents water toxicity data collected in 1992 and 1993 by the BPTCP that are the basis for the 1996 listing. No additional data were reviewed during the water quality assessments in 1998 and 2002 for this reach. The values exceeding the narrative water quality objective for toxicity are noted in bold.

Table 8. Summary of Toxicity Test Results that Form the Basis for the Water Column Toxicity Listing on Calleguas Creek Reach 5

Parameter	Sample Date			
	7/23/92	10/23/92	1/21/93	4/2/93
Pimephales promelas				
Survival (%)	**68.2***	93.5	76.7	96.7
Growth (mg)	0.251*	0.35	0.445	0.419
Ceriodaphnia dubia				
Survival (%)	100	**0***	**0***	**0***
Reproduction	36.9	0.11*	0*	0*
Selenastrum capricornutum				
Cells/mL	150000	1600000	390000	570000

Bolded indicates results believed to be the basis for the listing * Indicates significance difference from control at P ≤ 0.05; Bailey et al. 1996

Reach: Calleguas Creek Reach 9B (Conejo Creek Main Stem)

Formerly: Conejo Creek/Arroyo Conejo – 1996 303(d) list; Part of Conejo Creek Reaches 1 and 2 – 1998 303(d) list

Current 303(d) listing: 2002 – Toxicity

Previous 303(d) listings: 1996 and 1998 – Water Toxicity

Basis: The listing of water toxicity in Calleguas Creek Reach 9B on the 1996 303(d) list reads as follows: "Wat Toxicity: poor survival rates[5]". The "[5]" references water quality data collected for the California State Water Resources Board's 1995 draft version of the report "Final Report: Toxicity Study of the Santa Clara River, San Gabriel River, and Calleguas Creek". On the 1996 303(d) list, Calleguas Creek Reaches 9A, 9B, 10, and 13 were all one reach. In 1998 and 2002 when the reaches for Calleguas Creek were redefined, the 1996 listings were applied to all of the reaches unless data were available to demonstrate that the reach should not be listed. Consequently, listing data are not available for each of these reaches specifically. The data used to list all of the reaches were collected in what is now called Calleguas Creek Reach 9A (Conejo Creek). Table 9 presents water toxicity data collected in 1992 and 1993 that are the basis for the 1996 listing. No additional data were reviewed during the water quality assessments in 1998 and 2002 for this reach. The values exceeding the narrative water quality objective for toxicity are noted in bold.

Table 9. Summary of Toxicity Test Results that Form the Basis for the Water Column Toxicity Listing on Calleguas Creek Reach 9B

Parameter	Sample Date			
	7/23/92	10/23/92	1/21/93	4/2/93
Pimephales promelas				
Survival (%)	95	76.6*	96.7	91.7
Growth (mg)	0.337*	0.226*	0.426	0.313
Ceriodaphnia dubia				
Survival (%)	0*	0*	100	100
Reproduction	0.4*	0*	25.7	25.8
Selenastrum capricornutum				
Cells/mL	61000*	1020000	1500000*	110000

Bolded indicates results believed to be the basis for the listing * Indicates significance difference from control at P ≤ 0.05; Bailey et al. 1996

Reach: Calleguas Creek Reach 10 (Hill Canyon Reach of Conejo Creek)
Formerly: Conejo Creek/Arroyo Conejo– 1996 303(d) list; Part of Conejo Creek Reaches 2 and 3 – 1998 303(d) list
Current 303(d) listing: 2002 – Toxicity
Previous Listings: 1996 and 1998 – Water Toxicity
Basis: The original 1996 listing was based on information presented in the LARWQCB 1996 WQA. The listing of water toxicity in Calleguas Creek Reach 10 on the 1996 303(d) list reads as follows: "Wat Toxicity: poor survival rates[5]". The "5" references water quality data collected for the California State Water Resources Board's 1995 draft version of the report "Final Report: Toxicity Study of the Santa Clara River, San Gabriel River, and Calleguas Creek". On the 1996 303(d) list, Calleguas Creek Reaches 9A, 9B, 10, and 13 were all one reach. In 1998 and 2002 when the reaches for Calleguas Creek were redefined, the 1996 listings were applied to all of the reaches unless data were available to demonstrate that the reach should not be listed. Consequently, listing data are not available for each of these reaches specifically. The data used to list all of the reaches were collected in what is now called Calleguas Creek Reach 9A (Conejo Creek). Table 9 presents water toxicity data collected in 1992 and 1993 that are the basis for the 1996 listing. No additional data were reviewed during the water quality assessments in 1998 and 2002 for this reach. The values exceeding the narrative water quality objective for toxicity are noted in bold.

Reach: Calleguas Creek Reach 11 (Arroyo Santa Rosa)
Formerly: Arroyo Santa Rosa Reaches 1 and 2 – 1996 and 1998 303(d) lists
Current 303(d) listing: 2002 – Toxicity
Previous 303(d) listings: No previous listings for water column toxicity.
Basis: In the 1996 and 1998 WQA, this reach was not assessed and no listings were placed on the 1996 and 1998 303(d) lists. In 2002, toxicity was added to the 303(d) list as a result of the redefinition of reaches.

Reach: Calleguas Creek Reach 13 (South Fork Conejo Creek)
Formerly: Conejo Creek/Arroyo Conejo – 1996 303(d) list; Part of Conejo Creek Reaches 3 and 4 – 1998 303(d) list
Current 303(d) listing: 2002 – Toxicity
Previous 303(d) listings: 1996 and 1998 Water Toxicity

Basis: The original 1996 listing was based on information presented in the LARWQCB 1996 WQA. The listing of water toxicity in Calleguas Creek Reach 13 on the 1996 303(d) list reads as follows: "Wat Toxicity: poor survival rates^5". The "^{5}" references water quality data collected for the California State Water Resources Board's 1995 draft version of the report "Final Report: Toxicity Study of the Santa Clara River, San Gabriel River, and Calleguas Creek". On the 1996 303(d) list, Calleguas Creek Reaches 9A, 9B, 10, and 13 were all one reach. In 1998 and 2002 when the reaches for Calleguas Creek were redefined, the 1996 listings were applied to all of the reaches unless data were available to demonstrate that the reach should not be listed. Consequently, listing data are not available for each of these reaches specifically. The data used to list all of the reaches were collected in what is now called Calleguas Creek Reach 9A (Conejo Creek). Table 9 presents water toxicity data collected in 1992 and 1993 that are the basis for the 1996 listing. No additional data were reviewed during the water quality assessments in 1998 and 2002 for this reach. The values exceeding the narrative water quality objective for toxicity are noted in bold.

2.3.2 Organophosphate Pesticides in Water Listing

The following presents the available information on the development of the 303(d) listing for organophosphate pesticides in water in Reach 7.

Reach: Calleguas Creek Reach 7 (Arroyo Simi)
Formerly: Arroyo Simi and a portion of Arroyo Las Posas – 1996 303(d) list; Arroyo Simi Reaches 1 and 2 and a portion of Arroyo Las Posas Reach 2 – 1998 303(d) list
Current 303(d) listing: Organophosphate Pesticides
Previous 303(d) listings: No previous listings for organophosphates.
Basis: The 2002 listing reads as follows: "Organophosphate Pesticides." This listing was based on information presented in the LARWQCB 2002 Water Body Fact Sheets Supporting the Section 303(d) Recommendations. The listing is based on 22 water samples, in which toxicity was documented in 1998-99. Subsequent chemistry and toxicity identification evaluations (TIEs) identified ammonia, chlorpyrifos and diazinon.

During the Calleguas Creek Characterization Study (CCCS) (LWA, 2000) completed in 1999, six samples were analyzed for toxicity, and 12 samples were analyzed for organics in Reach 7. Of the six samples analyzed for toxicity, *Ceriodaphnia dubia* mortality and diminished reproduction was observed in 67% of the samples. *Pimephales promelas* mortality and diminished growth were also observed in 83% of the samples. Of the 12 samples analyzed for organics, one sample exceeded the CDFG diazinon chronic criterion (0.05 ug/L), two exceeded the CDFG (0.08 ug/L) acute criterion, and three exceeded the USEPA (0.1 ug/L) acute criterion. There were no detected exceedances of the USEPA or CDFG chlorpyrifos criteria. In addition, a study completed by Anderson et al. (2002), presented results of TIEs conducted on two Arroyo Simi samples, suggesting diazinon was the cause of toxicity. The 2002 organophosphate pesticide listings are based on both toxicity and water chemistry data for pesticides that exceed the narrative toxicity and narrative pesticide objectives in the Basin Plan.

2.3.3 Chlorpyrifos in Fish Tissue Listings

The following presents the available information on the development of the 303(d) listings for chlorpyrifos in fish tissue in Reaches 4 and 5.

Reach: Calleguas Creek Reach 4 (Revolon Slough)
Formerly: Revolon Slough and Beardsley Channel/Wash – 1996 303(d) list; Revolon Slough Main Branch: Mugu Lagoon to Central Avenue – 1998 303(d) list
Current 303(d) listing: Chlorpyrifos (tissue)
Previous Listings:
1996 – Elevated Tissue Levels (Chlorpyrifos)
1998 – Chlorpyrifos Elevated levels of Chlorpyrifos in tissue.
Basis: In 1996, chlorpyrifos in fish tissue was listed based on the 1996 WQA. The 1996 listing of chlorpyrifos in fish tissue in Revolon Slough in the WQA reads as follows: "Tissue ('93): chlorpyrifos (EDL95)[3]". The "3" references that the data were collected through the California State Water Resources Board's Toxic Substances Monitoring Program (TSMP). The EDL95 (Elevated Data Level 95%) represents the "standard" that was exceeded. Table 10 presents fish tissue data collected by the TSMP in 1993 that are the basis for the 1996 listing. These data were collected on Revolon Slough at Wood Road from a combined sample of 22 *Pimephales promelas*. Additional data, presented in Table 10, were collected on Revolon Slough at Wood Road in 1994 and 1997. The elevated levels of chlorpyrifos in tissue are highlighted in bold in the table.

Table 10. Summary of Chlorpyrifos Fish Tissue Data Collected by the TSMP in Revolon Slough at Wood Road

Sample Date	Wet Chemical Tissue Concentrations	Lipid Weight Organic Chemical Tissue Concentrations
6/20/1993	**100 ppb**	**1900 ppb**
6/23/1994	10 ppb	166 ppb
7/16/1997	18 ppb	250 ppb

Bolded indicates results believed to be the basis for the listing **Note:** *Pimephales promelas* (fathead minnow) was the test species.

Reach: Calleguas Creek Reach 5 (Beardsley Channel)
Formerly: Revolon Slough and Beardsley Channel/Wash – 1996 303(d) list; Beardsley Channel (Above Central Avenue) – 1998 303(d) list
Current 303(d) listing: Chlorpyrifos (tissue)
Previous Listings:
1996 – Elevated Tissue Levels (Chlorpyrifos)
1998 – Chlorpyrifos Elevated levels of chlorpyrifos in tissue.
Basis: In the 1996 303(d) list, Beardsley Wash and Revolon Slough were combined as one reach. In 1998, when the two reaches were separated, the listings from Revolon Slough were applied to Beardsley Wash unless data were available to demonstrate that the listing was not applicable. Because the only data available for these two reaches were those collected at Wood Road on Reach 4, the data presented in Table 10 form the basis of this listing.

2.3.4 Use of EDLs to Form the Basis of 303(d) Listings

As described in the 1996 WQA, "Fish tissue Elevated Data Level (EDL) values are an internal state comparative measure that ranks a given concentration of a particular substance with previous data from the state programs. EDLs are calculated by ranking all of the results for a given chemical from the highest concentration measured down to and including those records where the chemical is not detected." An EDL value of 95 (EDL95) indicates that the pollutant concentration in fish tissue found in that particular sample is higher than the pollutant concentrations found in 95% of fish tissue samples collected throughout the state. Guidance presented in the LARWQCB 303(d) listing Staff Reports in 1998 and 2002 (LARWQCB, 1998;

2002a) indicate EDLs alone are not sufficient assessment guidelines for determining impairment, and listings based solely on EDL exceedances should be removed from the 303(d) list. Although other EDL based listings were removed in 1998 and 2002 as a result of this guidance, the chlorpyrifos in fish tissue listing remained on the list, likely as a result of concerns about water column concentrations of these pollutants. In 1997, chlorpyrifos was identified as contributing to *C. dubia* mortality in samples collected from Revolon Slough and Beardsley Channel (Anderson et al., 2001)

At the time the samples were collected (1993) on which the listings were based, analytical methods at contract laboratories could not measure chlorpyrifos in water at sufficiently low detection limits to identify it at levels at or below water quality criteria. However, analytical methods have now progressed to the point at which water column concentrations of these pollutants can be detected at levels of concern. As presented in the following Current Conditions section, water chemistry samples collected through various programs in Revolon Slough (1995 through 2004) have indicated the presence of chlorpyrifos exceeding water quality criteria.

Because the state of the science in measuring pesticides in water has advanced from the time of the initial listing this TMDL focuses on identifying targets that prevent exceedances of the narrative pesticide and toxicity standards in water as well as numeric chlorpyrifos water quality criteria. The monitoring program of this TMDL will evaluate the adequacy of the water column targets to address the fish tissue listings. If necessary, the Regional Board can revise the numeric targets during the implementation period of the TMDL.

2.4 *Problem Statement Summary*

All of the listings presented in this Problem Statement section and in summary in Table 11 will be addressed by this TMDL.

Table 11. Calleguas Creek Watershed Reaches on the 2002 303(d) List for Toxicity and Organophosphate Pesticides

Reach		Impairment			
		Water Column Toxicity	Sediment Toxicity	Chlorpyrifos in Fish Tissue	Organophosphate Pesticides in Water
1	Mugu Lagoon		X		
	Duck Pond Agricultural Drains/Mugu Drain/Oxnard Drain No 2		X		
2	Calleguas Creek South		X		
4	Revolon Slough	X		X	
5	Beardsley Channel	X		X	
7	Arroyo Simi				X
9B	Conejo Creek Main Stem	X			
10	Hill Canyon	X			
11	Arroyo Santa Rosa	X			
13	Conejo Creek South Fork	X			

3 Current Conditions

Since the mid-1990's various studies have been conducted to assess water and sediment quality in the CCW. Portions of the data collected through these studies were incorporated in to the 1996, 1998, and 2002 WQAs to identify exceedances of water quality objectives. The portion of the available data that formed the basis of the listings was presented in the Problem Statement section. The purpose of the Current Conditions section is to present relevant environmental monitoring data that may not have been included in the WQAs. Relevant environmental monitoring data collected in each reach of the CCW are presented in this section. These environmental monitoring data include, where available:

1. Water toxicity data;
2. Sediment toxicity data;
3. Toxicant identification evaluation (TIE) summaries;
4. Water chemistry data; and,
5. Sediment chemistry data.

3.1 *Use of Environmental Data in Current Conditions Section*

Where possible, constituents responsible for contributing to water and/or sediment toxicity are identified. Water and sediment quality data presented below describe constituents identified as contributing to toxicity in a given reach based on TIEs. Chlorpyrifos and/or diazinon water quality data are also presented because several reaches are on the 2002 303(d) list for these constituents. Receiving water quality data have been gathered through a variety of monitoring programs and incorporated in the CCW Database (LWA, 2004a). Table 12 presents the studies and associated data type used to develop the Current Conditions section.

Table 12. Summary Table of Data Sources Used to Develop Toxicity TMDL Current Conditions Section

Data Source[1]	Begin Date	End Date	Chlorpyrifos and/or Diazinon Data	Toxicity Data
205(j) Non Point Source Study (LWA, 2004a)	11/98	5/99	W	
Bay Protection Toxic Cleanup Program – BPTCP (SWRCB, 1998)	6/96	2/97	S	S
Calleguas Creek Characterization Study – CCCS (LWA, 2000)	7/98	5/99	W, S	W, S
Calleguas Creek Watershed TMDL Work Plan Monitoring Plans (LWA, 2004)	8/03	8/04	W, S	W, S
Camarillo Wastewater Treatment Plant NPDES Monitoring (City of Camarillo, 1997-2000)	2/97	8/00	W	
City of Thousand Oaks Department of Water (City of Thousand Oaks, 1997-2001)	2/97	8/01	W	
State Mussel Watch Program – SMWP (SWRCB, 2004a)	1/89	9/92	S	
Toxic Substance Monitoring Program – TSMP (SWRCB, 2004b)	4/85	8/00	S	
United States Navy (personal communication, Granade)	1/94	6/02	W	S
University of California Davis Study (Anderson *et al.*, 2002)	3/95	6/99	W	W
University of California Los Angeles Study (Abrol *et al.*, 2003)	7/99	7/99[2]	W	
Ventura County Watershed Protection District – VCWPD (VCWPD 1998-2004)	1/98	2/04	W	W

1 Complete references for these studies are provided in the References section of this report when available.
2 Receiving water samples were only collected on one day through this program.
W Represents samples collected in water.
S Represents samples collected in sediments.

The following four studies are repeatedly discussed in this section and have been abbreviated as follows:

1. A University of California Davis Study referred to as "UC Davis Study" (Anderson et al., 2002). Two errors were found in the reported values for chlorpyrifos in water in the text of this study. In conferring with the primary author (B. Anderson, pers. comm. 2004), the correct values were identified and included in this document and the watershed database.
2. Ventura County Watershed Protection District NPDES stormwater monitoring program reports and data referred to as "VCWPD" (VCWPD, 1998 through 2004).
3. Calleguas Creek Characterization Study referred to as "CCCS" (LWA, 2000).
4. CCW TMDL Work Plan Monitoring Plans referred to as "TMDL Work Plan" (LWA, 2004a).

Where toxicity is discussed the word "observed" is used to describe a significant toxic response in an environmental sample. A toxic response was considered significant when the environmental sample response was significantly different than the control treatment response at the 95% confidence level ($p < 0.05$). For the purposes of this TMDL acute endpoints refer to mortality and chronic endpoints refer to growth, reproduction, and/or fertilization. Chronic endpoints are presented when available. In instances where mortality was 100%, chronic endpoints were not measured. Because some toxicity tests were set up only to measure acute endpoints (mortality) the number of acute and chronic tests may differ.

Development of this TMDL included monitoring of a variety of constituents in water, sediment, and fish tissue during 2003-2004 (referred to as TMDL Work Plan monitoring). The purpose of TMDL Work Plan monitoring was to augment previously existing data for the CCW, which contained a high proportion of non-detected values and very few sampling events occurring concurrently across mediums (water, sediment, fish tissue). Analysis of TMDL Work Plan samples used methods with lower detection limits than much of the previously existing data and included several events with concurrent water, fish tissue, and sediment monitoring. These data significantly improve understanding of current conditions in the CCW and also improve the capability for data analysis and modeling.

3.1.1 Development of Summary Statistics

A large proportion of data used to develop the summary statistics for this TMDL are non-detected data. There are three classes of procedures to handle non-detected data: 1) simple substitution, 2) distributional, and 3) robust methods. A full discussion of the three procedures can be found in *Statistical Methods in Water Resources* (Helsel and Hirsch, 1992). While the simple substitution method is widely used, there is no theoretical basis for its use. Data used in the Toxicity TMDL development were collected over time and by different programs, so there are a variety of non-detected levels. The non-detect levels are comparable to the maximum measured values and one-half the higher non-detect levels are greater than the median of the data sets. Simple substitution is not used in the data analysis. Distributional methods force both measured data and non-detects to follow an assumed distribution type. So long as the data follow the assumed distribution, unbiased estimates of summary statistics can be calculated, however, if the data do not exactly follow the assumed distribution, there will be a bias to summary statistics. Robust methods use the measured data to estimate an assumed distribution that is then used to fill-in the non-detect values. The fill-in non-detects are only used to estimate summary statistics and are not considered estimates of specific samples. The robust methods use the collection of measured values and fill-in non-detects to calculate the summary statistics. Robust methods are not as sensitive to the choice of assumed distribution as the distributional method, and summary statistics can be directly calculated using fill-in values. Because the non-detect data are filled-in after the distribution is calculated, multiple non-detect levels are easily handled by the method. The robust method of regression on order statistics (ROS) is used in the data analysis for the Toxicity TMDL to provide a statistically defensible analytical procedure and to protect against potential errors of a distributional method.

The robust method ROS is used to incorporate non-detect information in the analyses performed for the Toxicity TMDL. A log-normal distribution is flexible in shape providing reasonable approximations to data which are nearly symmetric (normally distributed) as well as positively-skewed distributions (Helsel and Hirch, 1992). The log-normal distribution is widely used in practice to represent environmental data [California State Implementation Plan (SWRCB, 2000) and USEPA's Technical Support Document (1991)]. ROS utilizes the measured data (uncensored) in an analysis to estimate the log-normal distribution of the concentrations (Helsel, 1988, 1990). The initial step of the ROS method is to calculate probability-plotting positions (i.e. z-scores or standard deviates) for each data point (censored and uncensored) based on the ordering of all data. A least-squares regression is performed to fit a regression of the log-transformed measured values to their probability plotting positions there-by defining the best fit log-normal distribution to the data. The censored data (non-detects) are assigned values based on their probability plotting positions and the calculated distribution (Helsel, 1990 and Shumway, 2002). Summary statistics are then calculated based on the uncensored data points and the filled-in censored values. Criteria for sufficient data to use the ROS method are: 1) at least 20% and preferably 50% detected data and 2) at least three unique detected values. Instances of insufficient detected data are marked in the summary statistics tables.

Because of limited available data, grab and composite samples are treated in the analysis as equivalent and equally representative of the sampled water, also estimated and qualified data are used as normal detected values. Both uses of the data may introduce errors into the analysis, as grab samples may not be equivalent to composite samples and may not be representative of the targeted source type, and estimated values, while being a better estimate of the true value than the reporting limit, may not reflect the true value in the water accurately.

3.1.1.1 Environmental Data Used

The current condition summary statistics tables presented for each reach consider only more recent data collected from 1995-2004. This time frame is selected for these tables because the first 303(d) listings in the CCW were in 1996 and also because detection limits improved significantly during this time period. Water chemistry data collected in receiving waters in the CCW and compiled in the CCW Database (LWA, 2004a) were used to develop the current conditions summary statistics. In one instance water samples collected during a storm event were split and analyzed as filtrate and filtered solids. The measured values of the filtrate and filtered solids were combined as a total value before statistical analysis was conducted. This was done so the stormwater data would be comparable to the remaining data which had been analyzed as whole samples.

Sediment chemistry data collected in receiving waters in the CCW and compiled in the CCW Database (LWA, 2004a) were used to develop the current conditions summary statistics. Only sediment samples identified as collected at a depth interval beginning at zero were considered as sediment toxicity samples are collected from the upper two to three centimeters of the streambed. Samples with no depth indicated were also considered as it was assumed if no depth was indicated in the original data source samples were collected from the top of the streambed. During two sediment sampling events, sediment samples were split into two grain size fractions and analyzed separately. The measured values of the two grain size fractions were combined based on the percent grain size in each fraction before statistical analysis was conducted. This was done so these sediment data would be comparable to the remaining data which had been analyzed as whole samples.

The bulk of the data from the sources cited in Table 12 were used in this analysis. A large proportion of data used to develop the summary statistics for this section are non-detected data. However, as mentioned directly above, the ROS method has defined data requirements for developing summary statistics. Due to the number of non-detected values at relatively high detection limits the ability to develop summary statistics was limited. To develop summary statistics to characterize water quality in each reach non-detected samples were removed when detection limits were higher than concentrations considered characteristic of the reach based on detected values. Table 13 presents the number of samples removed by reach and site as well as the range of detection limits removed. No sediment chemistry results were removed as a result of non-detect values at high detection limits.

Table 13. Number of Non-Detect Values Removed Due to High Detection Limits from Receiving Water Sampling Sites

Reach	Site	Number of Non-Detect Samples Removed due to High DLs		Range of Removed DLs (ug/L)	
		Diazinon	Chlorpyrifos	Diazinon	Chlorpyrifos
3	Camarillo – W-15	2	0	2	
	VCWPD – ME-CC	12	12	2	2
9B	Camarillo – W-16	2	0	2	
10	Hill Canyon – W-18	10	10	1 - 2	1.5 - 2
	Hill Canyon – W-19	11	11	1 - 2	1.5 - 2
11	Olsen Rd – W-17	14	11	1 - 2	1.5 - 2
Total Number Removed		**51**	**44**		

3.2 *Current Conditions by Reach*

Reach: Calleguas Creek Reach 1 (Mugu Lagoon)

Mugu Lagoon is listed on the 2002 303(d) list for sediment toxicity based on toxicity tests conducted as part of the BPTCP in 1993.

Sediment Toxicity

Studies conducted by the BPTCP (SWRCB, 1998), the Navy (Tetra Tech, 2000; 2003), and UCLA (Anghera, 2004) have analyzed bulk sediment samples for toxicity in Mugu Lagoon. Bulk sediment samples have been analyzed for toxicity to the amphipods *Eohaustorius estuarius, Ampelisca abdita,* and *Rhepoxynius abronius,* and the polychaete *Neanthes arenceodenta.* Because of several differences in methodologies among these studies (e.g. sample collection, test methods) the studies are not directly comparable and the analysis of these studies is solely qualitative.

Significant mortality to *R. abronius* was observed in 1994 by the BPTCP at the Mugu Entrance station and *E. estuarius* in 1997 at the Central Mugu Lagoon – B1 station (see map in Appendix I). Studies conducted by the Navy in 1994 observed significant mortality to *E. estuarius* (at Site 2) and *A. abdita* (at Site 5) (see map in Appendix I). Additionally, mean weight of *N. arenceodenta* was significantly decreased at Site 2. In 1997, the Navy performed a follow-up validation study to the toxicity observed in 1994. Sediment toxicity tests using *A. abdita* were performed at eight stations at Site 11 and at eight identified reference stations. Although mortality was high at several stations, statistical comparison of the mortality results showed no significant difference between Site 11 and the reference stations. As part of a UCLA graduate study several toxicity tests were performed using *E. estuarius*. High mortality (greater than 50%) was observed at several stations, however, the report did not present results based on significant difference from control organisms. Complete mortality was observed at two sites on Creek A (see map in Appendix I).

Outside of collecting sediment chemistry data, none of the above referenced studies gathered additional information to conclusively identify the constituent(s) causing observed toxicity. However, sediment chemistry data collected during these studies were compared to sediment quality guidelines. The guidelines are values used to interpret the relationship between sediment chemistry and biological impacts. Based on this evaluation, presented in Appendix I, constituents that have exceeded guidelines that may be considered for investigation through future monitoring in Mugu Lagoon include: total chlordane, PCBs, DDD, DDT, DDE, arsenic, cadmium, copper, lead, nickel, and zinc. Appendix I presents a more detailed description of the available Mugu Lagoon data as well as the comparison to sediment quality guidelines.

Reach: Calleguas Creek Reach 2 (Calleguas Creek South)

Calleguas Creek South is listed on the 2002 303(d) list for sediment toxicity. In addition, water quality data have indicated the presence of chlorpyrifos and diazinon (Table 14).

Table 14. Summary Statistics for Relevant Water Quality Data in CCW Reach 2

Constituent	n	% Detected	Number Detected	Units	Range of Detection Limits	Mean	Standard Deviation	Median	Maximum Detected Value	% Above Criteria[1,2]
Chlorpyrifos	12	17%	2	ug/L	0.005-0.05	NA	NA	NA	0.481	17%
Diazinon	12	67%	8	ug/L	0.005-0.05	0.087	0.111	0.045	0.356	17%

1 % Above Criteria is calculated using only detected values that exceeded the criteria. These values could be higher because not all samples were tested at detection limits below numeric targets.

2 Criteria used: Chlorpyrifos CDFG chronic (0.014 ug/L) Diazinon: USEPA chronic and acute (0.10 ug/L).

NA Insufficient detected data to develop some summary statistics

Sediment Toxicity

Studies conducted through two programs (CCCS and TMDL Work Plan) have analyzed sediment samples for toxicity in this reach. A total of four bulk sediment samples have been analyzed for toxicity to *E. estuarius* and two bulk sediment samples have been analyzed for toxicity to *H. azteca*. In two porewater samples analyzed for toxicity to *C. dubia*, mortality was observed in one sample and reproductive toxicity was observed in the other sample. Mortality of *H. azteca* was observed in one of the two samples (50%). Mortality of *E. estuarius* was observed in three of the four samples (75%). In two of these three samples, toxicity was not above the established trigger level (>50% survival toxicity) set in the TMDL Work Plan monitoring program for further investigation. The other sample was above the trigger and sediment porewater toxicity testing was performed before initiating Phase I TIE procedures on the porewater. However, a Phase I TIE was not performed on this sample as the porewater from this sample was not toxic to *E. estuarius* survival.

Based on the available information, it is not clear which pollutant(s) are contributing to sediment toxicity in this reach. As such no sediment chemistry data are provided.

Reach: Calleguas Creek Reach 3 (Calleguas Creek)

Calleguas Creek is not listed on the 2002 303(d) list for water or sediment toxicity. However, studies have identified occurrences of water and sediment toxicity to various test organisms in samples collected in this reach (CCCS and VCWPD). In addition, water quality data have indicated the presence of chlorpyrifos and diazinon. The following is a discussion of current conditions as they relate to the presence of chlorpyrifos and diazinon in water and water and sediment toxicity in this reach. Table 15 presents relevant summary statistics for water quality data.

Water Toxicity

Studies conducted through three programs (VCWPD, CCCS, and TMDL Work Plan) have analyzed water samples for toxicity in this reach. A total of 28 samples have been analyzed for toxicity to *C. dubia*, 10 samples have been analyzed for toxicity to *Menidia beryllina*, and six samples have been analyzed for toxicity to *Pimephales promelas*. Mortality to *M. beryllina* was observed in one sample (10%). No mortality or growth toxicity were observed in any of the *P. promelas* samples. *C. dubia* mortality was observed in eight of 28 samples (29%) and reproductive toxicity was observed in seven of 16 samples (44%).

One TIE was conducted in this reach through the TMDL Work Plan. This TIE was initiated on the sample immediately after it was received by the laboratory in an attempt to characterize degrading toxicity observed in the previous sample collected in this reach. Reproductive toxicity to *C. dubia* was observed in this sample but mortality was not. However, in the TIE sample treated with piperonyl butoxide (PBO), significant mortality and reproductive toxicity were observed. PBO is used to inhibit the metabolism of a test species to eliminate toxicity related to metabolically activated compounds such as diazinon and chlorpyrifos. The presence of toxicity in the PBO treated sample suggests that a compound detoxified through the test species' metabolism was present at sub-lethal levels.

Based on the available information, it is not clear what pollutant(s) are contributing to water toxicity in this reach.

Table 15. Summary Statistics for Relevant Water Quality Data in Reach 3

Constituent	n	% Detected	Number Detected	Units	Range of Detection Limits	Mean	Standard Deviation	Median	Maximum Detected Value	% Above Criteria[1,2]
Chlorpyrifos	25	32%	8	ug/L	0.005-0.250	0.027	0.080	0.005	0.405	24%
Diazinon	30	53%	16	ug/L	0.005-0.250	0.060	0.074	0.031	0.280	13%

1 % Above Criteria is calculated using only detected values that exceeded the criteria. These values could be higher because not all samples were tested at detection limits below numeric targets.
2 Criteria used: Chlorpyrifos CDFG chronic (0.014 ug/L) Diazinon: USEPA chronic and acute (0.10 ug/L).

Sediment Toxicity

Studies conducted through two programs (CCCS and TMDL Work Plan) have analyzed sediment samples for toxicity in this reach. A total of six bulk sediment samples have been analyzed for toxicity to *H. azteca*. In two porewater samples analyzed for toxicity to *C. dubia*, mortality was observed in one sample and reproductive toxicity was observed in the other sample. Mortality to *H. azteca* was observed in two of six bulk sediment samples (33%) and five of six (80%) porewater samples. Significant growth reduction in *H. azteca* was observed in one of three samples (33%).

Through the TMDL Work Plan, two TIEs were conducted on porewater extracted from bulk sediment toxic to *H. azteca*. In the first TIE conducted, chlorpyrifos was identified as a potential toxicant in the porewater, based on the TIEs and porewater chemistry. Chlorpyrifos in porewater was measured at 0.067 ug/L, above the low range of published LC_{50} values for *H. azteca* of 0.04-0.14 ug/L. However, the Phase I and Phase II TIE did not conclude that chlorpyrifos was the only cause of toxicity. The potential exists that another organic compound was contributing to toxicity. In addition to the detection of chlorpyrifos in porewater, total ammonia (0.58 mg/L) and the triazine herbicide prometryn (0.003 ug/L) were detected. Studies have indicated that the triazine herbicide atrazine can have synergistic effects that potentiate (increase) the toxicity of chlorpyrifos (Lindstrom and Lydy, 1997; Belden and Lydy, 2000; Anderson and Lydy, 2002; Clark *et al.*, 2002). The results of these same studies suggest the potential for similar interactions to occur between prometryn and chlorpyrifos. Synergistic effects on toxicity (also described as potentiating toxicity) are considered to exist when the total effect of the combination of constituents are greater than the sum of the individual effects. However, the concentrations at which prometryn were detected in this sample are 3000 times lower than the concentrations of atrazine at which synergistic effects were observed in the cited studies. Although ammonia toxicity has been shown to be additive to OP pesticide toxicity (Bailey et al., 2001), total ammonia levels measured in porewater (0.58 mg/L) were well below the 96-hr acute LC50 values of 14.2-19.8 mg/L total ammonia (Whiteman, 1996 and Ankley et al. 1995). Chlorpyrifos was not detected in the bulk sediment at a detection limit of 0.005 ug/g.

The second TIE conducted on porewater identified ammonia as a potential toxicant to *H. azteca* based on the TIE and porewater chemistry data. Ammonia in porewater was measured at 20 mg/L, above the 96-hr acute LC50 values of 14.2-19.8 mg/L total ammonia (Whiteman, 1996 and Ankley et al. 1995). In addition, the addition of PBO increased toxicity suggesting that a compound detoxified through the test species' metabolism was present at sub-lethal levels.

Based on the available information, chlorpyrifos and ammonia have been identified as contributing to sediment toxicity in this reach. Porewater data indicates the presence of the triazine herbicide prometryn, which may potentiate toxicity caused by chlorpyrifos, although these herbicides were detected at concentrations that were orders of magnitude lower than levels identified as potentiating toxicity in available studies. TIEs do not suggest toxicity is being potentiated by or solely caused by prometryn. It has not been demonstrated that potentiation occurs at the relatively low concentrations observed. In addition, porewater data indicate the presence of ammonia which could increase toxicity due to additive effects or solely cause toxicity.

Table 16. Summary Statistics for Relevant Sediment Quality Data for Reach 3

Constituent	N	% Detected	Number Detected	Units	Range of Detection Limits	Mean	Standard Deviation	Median	Maximum Detected Value
Ammonia in Porewater	2	100%	2	mg/L	0.01	NA	NA	NA	20
Prometryn Porewater	2	50%	1	ug/L	0.001	NA	NA	NA	0.003
Chlorpyrifos in Porewater	1	100%	1	ug/L	0.001	NA	NA	NA	0.067
Chlorpyrifos in Bulk Sediment	6	17%	1	ug/g	0.001-0.01	NA	NA	NA	0.005

NA Insufficient data to develop summary statistics

Reach: Calleguas Creek Reach 4 (Revolon Slough)

Revolon Slough is on the 2002 303(d) list for water toxicity and chlorpyrifos in fish tissue. As presented in the Problem Statement section, this TMDL will focus on addressing chlorpyrifos in water as opposed to fish tissue. Studies have indicated the presence of chlorpyrifos and diazinon in water and sediment toxicity to various test organisms in samples collected in this reach (UC Davis, CCCS, TMDL Work Plan and

VCWPD). Table 17 presents relevant summary statistics for water quality data. The following is a discussion of current conditions as they relate to the presence of water and sediment toxicity and chlorpyrifos and diazinon in water.

Water Toxicity

Studies conducted through four programs (UC Davis, VCWPD, CCCS, and TMDL Work Plan) have analyzed water samples for toxicity in this reach. A total of 30 samples have been analyzed for toxicity to *C. dubia*, one sample has been analyzed for toxicity to *M. beryllina*, 10 samples have been analyzed for toxicity to *Americamysis bahia*, 12 samples have been analyzed for toxicity to *P. promelas*, and 13 samples have been analyzed for toxicity to *Selenastrum capricornutum*. *C. dubia* mortality was observed in 16 of 39 samples (53%) and reproductive toxicity was observed in three of 13 samples (23%). Mortality was observed in four of 10 samples (40%) and growth toxicity was observed in two of seven samples (29%) tested with *A. bahia*. Mortality to *M. beryllina* was not observed. Mortality to *P. promelas* was observed in four of 12 (33%) and growth toxicity was observed in six of eight (75%) samples. Growth toxicity to *S. capricornutum* was observed in 12 samples (92%).

A total of 10 TIEs have been conducted in this reach through the VCWPD (2), the UC Davis study (5), and the TMDL Work Plan (3). The TIEs conducted by the VCWPD found the primary causes of mortality of *C. dubia* to be metabolically-activated organophosphate compounds and non-polar organic compounds. These TIEs also suggested volatile compounds were possibly contributing to toxicity. The TIE results and the associated water quality data for these samples indicate that chlorpyrifos and diazinon were probably contributing to mortality of *C. dubia*. In both instances chlorpyrifos and diazinon were measured above published LC_{50} values of 0.06-0.09 ug/L and 0.11 ug/L, respectively. In one sample 4-4 DDT was measured at 0.155 ug/L. Although no published 4-4 DDT LC_{50} for *C. dubia* could be located, 4-4 DDT LC_{50} values for *Daphnia magna*, a similar species, presented in the USEPA DDT water quality criteria document (1980) range from 1.48 – 4 ug/L, suggesting DDT was not likely the cause of toxicity in this sample. *C. dubia* are closely related and morphologically similar to *Daphnia* (USEPA, 2002a). The acute sensitivity of *C. dubia* has been compared to *D. magna* under similar test conditions and in most cases *C. dubia* was more sensitive (Mount and Norberg 1984).

All five of the UC Davis study TIEs also indicated toxicity to *C. dubia* was due to metabolically-activated pesticides. Concentrations of chlorpyrifos in four of the samples (0.06, 0.09, 0.92, 0.11 ug/L) met or exceeded the 96-hr LC_{50} for *C. dubia* (0.06-0.09 ug/L). Chlorpyrifos was not detected in one sample at a detection limit of 0.044 ug/L. Concentrations of diazinon in one sample (0.20 ug/L) exceeded the 7-day LC_{50} for *C. dubia* (0.11 ug/L). Diazinon was detected in one other sample (0.03) below the 7-day LC_{50} and was not detected in the remaining three samples at detection limits below 0.04 ug/L. Carbaryl, which unlike chlorpyrifos and diazinon does not need metabolic activation for effectiveness, was detected in three of the five samples, but concentrations were significantly lower than the reported LC_{50} (11.6 ug/L). TIE manipulation of *S. capricornutum* samples did not result in reduction of toxicity, and the results indicate that *S. capricornutum* toxicity was not caused by chlorine or non-polar organic compounds.

Three TIEs were conducted through the TMDL Work Plan. The first TIE was initiated on the sample immediately after it was received by the laboratory in an attempt to characterize degrading toxicity observed in the previous sample collected in this reach. No mortality or growth toxicity to *C. dubia* were observed in this sample. However, in the TIE sample treated with PBO, significant mortality and growth toxicity were observed. PBO is used to inhibit the metabolism of a test species to eliminate toxicity related to metabolically activated compounds such as diazinon and chlorpyrifos. The presence of toxicity in the

PBO treated sample suggests that a compound detoxified through the test species' metabolism was present at sub-lethal levels.

Results of the second TIE conducted on the one storm water toxicity sample collected in this reach through the TMDL Work Plan suggest that one or more OP pesticides are likely responsible for the observed toxicity. Water chemistry indicates the presence of chlorpyrifos (0.119 ug/L) above published LC_{50} values of 0.06-0.09 ug/L and diazinon (0.023 ug/L) well below the 7-day LC_{50} value of 0.11 ug/L. Additionally, the triazine herbicides prometryn (0.121 ug/L) and simazine (0.559 ug/L) were detected and may potentiate chlorpyrifos toxicity based on research indicating a synergistic relationship between chlorpyrifos and the triazine herbicide atrazine (Lindstrom and Lydy, 1997; Belden and Lydy, 2000; Anderson and Lydy, 2002; Clark *et al.*, 2002). However, the concentrations at which prometryn and simazine were detected in this sample are 83 and 18 times lower, respectively, than the concentrations of atrazine at which synergistic effects were observed in the cited studies.

Results of the final TIE conducted through the TMDL Work Plan identified chlorpyrifos as contributing to toxicity. Chlorpyrifos was measured in the sample at 0.135 ug/L, above published LC_{50} values of 0.06-0.09 ug/L. Additionally, the triazine herbicide prometryn was detected at 0.116 ug/L and may potentiate chlorpyrifos toxicity based on research indicating a synergistic relationship between chlorpyrifos and the triazine herbicide atrazine (Lindstrom and Lydy, 1997; Belden and Lydy, 2000; Anderson and Lydy, 2002; Clark *et al.*, 2002). However, the concentrations at which prometryn were detected in this sample are 86 times lower than the concentrations of atrazine at which synergistic effects were observed in the cited studies.

Based on the available information, chlorpyrifos has been identified as contributing to water toxicity in this reach. Water chemistry data indicates the presence of triazine herbicides prometryn and simazine, which may potentiate toxicity caused by chlorpyrifos, although these herbicides were detected at concentrations that are an order of magnitude lower than levels identified as potentiating toxicity in available studies. TIEs do not suggest toxicity is being potentiated by or solely caused by these herbicides. It has not been demonstrated that potentiation occurs at the relatively low concentrations observed.

Table 17. Summary Statistics for Relevant Water Quality Data in Reach 4

Constituent	n	% Detected	Number Detected	Range of Detection Limits	Units	Mean	Standard Deviation	Median	Maximum Detected Value	% Above Criteria[1,2]
Atrazine	10	0%	0	0.005-0.047	ug/L	ND	ND	ND	ND	NC
Prometon	4	0%	0	0.005	ug/L	ND	ND	ND	ND	NC
Prometryn	2	100%	2	0.005	ug/L	NA	NA	NA	0.121	NC
Simazine	12	33%	4	0.005-0.06	ug/L	1.17	3.73	0.013	13.0	NC
Simetryn	3	0%	0	0.005	ug/L	ND	ND	ND	ND	NC
Chlorpyrifos	38	55%	21	0.005-2.0	ug/L	0.181	0.296	0.056	1.46	53%
Diazinon	38	47%	18	0.005-2.0	ug/L	0.121	0.218	0.040	1.2	29%

1 % Above Criteria is calculated using only detected values that exceeded the criteria. These values could be higher because not all samples were tested at detection limits below numeric targets.
2 Criteria used: Chlorpyrifos CDFG chronic (0.014 ug/L) Diazinon: USEPA chronic and acute (0.10 ug/L)
NA Insufficient detected data to develop some summary statistics
NC No criteria for these constituents
ND No detected data

Sediment Toxicity

Studies conducted through two programs (CCCS and TMDL Work Plan) have analyzed sediment samples for toxicity in this reach. A total of five bulk sediment samples have been analyzed for toxicity to *H. azteca*. Mortality to *H. azteca* was observed in three of five samples (60%) and growth toxicity was observed in one of three samples (33%). Two porewater samples have been analyzed for toxicity to *H. azteca* with mortality observed in both samples. Two porewater samples have been analyzed for toxicity to *C. dubia* with no mortality or reproductive toxicity observed in the samples.

Three TIEs have been conducted in this reach through the TMDL Work Plan. In the first TIE conducted on porewater from a sediment sample collected in this reach chlorpyrifos was identified as a potential toxicant to *H. azteca* based on the TIE and porewater chemistry. Analysis of sediment porewater measured chlorpyrifos at 0.933 ug/L, well above the reported 96-hr LC_{50} for *H. azteca* survival (0.04-0.14 ug/L), and the total ammonia concentration measured in porewater (18.3 mg/L), was within the range of the 96-hr acute LC_{50} values of 14.2-19.8 mg/L total ammonia (Whiteman, 1996 and Ankley et al. 1995). The TIE and porewater chemistry results suggest co-occurring ammonia and chlorpyrifos toxicity. Additionally, the triazine herbicide prometryn was detected at 0.048 ug/L and may potentiate chlorpyrifos toxicity based on research indicating the herbicide atrazine can have synergistic effects that potentiate (increase) the toxicity of chlorpyrifos (Lindstrom and Lydy, 1997; Belden and Lydy, 2000; Anderson and Lydy, 2002; Clark *et al.*, 2002). However, the concentrations at which prometryn were detected in this sample are 200 times lower than the concentrations of atrazine at which synergistic effects were observed in the cited studies. Ammonia toxicity has been shown to be additive to OP pesticide toxicity (Bailey *et al.*, 2001). In this sample, chlorpyrifos was detected in the bulk sediment at 0.0458 ug/g.

In the second TIE conducted on porewater, results suggested that ammonia and one or more organic compounds contributed to toxicity to *H. azteca*. The total ammonia concentration measured in porewater (16.2 mg/L) was within the range of the 96-hr acute LC_{50} values of 14.2-19.8 mg/L total ammonia (Whiteman, 1996 and Ankley et al. 1995). In addition, the chlorpyrifos concentration measured in porewater (0.251 ug/L) was above the reported 96-hr LC_{50} for *H. azteca* survival (0.04-0.14 ug/L). These results indicated the potential for co-occurring additive ammonia and chlorpyrifos toxicity. The triazine herbicide prometryn was also detected, but the analytical laboratory was not able to quantify the concentration. As mentioned previously, studies have indicated that the triazine herbicide atrazine can potentiate chlorpyrifos toxicity (Lindstrom and Lydy, 1997; Belden and Lydy, 2000; Anderson and Lydy, 2002; Clark *et al.*, 2002), suggesting the potential for similar interactions to occur between prometryn and chlorpyrifos. Ammonia toxicity has been shown to be additive to OP pesticide toxicity (Bailey *et al.*, 2001). In this sample, chlorpyrifos was not detected in the bulk sediment at a detection limit of 0.007 ug/g.

In the final TIE conducted on porewater, results suggested that ammonia and one or more organic compounds contributed to toxicity to *H. azteca*. The total ammonia concentration measured in porewater (22 mg/L) was above the 96-hr acute LC_{50} values of 14.2-19.8 mg/L total ammonia (Whiteman, 1996 and Ankley et al. 1995). In addition, the chlorpyrifos concentration measured in porewater (0.108 ug/L) was within the range of the reported 96-hr LC_{50} for *H. azteca* survival (0.04-0.14 ug/L). These results indicated the potential for co-occurring additive ammonia and chlorpyrifos toxicity. Additionally, the triazine herbicide prometryn was detected at 0.198 ug/L and may potentiate chlorpyrifos toxicity based on research indicating the herbicide atrazine can have synergistic effects that potentiate (increase) the toxicity of chlorpyrifos (Lindstrom and Lydy, 1997; Belden and Lydy, 2000; Anderson and Lydy, 2002; Clark *et al.*, 2002). However, the concentrations at which prometryn were detected in this sample are 50 times lower than the concentrations of atrazine at which synergistic effects were observed in the cited studies. Ammonia toxicity has been shown to be additive to OP pesticide toxicity (Bailey *et al.*, 2001). In this sample, chlorpyrifos was detected in the bulk sediment at 0.006 ug/g.

Based on the available information, chlorpyrifos and ammonia have been identified as contributing to sediment toxicity in this reach. Porewater chemistry data indicates the presence of triazine herbicide prometryn, which may potentiate toxicity caused by chlorpyrifos, although these herbicides were detected at concentrations that were at least an order of magnitude lower than levels identified as potentiating toxicity in available studies. Furthermore, it has not been demonstrated that potentiation occurs at the relatively low concentrations observed. TIEs do not suggest toxicity is being potentiated by or solely caused by prometryn.

Table 18. Summary Statistics for Relevant Sediment Quality Data in Reach 4

Constituent	n	% Detected	Number Detected	Units	Range of Detection Limits	Mean	Standard Deviation	Median	Maximum Detected Value
Ammonia Porewater	3	100%	3	mg/L	0.01	18.8	2.94	18.7	18.3
Prometryn Porewater	3	100%	3	ug/L	0.001	NA	NA	NA	0.198
Chlorpyrifos Porewater	2	100%	2	ug/L	0.001	0.430	0.441	0.294	0.933
Chlorpyrifos in Bulk Sediment	11	73%	8	ug/g	0.001-0.007	0.011	0.012	0.008	0.17

NA Insufficient data to develop summary statistics

Reach: Calleguas Creek Reach 5 (Beardsley Channel)

Beardsley Channel is on the 2002 303(d) list for water toxicity and chlorpyrifos in fish tissue. As discussed in the Problem Statement section, this TMDL will focus on addressing chlorpyrifos in water as opposed to fish tissue. Additional studies have indicated the presence of chlorpyrifos and diazinon in water. Table 19 presents summary statistics for relevant water quality data. The following is a discussion of current conditions as they relate to the presence of water toxicity and chlorpyrifos and diazinon in water.

Water Toxicity

Studies conducted through the UC Davis Study and the TMDL Work Plan have analyzed water samples for toxicity in this reach. A total of eight samples have been analyzed for toxicity to *C. dubia* and nine samples have been analyzed for toxicity to *A. bahia*. *C. dubia* mortality was observed in three of eight samples (38%) and reproductive toxicity was observed in none of the five samples tested. *A. bahia* mortality was observed in two samples (22%) and growth toxicity was observed in three samples (33%).

Two TIEs have been conducted in this reach through the UC Davis study. Both TIEs indicated chlorpyrifos as the cause of mortality of *C. dubia*. The concentrations of chlorpyrifos in each sample (0.177 and 0.149 ug/L) exceeded the 96-hr LC_{50} for *C. dubia* (0.06-0.09 ug/L). Recent water toxicity testing through the TMDL Work Plan observed intermittent acute and chronic toxicity to test species. However, none of these samples were above the established trigger level (>50% mortality) for TIE initiation.

Although more recent water toxicity testing through the TMDL Work Plan has not determined a toxicant, based on the UC Davis Study, chlorpyrifos has been identified as contributing to water toxicity in this reach. Chlorpyrifos has been detected during sampling conducted through the TMDL Work Plan monitoring program. As discussed previously, triazine herbicides may potentiate chlorpyrifos toxicity. Triazine herbicides have been detected in this reach; however, TIEs conducted in this reach have not suggested that triazine herbicides are potentiating chlorpyrifos toxicity. Water quality summary statistics for these constituents are provided along with diazinon and chlorpyrifos information in Table 19.

Table 19. Summary Statistics for Relevant Water Quality Data in Reach 5

Constituent	n	% Detected	Number Detected	Units	Range of Detection Limits	Mean	Standard Deviation	Median	Maximum Detected Value	% Above Criteria[1,2]
Atrazine	12	0%	0	ug/L	0.005-0.047	ND	ND	ND	ND	NC
Prometon	6	0%	0	ug/L	0.005	ND	ND	ND	ND	NC
Prometryn	4	100%	4	ug/L	0.005	0.035	0.025	0.029	0.07	NC
Simazine	12	25%	3	ug/L	0.005-0.06	0.567	0.706	0.292	2.07	NC
Simetryn	6	0.0%	0	ug/L	0.005	ND	ND	ND	ND	NC
Chlorpyrifos	16	75%	12	ug/L	0.005-0.044	0.061	0.051	0.042	0.177	75%
Diazinon	16	13%	2	ug/L	0.005-0.038	NA	NA	NA	0.317	6%

1 % Above Criteria is calculated using only detected values that exceeded the criteria. These values could be higher because not all samples were tested at detection limits below numeric targets.
2 Criteria used: Chlorpyrifos CDFG chronic (0.014 ug/L) Diazinon: USEPA chronic and acute (0.10 ug/L).
NA Insufficient detected data to develop some summary statistics
NC No criteria for these constituents
ND No detected data

Reach: Calleguas Creek Reach 6 (Arroyo Las Posas)

Arroyo Las Posas is not on the 2002 303(d) list for water or sediment toxicity. However, the CCCS and the TMDL Work Plan identified occurrences of water and sediment toxicity to various test organisms in samples collected in this reach. In addition, water quality data have indicated the presence of chlorpyrifos and diazinon. Table 20 presents summary statistics for relevant water quality data. The following is a discussion of current conditions as they relate to the presence of water and sediment toxicity and chlorpyrifos and diazinon in water.

Water Toxicity

Studies conducted through two programs (CCCS and TMDL Work Plan) have analyzed water samples for toxicity in this reach. A total of 14 samples have been analyzed for toxicity to *C. dubia* and six samples have been analyzed for toxicity to *P. promelas*. *C. dubia* mortality was observed in three samples (21%) and reproductive toxicity was observed in nine samples (64%). Mortality and growth toxicity to *P. promelas* was not observed.

In the one TIE conducted in this reach through the TMDL Work Plan, diazinon was identified as causing mortality. Diazinon was measured at 0.289 ug/L, exceeding the 7-day LC_{50} value of 0.11 ug/L for *C. dubia*. Additionally, the triazine herbicides simazine (0.028 ug/L) and atrazine (0.011 ug/L) were detected and may potentiate diazinon toxicity based on research indicating a synergistic relationship between diazinon and the triazine herbicide atrazine (Belden and Lydy, 2000; Anderson and Lydy, 2002). The results of these same studies suggest the potential for similar interactions to occur between simazine and diazinon. However, the concentrations at which simazine and atrazine were detected in this sample are 300 and 900 times lower, respectively, than the concentrations of atrazine at which synergistic effects were observed in the cited studies.

Based on the available information diazinon has been identified as contributing to water toxicity in this reach. Water chemistry data indicates the presence of the triazine herbicides simazine and atrazine, which may potentiate toxicity caused by chlorpyrifos, although these herbicides were detected at concentrations that were orders of magnitude lower than levels identified as potentiating toxicity in available studies. It has not been demonstrated that potentiation occurs at the relatively low concentrations observed. TIEs do not suggest toxicity is being potentiated by or solely caused by these herbicides.

Table 20. Summary Statistics for Relevant Water Quality Data in Reach 6

Constituent	n	% Detected	Number Detected	Units	Range of Detection Limits	Mean	Standard Deviation	Median	Maximum Detected Value	% Above Criteria[1,2]
Ammonia as N	9	90%	8	mg/L	0.01	0.572	0.792	0.127	2.20	0%
Atrazine	6	83%	5	ug/L	0.005	0.014	0.004	0.013	0.019	NC
Prometon	6	33%	2	ug/L	0.005	NA	NA	NA	0.011	NC
Prometryn	4	0%	0	ug/L	0.005	ND	ND	ND	ND	NC
Simazine	6	50%	3	ug/L	0.005	0.028	0.01	0.026	0.04	NC
Simetryn	6	0%	0	ug/L	0.005	ND	ND	ND	ND	NC
Chlorpyrifos	10	30%	3	ug/L	0.005	0.013	0.028	0.001	0.087	20%
Diazinon	10	60%	6	ug/L	0.005	0.057	0.086	0.024	0.289	10%

1 % Above Criteria is calculated using only detected values that exceeded the criteria.

2 Criteria used: Chlorpyrifos CDFG chronic (0.014 ug/L) Diazinon: USEPA chronic and acute (0.10 ug/L) Ammonia: CCW Nutrients TMDL chronic (2.63 mg/L).

NA Insufficient detected data to develop some summary statistics

NC No criteria for these constituents

ND No detected data

Sediment Toxicity

Studies conducted through two programs (CCCS and TMDL Work Plan) have analyzed sediment samples for toxicity in this reach. A total of five bulk sediment samples have been analyzed for toxicity to *H. azteca*. Mortality to *H. azteca* was observed in one sample (20%) and growth toxicity was not observed. Two samples have been analyzed for porewater toxicity to *C. dubia*, mortality was not observed in either sample. Sediment toxicity was observed in this reach during one sampling event conducted through the CCCS in November 1998. However, during the more recent TMDL Work Plan monitoring (August 2003 through April 2004) no toxicity was observed in sediment. No TIEs have been conducted in this reach. Based on the available information sediment toxicity in this reach is either intermittent or there is not an impairment in this reach. This reach is not on the 303(d) list for sediment toxicity.

Reach: Calleguas Creek Reach 7 (Arroyo Simi)

The Arroyo Simi is listed for organophosphate pesticides in water; however, as presented in the Problem Statement section, chlorpyrifos and diazinon were identified as the two OP pesticides contributing to the impairment in this reach. Additionally, studies have identified occurrences of water and sediment toxicity to various test organisms in samples collected in this reach. Table 21 presents summary statistics for relevant water quality data. The following is a discussion of current conditions as they relate to the presence of chlorpyrifos and diazinon in water and water and sediment toxicity in this reach.

Water Toxicity

Studies conducted through three programs (UC Davis, CCCS, and TMDL Work Plan) have analyzed water samples for toxicity in this reach. A total of 32 samples have been analyzed for toxicity to *C. dubia* and 22 samples have been analyzed for toxicity to *P. promelas*. *C. dubia* mortality was observed in 11 of 32 samples (34%) and reproductive toxicity was observed in 20 of 27 samples (74%). Mortality to *P. promelas* was observed in 14 of 22 (64%) and growth toxicity was observed in six of 18 (33%) samples.

A total of seven TIEs have been conducted in this reach through the UC Davis study (3), the CCCS (3) and the TMDL Work Plan (1). The three TIEs conducted in the UC Davis study suggest diazinon was the cause of toxicity. The concentrations of diazinon in each sample (0.410, 0.400, and 0.430 ug/L) exceeded the 7-day LC_{50} for *C. dubia* (0.11 ug/L). Chlorpyrifos was not detected in any of these samples. Manipulation of pH in five *P. promelas* samples collected downstream of the SVWQCP resulted in a reduction of toxicity. Unionized ammonia concentrations in these samples ranged from 2.39-4.76 mg/L exceeding the reported LC_{50} of 0.6-1.0 mg/L. This suggests ammonia was a cause of mortality of *P. promelas*.

In two of the TIEs conducted for the CCCS, the observed toxicity was no longer present in the ambient sample at completion of the TIE making the results inconclusive. For the remaining TIE, ammonia was identified as a toxicant. Although removal of ammonia reduced toxicity, the overall toxicity remained significant, suggesting additional constituents are contributing to observed toxicity.

In the one TIE conducted in this reach through the TMDL Work Plan, diazinon was identified as causing toxicity. Diazinon was measured at 0.379 ug/L, well above the 7-day LC_{50} value for *C. dubia* of 0.11 ug/L. Additionally, the triazine herbicide simazine (0.021 ug/L) was detected and may potentiate diazinon toxicity based on research indicating a synergistic relationship between diazinon and the triazine herbicide atrazine (Belden and Lydy, 2000; Anderson and Lydy, 2002). However, the concentration at which simazine was detected in this sample is 475 times lower than the concentrations of atrazine at which synergistic effects were observed in the cited studies.

Based on the available information diazinon and ammonia have been identified as contributing to water toxicity in this reach. Water chemistry data indicates the presence of the triazine herbicide simazine, which may potentiate toxicity caused by diazinon, although this herbicides were detected at concentrations that were orders of magnitude lower than levels identified as potentiating toxicity in available studies. It has not been demonstrated that potentiation occurs at the relatively low concentrations observed. Water chemistry data indicate the presence of ammonia which could increase toxicity due to additive effects. TIEs do not suggest toxicity is being potentiated by or solely caused by simazine.

Table 21. Summary Statistics for Relevant Water Quality Data in Reach 7

Constituent	n	% Detected	Number Detected	Units	Range of Detection Limits	Mean	Standard Deviation	Median	Maximum Detected Value	% Above Criteria[1,2]
Ammonia as N	10	100%	10	mg/L	0.01	5.17	5.35	2.32	17.00	50%
Atrazine	3	100%	3	ug/L	0.005	0.014	0.005	0.014	0.018	NC
Prometon	6	17%	1	ug/L	0.005-0.1	NA	NA	NA	0.014	NC
Prometryn	1	0%	0	ug/L	0.005	ND	ND	ND	ND	NC
Simazine	6	33%	2	ug/L	0.005-0.5	NA	NA	NA	0.031	NC
Simetryn	3	0%	0	ug/L	0.005	ND	ND	ND	ND	NC
Chlorpyrifos	23	17%	4	ug/L	0.005-0.05	NA	NA	0.038[3]	0.361	13%
Diazinon	26	69%	18	ug/L	0.005-0.05	0.122	0.150	0.056	0.451	27%

1 % Above Criteria is calculated using only detected values that exceeded the criteria. These values could be higher because not all samples were tested at detection limits below numeric targets.
2 Criteria used: Chlorpyrifos CDFG chronic (0.014 ug/L) Diazinon: USEPA chronic and acute (0.10 ug/L) Ammonia: CCW Nutrients TMDL chronic (2.35 mg/L).
3 Developed using detected data only.
NA Insufficient detected data to develop some summary statistics
NC No criteria for these constituents
ND No detected data

Although the listing for this reach is "Organophosphate Pesticides", numeric targets will be set for chlorpyrifos and diazinon to address this listing as diazinon has been identified as an OP pesticide contributing to toxicity and both have been observed to exceed water quality criteria.

Sediment Toxicity

Studies conducted through two programs (CCCS and TMDL Work Plan) have analyzed sediment samples for toxicity in this reach. Five bulk sediment samples have been analyzed for toxicity to *H. azteca*. Mortality to *H. azteca* was observed in one of five samples (20%) and growth toxicity was observed in one of three samples (33%). Two porewater samples have been analyzed for toxicity to *C. dubia* with no mortality or reproductive toxicity observed in the samples. The only observed sediment toxicity in this reach occurred during one sampling event conducted through the CCCS in November 1998. However, during the more recent TMDL Work Plan monitoring (August 2003 through April 2004) no toxicity was observed in sediment. No TIEs have been conducted in this reach. Based on the available information sediment toxicity in this reach is either intermittent or there is not an impairment in this reach. This reach is not listed on the 303(d) list for sediment toxicity.

Reach: Calleguas Creek Reach 8 (Tapo Canyon)

Tapo Canyon is not listed on the 2002 303(d) list for toxicity. However, water quality data have indicated the presence of chlorpyrifos and diazinon (Table 22).

Table 22. Summary Statistics for Relevant Water Quality Data in Reach 8

Constituent	N	% Detected	Number Detected	Units	Range of Detection Limits	Mean	Standard Deviation	Median	Maximum Detected Value	% Above Criteria[1,2]
Chlorpyrifos	16	6%	1	ug/L	0.005-0.05	NA	NA	NA	0.080	6%
Diazinon	16	19%	3	ug/L	0.005-0.05	NA	NA	0.2[3]	0.550	19%

1 % Above Criteria is calculated using only detected values that exceeded the criteria. These values could be higher because not all samples were tested at detection limits below numeric targets.
2 Criteria used: Chlorpyrifos CDFG chronic (0.014 ug/L) Diazinon: USEPA chronic and acute (0.10 ug/L).
3 Developed using detected data only.
NA Insufficient detected data to develop some summary statistics

Reach: Calleguas Creek Reach 9A (Conejo Creek)

Conejo Creek is not listed on the 2002 303(d) list for water or sediment toxicity. However, studies have identified occurrences of water and sediment toxicity to various test organisms in samples collected in this reach (CCCS and TMDL Work Plan). In addition, water quality data have indicated the presence of chlorpyrifos and diazinon. Table 23 presents summary statistics for relevant water quality data. The following is a discussion of current conditions as they relate to the presence of water and sediment toxicity and chlorpyrifos and diazinon in water.

Water Toxicity

Studies conducted through two programs (CCCS and TMDL Work Plan) have analyzed water samples for toxicity in this reach. A total of 16 samples have been analyzed for toxicity to *C. dubia* and six samples have been analyzed for toxicity to *P. promelas*. *C. dubia* mortality was observed in three samples (19%) and reproductive toxicity was observed in seven samples (44%). Mortality to *P. promelas* was not observed, however, growth toxicity was observed in two samples (33%).

A total of three TIEs have been conducted in this reach through the TMDL Work Plan. In the first TIE, toxicity degraded during the Phase I TIE and results were inconclusive. Results of the TIE conducted on the one storm water toxicity sample collected in this reach through the TMDL Work Plan suggest that one or more OP pesticides are likely responsible for the observed toxicity. Water chemistry measured diazinon at 0.233 ug/L exceeding the 7-day LC_{50} value of 0.11 ug/L. The OP pesticide dimethoate was measured at 0.508 ug/L; however, there are no readily available dimethoate toxicity data with respect to *C. dubia*. Pacific EcoRisk, the toxicity testing laboratory contracted for the TMDL Work Plan, found that dimethoate concentrations as high as 1.46 ug/L would not be expected to impair *C. dubia* survival or reproduction, indicating that dimethoate was not causing the observed toxicity. The triazine herbicides prometryn (0.235 ug/L) and simazine (0.28 ug/L) were detected and may potentiate diazinon toxicity based on research indicating a synergistic relationship between diazinon and the triazine herbicide atrazine (Belden and Lydy, 2000; Anderson and Lydy, 2002). However, the concentrations at which prometryn and simazine were detected in this sample are 40 and 35 times lower, respectively, than the concentrations of atrazine at which synergistic effects were observed in the cited studies. Results of the final TIE conducted through the TMDL Work Plan were inconclusive as toxicity degraded during the Phase I TIE. However, diazinon was measured at 0.213 ug/L, exceeding the 7-day LC_{50} value of 0.11 ug/L.

Based on the available information, diazinon has been identified as contributing to water toxicity in this reach. Water chemistry data indicates the presence of the triazine herbicides prometryn and simazine, although these herbicides were detected at concentrations that were orders of magnitude lower than levels identified as potentiating toxicity in available studies. It has not been demonstrated that potentiation occurs at the relatively low concentrations observed. TIEs do not suggest toxicity is being potentiated by or solely caused by these herbicides.

Table 23. Summary Statistics for Relevant Water Quality Data in Reach 9A

Constituent	n	% Detected	Number Detected	Units	Range of Detection Limits	Mean	Standard Deviation	Median	Maximum Detected Value	% Above Criteria[1,2]
Atrazine	3	0%	0	ug/L	0.005	ND	ND	ND	ND	NC
Prometon	4	0%	0	ug/L	0.005-0.1	ND	ND	ND	ND	NC
Prometryn	1	100%	1	ug/L	0.005	NA	NA	NA	0.235	NC
Simazine	4	75%	3	ug/L	0.005-0.5	0.089	0.128	0.042	0.280	NC
Simetryn	3	0%	0	ug/L	0.005	ND	ND	ND	ND	NC
Chlorpyrifos	15	0%	0	ug/L	0.005-0.05	ND	ND	ND	ND	0%
Diazinon	15	53%	8	ug/L	0.005-0.05	0.089	0.110	0.035	0.354	33%

1 % Above Criteria is calculated using only detected values that exceeded the criteria. These values could be higher because not all samples were tested at detection limits below numeric targets.
2 Criteria used: Chlorpyrifos CDFG chronic (0.014 ug/L) Diazinon: USEPA chronic and acute (0.10 ug/L).
NA Insufficient detected data to develop some summary statistics
NC No criteria for these constituents
ND No detected data

Sediment Toxicity

Studies conducted through two programs (CCCS and TMDL Work Plan) have analyzed sediment samples for toxicity in this reach. A total of six bulk sediment samples have been analyzed for toxicity to *H. azteca*. Mortality to *H. azteca* was observed in three of six samples (50%) and growth toxicity was observed in two of four samples (50%). Three porewater samples have been analyzed for toxicity to *H. azteca* with mortality observed in all three samples. Two porewater samples have been analyzed for toxicity to *C. dubia* with no mortality or reproductive toxicity observed in the samples.

Two Phase I TIEs were conducted in this reach through the TMDL Work Plan. The first TIE was somewhat inconclusive. The results suggested there are possibly multiple compounds causing toxicity which may or may not include metals, organics, and/or ammonia. Total ammonia levels was measured in the porewater at 3.03 mg/L, below 96hr-hr acute LC_{50} values of 14.2-19.8 mg/L total ammonia (Whiteman, 1996 and Ankley et al. 1995). However, ammonia has shown to cause additive toxicity in the presence of other compounds (i.e., metals and OP pesticides [Bailey *et al.*, 2001]).

In the second TIE conducted on porewater, results suggested organics were one cause of toxicity. Furthermore, the addition of PBO increased toxicity suggesting that a compound detoxified through the test species' metabolism was present at sub-lethal levels. Diazinon was measured in the porewater at 1.05 ug/L below the 10-day LC_{50} of 6.5 ug/L for *H. azteca* but was not identified as a toxicant. The triazine herbicide prometryn was also detected at 0.094 ug/L. In this sample, diazinon was measured in the bulk sediment at a detection limit of 0.007 ug/g. A Phase II TIE conducted on this sample was inconclusive.

Based on the available information, it is not clear what constituent(s) are contributing to sediment toxicity in this reach. However, TIE data suggest the constituent(s) are organic in nature.

Table 24. Summary Statistics for Relevant Sediment Quality Data in Reach 9A

Constituent	n	% Detected	Number Detected	Units	Range of Detection Limits	Mean	Standard Deviation	Median	Maximum Detected Value
Ammonia Porewater	1	100%	1	mg/L	0.01	NA	NA	NA	3.03
Diazinon in Porewater	1	100%	1	ug/L	0.001	NA	NA	NA	1.05
Chlorpyrifos in Bulk Sediment	4	0%	0	ug/g	0.001-0.007	ND	ND	ND	ND
Diazinon in Bulk Sediment	4	0%	1	ug/g	0.005	NA	NA	NA	0.007

NA Insufficient data to develop summary statistics
ND No detected data

Reach: Calleguas Creek Reach 9B (Conejo Creek Main Stem)

The Conejo Creek Main Stem is listed on the 2002 303(d) list for water toxicity. In addition, water quality data have indicated the presence of chlorpyrifos and diazinon. Table 25 presents summary statistics for relevant water quality data. The following is a discussion of current conditions as they relate to the presence of water toxicity and chlorpyrifos and diazinon in water.

Water Toxicity

Studies conducted through two programs (UC Davis and TMDL Work Plan) have analyzed water samples for toxicity in this reach. A total of 17 samples have been analyzed for toxicity to *C. dubia* and eight samples have been analyzed for toxicity to *P. promelas*. *C. dubia* mortality was observed in five of 17 samples (29%) and reproductive toxicity was observed in five of 13 samples (38%). Mortality to *P. promelas* was observed in four samples (50%) and growth toxicity was observed in one sample (13%).

A single Phase I and II TIE test was conducted through the UC Davis study. The results of the TIE testing indicated diazinon was a potential cause of toxicity to *C. dubia*. The concentration of diazinon was measured at 0.230 ug/L, which is well above the 7-day LC_{50} for *C. dubia* (0.11 ug/L). Manipulation of pH in three *P. promelas* samples resulted in a reduction of toxicity. Unionized ammonia concentrations in these samples (2.12, 2.77, and 5.23 mg/L) exceed the reported LC_{50} of 0.6-1.0 mg/L. This suggests that ammonia was a cause of mortality of *P. promelas*.

One TIE analysis was attempted in this reach through the TMDL Work Plan. However, toxicity degraded in the sample during the TIE process resulting in an inconclusive TIE.

Based on the available information diazinon and ammonia are identified as contributing to water toxicity in this reach.

Table 25. Summary Statistics for Relevant Water Quality Data in Reach 9B

Constituent	n	% Detected	Number Detected	Units	Range of Detection Limits	Mean	Standard Deviation	Median	Maximum Detected Value	% Above Criteria^{1,2}
Ammonia as N	9	90%	8	ug/L	0.01	0.4	0.8	0.045	2.15	0%
Chlorpyrifos	15	20%	3	ug/L	0.005-0.05	0.011	0.020	0.002	0.06	13%
Diazinon	19	53%	10	ug/L	0.005-0.25	0.064	0.073	0.03	0.23	21%

1 % Above Criteria is calculated using only detected values that exceeded the criteria. These values could be higher because not all samples were tested at detection limits below numeric targets.

2 Criteria used: Chlorpyrifos CDFG chronic (0.014 ug/L) Diazinon: USEPA chronic and acute (0.10 ug/L) Ammonia: CCW Nutrients TMDL chronic (3.36 mg/L)

Reach: Calleguas Creek Reach 10 (Hill Canyon Reach of Conejo Creek)

Hill Canyon is listed on the 2002 303(d) list for water toxicity. Additional studies have indicated the presence of chlorpyrifos and diazinon in water and sediment toxicity to various test organisms in samples collected in this reach (CCCS and TMDL Work Plan). Table 26 presents summary statistics for relevant water quality data. The following is a discussion of current conditions as they relate to the presence of chlorpyrifos and diazinon in water and water and sediment toxicity in this reach.

Water Toxicity

Studies conducted through two programs (CCCS and TMDL Work Plan) have analyzed water samples for toxicity in this reach. A total of 16 samples have been analyzed for toxicity to *C. dubia* and six samples have been analyzed for toxicity to *P. promelas. C. dubia* mortality was observed in four of 16 samples (25%) and reproductive toxicity was observed in seven of 15 samples (47%). Mortality to *P. promelas* was observed in three of six (50%) samples and growth toxicity was observed in one of three samples (33%).

Two Phase I TIEs were conducted in this reach through the CCCS. However, toxicity degraded during the TIE process, making TIE results inconclusive. Based on the available information it is not clear what pollutant(s) are contributing to water toxicity in this reach.

Table 26. Summary Statistics for Relevant Water Quality Data in Reach 10

Constituent	n	% Detected	Number Detected	Units	Range of Detection Limits	Mean	Standard Deviation	Median	Maximum Detected Value	% Above Criteria^{1,2}
Chlorpyrifos	16	0%	0	ug/L	0.005-0.5	ND	ND	ND	ND	0%
Diazinon	16	38%	6	ug/L	0.005-0.5	0.047	0.029	0.029	0.158	19%

1 % Above Criteria is calculated using only detected values that exceeded the criteria. These values could be higher because not all samples were tested at detection limits below numeric targets.

2 Criteria used: Chlorpyrifos CDFG chronic (0.014 ug/L) Diazinon: USEPA chronic and acute (0.10 ug/L).

NA Insufficient detected data to develop some summary statistics

ND No detected data

Sediment Toxicity

Studies conducted through two programs (CCCS and TMDL Work Plan) have analyzed sediment samples for toxicity in this reach. A total of five samples have been analyzed for toxicity to *H. azteca*. Mortality to *H. azteca* was observed in one sample (20%) and no growth toxicity was observed in three samples. Three porewater samples have been analyzed for toxicity to *H. azteca* with no mortality observed. Two porewater samples have been analyzed for toxicity to *C. dubia* with no mortality or reproductive toxicity observed in the samples. Sediment toxicity was observed in this reach during the CCCS with two sampling events occurring in November 1998 and May 1999. However, during the more recent TMDL Work Plan monitoring (August 2003 through April 2004) no toxicity was observed in sediment. No TIEs have been conducted in this reach. Based on the available information it is not clear if there is a sediment toxicity impairment in this reach. This reach is not listed on the 303(d) list for sediment toxicity.

Reach: Calleguas Creek Reach 11 (Arroyo Santa Rosa)

The Arroyo Santa Rosa is listed on the 2002 303(d) list for water toxicity. However, since the closure of the Olsen Road Water Reclamation Plant in 2002 there is no flow in this reach except during wet weather conditions that cause sufficient runoff to generate flow. Only one sample has been collected in this reach after the closure of the Olsen Road Plant. This sample was collected during wet weather conditions in February 2004 through the TMDL Work Plan monitoring. Reproductive toxicity to *C. dubia* was observed in this sample, but mortality was not observed. No TIEs have been conducted in this reach. Based on the available information it is not clear what pollutant(s) contributed to *C. dubia* reproductive toxicity in this reach during the February 2004 storm event.

Reach: Calleguas Creek Reach 12 (North Fork Conejo Creek)

The North Fork of the Conejo Creek is not listed on the 2002 303(d) list for toxicity. Water quality data have indicated the presence of diazinon (Table 27). However, diazinon was not detected above numeric targets in any of the samples and the reach does not seem to be impaired.

Table 27. Summary Statistics for Relevant Water Quality Data in Reach 12

Constituent	n	% Detected	Number Detected	Units	Mean	Range of Detection Limits	Standard Deviation	Median	Maximum Detected Value	% Above Criteria[1]
Chlorpyrifos	6	0%	0	ug/L	NA	0.005	ND	ND	ND	0%
Diazinon	13	23%	3	ug/L	0.008	0.005-0.03	0.011	0.03[2]	0.035	0%

1 Criteria used: Chlorpyrifos CDFG chronic (0.014 ug/L) Diazinon: USEPA chronic and acute (0.10 ug/L). These values could be higher because not all samples were tested at detection limits below numeric targets.
2 Developed using detected data only.
NA Insufficient detected data to develop some summary statistics
ND No detected data

Reach: Calleguas Creek Reach 13 (South Fork Conejo Creek)

The South Fork of the Conejo Creek is listed on the 2002 303(d) list for water toxicity. In addition, water quality data have indicated the presence of diazinon. Table 28 presents summary statistics for relevant water quality data. The following is a discussion of current conditions as they relate to the presence of diazinon in water and water toxicity in this reach.

Water Toxicity

Studies conducted through the TMDL Work Plan have analyzed nine water samples for toxicity to *C. dubia* in this reach. *C. dubia* mortality was observed in one of nine samples (9%) and reproductive toxicity was observed in six of nine samples (55%). No TIEs have been conducted in this reach. Based on the available information it is not clear what pollutant(s) are contributing to water toxicity in this reach.

Table 28. Summary Statistics for Relevant Water Quality Data in Reach 13

Constituent	n	% Detected	Number Detected	Units	Range of Detection Limits	Mean	Standard Deviation	Median	Maximum Detected Value	% Above Criteria[1,2]
Chlorpyrifos	13	0%	0	ug/L	0.005-0.05	ND	ND	ND	ND	0%
Diazinon	20	40%	8	ug/L	0.005-0.05	0.019	0.018	0.013	0.066	0%

1 % Above Criteria is calculated using only detected values that exceeded the criteria. These values could be higher because not all samples were tested at detection limits below numeric targets.
2 Criteria used: Chlorpyrifos CDFG chronic (0.014 ug/L) Diazinon: USEPA chronic and acute (0.10 ug/L).
NA Insufficient detected data to develop some summary statistics
ND No detected data

3.3 *Additive/Synergistic Toxicity*

Studies of chlorpyrifos and diazinon toxicity conducted by Bailey et al. (1997) "suggests that the two pesticides were additive with respect to acute toxicity." The presence of other constituents can also result in toxicity that is additive or synergistic to the toxicity caused by OP pesticides, such as chlorpyrifos and diazinon. Several of the TIEs conducted on toxic sediment samples indicate that ammonia may be causing additive toxicity in the presence of chlorpyrifos and diazinon. This is consistent with results of a study completed by Bailey et al., in 2001. The data collected through this study "suggest that diazinon and ammonia exhibit somewhat less than additive toxicity when present together in solution."

Two constituents are considered to have a synergistic effect when the effect of the combination of the constituents is greater than the sum of the individual effects. Synergistic effects can potentiate toxicity by causing reactions within organisms that accelerate the processes through which a constituent causes toxicity. For example, OP pesticides inhibit the neurotransmitter enzyme acetylcholinesterase (AChE). Inhibition of AChE causes the accumulation of the neurotransmitter enzyme acetylcholine at the nerve endings. This results in excessive transmission of nerve impulses, thereby causing mortality. Recent research has suggested that in the presence of the triazine herbicides atrazine and cyanazine, the biotransformation efficiency of chlorpyrifos and diazinon is increased (Lindstrom and Lydy, 1997; Belden and Lydy, 2000; Anderson and Lydy, 2002; Clark et al., 2002). This results in higher rates of AChE inhibition and increased chlorpyrifos- and diazinon-associated toxicity. The increased chlorpyrifos- and diazinon-associated toxicity is greater than the sum of the individual effects and is therefore considered to be synergistic.

This research is important to consider as the triazine herbicides atrazine, prometryn, and simazine have been detected in toxic samples where chlorpyrifos and diazinon were identified as toxicants. However, the results of these studies are not directly comparable to conditions in the CCW because 1) the concentrations of atrazine at which synergistic effects were observed in these studies are over 500 times higher than what have been observed in waters in the CCW and 2) the majority of the test species used in these studies are different than the standard test species used to measure toxicity in the CCW. The processes associated with atrazine and cyanazine that cause synergistic effects with OP pesticides may occur with other triazine herbicides or may affect some species at the low concentrations observed in CCW samples. This possibility is suggested in the Current Conditions section. However, it is not possible based on the available information to conclude that triazine herbicides are having an affect on the toxicity of chlorpyrifos and diazinon in the CCW.

The aforementioned research suggests that due to the possibility of additive or potentiated toxicity, achievement of chlorpyrifos and/or diazinon numeric targets may not result in complete removal of toxicity associated with these constituents. However, at this time there is no evidence to suggest that conditions in the CCW warrant an adjustment of numeric targets to consider the possibility of additive or synergistic effects. Future monitoring will continue to test samples for the presence of triazine herbicides and when TIEs are conducted, the potential for synergistic effects will be considered.

3.4 *Water Toxicity Summary*

Table 29 presents a summary of acute and chronic toxicity tests and suspected toxicants by reach. Additionally, exceedances of the diazinon and chlorpyrifos water quality criteria are presented. Chlorpyrifos, diazinon, and ammonia have been identified as constituents causing acute toxicity (mortality) in water in various reaches. The triazine herbicides atrazine, prometryn, and simazine have been detected in toxic samples and have the potential to increase toxicity of OP pesticides. However, these herbicides were not observed to increase toxicity or cause toxicity on their own. A single TIE results suggested non-polar organics contributed to toxicity in one sample; however, water quality data for this sample did not identify this suite of constituents at levels known to be acutely toxic to the test species. In addition, unknown toxicity continues to exist as the toxicant(s) causing toxicity have not been identified in all reaches at all times toxicity was observed.

The information provided in the Current Conditions section identified toxicity in water in the following reaches not on the 2002 303(d) list for toxicity: 3, 6, 7, and 9A. Diazinon and/or chlorpyrifos were observed to exceed criteria in the following reaches not on the 303(d) list for these constituents: 2, 3, 6, 8, 9A, 9B, 10, and 11. In addition to the listings presented in the Problem Statement section, this TMDL will address water toxicity, chlorpyrifos and diazinon in these reaches.

Table 29. Water Toxicity Testing Summary for the CCW

Reach	2002 303(d) Listings	# of acute tests	% with acute toxicity	# of chronic tests	% with chronic toxicity	Suspected Toxicant(s) identified through TIEs	Chlorpyrifos above criteria[2]	Diazinon above criteria[2]
2	NL	NT	NT	NT	NT	NT	Y	Y
3	NL	44	20%	36	22%	Inconclusive	Y	Y
4	T, FT	53	45%	42	55%	Chlorpyrifos[1]	Y	Y
5	T, FT	17	29%	14	21%	Chlorpyrifos	Y	Y
6	NL	20	15%	20	45%	Diazinon[1]	Y	Y
7	OP	54	46%	45	58%	Diazinon[1]	Y	Y
8	NL	NT	NT	NT	NT	NT	Y	Y
9A	NL	22	14%	22	41%	Diazinon[1]	N	Y
9B	T	25	36%	21	29%	Diazinon and Ammonia	Y	Y
10	T	22	32%	18	44%	Inconclusive	N	Y
11	T	1	0%	1	100%	No TIEs conducted	ND	ND
12	NL	NT	NT	NT	NT	NT	N	N
13	T	9	11%	9	67%	No TIEs conducted	N	N

T Listed for water column toxicity FT Listed for chlorpyrifos in fish tissue OP Listed for organophosphate pesticides
NL Not listed for water column toxicity, chlorpyrifos in fish tissue, or organophosphate pesticides.
NT Toxicity testing was not conducted in this reach.
ND Not detected in the one sample collected during storm conditions on February 25, 2004.

1 TIE data suggests water toxicity caused by chlorpyrifos or diazinon may be potentiated, but not solely caused, by triazine herbicides.

2 Criteria used: Chlorpyrifos CDFG chronic (0.014 ug/L) Diazinon: USEPA chronic and acute (0.10 ug/L).

A comparison of dry weather and wet weather acute toxicity tests suggests that, although significantly fewer wet weather samples have been collected, occurrences of acute toxicity observed in samples collected during wet weather are more frequent and lead to higher rates of complete mortality (Table 30). Figure 2 displays the number of acute water toxicity tests completed in the CCW by month. This figure suggests that toxicity occurs intermittently in the CCW and more frequently in January and February than in other months of the year.

Table 30. Dry Versus Wet Weather Occurrences of Acute Toxicity in the CCW

	Dry Weather	Wet Weather
Number of Events	56	12
Number of Acute Toxicity Tests	244	23
Number of Tests with Acute Toxicity	71	15
% of Tests with Acute Toxicity	29%	65%
Number of Tests with 100% Mortality	29	12
% with 100% Mortality	41%	80%

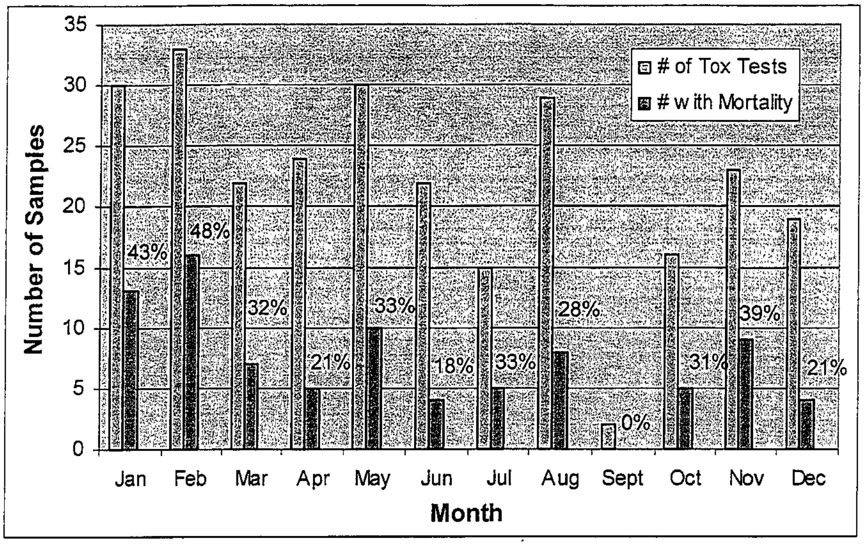

Figure 2. Acute water toxicity by month in all CCW reaches.

3.5 *Sediment Toxicity Summary*

Table 31 presents a summary of acute and chronic toxicity tests and suspected toxicants by reach. Chlorpyrifos and ammonia have been identified as constituents causing acute toxicity (mortality) in sediment in various reaches. The triazine herbicide prometryn has been detected in toxic samples and has the potential to increase toxicity. However, these herbicides were not observed to increase toxicity or cause toxicity on their own. Toxicity of unknown causes continues to be observed in Reach 2 and the toxicant(s) causing toxicity have not been identified. Sediment toxicity observed in Reaches 6, 7, and 10 through the CCCS monitoring program were not confirmed during the TMDL Work Plan monitoring, suggesting that toxicity observed in these reaches is intermittent. The information provided in the Current Conditions section identified toxicity in sediment in the following reaches not on the 2002 303(d) list: 3, 4, and 9A. In addition to the listings presented in the Problem Statement section, this TMDL will address sediment toxicity in these reaches. Figure 3 displays the number of acute sediment toxicity tests completed in the CCW by month.

Table 31. Sediment Toxicity Testing Summary for the CCW

Reach	2002 303(d) Sediment Toxicity Listing	# of acute tests	% with acute toxicity	# of chronic tests	% with chronic toxicity	# porewater tested	% with porewater mortality	Suspected Toxicant(s) identified through TIEs
1	X	74	30%[1]	8	38%	NA	NA	NA
2	X	6	75%	NA	NA	3	33%	Inconclusive
3		6	30%	3	0%	4	75%	Chlorpyrifos and Ammonia[2]
4		6	67%	3	33%	5	60%	Chlorpyrifos and Ammonia[3]
6		5	20%	3	0%	2	0%	Inconclusive[4]
7		5	20%	3	33%	2	0%	Inconclusive[4]
9A		6	50%	3	33%	6	50%	Inconclusive[5]
10		5	20%	3	0%	2	0%	Inconclusive[4]

NA This type of toxicity testing was not conducted in this reach.

1 Not all of the toxicity data available for Reach 1 either indicate the magnitude of mortality and/or the mortality of an environmental sample relative to the control. In an effort to characterize sediment toxicity, where available, toxicity tests with greater than 50% mortality were considered acutely toxic.

2 TIE data suggests sediment toxicity caused by chlorpyrifos may be potentiated, but not solely caused, by the triazine herbicide prometryn and/or ammonia. Additional constituents may contribute to toxicity.

3 TIE data suggests at times sediment toxicity caused by chlorpyrifos may be potentiated, but not solely caused, by the triazine herbicide prometryn and/or ammonia.

4 Based on the available information it is not clear if there is a sediment toxicity impairment in this reach.

5 The potential toxicants contributing to sediment toxicity in this reach were not conclusively identified; however, based on the TIEs; contributing toxicants may include multiple compounds.

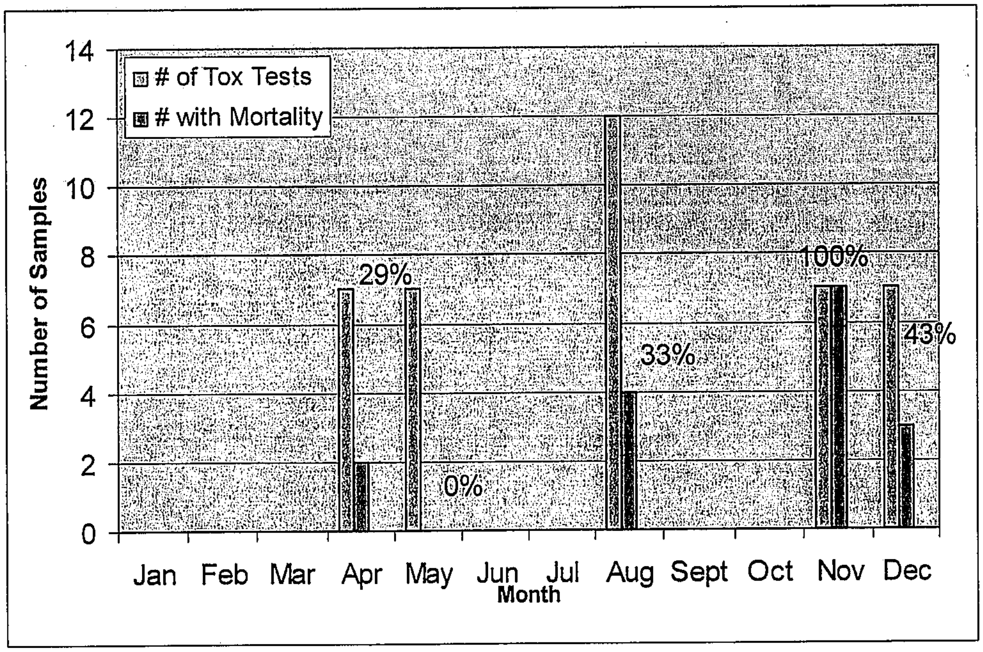

Figure 3. Acute sediment toxicity by month in all CCW reaches.

4 Numeric Targets

To address the constituents identified in the Current Conditions section believed to be contributing to toxicity; this section presents numeric targets for chlorpyrifos and diazinon. In addition, numeric targets for water and sediment toxicity are presented to address current and future occurrences of toxicity of unknown causes. Numeric targets addressing ammonia toxicity in water are presented in the Total Maximum Daily Loads for Nitrogen Compounds and Related Effects: Calleguas Creek, Tributaries, and Mugu Lagoon (LARWQCB, 2002). Although toxicity testing and TIEs have not indicated organochlorine pesticides or PCBs are contributing to toxicity in water or sediment, numeric targets presented in the CCW Organochlorine Pesticides and PCBs TMDL Numeric Targets section will address the potential contribution of toxicity attributable to 303(d) listed organochlorine pesticides and PCBs. The numeric targets for chlorpyrifos, diazinon, and toxicity are values that will result in the protection of beneficial uses. If additional constituents are identified as contributing to water and/or sediment toxicity and these constituents are not appropriately addressed by other TMDLs, numeric targets will need to be developed.

4.1 *Ammonia Targets*

As discussed above, ammonia toxicity in water has been addressed through the Total Maximum Daily Loads for Nitrogen Compounds and Related Effects: Calleguas Creek, Tributaries, and Mugu Lagoon (CCW Nutrients TMDL) (LARWQCB, 2002). The targets presented in the CCW Nutrients TMDL were developed using the revised ammonia objectives set forth in the *Amendment to the Water Quality Control Plan for the Los Angeles Region to Update the Ammonia Objectives for Inland Surface Waters (including enclosed bays, estuaries and wetlands) with Beneficial Use designations for protection of "Aquatic Life" Resolution 2002-011 April 25, 2002.* This amendment revising the ammonia objectives was based on the USEPA's *1999 Update of Ammonia Ambient Water Quality Criteria for Ammonia.* The targets in the CCW Nutrients TMDL will be used to address toxicity associated with ammonia unless additional monitoring determines they are not removing toxicity due to ammonia in the watershed. As discussed in the Current Conditions section, ammonia in sediments may be contributing to toxicity in Reaches 3 and 4. Numeric targets presented in the CCW Nutrients TMDL are assumed to address all toxic effects of ammonia, including toxicity in sediments. If achievement of those numeric targets does not adequately address these toxic effects, additional targets will be developed through future updates of the CCW Nutrients TMDL.

4.2 *Organochlorine Pesticides Targets*

Although toxicity testing and TIEs have not indicated organochlorine pesticides or PCBs are contributing to toxicity in water or sediment, numeric targets presented in the CCW Organochlorine Pesticides and PCBs TMDL Numeric Targets section will address the potential contribution of toxicity attributable to 303(d) listed organochlorine pesticides and PCBs.

4.3 *OP Pesticides (Chlorpyrifos and Diazinon) Targets*

There are no promulgated water quality objectives for chlorpyrifos or diazinon. An analysis of the alternatives available for numeric targets for these constituents have been conducted through this and previous TMDLs (CVRWQCB, 2001, 2003; SFBRWQCB, 2004). The alternatives included:

1. No observable levels of chlorpyrifos or diazinon;
2. Water quality criteria developed using USEPA's 1985 Guidelines for Deriving Numeric National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses;

3. Water quality criteria developed based on single-species toxicity tests;
4. Probabilistic ecological risk assessment (PERA) methodology; and,
5. Microcosm and mesocosm studies.

The analysis performed by this and previous TMDL efforts found water quality criteria developed using USEPA guidance to be the most appropriate. The reasoning for selecting water quality criteria developed using USEPA guidance (Number 2 above) are 1) that they are based on established guidelines and 2) these criteria are inherently protective of aquatic life because they are based on aquatic toxicity testing. As these guidelines currently provide an accepted approach for developing water quality criteria to protect fish and aquatic invertebrates, the chlorpyrifos and diazinon numeric targets presented in this section are based on water quality criteria developed using USEPA guidance.

4.3.1 Chlorpyrifos Targets

Table 32 presents chlorpyrifos water quality criteria developed using USEPA's 1985 guidelines. Water quality criteria were developed by both the USEPA (1986) and the CDFG (2000) using USEPA guidelines. In developing the water quality criteria, the USEPA and the CDFG reviewed acute and chronic toxicity data for at least eight families of aquatic animals as recommended by the USEPA (1985).

Table 32. Existing Chlorpyrifos Water Quality Criteria for the Protection of Aquatic Life

Acute Criteria (1-hour maximum concentration)	Freshwater	Saltwater
	ug/L	ug/L
CDFG[1]	0.025	0.02
USEPA[2]	0.083	0.011
Chronic Criteria (4-day average concentration)		
CDFG[1]	0.014	0.009
USEPA[2]	0.041	0.0056

[1] CDFG, 2000 [2] USEPA, 1986

There is no clear guidance on the appropriateness of selecting the CDFG versus the USEPA criteria for numeric targets. In addition, previously developed TMDLs in other regions of the State provide little reasoning on a methodology for selecting between the two. Consequently, an analysis of the differences between the two criteria was conducted. The CDFG criteria were developed more recently than the USEPA criteria and contain an analysis of a much larger number of studies. More recent studies included a number of tests on sensitive genera, *C. dubia* and *Neomysis*, which were not available when the USEPA criteria were developed. Because the CDFG criteria contain an analysis of a larger range of tests and species and include data from two of the most sensitive genera, the CDFG developed chlorpyrifos criteria were selected as the concentration-based numeric targets.

Numeric Targets for Chlorpyrifos

Freshwater Numeric Targets[1]	
Chronic Criterion: 0.014 ug/L:	The four-day average concentration of chlorpyrifos in freshwater shall not exceed 0.014 ug/L more than once every three years.
Acute Criterion: 0.025 ug/L:	The one-hour average concentration of chlorpyrifos in freshwater shall not exceed 0.025 ug/L more than once every three years.
Saltwater Numeric Targets[2]	
Chronic Criterion: 0.02 ug/L:	The four-day average concentration of chlorpyrifos in saltwater shall not exceed 0.014 ug/L more than once every three years.
Acute Criterion: 0.009 ug/L:	The one-hour average concentration of chlorpyrifos in saltwater shall not exceed 0.025 ug/L more than once every three years.

1 Freshwater targets apply in all reaches of the CCW except for Mugu Lagoon
2 Saltwater targets apply in Mugu Lagoon

Currently there are no criteria or guidelines for use as numeric targets to address chlorpyrifos in fish tissue. Chlorpyrifos in freshwater fish tissue rapidly depurate within several days of removal from exposure (USEPA, 1999). As such, it is assumed that reductions in water column concentrations will result in reductions in levels in fish tissue. In addition, as the chlorpyrifos in fish tissue listings were established to be protective of aquatic life and as the water column numeric targets were also developed to be protective of aquatic life, the water column numeric targets are believed to address the chlorpyrifos in fish tissue listings.

There are no criteria or guidelines for chlorpyrifos in sediment to address associated sediment toxicity. Chlorpyrifos adsorbs strongly to organic matter (log K_{OW} 4.70; mean K_{OC} 6070) (USEPA, 1999) and certain types of fine clay sediments (Summerfelt, 2001). Because of chlorpyrifos' affinity for particles, this TMDL makes the simplifying assumption that attainment of the water column targets for chlorpyrifos will result in attainment of acceptable chlorpyrifos concentrations in suspended and bottom sediments. That assumption is demonstrated explicitly in the linkage analysis.

The SWRCB is currently developing sediment quality guidelines. Therefore, it is premature to set sediment quality targets in this TMDL. The development of chlorpyrifos sediment quality guidelines will be evaluated for inclusion into the CCW Toxicity TMDL. If implementation actions to attain the chlorpyrifos target in water do not eliminate associated sediment toxicity, further action will be investigated.

As described in the Current Conditions section, there may be instances where toxicity associated with chlorpyrifos is increased due to the presence of other constituents such as ammonia, diazinon, or triazine herbicides. However, the studies that suggest the potential for increased toxicity used concentrations of chlorpyrifos at least twice as high as the acute numeric target (Lindstrom and Lydy, 1997; Belden and Lydy, 2000; Bailey *et al.*, in 2001; Anderson and Lydy, 2002; Clark *et al.*, 2002). In addition, at this time there is no evidence to suggest that conditions in the CCW warrant an adjustment of numeric targets to consider the possibility of additive or synergistic effects. If future monitoring determines these numeric targets do not adequately address toxicity associated with chlorpyrifos, the numeric target may need to be revised.

4.3.2 Diazinon Targets

Table 33 presents water quality criteria available for diazinon developed using USEPA's 1985 guidelines. Water quality criteria were developed by both the USEPA (2000) and the CDFG (2000) using USEPA guidelines. In developing the water quality criteria the USEPA and the CDFG reviewed acute and chronic toxicity data for eight families of aquatic animals as recommended by the USEPA (1985).

Table 33. Existing Diazinon Water Quality Criteria for the Protection of Aquatic Life

Acute Criteria (1-hour maximum concentration)	Freshwater ug/L	Saltwater ug/L
CDFG[1]	0.08	NA
USEPA[2]	0.10	0.82
Chronic Criteria (4-day average concentration)		
CDFG[1]	0.05	NA
USEPA[2]	0.10	0.40

[1] CDFG, 2000 [2] USEPA, 2000a

NA – no saltwater acute or chronic criteria were developed by CDFG due to inadequate data.

As discussed above, there is no clear guidance on the appropriateness of selecting between the criteria, and previously developed TMDLs in other regions of the State provide little reasoning on a methodology for selecting between the two. Unlike the chlorpyrifos criteria, both the USEPA and CDFG criteria were developed during a similar time frame (late nineties) so there are fewer differences between the two datasets used for the analysis. However, the USEPA dataset is larger than the one used by the CDFG. Additionally, the two criteria development processes used different analyses to determine which tests were acceptable. For these reasons, a more detailed analysis of the differences between the two criteria was conducted.

The two major influences on the calculation of both the USEPA and CDFG diazinon criteria are the genus mean acute value (GMAV) for the four most sensitive genera and the total number of genera used in the calculations. For both the USEPA and CDFG criteria, the four most sensitive genera are the same (1-*Gammarus*, 2-*Ceriodaphnia*, 3-*Daphnia*, 4-*Simocephalus*). The differences between the two criteria are the values used for *Ceriodaphnia* and *Daphnia*. In the CDFG criteria document, studies on these two genera were conducted by CDFG and used to determine the GMAV. Although the CDFG studies were not included in the USEPA criteria calculations, apparently because they were not available to USEPA, the USEPA's dataset was still larger for the two genera. In addition, the USEPA GMAVs (0.3773 and 0.902) for these two genera are lower than the CDFG GMAVs (0.44 and 1.06). Meaning that if the USEPA had included the additional CDFG studies the USEPA GMAVs would have been higher thereby resulting in higher criteria. Therefore, the USEPA are based on more conservative GMAVs for the most sensitive genera used to determine the criteria. Additionally, the USEPA criteria calculations use 20 genera as compared to the 15 genera used by the CDFG. This difference in the number of genera appears to be the major difference between the two criteria. If the USEPA criteria are recalculated using only 15 genera, the resulting criteria is almost identical to the CDFG (0.075 µg/L vs. 0.08 µg/L). Conversely, if the CDFG criteria are recalculated using 20 genera, the resulting criteria are identical to the USEPA values. Since the USEPA guidelines (1985) state that all available data should be collected and questionable data should not be used in the development of water quality criteria, the larger USEPA dataset should be used in calculating the criteria. Because the USEPA criteria are based on the larger dataset and the more conservative values for the most sensitive genera, the USEPA-developed diazinon criteria will be the concentration-based numeric targets.[1]

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[1] In a letter dated May 19, 2004, from the US Geological Survey (USGS), Columbia Environmental Research Center to Dr. Lenwood Hall at the University of Maryland, Chris Ingersoll (USGS) documents that two studies presenting data on *Gammarus*

Numeric Targets for Diazinon

Freshwater Numeric Targets[1]	
Chronic Criterion: 0.10 ug/L:	The four-day average concentration of diazinon in freshwater shall not exceed 0.10 ug/L more than once every three years.
Acute Criterion: 0.10 ug/L:	The one-hour average concentration of diazinon in freshwater shall not exceed 0.10 ug/L more than once every three years.
Saltwater Numeric Targets[2]	
Chronic Criterion: 0.40 ug/L:	The four-day average concentration of diazinon in saltwater shall not exceed 0.40 ug/L more than once every three years.
Acute Criterion: 0.82 ug/L:	The one-hour average concentration of diazinon in saltwater shall not exceed 0.82 ug/L more than once every three years.

1 Freshwater targets apply in all reaches of the CCW except for Mugu Lagoon
2 Saltwater targets apply in Mugu Lagoon

Diazinon was not identified as causing or contributing to sediment toxicity in the CCW. Diazinon binds only moderately to soil and sediment (K_{OW} 2000 and K_{OC} ~1000-1800) (Ogle, 2004). The SWRCB is currently developing sediment quality guidelines. The development of diazinon sediment quality guidelines will be evaluated for inclusion into the Toxicity TMDL.

As described in the Current Conditions section, there may be instances where toxicity associated with diazinon is increased due to the presence of other constituents such as ammonia, chlorpyrifos, or triazine herbicides. However, the studies that suggest the potential for increased toxicity used concentrations of diazinon at least twice as high as the numeric target (Lindstrom and Lydy, 1997; Belden and Lydy, 2000; Bailey *et al.*, in 2001; Anderson and Lydy, 2002). In addition, at this time there is no evidence to suggest that conditions in the CCW warrant an adjustment of numeric targets to consider the possibility of additive or synergistic effects. If future monitoring determines these numeric targets do not adequately address toxicity associated with diazinon, the numeric target may need to be revised.

4.4 *Water Toxicity Target*

To protect the aquatic life beneficial use in the CCW and meet the Basin Plan narrative toxicity objective, causes of toxicity observed in ambient water in the watershed must be identified when possible. The Basin Plan narrative toxicity objective does not allow acute toxicity in any receiving waters or chronic toxicity outside designated mixing zones and states that limits for specific toxicants can be established to control toxicity identified under Toxicity Identification Evaluations (TIEs). The targets for the constituents listed above are designed to address toxicity that has been identified in the watershed to date. However, toxicity

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fasciatus [Johnson and Finley (1980) and Mayer and Ellersieck (1986)] reported the 96-h LC_{50} of 0.2 ug/l. The 96-h LC_{50} of 0.2 ug/l presented in these two studies were used to develop both the USEPA and CDFG water quality criteria. However, a recent review of the original data sheets from tests conducted on March 18, 1966 by the USGS found what appears to be an error and that the 96-h LC_{50} should have been reported as 2.0 ug/l. Because of this apparent error, both the USEPA and CDFG diazinon criteria are questionable. The Central Valley Regional Board considers the use of revised CDFG diazinon criteria, which do not use the questionable data, in the Peer Review Draft Staff Report for the San Joaquin River OP Pesticide TMDL (2005). The USEPA diazinon criteria may be revised after incorporating comments and additional data submitted by March 30, 2004 as part of the criteria development process. It is anticipated the information regarding the apparent error as well as additional acute and chronic toxicity data (including studies in the CDFG's criteria document) may be considered and may result in a revision to the EPA diazinon water quality criteria. As a result, any revisions to the diazinon water quality criteria can be considered by the Regional Board during the implementation period of the CCW Toxicity TMDL.

of unknown causes may still occur in the future. To meet the narrative toxicity objective, a numeric toxicity target of 1 chronic toxicity unit (1 TUc) is established. A chronic toxicity target was selected because it addresses the potential adverse effects of long term exposure to lower concentrations of a pollutant and is therefore more protective than an acute toxicity target that may not address potential effects of longer term exposures. Equation 1 describes the calculation of a TUc.

Equation 1 TU_c = Toxicity Unit Chronic = 100/NOEC (no observable effects concentration).

The NOEC (no observable effects concentration) is defined in the USEPA's Technical Support Document (TSD) as "the highest concentration of toxicant, in terms of percent effluent, to which the test organisms are exposed, that causes no observable adverse effect" (USEPA, 1991). To calculate the TUc: TUc = 100% ÷ the sample concentration, derived using hypothesis testing, to cause no observable effect, with the sample concentration expressed as a percentage. For example, if a chronic test is conducted using a dilution series (a series of original samples diluted to various concentrations) of 100%, 50%, 25%, 12.5%, and 6.25% and the lowest observed effect concentration (LOEC = lowest concentration of toxicant to which the test organisms are exposed that causes an observed effect derived using hypothesis testing) is 25% then the NOEC is estimated to be 12.5% using hypothesis testing. Therefore, the TUc would equal 100/12.5 = 8 toxic units.

4.4.1 Alternatives Considered for Water Toxicity Target

Two alternatives were considered in developing the toxicity numeric target. These alternatives were 1) calculating the TUc using a statistically derived "no observable effects concentration" (NOEC) using hypothesis testing and 2) calculating the TUc using a point estimate such as an inhibition concentration (IC). The second alternative (IC25) is recommended by USEPA's TSD (1991) for several reasons including:

- The IC_{25} value represents a point estimate that interpolates effects from actual sample concentrations at which measured effects occur during a chronic test;
- The IC_{25} is not dependent upon the selection of the concentrations of the samples tested; and,
- A coefficient of variation can be calculated for ICs as they are point estimates as opposed to a statistically derived NOEC using hypothesis testing for which no estimates of precision can be calculated.

However, alternative one was the selected alternative as it is consistent with current Los Angeles Regional Board and USEPA NPDES permitting practice. If the Regional Board revises NPDES permits to calculate a TUc using inhibition concentrations (ICs) or other point estimate methodology, the Regional Board may reconsider the water toxicity numeric target.

4.5 *Sediment Toxicity Target*

To protect the aquatic life beneficial use in the CCW and meet the Basin Plan narrative toxicity objective, causes of toxicity observed in sediment in the watershed must be identified when possible. The Basin Plan narrative toxicity objective states that limits for specific toxicants can be established to control specific pollutants identified as causes of toxicity. The targets for the constituents listed above are assumed to address toxicity that has been identified in the watershed to date. However, toxicity of unknown causes may still occur in the future, and a numeric sediment toxicity target is established to allow objective evaluation of the narrative toxicity objective. Because sediment toxicity tests do not provide point estimates (e.g. IC25 or LC50), sediment toxicity targets can not be expressed as a specific toxicity unit (TU) threshold value as recommended for aquatic toxicity. Therefore, the proposed sediment toxicity target is set at no observable sediment toxicity with sediment samples defined as toxic if the following two criteria are met: 1) there is a significant difference ($p<0.05$) in mean organism response (e.g., percent survival) between a sample and the control as determined using a separate-variance t-test, and 2) the mean organism response in the toxicity test (expressed as a percent of the laboratory control) was less than the threshold based on the 90th percentile Minimum Significant Difference (MSD) value expressed as a percent of the control value.

For the purpose of setting a consistent and objective target for sediment toxicity, the proposed approach is based on the September 2004 *Water Quality Control Policy For Developing California's Clean Water Act Section 303(d) List* (SWRCB, 2004c). The guidance allows for a selection between either of the two criteria listed above to define a sediment sample as toxic. This TMDL implements this guidance in a manner similar to the BPTCP (SWQCB, 1998) and work completed for the San Francisco Estuary Institute (Thompson *et al.*, 1997) by using both criteria. A determination of statistical significance is a necessary and standard requirement for any toxicity test. However, statistical significance is dependent on the variability of test replicates for each test as well as the magnitude of the difference between the sample and the control. As a result, the magnitude of toxic effect considered "significant" varies for each individual test and in cases where replicate variability is low, very small differences from controls can be statistically significant, even when they may not be biologically or ecologically relevant. The primary purpose of the second tier MSD criterion for toxicity is to provide a less variable toxicity target. While the MSD is still a function of the statistical characteristics of a specific test protocol, it has the advantage of providing a more consistent target that has a greater likelihood of being biologically and ecologically relevant.

The 90th percentile MSD value is specific for each specific toxicity test protocol and is determined by identifying the magnitude of difference that can be detected 90% of the time by a specific test method (Schimmel *et al.*, 1994; Thursby and Schlekat, 1993). This is equivalent to setting the level of statistical power at 0.90 for these comparisons. Determining the MSD for the toxicity target is accomplished by determining the MSD for each individual t-test conducted, and identifying or estimating the upper 90th percentile MSD (the MSD that is larger than or equal to 90% of the MSD values generated). The 90th percentile MSD values developed by the BPTCP (SWQCB, 1998) range from as low as 10% to as high as 45%, which translates to minimum detectable percent differences from controls of 90% to 55% Table 34. If there are sufficient toxicity test results available for the CCW, the MSD used for the toxicity target can be derived from these data. Otherwise, most of the BPTCP MSD values are based on a large number of individual tests and provide a reasonable benchmark for the toxicity target MSDs for individual test methods.

The following is a description of MSDs and how a toxic effect would be identified (SWRCB, 1996):

> "In toxicity tests, the MSD represents the smallest difference between the control mean and a treatment mean (the effect size) that leads to the statistical rejection of the null hypothesis (H_0: no difference). Any effect size equal to or larger than the MSD would result in a finding of statistically significant difference. For example, if the control mean for mysid growth were 80 ug/mysid and the MSD were 20, any treatment with mean mysid weight less than or equal to 60 ug would be significantly different from the control and considered toxic."

Table 34. Range of MSD Values as Reported in *Sediment Chemistry, Toxicity, and Benthic Community Conditions in Selected Water Bodies of the Load Angeles Region* (SWRQCB, 1998)

Species	Name	MSD	% of Control	N
Ee	Eohaustorius	25	75	385
Hr	Haliotis (5 reps)	10	90	131
Hr	Haliotis (3 reps)	36	64	336
Hr	Haliotis (all reps)	32	68	467
Me	Mytilus	20	80	223
Na Sv	NEanthes Sv	36	64	335
Na Wt	NEathes Wt	56	44	335
Ra	Rhepoxynius	23	77	720
Sp Dev	Urchin Dev (5 reps)	22	78	309
Sp Dev	Urchin Dev (3 reps)	45	55	630
Sp Dev	Urchin Dev (all)	40	60	939
Sp Fert	Urchin Fert	12	88	79
Sp SWI	Urchin SWI	41	59	109

The State Board is currently developing sediment quality guidelines. The development of relevant sediment quality guidelines as they relate to the definition of sediment toxicity will be incorporated into the CCW Toxicity TMDL, if appropriate.

5 Source Analysis

The Source Analysis section includes a discussion of the potential sources of chlorpyrifos and diazinon as these two OP pesticides have been identified as causing water and/or sediment toxicity in the CCW. Potential contributions to toxicity from ammonia are addressed by the CCW Nutrients TMDL. Although toxicity testing and TIEs have not indicated organochlorine pesticides or PCBs as contributing to toxicity in water or sediment, a source analysis of 303(d) listed organochlorine pesticides and PCBs is presented in the CCW Organochlorine Pesticides and PCBs TMDL.

As presented in the Current Conditions section, the cause(s) of unknown toxicity in listed reaches have not been fully identified. Based on toxicity investigations the constituents causing unknown toxicity are likely organic in nature and possibly pesticides. These pesticides could include other OP pesticides, replacement pesticides for OP pesticides (i.e. pyrethroids), or some other yet to be identified pesticide that is in itself toxic or potentiates toxicity. Monitoring, as outlined in the Implementation Plan section, will continue to investigate toxicity of unknown causes. If additional constituents are identified as contributing to water and/or sediment toxicity and these constituents are not appropriately addressed by other TMDLs, a source analysis will be conducted.

5.1 *Data Resources*

Several data resources were used to identify and quantify potential sources of diazinon and chlorpyrifos to the various reaches in the CCW. The primary data resources used for this analysis include pesticide use and sales data from the California Department of Pesticide Regulation (DPR) and water quality data from a variety of monitoring programs.

5.1.1 Use of Environmental Data in Source Analysis Section

Water quality data that can be correlated to land use have been gathered through a variety of monitoring programs and incorporated in the CCW Database (LWA, 2004a). Table 35 presents a summary of the available water quality data used to investigate contributions of chlorpyrifos and diazinon to water from various land uses.

Table 35. Summary Table of Land Use Discharge Data Sources Used in Source Analysis for Chlorpyrifos and Diazinon

Data Source[1]	Begin Date	End Date	Urban Land Use Sites	Agricultural Land Use Sites	Groundwater Sites	POTW
205(j) Non Point Source Study (LWA, 2004a)	11/98	5/99	X	X		
Calleguas Creek Characterization Study – CCCS (LWA, 2000)	8/98	5/99	X	X	X	X
CCW TMDL Work Plan Monitoring Plans	8/03	8/04	X			
Camarillo WRP (LWA, 2000)[2]	8/98	5/99				X
Hill Canyon WWTP (LWA, 2000)[2]	8/98	5/99				X
Moorpark WWTP (LWA, 2000)[2]	9/97	11/98				X
Olsen Road WRP (LWA, 2000)[2]	8/98	5/99				X
Simi Valley WQCP (LWA, 2000)[2]	8/98	5/99				X
Ventura County Watershed Protection District – VCWPD (VCWPD 1998-2004)	3/94	2/04	X	X		

1 Complete references for these studies are provided in the References section of this report when available.

2 The only available chlorpyrifos and diazinon data characterizing POTW effluent were collected one year period, primarily through the CCCS.

5.1.2 Development of Summary Statistics

As discussed in the Current Conditions section, a large proportion of data used to develop the summary statistics for this TMDL are non-detected data. The ROS method was selected to deal with the inherent uncertainty in characterizing the true range of conditions in instances where a large portion of the data are non-detected. For a more detailed discussion of the ROS method, please see the Development of Summary Statistics section presented in the Current Conditions section. As mentioned previously in the Current Conditions section, because of limited available data, grab and composite samples are treated in the analysis as equivalent and equally representative of the sampled water, also estimated and qualified data are used as normal detected values.

5.1.2.1 Environmental Data Used

The available land use data compiled in the CCW Database (LWA, 2004a) were used to develop the source analysis summary statistics. The bulk of the data cited in Table 35 were used in this analysis. A large proportion of data used are non-detected data. However, the ROS method has defined data requirements for developing summary statistics. Due to the number of non-detected values at relatively high detection limits the ability to develop summary statistics was limited. To develop summary statistics to characterize water quality in each reach non-detected samples were removed when detection limits were higher than concentrations considered characteristic of individual land use sites based on detected values. Table 36 presents the number of samples removed by land use site as well as the range of detection limits removed.

Table 36. Number of Non-Detect Values Removed Due to High Detection Limits from Land Use Sampling Sites

Sample Station Type	Number of Non-Detect Samples Removed due to High Detection Limits		Range of Removed DLs (ug/L)	
	Diazinon	**Chlorpyrifos**	**Diazinon**	**Chlorpyrifos**
Effluent Discharge	1	0	2	
Commercial Runoff	1	1	50	100
Industrial Runoff	2	2	50	100
Residential Runoff	2	2	50	100
Agricultural Runoff	10	1	2	2
Total Number Removed	**16**	**6**		

5.1.3 Pesticide Use Data

Pesticide Use Report (PUR) data from DPR provide detailed information about pesticide application rates according to crop types for each county in the state. Prior to 1990, limited use reporting requirements existed. In 1990, California began requiring full use reporting for all agricultural pesticide use and commercial pest control applications. These data are reasonably comprehensive and accurate for agricultural, restricted, and commercial applications. As outlined in the *Summary of Pesticide Use Report Data – 2002*, the following pesticide uses are considered "reported uses" requiring applicators to submit detailed use reports to the County Agricultural Commissioner:

- For the production of any agricultural commodity, except livestock;
- For the treatment of post-harvest agricultural commodities;
- For landscape maintenance in parks, golf courses, and cemeteries;
- For roadside and railroad rights-of-way;
- For poultry and fish production;
- Any application of a restricted material;
- Any application of a pesticide with the potential to pollute ground water (listed in section 6800(b) of the California Code of Regulations, Title 3, Division 6, Chapter 4, Subchapter 1, Article 1) when used outdoors in industrial and institutional settings; and,
- Any application by a licensed pest control operator.

Exclusions from reporting requirements include industrial, institutional, and residential landscape and garden pesticide uses. These uses are collectively referred to as "unreported uses". Published PUR data contain extensive information about the quantities and types of pesticides used in each county, as well as information about the acreage and types of crops treated. These data are collected by county agriculture commissioners in most counties and then passed along to DPR for QA/QC and database management. Analysis of PUR data in this document examines the years 1998-2003.

5.1.4 Pesticide Sales Data

Pesticide registrants, pest control dealers and pesticide brokers are mandated to report the total dollar value and total pounds or gallons of each product they sell for use in California. The active ingredient in any pesticide product is the chemical or chemicals that kill or otherwise controls target pests. Regulations require that when there are three or fewer registrants reporting sales of a pesticide product containing the same active ingredient, such reports are considered trade secrets and cannot be disclosed by DPR. Sales data do provide a cumulative sales total for all active ingredients, disclosed and undisclosed, including: insecticides, miticides, fumigants, nematicides, rodenticides, desiccants, defoliants, growth regulators, herbicides, bactericides, antimicrobials, algicides, and fungicides. Also included in the total are chemical adjuvants, which are considered pesticides under California law; these include emulsifiers, spreaders, water modifiers, and other chemicals added to pesticides to enhance their effectiveness. Pesticides sales data are not categorized by county or city; rather, the sales data are only available for the State as a whole.

5.2 *Land Use*

There are about 344 square miles in the CCW, approximately 51% of which is utilized by some form of human activity (DWR, 2000). About half of these utilized lands are urban or urban landscape, and about half are used for agriculture (Figure 4). The non-utilized land is comprised of native vegetation (96%), as well as waterbodies and barren or idle lands. The category 'urban landscape' includes cemeteries, golf courses, and other urban lawn areas. Agricultural lands primarily yield truck crops and citrus. Lemons, avocados, strawberries, green beans, celery, and onions are the most common crops. The term "truck crop" describes vegetables grown in furrows that go straight to market when harvested (e.g. green beans, peppers, celery, tomatoes), and the term "field crop" indicates crops such as cotton, flax, hops, and sugar beets that do not necessarily go straight to market. A detailed list of all land use types existing in the watershed by subcategory and acreage is found in Appendix II. In recent decades the CCW has experienced dramatic growth in urban residential and commercial development, but historically a much larger percentage of land was used for farming.

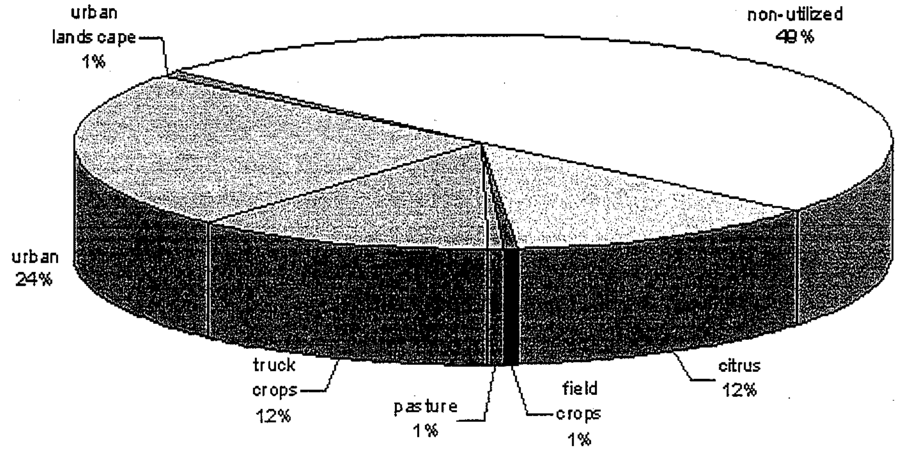


Figure 4. Land use in CCW (Department of Water Resources, 2000 land use layer).

5.2.1 Urban Land Use

About two thirds of the urban lands within the watershed are residential, situated mostly in the central to upper portions of the watershed (Table 37, Figure 6). Less than three percent of all land in the watershed is dedicated to industrial and commercial purposes combined.

Table 37. Breakdown of Urban Land Use in CCW (SCAG, 2000 land use layer)

Urban Land Uses	Acres[1]	% of Urban Land Use	% of Watershed Area
Residential	28,898	68%	13%
Transportation & Utilities	5,003	12%	2%
Public Facilities & Institutions	4,063	10%	2%
Industrial	2,403	6%	1%
Commercial	2,399	6%	1%

1 The SCAG land use classification system is not identical to that of California Department of Water Resources, which is used for all other land use analysis in this document.

5.2.2 Agricultural Land Use

Current agricultural land uses vary spatially according to such factors as proximity to the coast, altitude, slope, and soil type. Figure 7 shows specific crop types grown in the area, according to subcategory. Citrus crops such as lemons, oranges, and avocados (considered citrus crops in land use maps) commonly occur in flat or gently sloping foothill areas that are slightly inland. Avocado orchards tend to be located upslope of lemon groves and oranges are usually grown further inland than lemons. Floodplain areas are currently predominated by a wide range of truck crops such as strawberries, peppers, green beans, celery, onions, garlic, lettuce, melons, and squash; as well as turf farms and various types of nurseries. The uppermost portions of the watershed are not cultivated extensively.

Agricultural activities in the watershed are somewhat challenging to characterize at a fine scale due to several factors. Although some changes in crop composition occur slowly over many years (such as conversion of field crops to truck crops and the disappearance of walnut groves, both during the period 1932-1969), there are also constant changes in crop selection from year to year as farmers adjust to fluctuating market prices or strive to preserve soil by rotating their crops/fields. Additionally, many fields are used to grow successive crops during a single calendar year. This multi-cropping technique is most common in the lower parts of the watershed, adjacent to Revolon Slough and Lower Calleguas Creek. Fields that are multi-cropped do not always follow a time interval that begins and ends within the course of a calendar year. For example, it is common to grow three crops of strawberries in a two year period with some other crop such as barley following the first two strawberry harvests. Growers of turf often plant celery, cabbage or cauliflower in rotation with turf crops to reduce the negative effects upon soil that occur when turf is harvested (personal communication, McIntyre). Agricultural activity within the Oxnard Plain is spatially heterogeneous with highly variable multi-cropping activity.

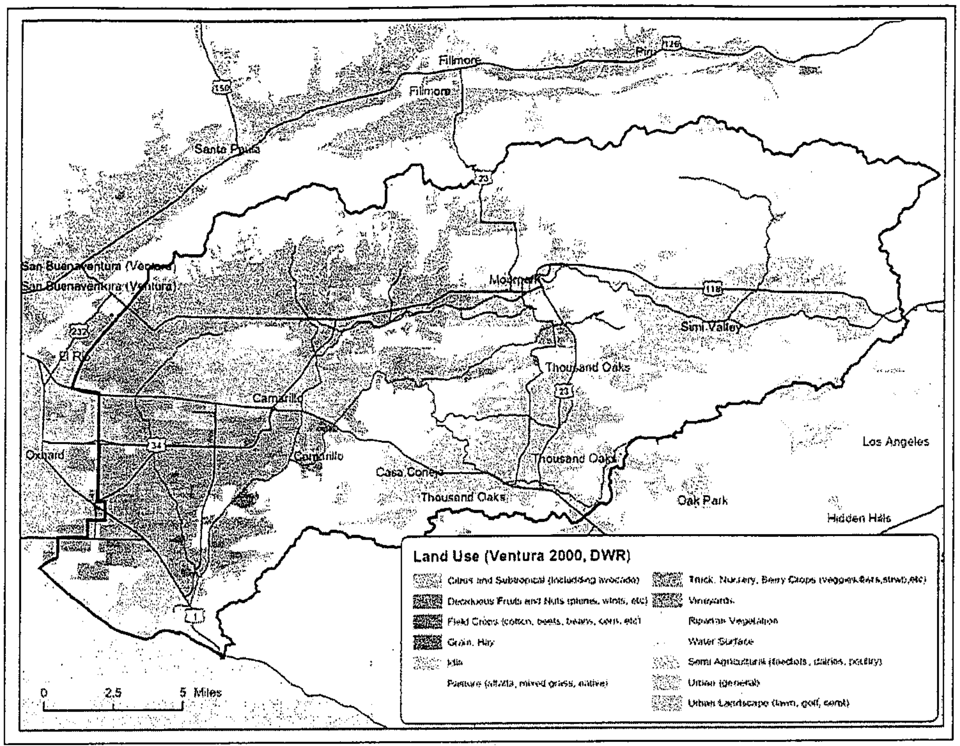


Figure 5. Land use in the CCW, 2000 (California Department of Water Resources).

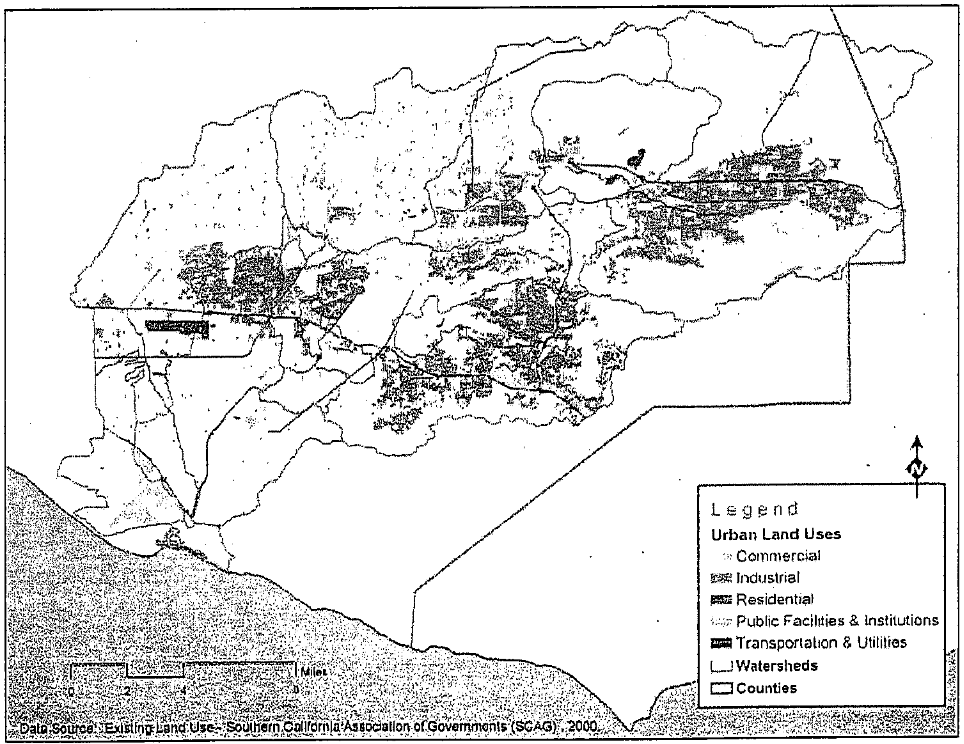


Figure 6. Urban land uses in the CCW (SCAG 2000).

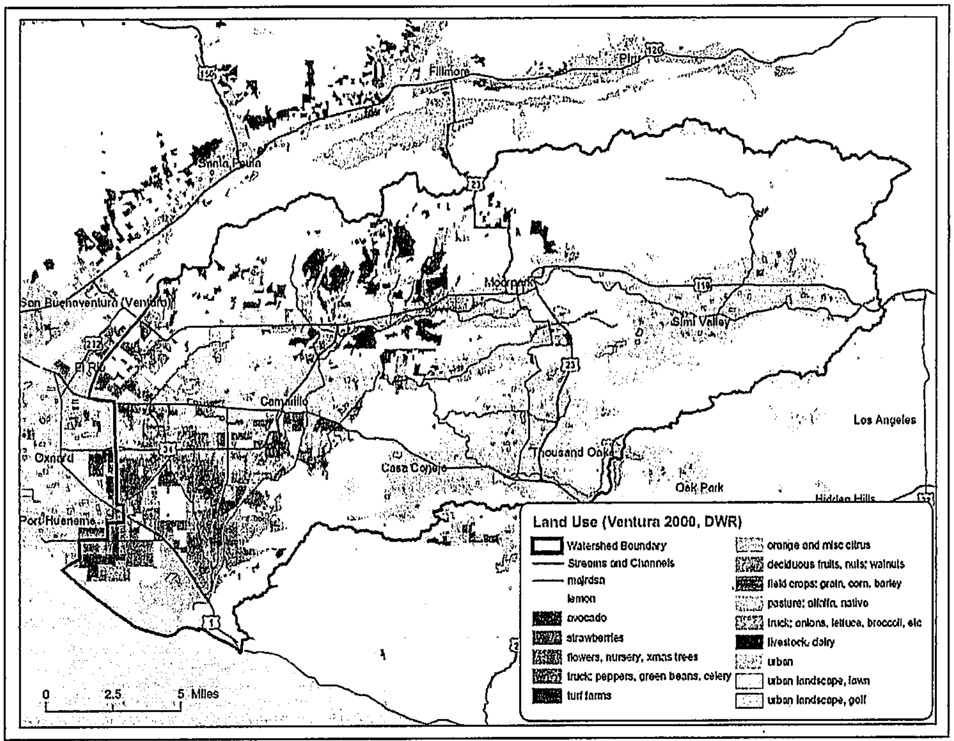


Figure 7. Land use in the CCW by specific crop, 2000 (California Department of Water Resources).

5.3 *Sources of Diazinon and Chlorpyrifos to Calleguas Creek Watershed*

Potential sources of diazinon and chlorpyrifos to waterways in the CCW include urban and agricultural discharges, POTWs, groundwater, atmospheric deposition, imported water, and native space runoff. Each of these potential sources is addressed in the following section.

5.3.1 Diazinon and Chlorpyrifos Use in Calleguas Creek Watershed

Diazinon and chlorpyrifos use in the CCW were analyzed using DPR's PURs for 1998 through 2003. PURs were used to estimate the total reported pounds of these pesticides applied in the CCW over this period, the uses of these pesticides, and temporal and spatial trends.

5.3.2 Phase Out of Uses

In June of 2000 and January of 2001, separate *Revised Risk Assessment and Agreement with Registrants* documents (USEPA, 2000b, 2001a) were released by the USEPA for chlorpyrifos and diazinon, respectively. These agreements, between the registrants/manufacturers and the USEPA, resulted in the modification of uses of these pesticides. To reduce residential risks of exposure from diazinon, retailers stopped sales of products registered for indoor use in December of 2002. In addition, sales to retailers of outdoor non-agricultural use products were completely phased out during 2003 with registrants buying back existing products commencing December 31, 2004. To reduce residential risks of exposure from chlorpyrifos, the agreement resulted in the classification of new end-use products and cancellation of some pre- and post-construction uses, home and lawn, and most other outdoor uses. To reduce non-residential risks of exposure from chlorpyrifos, uses in areas where children could be exposed were cancelled. The modifications to non-agricultural uses will likely result in removing all of the unreported uses of diazinon in 2004 and unreported uses of chlorpyrifos in 2005.

In addition, 30% of 2001 agricultural uses of diazinon were to be cancelled based on the agreement. Agricultural uses of chlorpyrifos were modified to reduce and/or cancel applications to apples, tomatoes, and grapes. Table 38 summarizes the provisions of the diazinon and chlorpyrifos revised risk assessments.

Additional use modifications for chlorpyrifos have been approved by the USEPA, but not yet approved by DPR. These modifications will change application practices for growers and will likely take effect before this TMDL implementation is completed. The label changes include buffer zones for the various application methods, limits on the total applications per year and the pounds per application. Use modifications for diazinon are currently under negotiations between the manufacturer and the USEPA. As the uses of diazinon and chlorpyrifos continue to change, the potential impacts on this TMDL will be addressed through actions in the Implementation Plan.

Table 38. Summary of Provisions of Diazinon and Chlorpyrifos Revised Risk Assessments (USEPA 2000, 2001a)

Use	Restriction
Chlorpyrifos	
Home and Non-Residential Use Restrictions	
Home lawn and most other outdoor uses; crack and crevice and most other indoor uses; full barrier (whole house) post-construction use as termiticide; indoor areas where children could be exposed (such as schools); outdoor areas where children could be exposed (such as parks).	**December 1, 2000:** Stop formulation **February 1, 2001:** Formulators stop sale **December 31, 2001:** Retailers stop sale
Spot and local post-construction use as a termiticide.	**December 1, 2000:** Stop formulation unless label has stop use date of December 31, 2002
Pre-construction use as a termiticide.	December 31, 2004: Stop production December 31, 2005: Stop use
Non-Agricultural Uses	
Indoor areas where children will not be exposed and outdoor areas where children will not be exposed including (golf courses, road medians, industrial plant sites, non-structural wood treatments, and public health uses for fire ant mounds and mosquito control).	**December 1, 2000:** New end-use product labels must reflect only these uses
Agricultural Uses	
Apples	**August – September, 2000:** Production of chlorpyrifos products labeled for post-bloom application is prohibited (only production for pre-bloom, dormant application is allowed) **December 31, 2000:** Post-bloom use is prohibited and tolerance will be lowered
Tomatoes	**August - September 2000:** Production of products for tomato use is prohibited **December 31, 2000:** Stop use, use will be canceled and tolerances will be revoked
Grapes	Tolerances will be revoked
All Agricultural Uses	**December 1, 2000:** Classify new end-use products for restricted use or package in large containers. New end-use products must bear revised Restricted Entry Intervals (REIs)
Diazinon	
Home Uses	
All indoor uses	**February 2001:** Cancellations effective after 30 day public comment period **March 1, 2001:** Manufacturing use products may no longer be used to formulate end use products for indoor uses. **December 31, 2002:** Retailers stop sales
Outdoor Non-Agricultural Uses	**2003:** Production phase down of 50% **June 30, 2003:** Stop formulation **August 31, 2003:** Retailers stop sales **December 31, 2004:** Commence buy back from retailers and expiration of product registrations
Agricultural Uses	
Alfalfa, Bananas, Beans (dried), Bermudagrass, Celery, Red Chicory (radicchio), Citrus, Clover, Coffee, Cotton, Cowpeas, Cucumbers, Dandelions, Kiwi, Lespedeza, Parsley, Parsnips, Pastures, Peppers, Irish Potatoes, Sweet Potatoes, Rangeland, Sheep, Sorghum, Spinach, Squash (summer and winter), Strawberries, Swiss chard, Tobacco, Tomatoes, Turnips	**January 10, 2001:** Proposed deletion of uses **February 2001:** Proposed cancellations may become effective after 30-day comment period.

5.3.3 Agricultural Use

Between 1998 and 2003, over 36,000 pounds of diazinon and 212,000 pounds of chlorpyrifos were reported to have been used for agricultural purposes in the CCW on a variety of crops (Table 39 and Table 40). Figure 8 and Figure 9 present total pounds of diazinon and chlorpyrifos applied in the CCW from 1998 through 2003 as well as reported monthly use. As indicated in Figure 8, the total annual use of diazinon has steadily declined between 1998 and 2003 (47 percent). Decreases in diazinon use between 2000 and 2003 average 9 percent per year and could be attributed to the phase-out of uses. The total amount of chlorpyrifos used in agriculture has remained relatively stable between 1998 and 2003 (Figure 9). The majority of diazinon applications occur in the spring between April and May, historically averaging 66 percent of total applications for the year. The majority of chlorpyrifos applications occur in the late summer to fall between August and November, historically averaging 79 percent of total applications for the year. Figure 10 and Figure 11 present spatial representations of agricultural use of diazinon and chlorpyrifos in the CCW, respectively.

Table 39. Diazinon - Top 15 Crops by Pounds Active Ingredient Applied from 1998 – 2003 (DPR)

Rank	Crop	Pounds of Active Ingredient (AI) Applied	% of Total[1]
1	Beans	17,489.2	45.5%
2	Onion	6,706.5	17.4%
3	Corn	2,209.4	5.7%
4	Lettuce	1,806.0	4.7%
5	Spinach	1,020.9	2.7%
6	Raspberry	1,007.4	2.6%
7	Cabbage	966.0	2.5%
8	Parsley	875.6	2.3%
9	N-Outdr Plants In Containers	844.6	2.2%
10	N-Grnhs Flower	835.9	2.2%
11	Cucumber	734.8	1.9%
12	N-Outdr Flower	623.5	1.6%
13	Broccoli	532.6	1.4%
14	Radish	503.8	1.3%
15	Squash	482.6	1.3%
	Total	36,639	95.3%

Table 40. Chlorpyrifos - Top 15 Crops by Pounds Active Ingredient Applied from 1998 – 2003 (DPR)

Rank	Crop	Pounds of Active Ingredient (AI) Applied	% of Total[1]
1	Lemon	167,957.3	78.6%
2	Strawberry	14,019.6	6.6%
3	Broccoli	11,928.6	5.6%
4	Corn	6,237.5	2.9%
5	Cabbage	4,007.6	1.9%
6	Orange	2,975.0	1.4%
7	Radish	1,580.4	0.7%
8	Chinese Cabbage (Nappa)	867.6	0.4%
9	Onion, Dry	837.9	0.4%
10	N-Outdr Flower	631.2	0.3%
11	N-Outdr Plants In Containers	466.0	0.2%
12	Bean	444.2	0.2%
13	Collards	331.2	0.2%
14	Cauliflower	279.0	0.1%
15	Bok Choy	233.1	0.1%
	Total	212,796	99.6%

1 Use of diazinon and chlorpyrifos on top 15 crops do not equal 100% of use for agricultural purposes

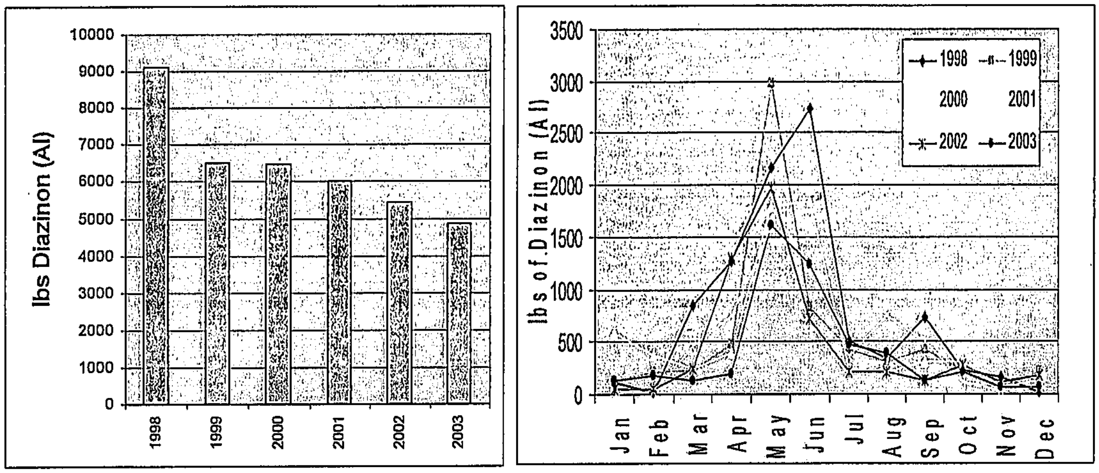


Figure 8. Reported diazinon agricultural use in CCW by year and month from 1998 – 2003 (DPR).

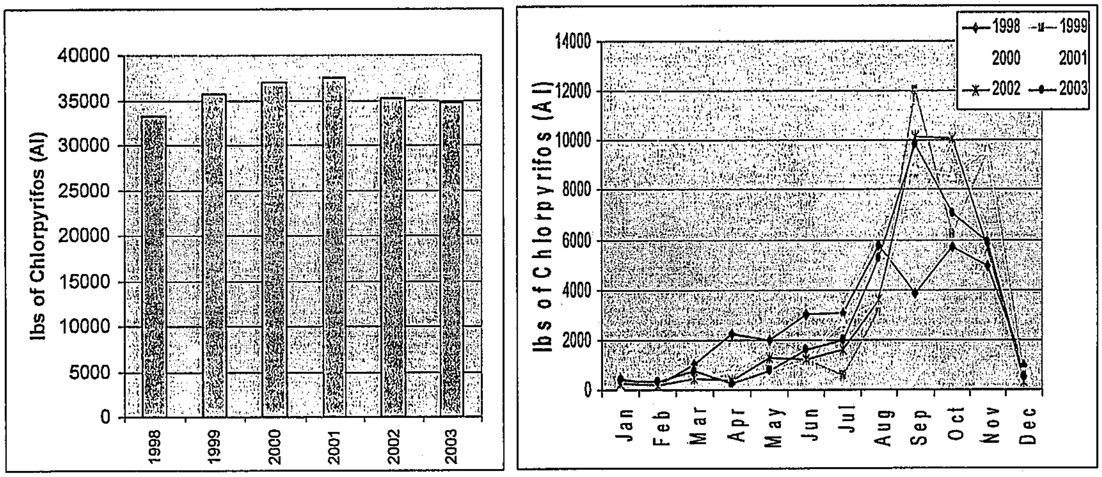


Figure 9. Reported chlorpyrifos agricultural use in CCW by year and month from 1998 – 2003 (DPR).

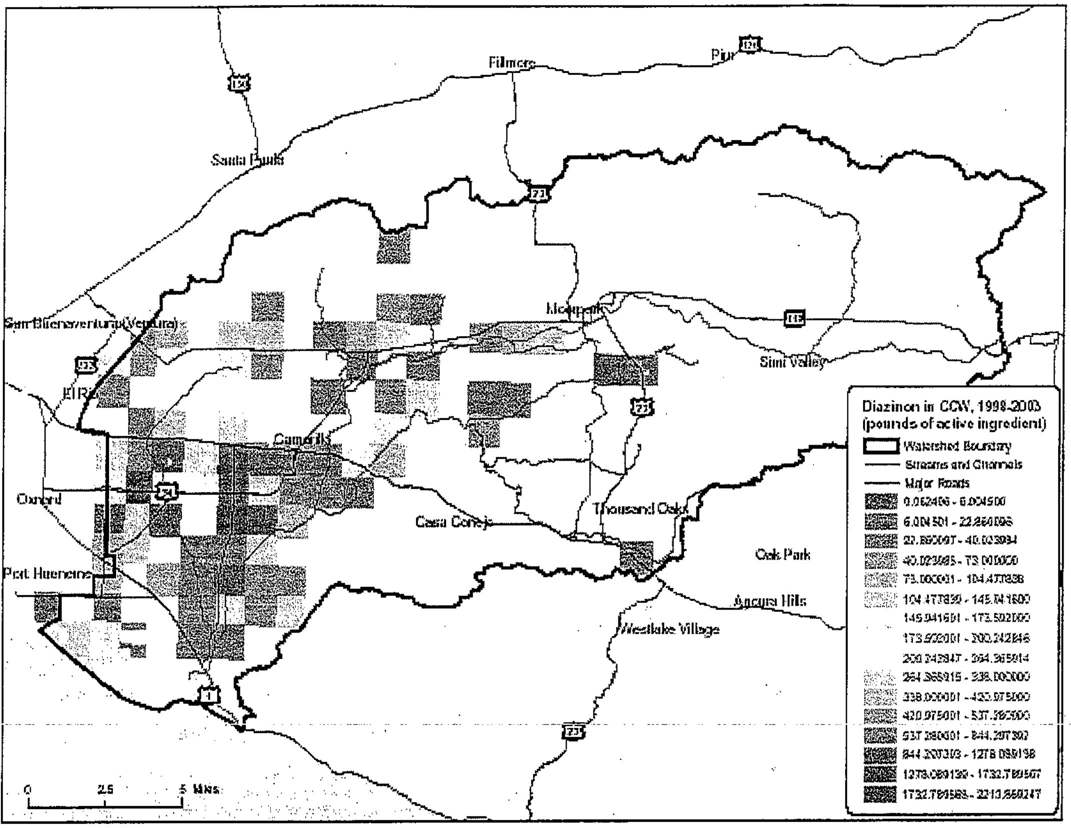


Figure 10. Cumulative agricultural diazinon use in the CCW from 1998-2003 (DPR).

Figure 10 shows the cumulative agricultural diazinon use in the CCW from 1998 – 2003. The majority of agricultural diazinon use occurs in the lower watershed. In comparing Figure 10 to Figure 7 (land use), one can see a correlation with the majority of use of diazinon in the Oxnard Plain, an area of concentrated agricultural activity. The Oxnard Plain is dominated by crops that constitute the bulk of diazinon use in the watershed, such as strawberries, beans, onions, lettuce, and squash (Table 39). The areas of relatively heavier use lie primarily along Revolon Slough (Reach 4) and Calleguas Creek (Reaches 2 and 3). Additionally, there are pockets of relatively higher use along Arroyo Las Posas, Arroyo Simi, Arroyo Santa Rosa (Reaches 6, 7, and 11, respectively).

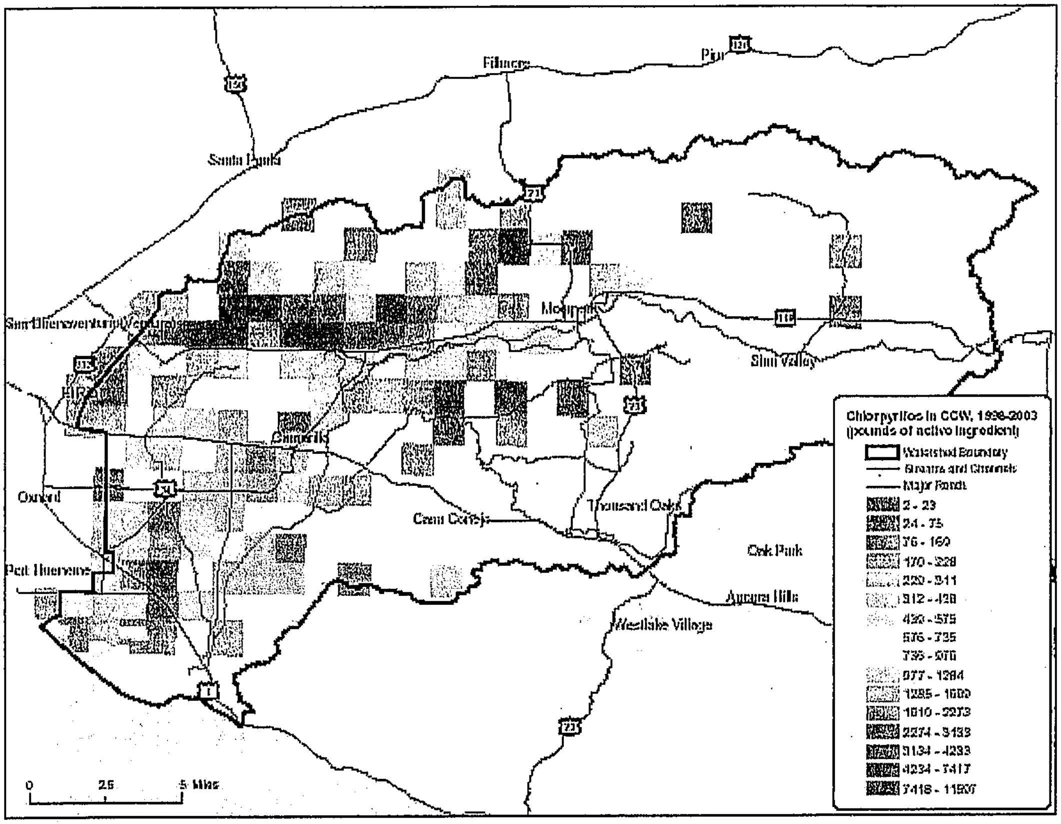


Figure 11. Cumulative agricultural chlorpyrifos use in the CCW from 1998-2003 (DPR).

Figure 11 shows the cumulative agricultural chlorpyrifos use in the CCW from 1998 – 2003. Chlorpyrifos use is more spatially distributed in the watershed than diazinon. In comparing Figure 11 to Figure 7 (land use), one can see a correlation of the heavier areas of chlorpyrifos use with citrus crops in the northwestern portion of the watershed and truck crops in the lower part of the watershed. These categories of crops represent the bulk of agricultural chlorpyrifos use as presented in Table 40. The areas of relatively heavier use lie primarily along Revolon Slough (Reach 4), Beardsley Channel (Reach 5), Calleguas Creek (Reaches 2 and 3), and the Arroyo Las Posas (Reach 6). Additionally, there are pockets of relatively higher use along the Conejo Reaches (9A, 9B, and 11).

5.3.3.1 Agricultural Pesticide Application

Diazinon and chlorpyrifos are applied to a wide variety of crops. Table 39 and Table 40 present the top 15 crops, in pounds of diazinon and chlorpyrifos applied, between 1998 and 2003. These 15 crops account for 95 percent of diazinon and 99 percent of chlorpyrifos agricultural use during this period. Between 1998 and 2002, 96 percent of chlorpyrifos was applied by ground-based equipment, four percent was applied aerially, and less than one percent was applied through other methods (injection, chemigation, etc.). During this same period, approximately 94 percent of diazinon was applied by ground-based equipment, six percent was applied aerially, and less than one percent was applied through other methods (injection, chemigation, etc.). Table 41 present the pounds of diazinon and chlorpyrifos applied through the various categories of applications. All crop types received either just ground-based applications or ground-based and aerial applications, with only one instance of an aerial only application to mustard in 1998.

Table 41. Diazinon and Chlorpyrifos Applied Through the Various Application Methods from 1998 – 2002

Constituent	Pounds Active Ingredient Applied				Percentage of Application		
	Ground	Aerial	Other	Total	Ground	Aerial	Other
Diazinon	31,488	1916	202	33,606	93.7%	5.7%	0.6%
Chlorpyrifos	171,561	7,120	281	78,962	95.9%	3.9%	0.2%

Ground – Ground-based equipment applied Aerial – Aerially applied
Other – Other application methods may include (injection, chemigation, etc.)

5.3.3.2 Agricultural Runoff Data

Data from all agricultural runoff sites that discharge directly to defined reaches in the CCW are aggregated to determine characteristic concentrations of chlorpyrifos and diazinon in return flows. These sites carry return flows from mixed agricultural sites representing a variety of crops. Samples were collected during both dry and wet weather. Table 42 presents summary statistics based on the available chlorpyrifos and diazinon data sampled from runoff dominated by agricultural land use activities. Figure 12 and Figure 13 present time series plots of the chlorpyrifos and diazinon agricultural runoff data, respectively. Current data are limited but fall within the range of what was observed historically. This is relatively consistent with what could be expected based on PUR data. As mentioned previously, chlorpyrifos use has not changed significantly and diazinon use has declined relatively slowly (except 1998-1999) over the time frame examined.

Table 42. Chlorpyrifos and Diazinon Agricultural Runoff Flows Data Summary

Constituent	Number of Samples	Number Detected	% Detected	Mean (ug/L)	Median (ug/L)	Range of Detection Limits (ug/L)	Maximum Detected Value (ug/L)
Chlorpyrifos	75	28	37.3%	0.179	0.050	0.044 – 2	3.3
Diazinon	66	15	22.7%	0.040	0.025	0.005 – 0.5	0.17

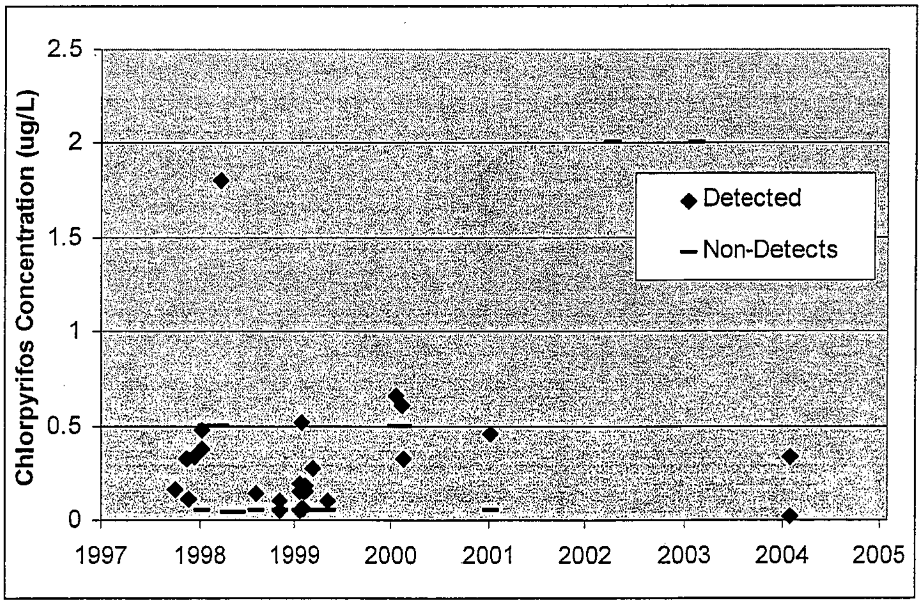


Figure 12. Time series plot of chlorpyrifos data from agricultural discharge monitoring sites.

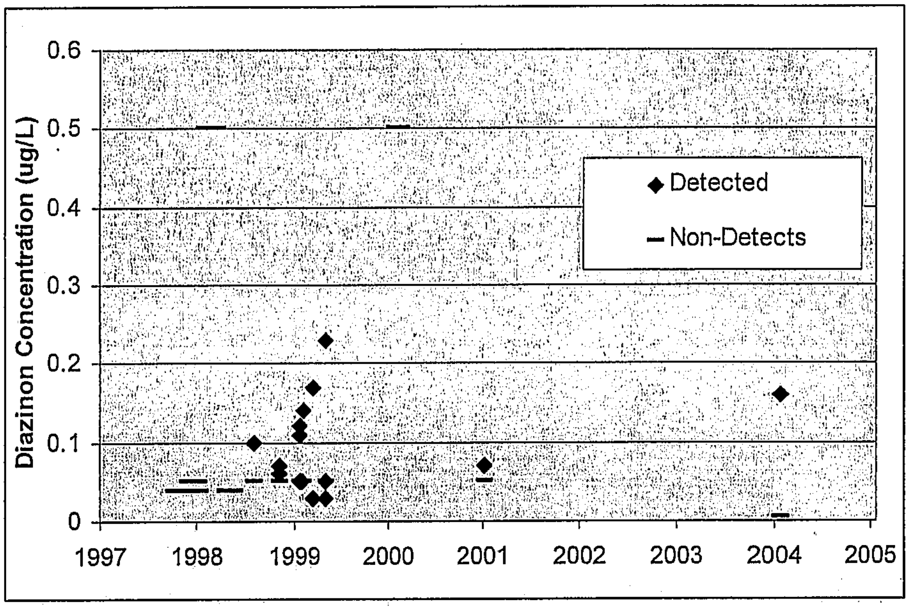
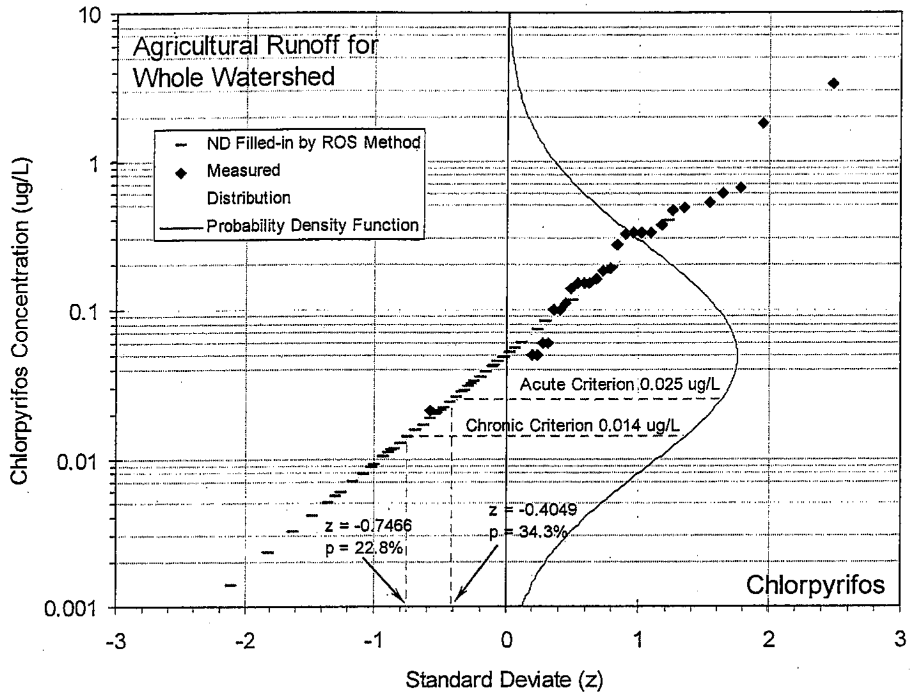


Figure 13. Time series plot of diazinon data from agricultural discharge monitoring sites.

The concentration log-normal probability distributions calculated via the ROS method for chlorpyrifos and diazinon are plotted in Figure 14. Superimposed on the figure are the 95th probability level and the probabilities associated with the in-stream water quality criteria. Less than a quarter of the chlorpyrifos samples are currently estimated to fall below the chronic criteria of 0.014 ug/L, and slightly more than one-third are below the acute criteria of 0.025 ug/L. It is estimated that 90% of the diazinon values are below the 0.1 ug/L acute and chronic water quality criteria. Fill-in values are plotted as horizontal lines on Figure 14 for samples where the pesticides were non-detected to illustrate the number of samples with high detection levels. The probability density functions (PDF) for chlorpyrifos and diazinon are superimposed on the respective plots. The PDFs plots as normal "bell" curves because the concentration scale is plotted as a log-scale. Standard deviate (or z-score, z, etc) is the number of standard deviations from the median, so z=0 is the median or 50%. The distribution regression line from the ROS method allows calculation of expected concentration given a probability, and is exactly equivalent to matching the probability of the PDF to a concentration. In Figure 14, the criteria are specifically called out in terms of standard deviate, probability, and plotting on the PDF. Both chlorpyrifos and diazinon plots are set to identical scales allowing comparison of graphical features. Visual inspection reveals that chlorpyrifos has a higher mean and is more variable because the intercept of the chlorpyrifos distribution line is higher than the diazinon line and the slope of the chlorpyrifos distribution line is greater than the diazinon distribution line. The PDFs highlight the difference in the chlorpyrifos and diazinon data sets as the chlorpyrifos PDF is more spread-out indicating higher variability. See the Current Conditions section for a more detailed discussion of the ROS method.



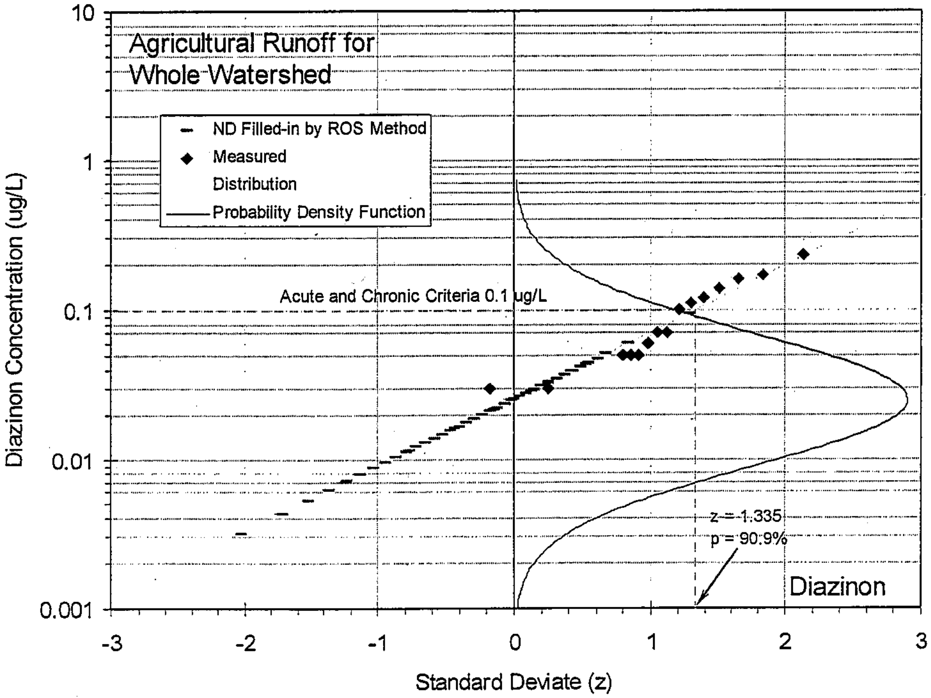


Figure 14. Agricultural runoff chlorpyrifos and diazinon concentration log-normal probability distributions. ND filled-in values represent the calculated values of the ND data via the ROS method and do not correspond to physical measurements. Both plots use identical scales.

5.3.3.3 Agricultural Application Compared to In-stream Concentration

A comparison between reported agricultural applications of chlorpyrifos and diazinon to in-stream water quality was conducted. The comparison was conducted to determine if there is a correlation between in-stream water quality and the timing of agriculture applications of chlorpyrifos and diazinon. PUR application data was aggregated by month by subwatershed and in-stream water quality data was averaged by month by subwatershed. It was presumed the mostly likely time a correlation would exist would be during the timing of heaviest applications. The heaviest use of chlorpyrifos occurs between August and November (approximately 79 percent), which coincides with the primary application of this pesticide to lemons. The heaviest use of diazinon occurs between April and May (approximately 66 percent), which coincides with the majority of applications to beans. Figure 15 present the results of this comparison for the Revolon Slough Subwatershed. No correlation between application and in-stream water quality is readably observable. In-stream water quality data are limited and were not available for all months. Additional data collected through the monitoring program presented in the Implementation Plan section will provide a more robust data set with which to conduct this comparison in the future.

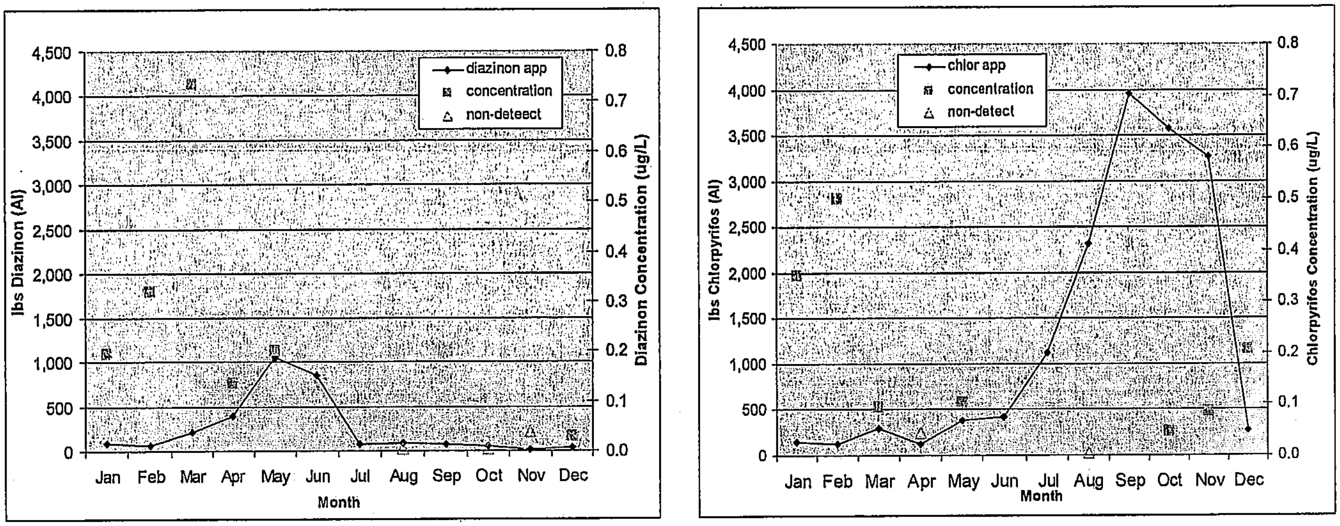


Figure 15. Average monthly application of chlorpyrifos and diazinon compared to in-stream water quality.

5.3.4 Urban Use

Certain non-agricultural uses of pesticides must be reported to the County and are subsequently included in PURs. The non-agricultural uses for chlorpyrifos and diazinon reported in the PURs were considered urban uses. Between 1998 and 2003 reported urban uses for diazinon and/or chlorpyrifos included structural pest control, landscape maintenance (parks, golf courses, and cemeteries), rights of way maintenance, vertebrate control, and public health pest control. The one application of diazinon for vertebrate control (~ 0.7 pounds) and the one application of chlorpyrifos for public health pest control (~ 1.7 pounds) reported between 1998 and 2003 were considered insignificant and were not incorporated in this analysis. Reported urban use data do not contain information on the location of pesticide application except for the county in which the application is made. As there is no way to reference reported urban uses, the location of these applications in Ventura County could not be determined. To address this issue, the amount of pesticides used for urban uses were multiplied by the percentage of urban area in Ventura

County located in the CCW. Based on the California Department of Water Resources' 2000 land use layer for Ventura County, approximately 51.2 percent of the urban area in Ventura County is located in the CCW. In 2003, an estimated 501 pounds of diazinon and 643 pounds of chlorpyrifos were reported used for urban purposes in the CCW, representing 51.2 percent of total reported urban uses in Ventura County.

Figure 16 and Figure 17 present estimated annual reported diazinon and chlorpyrifos urban uses in the CCW from 1998 through 2003. As indicated in Figure 16, the total annual use of diazinon for reported urban uses has declined by 80 percent between 1998 and 2003. The largest annual decrease in overall use occurred between 2001 and 2002 (53 percent) and 2002 and 2003 (60 percent). As indicated in Figure 17, the total annual reported urban use of chlorpyrifos has declined by 72 percent between 1998 and 2003, with the largest decrease occurring between 2000 and 2001 (79 percent). The decreases in reported urban uses of chlorpyrifos and diazinon could be the result of the phase out of most urban uses. Structural pest control is by the far the largest reported urban use for both diazinon and chlorpyrifos, although annual use for structural pest control is declining and will be completely banned on December 31, 2005. Concern has been raised with regard to the contribution of diazinon and chlorpyrifos from golf courses. In reviewing PUR data, the 15 golf courses located in the CCW did not report use of notable amounts of these constituents between 1998 and 2003.

Figure 16 and Figure 17 also present reported monthly diazinon and chlorpyrifos urban uses in the CCW from 1998 through 2003. Unlike agriculture, there is no clear trend in the monthly data for urban uses of diazinon or chlorpyrifos. In looking at historical monthly averages there does not seem to be a month or series of months that dominate total urban uses. However, urban use of diazinon and chlorpyrifos are unlikely to be a long-term source to the CCW as neither of these pesticides will be sold for non-agricultural uses as of December 31, 2005.

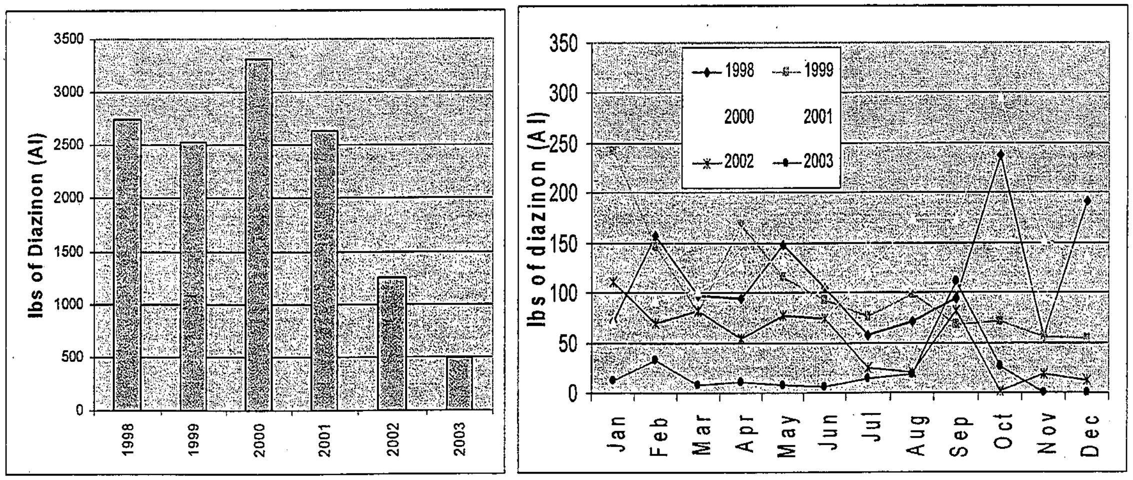


Figure 16. Reported diazinon urban use in CCW by year and month from 1998 – 2003 (DPR).

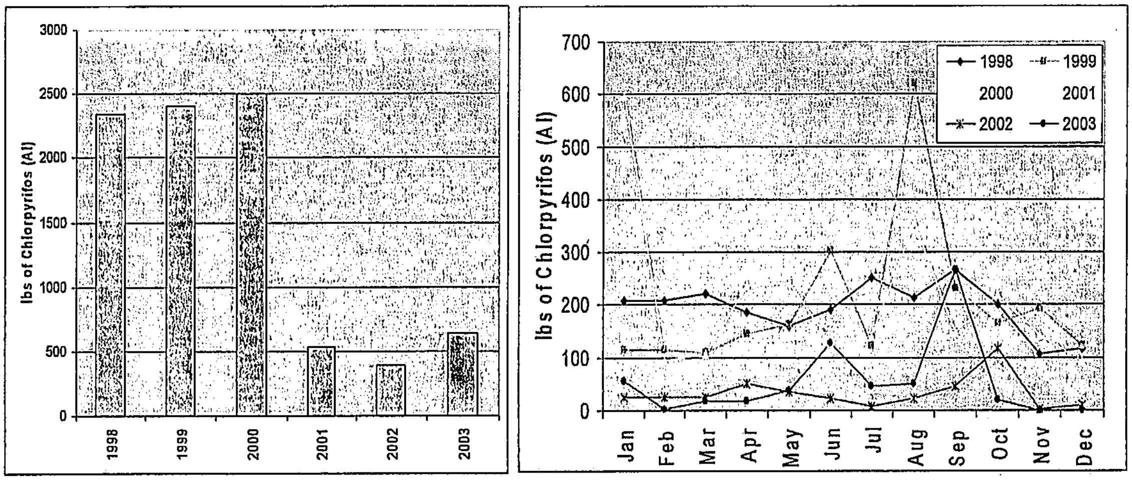


Figure 17. Reported chlorpyrifos urban use in CCW by year and month from 1998 – 2003 (DPR).

5.3.4.1 Unreported Use

Uses of pesticides excluded from reporting requirements include industrial, institutional, and home and garden pesticide uses. These uses are collectively referred to as "unreported uses". An estimate of unreported diazinon and chlorpyrifos use in the CCW was made based on the Survey of Residential Pesticide Use and Sales in San Diego Creek Watershed of Orange County California (Wilen, 2001). The survey, conducted between August and October 2000, estimated the amount of diazinon and chlorpyrifos sold for unreported use in the San Diego Creek watershed. Assuming all sales resulted in the use of the pesticide, unreported use for the CCW was estimated by multiplying the ratio of populations in the San Diego Creek watershed and the CCW. An analysis of the 2000 census and population data for the CCW yielded a population estimate of 334,000, approximately 42 percent of the San Diego Creek watershed (797,000). Based on relative populations and the results of the Wilen survey, an estimated 1,063 pounds of chlorpyrifos and 15,123 pounds of diazinon are used for unreported uses in an urban environment on an annual basis. Although this approach creates highly uncertain estimates, it does provide some level of understanding of the possible quantities of these pesticides available for unreported uses in an urban environment over the past few years. However, unreported urban use of diazinon and chlorpyrifos are unlikely to be a long-term source to the CCW as neither of these pesticides will be sold for unreported uses as of January 1, 2004. Reported urban uses of chlorpyrifos can still occur until December 31, 2005.

5.3.4.2 Estimated Time Frame/Reductions as a Result of Phase Out

As discussed previously, unreported urban uses of chlorpyrifos and diazinon were estimated at 1,063 pounds and 15,123 pounds, respectively. If it is assumed that temporal reduction of unreported use follows the same pattern as reported urban uses as shown in Figure 16 and Figure 17, then unreported use of diazinon and chlorpyrifos between 2000 and 2003 can be estimated as shown in Table 43.

Table 43. Estimated Annual Unreported Use of Diazinon and Chlorpyrifos (pounds AI)

Constituent	Year			
	2000	2001	2002	2003
Diazinon	15,123	12,087	5,724	2,290
Chlorpyrifos	1,063	228	166	273

Pesticide products containing diazinon come with a recommendation to apply between 0.000066 lb diazinon/sq.ft. and 0.0001 lb diazinon/sq.ft.[2] Using an average application rate of 0.000083 lb diazinon/sq.ft., the area that would be covered by application of the diazinon quantities shown in Table 43 are shown in Table 44. Similarly, pesticide products containing chlorpyrifos come with a recommendation to apply between 0.000025 lb chorpyrifos/sq.ft. and 0.00005 lb chlorpyrifos /sq.ft.[3] Using an average application rate of 0.000038 lb chlorpyrifos/sq.ft., the area that would be covered by application of the chlorpyrifos quantities shown in Table 43 are shown in Table 44.

Table 44. Area Covered Based on Diazinon and Chlorpyrifos Unreported Use Estimates

	Year			
	2000	2001	2002	2003
Quantity diazinon used (pounds AI)	15,123	12,087	5,724	2,290
Area in acres covered using 0.000083 lb diazinon /sq.ft.	4,180	3,341	1,582	633
Quantity chlorpyrifos used (pounds AI)	1,063	228	166	273
Area in acres covered using 0.000038 lb chlorpyrifos /sq.ft.	651	140	102	167
Total acreage covered by both pesticides	4,831	3,481	1,684	800

Table 37 shows a combined acreage for residential, commercial and industrial land use (i.e., sites of unreported pesticide uses) in the CCW of 33,700 acres. The maximum area covered by unreported use of diazinon and chlorpyrifos is 14 percent of the area in the CCW where unreported use is likely to occur. The previously mentioned Survey of Residential Pesticide Use and Sales in San Diego Creek Watershed (Wilen, 2001) gathered information regarding storage of pest control products. When asked how many pest control products were stored in their home, nine percent of survey respondents said they had no pesticides and 81 percent indicated they had between one and five pest control products. In addition, seven percent of respondents had between six and 10 products and three percent of respondents had more than 10 pest control products. When asked how long they stored pest control products, five percent of those who had pest control products indicated that the oldest product was less than one year old while 71 percent indicated that the oldest pest control product was between one and three years old. Based on these responses, approximately 79 percent of residents would be expected to either have no pesticides or store pesticides for less than three years. Therefore, it is likely that most of the pesticides used for unreported uses would be used up within three years of the date that retail sales are discontinued. This would correspond to urban sources of diazinon being significantly reduced by the end of 2007. Chlorpyrifos retail sales to non-licensed urban users ended in 2001; however, structural pest control applications were permitted until December 31, 2005. This would correspond to urban sources of chlorpyrifos being significantly reduced by the end of 2005. However, as 21 percent of residents indicated that the oldest pest control product was stored longer than three years, urban uses of chlorpyrifos and diazinon will likely continue past 2005 and 2007, respectively.

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[2] Label instructions for Diazinon Insecticide 25% Spray Concentrate, 5% Diazinon Granules, Ortho Diazinon Ultra Insect Spray. http://www.southernag.com/labels.htm; http://www.ortho.com/ (product guide)

[3] Label instructions for Dursban 2.5%Granular Insecticide, Dursban 1% Granular Insecticed, and Dursban Ant & Turf Granules. http://www.southernag.com/labels.htm

5.3.4.3 Urban Runoff Data

Urban runoff concentrations are calculated by combining runoff data from residential, commercial, and industrial land uses as well as mixed urban land uses. Chlorpyrifos and diazinon data for urban runoff were collected at selected characterization sites. All of the urban runoff sites are located in Ventura County; however, not all of the sites are located in the CCW. The underlying assumption is that the selected characterization sites are representative of all urban sites in the CCW. Samples were collected during both dry and wet weather. Table 45 presents the available chlorpyrifos and diazinon data sampled from runoff dominated by urban land use activities. Figure 18 and Figure 19 present time series plots of the chlorpyrifos and diazinon urban runoff data, respectively. Figure 18 shows that detected data for chlorpyrifos are limited, with only one recent detected value. This single detected data point falls within the range of what was observed historically. As presented in Figure 19, there are considerably more detected diazinon data points. The clustering of the more recent detected data is lower than historical data, with the bulk of the recent data below 0.1 ug/L and the bulk of the historic data greater than 0.3 ug/L. The lack of recent detected chlorpyrifos data and the seeming downward trend of detected diazinon data are consistent with declining urban uses.

Table 45. Chlorpyrifos and Diazinon Urban Runoff Flows Data Summary

Constituent	n	Number Detected	% Detected	Mean (ug/L)	Median (ug/L)	Range of Detection Limits (ug/L)	Maximum Detected Value (ug/L)
Chlorpyrifos	47	5	10.6%	NA	NA	0.005 – 0.5	0.45
Diazinon	50	27	54.0%	0.098	0.036	0.005 – 1.3	0.5

NA Insufficient detected data to determine mean.

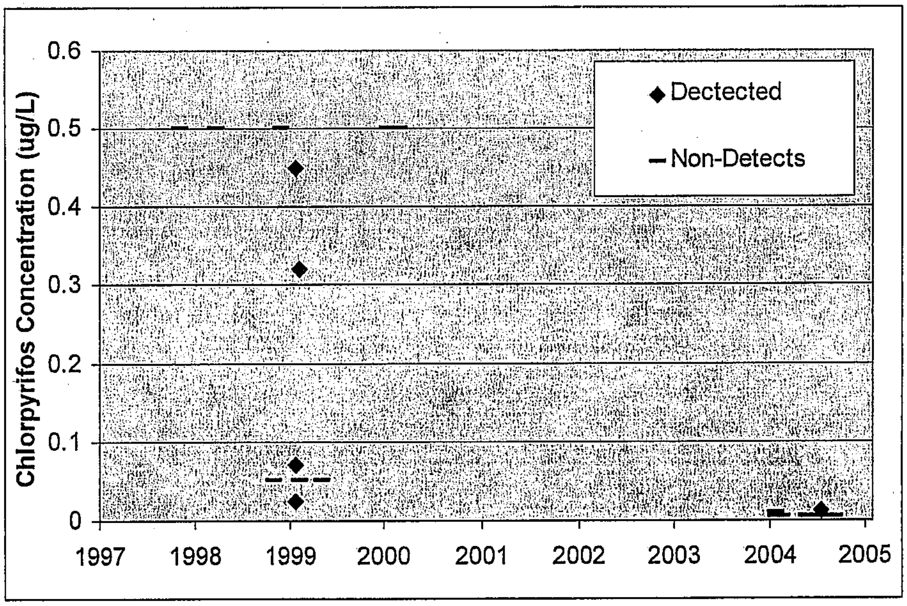


Figure 18. Time series plot of chlorpyrifos data from urban discharge monitoring sites.

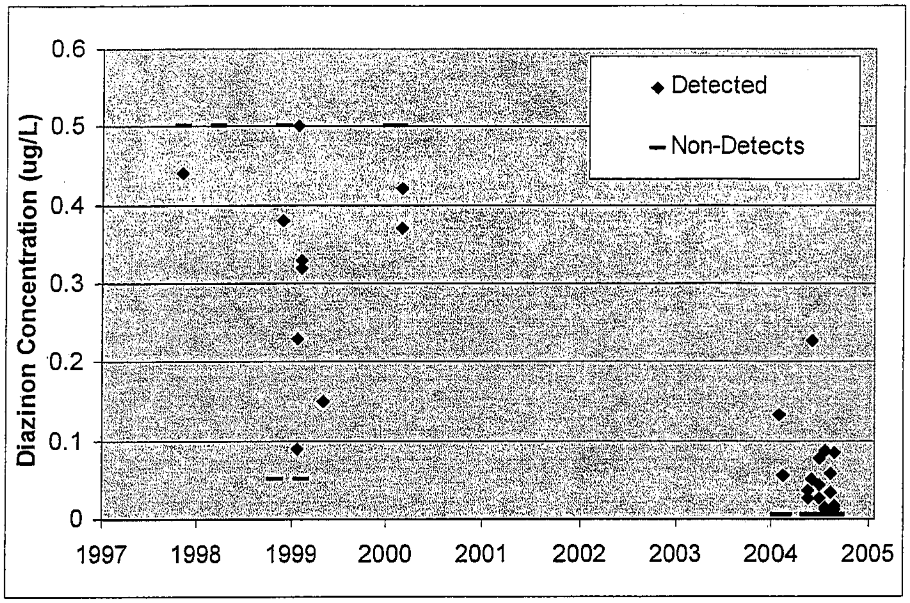
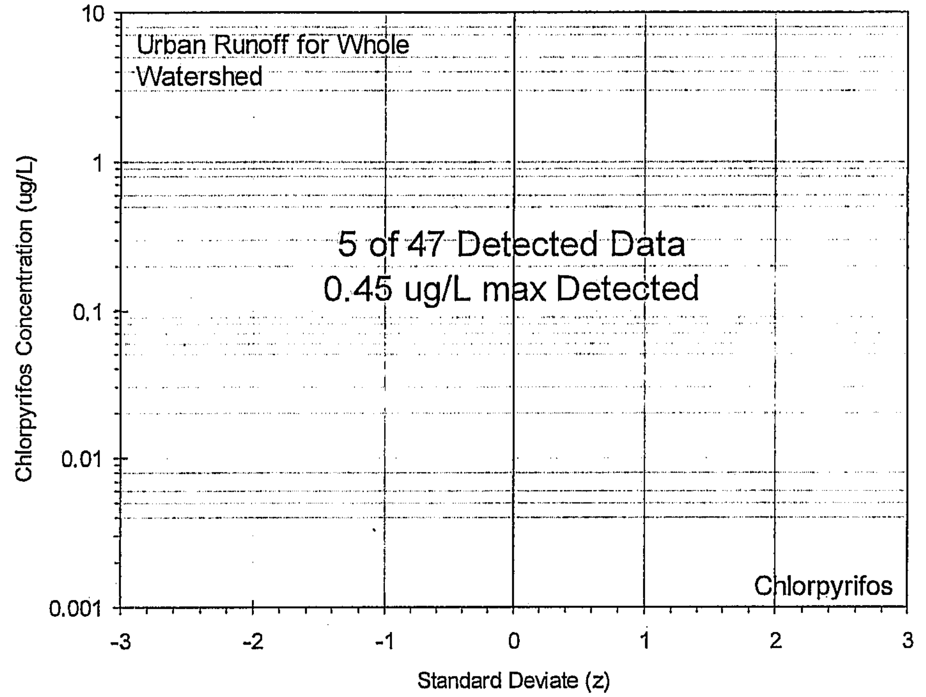


Figure 19. Time series plot of diazinon data from urban discharge monitoring sites.

Probability plots of available chlorpyrifos and diazinon data are presented in Figure 20. Chlorpyrifos was detected in only five of 26 samples, so a distribution plot could not be calculated. The probability plot of diazinon reveals the concentrations in urban runoff exceed receiving water quality objectives approximately 60% of the time. Likely due to the phase-out of the sale of chlorpyrifos and diazinon, there has been a decrease in urban runoff concentrations of these constituents, however all urban runoff data are included in the analysis as a conservative measure to prevent underestimation of the urban runoff contribution to receiving water load.



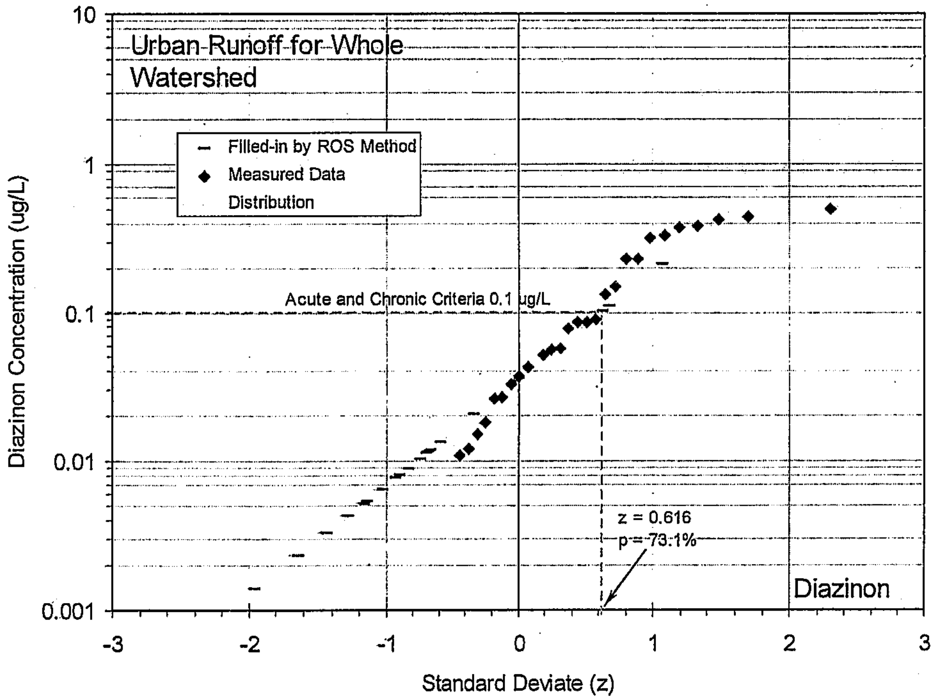


Figure 20. Distributions of chlorpyrifos and diazinon concentrations sampled from urban runoff. Data from all urban characterization sites combined. ND filled-in values represent the calculated estimate of the non-detected values via the ROS method and do not correspond to physical measurements.

5.3.5 Comparison of Agricultural, Urban, and Unreported Uses

Figure 21 presents a comparison of the total reported agricultural and urban uses of chlorpyrifos and diazinon. Agricultural uses account for the majority of use for both pesticides. For chlorpyrifos used between 1998 and 2003 in the CCW, agricultural uses represented between 93 and 99 percent of reported uses annually. For diazinon, agricultural uses represented between 66 and 91 percent of reported uses annually during the same period.

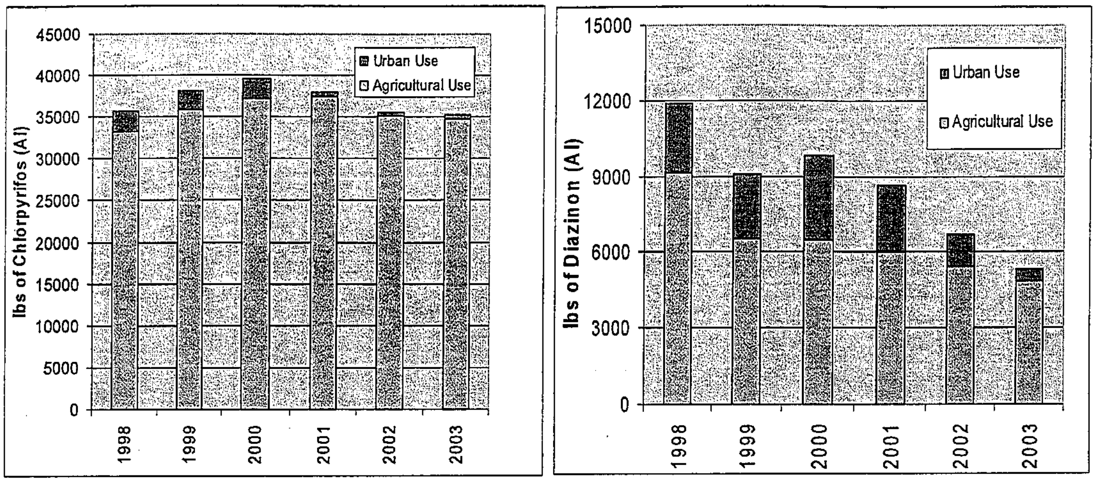


Figure 21. Comparison of reported agricultural and urban uses in CCW by year from 1998 – 2003 (DPR).

Figure 22 presents a comparison of the total reported uses (agricultural and urban) and estimated unreported uses of chlorpyrifos and diazinon. Estimated unreported uses of chlorpyrifos are relatively low in comparison to reported uses, consistent with the end of retail sales to non-licensed urban users in 2001. Estimated unreported uses of diazinon are relatively high in comparison to reported uses, although the observed percentage of total use reduces significantly over the time period examined.

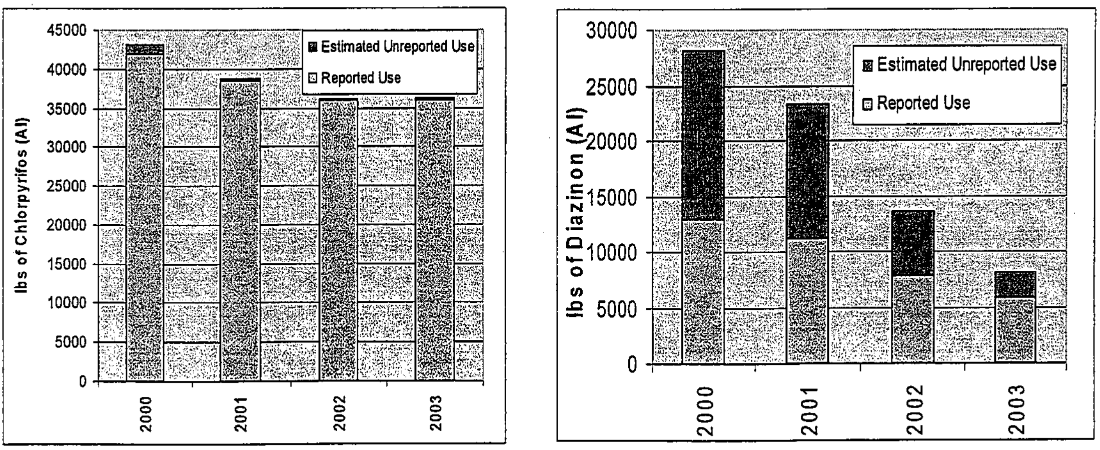


Figure 22. Comparison of reported uses (agricultural and urban) to estimated unreported uses in CCW by year from 2000 – 2003.

5.3.6 Publicly Owned Treatment Works

Publicly owned treatment works (POTWs) receive inputs of diazinon and chlorpyrifos via infiltration and inflow from stormwater runoff within their service areas, and may also receive inputs of such pesticides from washing of fruits, vegetables, and clothes and from the improper disposal of pesticides. All available data for chlorpyrifos and diazinon in POTW effluent in the CCW are listed in Table 46. It should be noted, the only available chlorpyrifos and diazinon data characterizing POTW effluent were collected between July 1998 and May 1999. Reported use, and likely unreported use, of these pesticides in urban environments have decreased since these data were collected. In turn, it is likely the loads and/or concentrations of these pesticides in POTW effluent have decreased. However, there is no clear way to adjust the available data to estimate current concentrations.

Table 46. Chlorpyrifos and Diazinon Detected Values for POTW Discharge in the CCW.

	Chlorpyrifos				Diazinon			
POTW	Number of Samples	Number Detected	% Detected	Detected Values (ug/L)	Number of Samples	Number Detected	% Detected	Detected Values (ug/L)
Simi Valley	4	0	0%	–	4	3	75%	0.25 0.25 0.14
Moorpark[1]	2	0	0%	–	3	2	67%	0.11 0.17
Olsen Road [2]	4	1	25%	0.03	4	0	0%	–
Hill Canyon	4	0	0%	–	4	0	0%	–
Camarillo	4	0	0%	–	4	2	50%	0.09 0.25
Camrosa[1]	0	0	–	–	0	0	0%	–

1 In general, Moorpark and Camrosa do not discharge to surface waters of the United States as these plants are designed to have zero discharge expect during abnormally wet years.
2 Olsen Rd decommissioned in 2002, all flow currently diverted to Hill Canyon.

5.3.7 Groundwater

Groundwater exfiltration and groundwater dewatering discharges are considered under the general heading of groundwater inputs to the CCW. Currently, the only dewatering wells included in this analysis are located in the Simi Valley area of the watershed. The groundwater flows in the Simi Valley are largely due to continuous pumping to lower the groundwater table. From a source perspective, the dewatering well discharges affect the CCW system in an equivalent manner to the natural exfiltration of groundwater. Four dewatering well discharge water samples did not reveal the presence of chlorpyrifos or diazinon in the Arroyo Simi groundwater. There is little information available on chlorpyrifos or diazinon in the groundwater in other areas of the CCW. Given that diazinon is moderately soluble in water there is the potential for this pesticide to infiltrate into groundwater, however, there is no data that indicates this is occurring in the watershed. Conversely, chlorpyrifos is relatively insoluble in water and is less likely to infiltrate into groundwater.

5.3.8 Atmospheric and Aerial Deposition

Atmospheric and aerial deposition includes wet and dry deposition components. Rainfall can associate with diazinon and chlorpyrifos due to volatilization of these pesticides in the atmosphere. Ambient air and wet-deposition monitoring has occurred for both chlorpyrifos and diazinon in other areas. Monitoring of chlorpyrifos in the Central Valley of California indicated atmospheric transport was occurring as far as the

Sierra Nevada Mountains (80 – 100 miles). Zabik and Seiber (1993) found that concentrations of chlorpyrifos in air decreased with distance from the source area with a maximum concentration of 6.5 ng/m^3 recorded in the valley. As presented in the Toxicology Profile for Diazinon (USDHHS, 1996), multiple studies have reported the presence of diazinon in atmospheric samples. In a sample collected near fruit and nut orchards in Parlier, California, reported mean concentrations of diazinon measured 76.8 ng/m^3 (Cited in USDHHS, 1996). In an experiment conducted by Alameda County (2001), diazinon solution was applied around the perimeter of a building. During ensuing rain events, occurring up to three months after initial application, diazinon was measured in all of the rainwater samples ranging from 3 to 15,000 ng/L. Application methods can vary based on crop type, applicator preference, etc., affecting volatilization rates and ultimately atmospheric and aerial deposition.

The rates of atmospheric and aerial deposition of chlorpyrifos and diazinon in urban areas have not been measured. Estimates have been determined using ambient concentrations and assumed deposition rates, but the determined rates carry a high degree of uncertainty and may be unrealistic (Ross, 2002). A study conducted by Dow AgroSciences (1998) at Orestimba Creek around agricultural sites in Stanislaus County involved surface water monitoring for a year. The researchers found that some concentration peaks detected for several OP pesticides could be associated with specific pesticide application events, and that the most probable transport process could be determined. For chlorpyrifos, nine of 13 attributable concentration peaks were a result of drift from the application site. For diazinon, five of 14 attributable peaks were a result of drift from the application site (SRWP, 2000).

Majewski and Baston (2002) conducted ambient air quality monitoring for OP pesticides in the Sacramento urban area and nearby agricultural areas during the period 1996-1997. Of 17 pesticides monitored during the study, chlorpyrifos, diazinon, and trifluralin accounted for 24 percent of the agricultural and 76 percent of the non-agricultural/urban pesticides used during the two-year study period.

The Southern California Coastal Water Research Project (SCCWRP) is beginning a study to determine the impact of atmospheric deposition of pesticides transported from sources within the airshed to waterbodies of interest in selected regions of Southern California. Results from the study may provide additional information to quantify pesticide deposition rates in urban areas.

The above studies do not provide enough information to determine the local deposition rate of chlorpyrifos and diazinon. Monitoring of wet and dry deposition rates of pesticides would provide the clearest information to incorporate the atmospheric contribution to the runoff water quality.

Wet deposition over agricultural and urban areas is implicitly included in the runoff measurements. Direct deposition to the waterways in the CCW is negligible in comparison to the deposition component of stormwater runoff as the water surface area for the entire watershed is less than 1% of the total watershed surface area. An identical approach for chlorpyrifos and diazinon has been adopted in the Newport Bay Toxics TMDL (USEPA, 2002b).

5.3.9 Imported Water

Imported water is a potential source of diazinon and chlorpyrifos to the watershed. Imported water is used for agriculture and urban irrigation, washing cars, and other purposes that result in runoff into storm drains or infiltration into groundwater. Drinking water and irrigation water are imported to the watershed from the State Water Project and the Freeman Diversion, respectively. The State Water Project pumps water from the San Francisco Bay Delta, which originates in northern and central California, including the Central Valley, an area of intense agricultural activity. Water suppliers regularly analyze their water for a variety of pollutants. As there is no evidence to the contrary, it is assumed there are no detectable levels of chlorpyrifos or diazinon in imported.

5.3.10 Native Space Runoff

Runoff from native areas of vacant, undeveloped, open space was considered "Native Space". However, there are no data currently available describing chlorpyrifos or diazinon concentrations in the native runoff in the CCW. A zero contribution of chlorpyrifos and diazinon from open space has been adopted in the Newport Bay TMDL (USEPA 2002b), however, a small but non-zero load from Native Space is incorporated into the TTMBM.

Summary

Figure 23 presents the relative magnitude of identified sources of chlorpyrifos to CCW during dry and wet weather conditions. Figure 24 presents the relative magnitude of identified sources of diazinon to CCW during dry and wet weather conditions. Figure 25 presents relative chlorpyrifos and diazinon loads based on season (wet season defined as October through April). Figure 26 presents relative chlorpyrifos and diazinon loads based on weather (i.e in-stream flowrate greater than the 86th percentile is considered wet weather). Agricultural and urban uses are the largest sources of these pesticides in the watershed. However, urban use of diazinon and chlorpyrifos are unlikely to be a long-term source to the CCW as neither of these pesticides will be sold for non-agricultural uses as of December 31, 2005. As a result, the proportion of the loading from urban sources will likely decrease some time after December 2005.

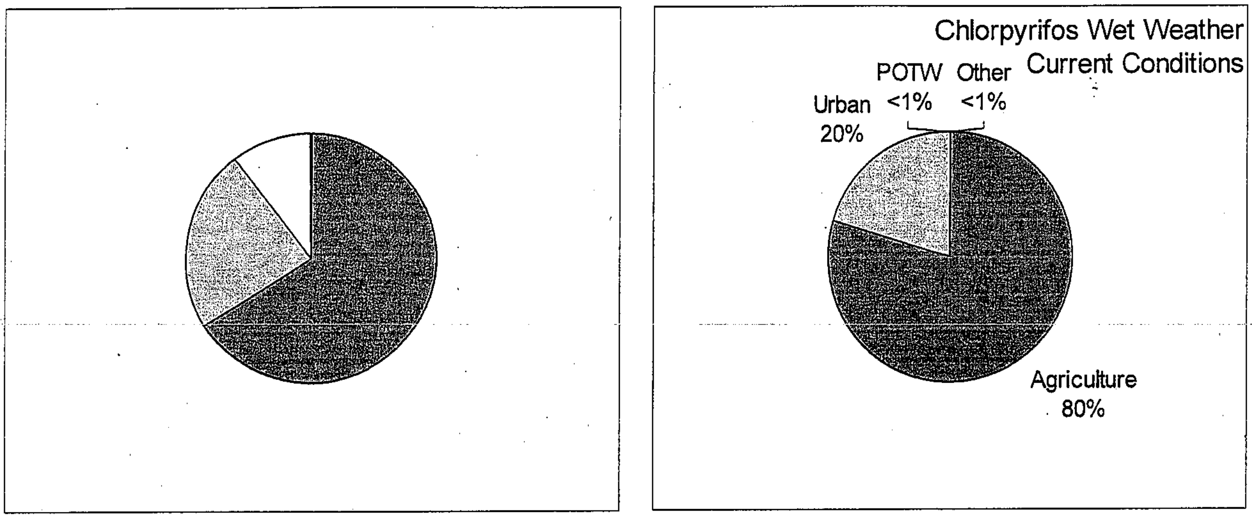


Figure 23. Chlorpyrifos loading from various land uses for entire CCW.

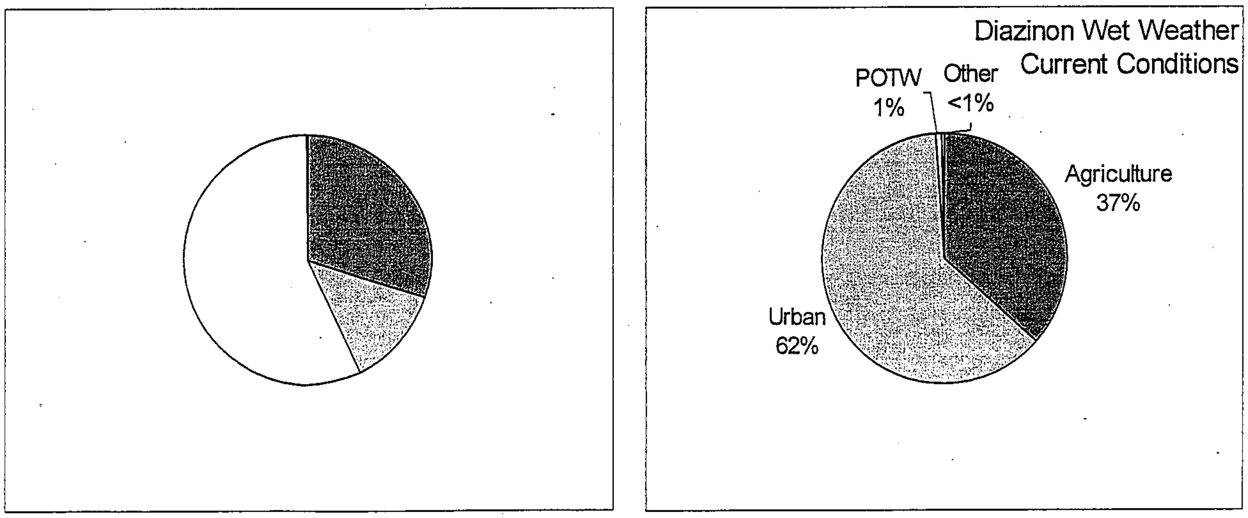


Figure 24. Diazinon loading from various land uses for entire CCW.

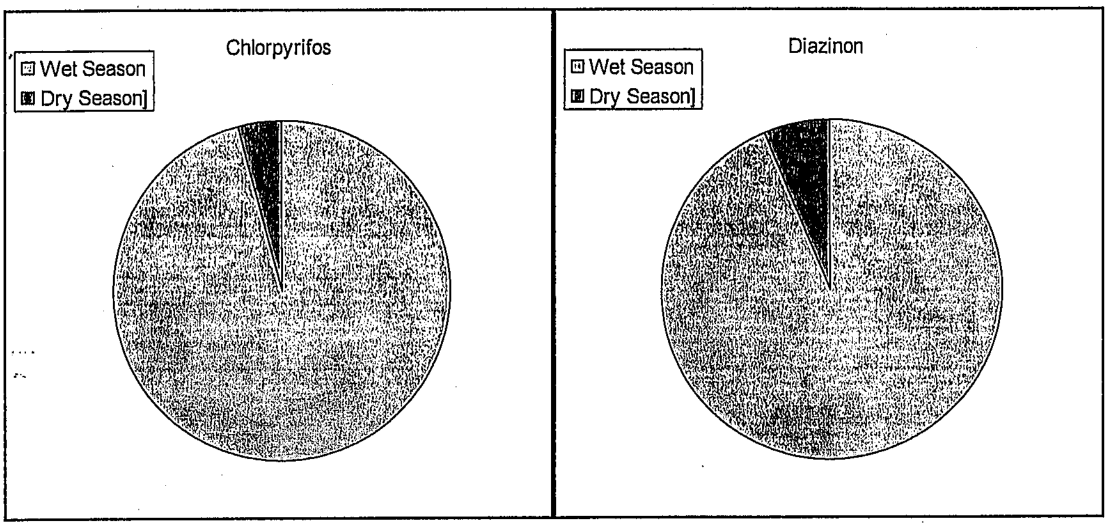


Figure 25. Relative chlorpyrifos and diazinon loads based on season. Where the wet season is defined as October through April.

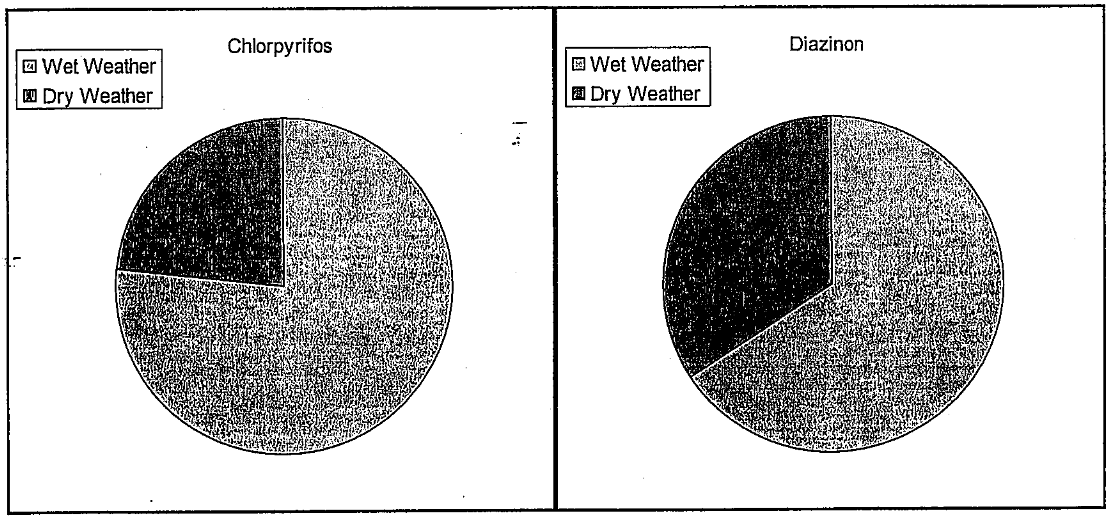


Figure 26. Relative chlorpyrifos and diazinon loads based on weather (i.e in-stream flowrate greater than the 86th percentile is considered wet weather).

6 Linkage Analysis

A brief review of the degradation processes and modeling of chlorpyrifos and diazinon in the CCW is presented in the Linkage Analysis section. Modeling was performed to provide decision support to understand the source and sinks of constituents identified as toxicological agents in the CCW, and not toxicity *per se*. The model focused on chlorpyrifos and diazinon as these two pesticides are 1) identified in the Current Conditions section as a likely cause of toxicity within the CCW; and, 2) these constituents are on the 303(d) list for reaches in the CCW. If additional constituents are identified as contributing to water and/or sediment toxicity and these constituents are not appropriately addressed by other TMDLs, a linkage analysis addressing these constituents may need to be developed. The modeling approach reflects the high degree of uncertainty in current conditions and the potential impacts of actions intended to affect those conditions. Numerous simplifying assumptions are required to address uncertainties at every step in the linkage between sources and impacts to beneficial uses. The assumptions cover uses and application rates; current sources and loading rates; and streambed and water column concentrations. A more detailed description of the model and the linkage analysis is provided in Attachment A.

6.1 *Model Selection*

Model selection criteria were developed to compare and evaluate potential numerical models to assess current and future loadings of chlorpyrifos and diazinon. These criteria were taken initially from the National Research Council's recommended TMDL model selection criteria (NRC, 2001), and then modified based on local issues and stakeholder concerns. The selection criteria were:

Links management options to targets
Appropriate level of complexity
  - Consistent with data
  - Reasonable relative to TMDL development schedule
Model and results are credible and acceptable
  - Consistent with scientific theory
  - Prediction uncertainty can be quantified
Acceptable costs
  - Need for long-term support
  - Useful for other TMDLs (e.g., bacteria and metals) & studies

The model selection process identified available models, categorized into four types of models, generally in order of increasing complexity:

Type 1, large-scale box model
Type 2, segmented stream model
Type 3, coupled watershed / waterbody model
Type 4, biotic response model

The model selection process aggregated two related decisions: 1) selection of the most appropriate model among the four types; and, 2) selection of the most appropriate model that fits each model type. The model selection criteria are summarized in Table 47.

Table 47. Model Selection Criteria and Descriptive Evaluation of Each Model Type for Chlorpyrifos and Diazinon in the CCW

Selection Criteria	Type 1	Type 2	Type 3	Type 4
Links management options to targets	Quantifies total mass per subwatershed; links changes on land to water processes	Need to link changes on land to water processes	Links changes in source loads, water column, and sediment content; no fish tissue model	Only models in-stream processes
Appropriate level of complexity: ▪ Consistent with available data ▪ Reasonable relative to TMDL development schedule	Appropriate for widespread, long time frame problem. Simulations applicable to whole reaches or conglomerate of reaches. Requires the least amount of data. Model development may take days to weeks.	Delineated based on TMDL reaches; can simulate response at a sub-reach scale using short time step. Requires moderate amount of data, which may not be available for CCW. Model development may require weeks to months.	Complex beyond knowledge and scale of sources and processes in CCW; rates require many detected data for calibration and validation; model sensitivity cannot be evaluated adequately with so much ND data. Model development may require months to years.	No data on food webs. Food web complexity and watershed resolution drive model development requirements.
Model and results are credible and acceptable: ▪ Consistent with scientific theory ▪ Prediction uncertainty can be quantified	Similar model used in Bay Area OPs TMDL approved by EPA; uses published rate constants and estimated source/sink loads; could test range of possible reaction rates and loads; can compare to data *trends* but not data *points*	Used in CCW Nutrients TMDL approved by EPA; uses published rate constants and estimated source/sink loads; would compare to data *trends* but not data *points*	Supported by EPA; worldwide applications to hydrology; little published on applicability to simulating OPs; simulates erosion & sediment transport, degradation processes; simulation results can be compared to concurrent observations	Supported by EPA; few applications to streams (lakes more common); insufficient fish tissue data to compare with model results
Acceptable costs: ▪ Need for long-term model support ▪ Useful for other TMDLs and studies	Lowest cost, minimal need for updates; easily converted for any constituent	Already developed and applied in CCW; can be adapted to simulate most constituents	VCWPD may support for flood control and stormwater purposes; could guide future monitoring to fit model input requirements; simulates most constituents	Food web changes over time would need to be monitored; different biota issues for other TMDL constituents

6.1.1 Selected Modeling Approach

The National Research Council (2001) provides some guidance for determining the appropriate level of complexity: "There is a common belief that the expected realism in the model can compensate for a lack of data, and the complexity of the model gives the impression of credibility. Starting with simple analyses and iteratively expanding data collection and modeling as the need arises is the best approach." The selected numerical modeling approach is summarized as follows:

- Set up Type 1 models for the six major subwatershed watershed features: Arroyo Simi, Arroyo Las Posas, Conejo and Calleguas Reaches, Revolon Slough Drainage, and Mugu Lagoon.
- Simulate using a day time step.
- Use the Dynamic Calleguas Creek Modeling System (DCCMS) to generate runoff and in-stream flowrates.
- Develop input loads and concentrations for major sources from available runoff quality data.
- Assume equilibrium conditions for partitioning between dissolved and adsorbed fractions.
- Simulate water column concentrations in creeks as compartments of the box models.
- Validate model performance to the extent possible with in-stream monitoring data.

As the selected model is a Type 1 mass balance approach, a spreadsheet program is used to create the model.

6.2 *Model Description*

The framework for the CCW Toxicity TMDL modeling effort is a spreadsheet-based mass balance water quality model. The model, dubbed the Toxicity TMDL Mass Balance Model (TTMBM), utilizes the flowrate calculations and precipitation data processing of the Dynamic Calleguas Creek Modeling System (DCCMS) developed in support of the Calleguas Creek Salts TMDL Work Plan (LWA, 2004b). A detailed description of the TTMBM is provided in Attachment A.

To model the desired constituents in the CCW, the entire watershed is divided into six subwatersheds based on the major drainages within the watershed, specifically: Arroyo Simi, Arroyo Las Posas, Conejo and Calleguas Reaches, Revolon Slough Drainage, and Mugu Lagoon. The subwatersheds are displayed in Figure 27.

Table 48 provides general information on the TTMBM subwatersheds. Each subwatershed is considered a single complete-mix computational element for determining in-stream flow and calculating the water quality due to processes present along stream reaches circumscribed by the subwatersheds.

Table 48. Toxicity TMDL Mass Balance Model Subwatershed Description

Subwatershed	TMDL Reaches	POTWs	Area		Perimeter mi.
			acres	sq. mi.	
Arroyo Simi	7, 8	Simi Valley WQCP Moorpark WRP	82,951	129.6	66.5
Las Posas	Upper 6	–	21,570	33.7	31.2
Conejo Creek	9B, 10, 11, 12, 13	Hill Canyon WWTP Olsen Rd. (1)	46,812	73.1	49.5
Calleguas Creek	2, 3, Lower 6, 9A	Camarillo WRP Camrosa WRP	17,239	26.9	35.5
Revolon Slough	4, 5	–	39,466	61.7	47.3
Mugu Lagoon	1	–	11,924	18.6	32

1 Olsen Rd decommissioned in 2002, all flow currently diverted to Hill Canyon.

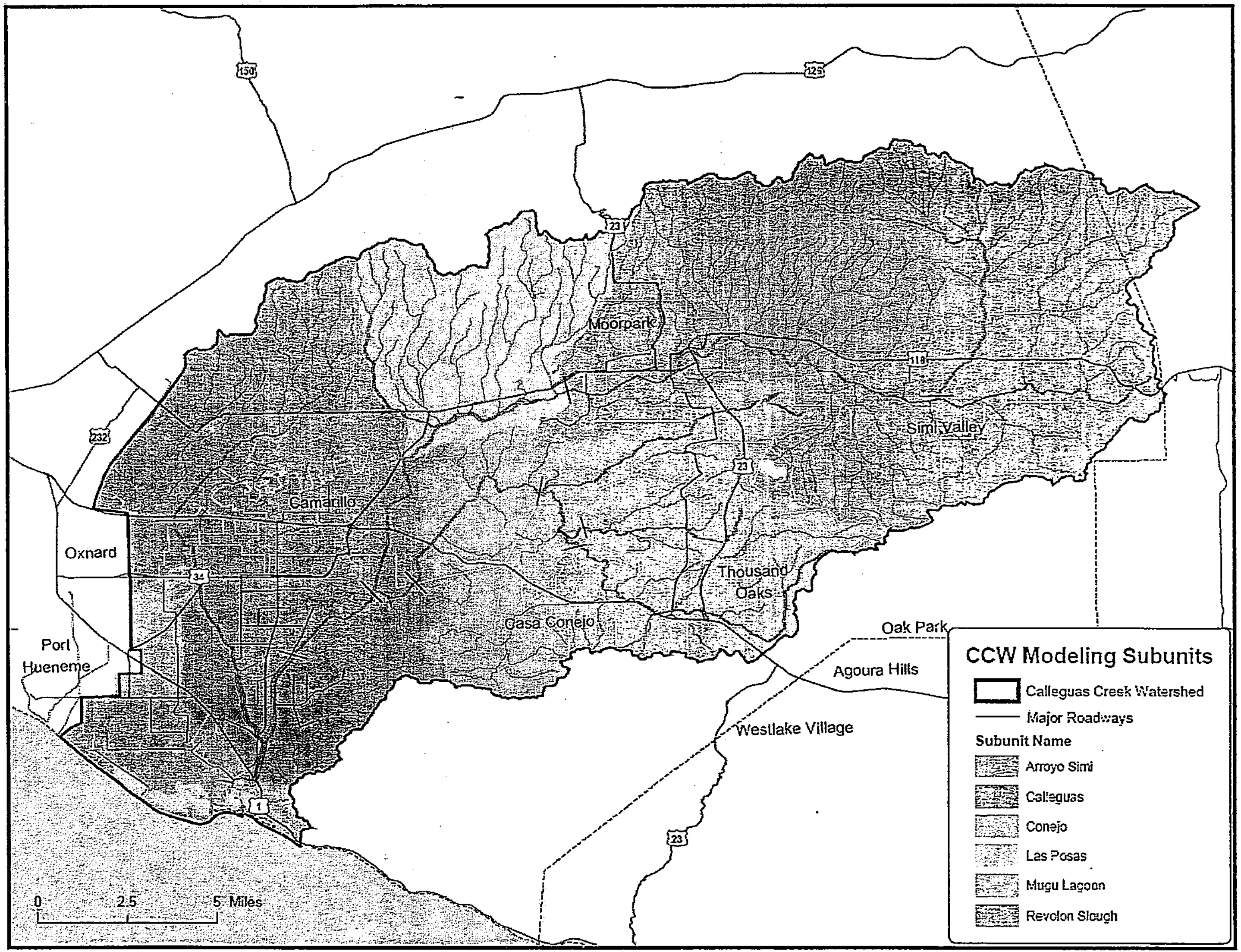


Figure 27. Subwatershed definition sketch for the Toxicity TMDL modeling effort.

Land-use patterns for each of the TTMBM subwatersheds are presented in listed in Table 49. In the Table, the areas of native (undeveloped), agricultural, and urban land uses are listed in terms of percentages of the subwatersheds, percentages of the total land use in the entire CCW, and the actual areas in acres and square miles for each subwatersheds. The calculations are based on the Department of Water Resources 2000 land use GIS data. Based on the information in Table 49, the Arroyo Simi Subwatershed encompasses a total of 82,951 acres (129.6 sq. mi.), and is 72.6% covered with undeveloped native land which is 55.8% of the total native land in the entire CCW.

Table 49. Land Use in Each TTMBM Subwatershed

Subwatershed	Land Use	Percent of Sub-watershed	Percent of Land Use in CCW	Area [1]	
				Acres	Sq. mi.
Arroyo Simi	Native	72.6	55.8	60,243	94.1
	Agriculture	3.6	5.2	2,958	4.6
	Urban	23.8	35.8	19,749	30.9
	Total	100.0	37.7	82,951	129.6
Las Posas	Native	41.8	8.4	9,018	14.1
	Agriculture	54.5	20.6	11,751	18.4
	Urban	3.7	1.5	800	1.3
	Total	100.0	9.8	21,570	33.7
Conejo Creek	Native	47.3	20.5	22,165	34.6
	Agriculture	7.8	6.4	3,657	5.7
	Urban	44.8	38.1	20,990	32.8
	Total	100.0	21.3	46,812	73.1
Calleguas Creek	Native	42.4	6.8	7,315	11.4
	Agriculture	40.2	12.2	6,926	10.8
	Urban	17.4	5.4	2,998	4.7
	Total	100.0	7.8	17,239	26.9
Revolon Slough	Native	12.6	4.6	4,965	7.8
	Agriculture	66.5	46.1	26,260	41.0
	Urban	20.9	14.9	8,240	12.9
	Total	100.0	17.9	39,466	61.7
Mugu Lagoon	Native	35.1	3.9	4,187	6.5
	Agriculture	45.1	9.4	5,374	8.4
	Urban	19.8	4.3	2,363	3.7
	Total	100.0	5.4	11,924	18.6
Whole CCW	Native	49.1	100.0	107,894	168.6
	Agriculture	25.9	100.0	56,926	88.9
	Urban	25.1	100.0	55,141	86.2
	Total	100.0	100.0	219,961	343.7

1 As per Department of Water Resources, 2000

6.3 *Data Used in Model*

Limited data set size and scatter has a great influence on the model development and validation. A summary of data available in the CCW by TTMBM Subwatershed is presented in Table 50. The number of chlorpyrifos and diazinon samples collected by runoff or receiving water type and the percent detected are listed in the table. Detection levels for the majority of chlorpyrifos samples are too high to be environmentally relevant (i.e. the detection limit is higher than applicable water quality criteria). Environmentally relevant detection levels for diazinon are utilized on a far greater percentage of samples than chlorpyrifos.

Data summaries for receiving water data that could be used for validation are listed in Table 51. To further limit the usefulness of the data, several subwatersheds only have detected data corresponding to dry-weather sampling, meaning the wet-weather performance of the model is unverifiable for several subwatersheds. A minimum of three unique detected data and more than 20% of all data must be detected to perform statistical analysis on the data set as per the ROS method, discussed previously in this document (Helsel, 1990). Most of the runoff and receiving water data sets available contain less than 40% detected values. Statistics generated from data sets with less than 40% detected values are considered estimates and are subject to error. Please see the Environmental Data Used section of the Current Conditions and Source Analysis sections for a more detailed discussion of the data used in this TMDL.

Because of limited available data, grab and composite samples are treated in the analysis as equivalent and equally representative of the sampled water, also estimated and qualified data are used as normal detected values. Both uses of the data may introduce errors into the analysis, as grab samples may not be equivalent to composite samples and may not be representative of the targeted source type, and estimated values, while being a better estimate of the true value than the reporting limit, may not reflect the true value in the water accurately. In the TTMBM, it is assumed the receiving water data are representative of surface waters in the entire subwatershed. A related simplifying assumption is that it is assumed the agricultural runoff and urban characterization sites are representative of all like land uses everywhere across the CCW.

Sampling conducted through the TMDL Work Plan Monitoring Plans (LWA, 2004a) helped increase the robustness of the data set used to develop the model. However, many of the above qualifications on the TTMBM can only be removed through continuing monitoring efforts using environmentally relevant detection limits (i.e. the detection limit is higher than applicable water quality criteria).

Table 50. Chlorpyrifos and Diazinon Data Summaries by Source Type in CCW

Source	**Chlorpyrifos**		**Diazinon**	
	n	**% Detected**	**n**	**% Detected**
Agricultural Runoff	75	37.3%	66	22.7%
Urban Runoff (1)	47	10.6%	50	54.0%
Pumped Groundwater	4	0.0%	4	0.0%
Effluent Discharge	18	5.6%	19	36.8%
Receiving Water	213	25.8%	239	45.2%

1 Some samples from out-of-watershed characterization site.

Table 51. Available Chlorpyrifos and Diazinon Data for Receiving Waters by Modeling Subwatershed

Subwatershed	Reaches	Chlorpyrifos		Diazinon	
		n	n Detected	n	n Detected
Mugu Lagoon	1	3	1	3	0
Revolon Slough	4, 5	54	33	54	20
Calleguas Creek	2, 3, 9A	52	10	57	32
Conejo Creek	9B, 10 -13	55	3	73	29
Las Posas	6	10	3	10	6
Arroyo Simi	7, 8	39	5	42	21

6.4 *Computational Element*

Each subwatershed is considered one distinct computational element where the inflow and outflow of water and mass are balanced across the subwatershed with conservation equations to calculate changes in in-stream flow and concentration in the receiving water. Over each time step, the stream reach within any subwatershed is assumed to behave as a steady-state complete-mix system. Each day of the simulation is treated as a distinct water quality calculation driven by the flows calculated by the DCCMS. Because of the relatively short reach length, stream geometry, and daily time step; flows can be considered in equilibrium on a daily basis. Assuming that each day is in equilibrium, precludes modeling the routing of peak flows through the CCW; however, the total volume of storm generated flows can be modeled. Assuming that each subwatershed behaves as a complete-mix system implies the in-stream concentration is constant at all locations within a subwatershed (Tchobanoglous and Schroeder, 1985). Because the concentration is modeled as constant for the entire subwatershed, all withdrawals from the reach, including the discharge to the downstream reach will have the same concentration by definition. A schematic of the computational element is displayed in Figure 28 with inputs and outputs displayed with an arrow pointing into the reach for additions, and pointing out from the reach to represent withdrawals. In Figure 28, flows from upstream reaches enter from the right and flow to downstream reaches exit to the left. Scour and deposition, sorption and desorption, sediment content, and direct atmospheric deposition are not currently included in the TTMBM.

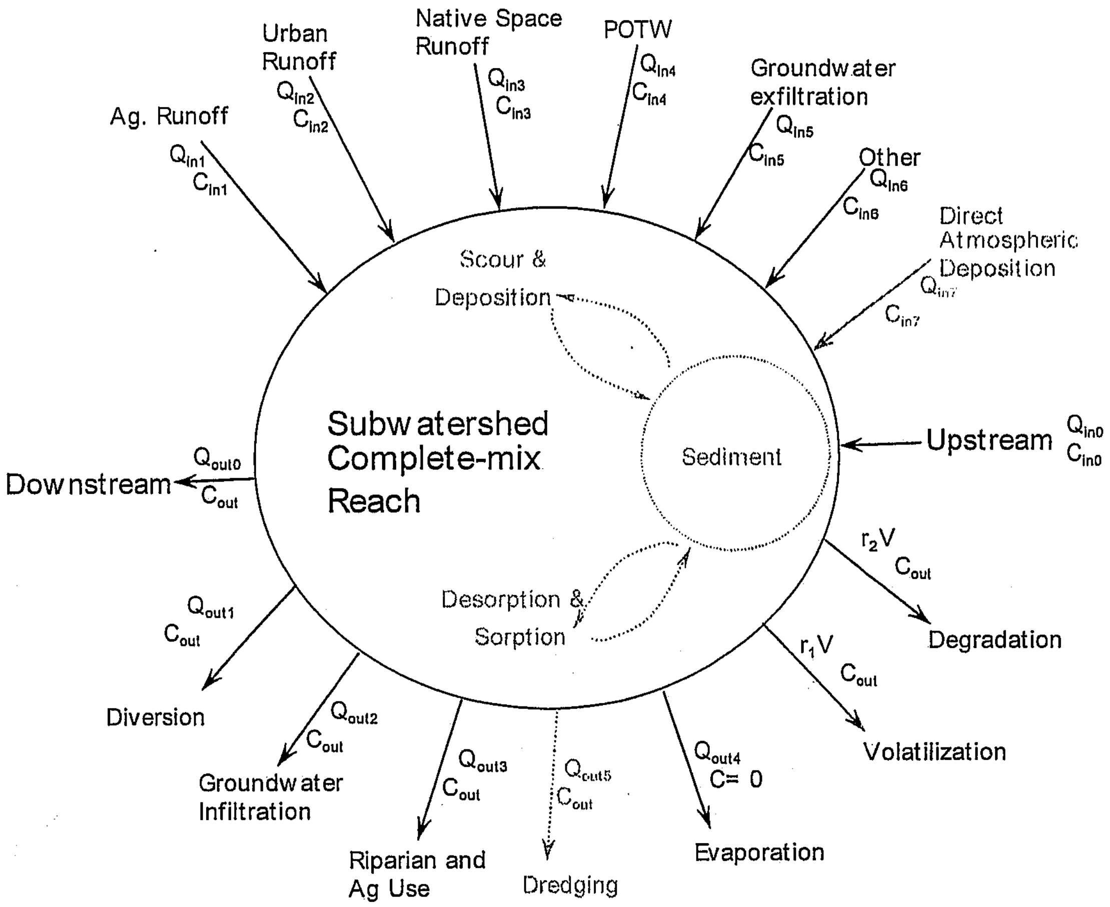


Figure 28. Schematic of inputs and outputs for a general computational element used in the CCMS mass balance model to estimate water flow and quality within surface water reaches. Direct atmospheric deposition, sediment interaction, and dredging are not included in the current version of the TTMBM.

6.4.1 Mass Balance Calculations

To calculate the stream discharge flow and in-stream concentration for a computational element, all inflow rates and concentrations must be specified along with all other withdrawals from the reaches. Each of the daily time steps is assumed to be steady-state. By making the steady-state assumption the ability to model peak flood routing is lost; however because of the relatively small size of the CCW, a smaller time step than one day would be required to capture a flood wave moving through the watershed.

6.4.2 Upstream Subwatersheds

Inflow and mass loading from the upstream subwatershed are added as inputs to the computational element. If the subwatershed is located at the top of a stream's drainage, there will be no upstream subwatershed and the TTMBM will assign a zero value for the flow and mass loading. If multiple upstream subwatersheds contribute to the computational element, the sum of the upstream outflows and sum of the mass loadings are considered.

6.4.3 Subwatershed Inflows of Constituents

Possible inflows considered in the model were: agriculture returns, urban runoff, native runoff, POTWs, groundwater exfiltration, and any other flows.

6.4.3.1 Agriculture Returns to Computational Elements

Agricultural runoff flowrate is calculated via the rational method within the DCCMS. Dry weather runoff is calculated using an average flow per unit area of agriculture land. Wet weather runoff is calculated by multiplying precipitation over the subwatershed by a runoff coefficient and agricultural land fraction of total area. Provisions are included in the DCCMS model to mimic tailing of runoff following precipitation events. For the CCW, only large rain events will cause appreciable, increased in-stream flow for more than one day. In general, the Revolon Slough Subwatershed produces the greatest amount of agricultural runoff, followed by the Las Posas Subwatershed. The Revolon Slough Subwatershed contains the bulk of the agricultural runoff data. Data from all agricultural runoff sites across the entire CCW are aggregated to determine characteristic concentrations of chlorpyrifos and diazinon in the return flows. Assuming that any individual sample is representative of agricultural runoff from any given location in the CCW, the concentration measurements may be paired with the DCCMS calculated agricultural runoff flows to determine loading. Specifically, the calculated agricultural runoff flowrate for the entire Revolon Slough Subwatershed is used to calculate the load from agricultural runoff to Revolon Slough.

In analyses conducted by Stow and Borsuk (2003) and Keller et al. (2004), a power curve was used as a regression for the data. A power relationship describes the change in loading for increasing runoff flowrate, because both changes in concentrations and flows are accounted for in the regression. The results of regressions for chlorpyrifos and diazinon loads in agricultural runoff against runoff flowrate are presented in Figure 29. By definition, the regression equation is the best fit through all the available data. For acute effects, it is more desirable to approximate the peaks in the data.

To provide an estimate of the upper bound to the scatter in the data, the upper 90th percentile prediction level of the regression is used to estimate pesticide loading. Statistically, the 90th percentile prediction interval represents the range where 9 out of 10 (90%) new measurements would fall. The 1 of 10 new measurements plotting outside the prediction interval are equally likely to be above the upper level or below the lower level, so the upper prediction level estimates the maximum of 95% of new measurements. The prediction intervals are calculated for any one additional measurement using standard statistical methods (Neter, et al. 1990). Because the prediction level is determined by an equation based on the regression parameters that would be cumbersome to incorporate into the TTMBM, a power curve is fit to the upper prediction level equation. As can be seen in Figure 29, the power curve fitted to the upper prediction represents the upper bound to the chlorpyrifos and diazinon loads for a large portion of the dataset. Agricultural runoff contribution to in-stream flowrates can exceed 1,000 cfs for the TTMBM subwatersheds. However, the limited range of available water quality data is evident in Figure 29. Figure 29 shows there are only water quality data for samples collected at agricultural runoff sites when the agricultural contributions to in-stream flowrates are less than 200 cfs.

Given the agricultural runoff flowrate in cfs, Equation 2 and Equation 3 are the fitted equations used in the TTMBM (as displayed in Figure 29) to determine the agricultural runoff loads for chlorpyrifos and diazinon in pounds/day, respectively.

Equation 2 $\text{Load}_{\text{ag runoff}}^{\text{chlorpyrifos}} = 0.00231 \cdot Q_{\text{ag runoff}}^{1.310}$

$Q_{\text{ag runoff}}$ = total agricultural runoff flowrate for a subwatershed (cfs)

Equation 3 $\text{Load}_{\text{ag runoff}}^{\text{diazinon}} = 0.00127 \cdot Q_{\text{ag runoff}}^{1.052}$

$Q_{\text{ag runoff}}$ = total agricultural runoff flowrate for a subwatershed (cfs)

In general, chlorpyrifos concentrations appear to increase with increasing daily precipitation, and diazinon concentrations appear to remain relatively constant, however neither regression is well correlated and both are heavily influenced by high concentration light precipitation or low concentration heavy precipitation events.

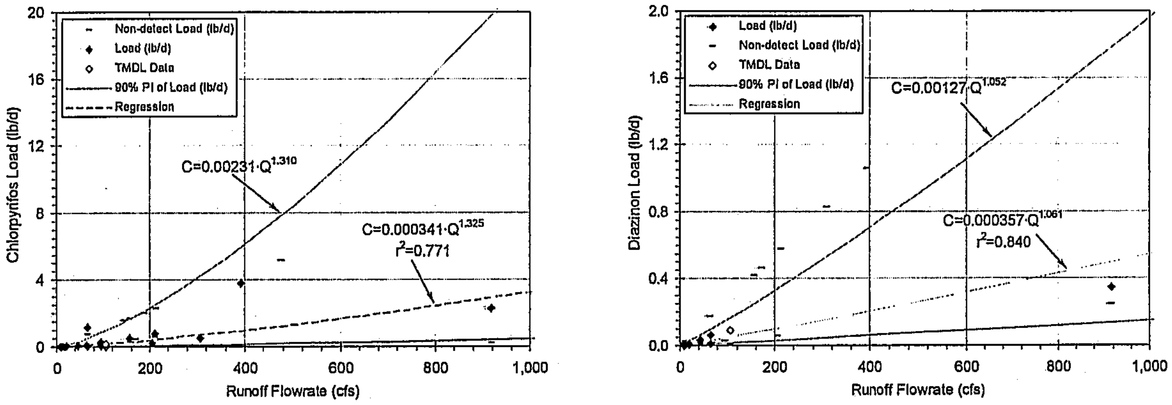


Figure 29. Chlorpyrifos and diazinon load in agricultural runoff as a function of flowrate. Dashed line represents the regression of data and the solid line is a fit to the upper 95th percentile confidence level of the regression. The solid line represents the loading used in the TTMBM.

6.4.3.2 Urban Runoff to Computational Elements

To the extent possible, urban runoff has been analyzed akin to the agricultural runoff. Many of the details discussed above apply to the urban runoff, but have not been repeated in the interest of brevity. Urban runoff is calculated as a mix of runoff from residential, commercial, and industrial land uses. Urban runoff is relatively poorly characterized with data, as indicated by the minimal data presented in the Source Analysis section. The Arroyo Simi and Conejo Subwatersheds produce the greatest amount of urban runoff as they contain a significant amount of urbanized area (Table 49).

As mentioned in the Source Analysis section, chlorpyrifos and diazinon data for urban runoff were collected at selected characterization sites located in Ventura County; however, not all of sites are located in the CCW. It is assumed the characterization sites are representative of all urban sites in the CCW.. The chlorpyrifos and diazinon loads as a function of urban runoff flowrate are displayed in Figure 30. In Figure 30, the regression to the data is displayed as a dashed line, and the power curve fit to the 90 percent prediction level of the regression is displayed as a solid line. The 90 percent prediction level is used in the TTMBM to estimate peaks in loadings to the receiving waters.

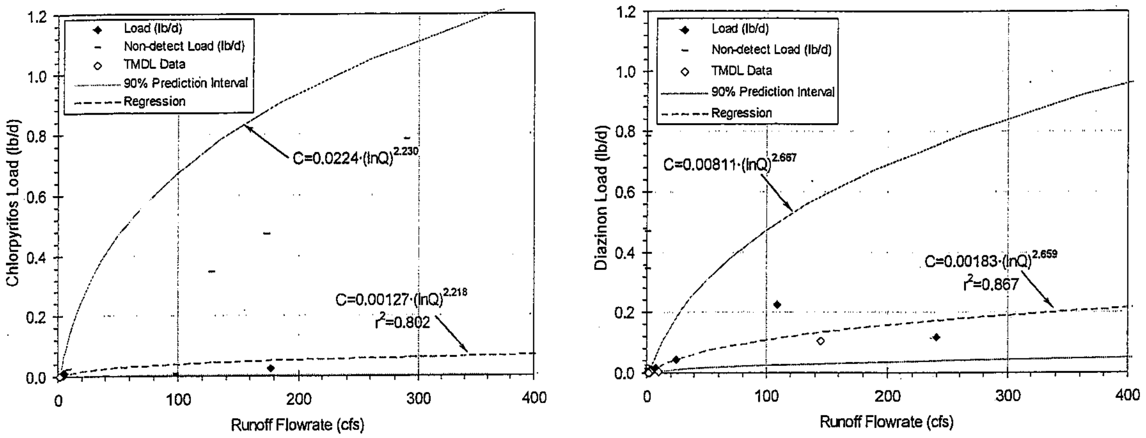


Figure 30. Chlorpyrifos and diazinon load in urban runoff as a function of flowrate. Dashed line represents the regression of data and the solid line is a fit to the upper 90th percentile prediction level of the regression. The solid line represents the loading used in the TTMBM.

While concentrations of chlorpyrifos and diazinon appear to decrease with increasing precipitation, the scatter in the data and limited number of data preclude making a definitive judgment. In-stream diazinon in urban dominated areas is characterized by linear or super-linear (the exponent on the runoff flowrate is greater than 1.0) load as a function of flows leading to the assumption that the urban runoff follows at least a linear relationship. The urban runoff chlorpyrifos and diazinon concentration data are available only for relatively light storms. If data were available for larger storms, a more definitive relationship could be determined. Given the urban runoff flowrate in cfs, Equation 4 and Equation 5, are used in the TTMBM to determine urban runoff loads for chlorpyrifos and diazinon in pounds/day, respectively.

Equation 4

$$\text{Load}_{\text{urban runoff}}^{\text{chlorpyrifos}} = 0.0224 \cdot ln\left(Q_{\text{urban runoff}}\right)^{2.230}$$

$Q_{\text{ag runoff}}$ = total agricultural runoff flowrate for a subwatershed (cfs)

Equation 5

$$\text{Load}_{\text{urban runoff}}^{\text{diazinon}} = 0.00811 \cdot ln\left(Q_{\text{urban runoff}}\right)^{2.667}$$

$Q_{\text{ag runoff}}$ = total agricultural runoff flowrate for a subwatershed (cfs)

6.4.3.3 Native (Open Space) Runoff to Computational Elements

The runoff from native areas of vacant, undeveloped, open space is calculated in a manner similar to urban runoff. As no information is currently available describing the native runoff chlorpyrifos or diazinon concentrations or loads in the CCW, the loads for chlorpyrifos and diazinon are calibrated to adjust the TTMBM output to better fit in-stream loads. Because the agriculture, urban, and POTW loads account for essentially all of the in-stream chlorpyrifos and diazinon loads, a detailed calibration of native runoff is unwarranted from a modeling perspective. However, the atmospheric deposition to native open space lands will determine the appropriate implementation action.

6.4.3.4 POTW Inflows to Computational Elements

For the DCCMS, effluent monitoring data from the treatment plants are used to develop statistical descriptions of the effluent flowrate. As described in the Source Analysis section, few data exist characterizing chlorpyrifos and diazinon in POTW effluent. Although use of these pesticides in the urban environment has decreased and in turn, their concentrations in POTW effluent have likely decreased, there is no clear way to adjust the available data to estimate current concentrations. To address the lack of data the effluent concentrations of chlorpyrifos and diazinon for each POTW are set in the TTMBM to the values of 0.05 μg/L, and 0.2 μg/L, respectively. Both values are determined by selecting concentrations in the range of measured values and matching dry weather TTMBM calculated loadings to the measured in-stream values. Multiplying the constant concentration by the DCCMS calculated effluent flowrate is used to determine the loading of chlorpyrifos and diazinon from each POTW to the surface waters in the CCW.

6.4.3.5 Groundwater Inputs to Computational Elements

Groundwater exfiltration and groundwater dewatering discharges are included under the general heading of groundwater inputs. Currently, the only dewatering wells included in the model are located in the Simi Valley Subwatershed. The groundwater flows in the Simi Valley are largely due to continuous pumping to lower the groundwater table. From a modeling perspective, the dewatering well discharges provide baseflow to the stream in an equivalent manner to the natural exfiltration of groundwater. Because available information indicates there is no chlorpyrifos or diazinon load associated with groundwater exfiltration, TTMBM loads are set to zero for groundwater contributions to the stream.

6.4.4 Subwatershed Outflows

Possible withdrawals or outflows from the CCW reaches include groundwater infiltration and diversions, agricultural use, and evaporation. First order degradation (combination of microbial and hydrolysis reactions) and volatilization from the surface waters are included in the TTMBM for both chlorpyrifos and diazinon. However, as the rates are small in comparison to the hydrologic movement through the watershed, the degradation and volatilization do not greatly affect loadings in receiving waters. Because of the complete-mix assumption, the concentration in each of the outflows is equal to the concentration calculated in the reach that is discharged to downstream subwatersheds.

6.4.4.1 Groundwater Infiltration from Computational Elements

Substantial groundwater infiltration occurs in the northern CCW and in the Conejo Creek region and are accounted for in the DCCMS. The infiltration rate is checked internally by the DCCMS to ensure negative flowrates are not produced if the streambed becomes dry. Infiltration removes a load of the constituents from the stream.

6.4.4.2 Riparian Vegetation Demand from Computational Elements

Riparian water demand is estimated in the DCCMS using the evapotranspiration rate and stream-side agricultural and vegetative area. Because the water is drawn from the stream before evaporating, constituents are carried from the stream to the root-zone. Constituents may accumulate in the root zone and would be subject to leaching back into the stream with baseflow; however, the back leaching is not included in the model.

6.4.5 Sediment Interactions

For the purposes of the Toxicity TMDL, sediment may either be suspended in runoff or in receiving waters, or the benthic stream bottom. Diazinon does not preferentially bind to soils and while sediments containing diazinon carried to receiving waters in runoff may be an important transport mechanism, the diazinon will tend to partition into the water phase. Runoff containing sediment and chlorpyrifos are an important transport mechanism to receiving waters. Water column chlorpyrifos (in the dissolved fraction) will interact with suspended and benthic sediments to approach equilibrium, increasing sediment content when water column concentrations are high, and acting to increasing the water column concentration when sediment contents are high. The particular thresholds of low and high are dependent on the sediment composition, organic matter present, etc. The size of colloids overlap the operational definition of suspended sediments and dissolved materials, however for the purposes of the Toxicity TMDL, the sorption of pesticides to colloids is thought to be operationally equivalent to sorption to suspended solids.

An important question that needs to be addressed by this TMDL is whether the numeric targets established are protective of all sensitive ecosystem endpoints. Because sediment quality objectives have not been established by the State of California, there is uncertainty as to what concentrations of chlorpyrifos in sediments are threats to beneficial uses. A review of the literature shows effect levels for benthic invertebrates in the range of 40 – 80 ug/kg. The lowest no-observable effect level found in the literature was 10 ug/kg (Callaghan, 2001). So it is important to ask whether attaining the proposed chronic water quality criteria based numeric target (0.014 ug/L) will ensure that sediments in Calleguas Creek watershed are below 10 ug/kg.

A simple thought experiment demonstrates that the water column targets assure attainment of 10 ug/kg chlorpyrifos in sediments. In the thought experiment (Figure 31), a beaker is filled with 1-liter of highly purified water. The TSS is zero, and the chlorpyrifos concentration is zero. 100 mg of sediments containing 10 ug/kg chlorpyrifos are added to bring the TSS up to 100 mg/L. The resulting chlorpyrifos concentration in the beaker is 0.001 ug/L:

(100 mg sed) x (10^{-6} kg sed / mg sed) x (10 ug chlorpyrifos / kg sed) / 1 L = 0.001 ug/L

Note that it doesn't matter whether or not the chlorpyrifos remains bound to the particles – the total (i.e., unfiltered) chlorpyrifos concentration in the beaker of water will be the same, regardless of adsorption and desorption. Note also that this experiment mimics a process known to occur in the watershed: soils and sediments carrying chlorpyrifos are eroded into surface waters, where they increase the water column total chlorpyrifos concentration.

By the same logic, adding 2000 mg sediment with a chlorpyrifos concentration of 10 ug/kg will bring the concentration in the beaker up to 0.02 ug/kg. This thought experiment can be repeated at different chlorpyrifos levels in sediments, as shown in Figure 32. Given that reaches of the Calleguas Creek watershed often have TSS levels exceeding 1000 mg/L, the conclusion of Figure 32 is that attainment of the 0.014 ug/L water column target is only possible at all relevant TSS concentrations if the concentration of sediments in the Calleguas Creek watershed is less than 10 µg/kg. Therefore, adopting the numeric target of 0.014 ug/L establishes an implicit margin of safety for protection of beneficial uses due to exposure to contaminated sediments.

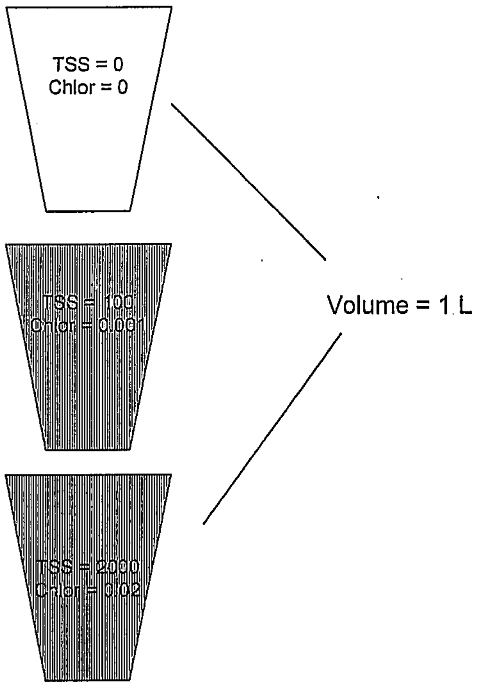


Figure 31. Conceptual illustration of a thought experiment to evaluate how chlorpyrifos in sediments transported to State Waters affects water column concentrations.

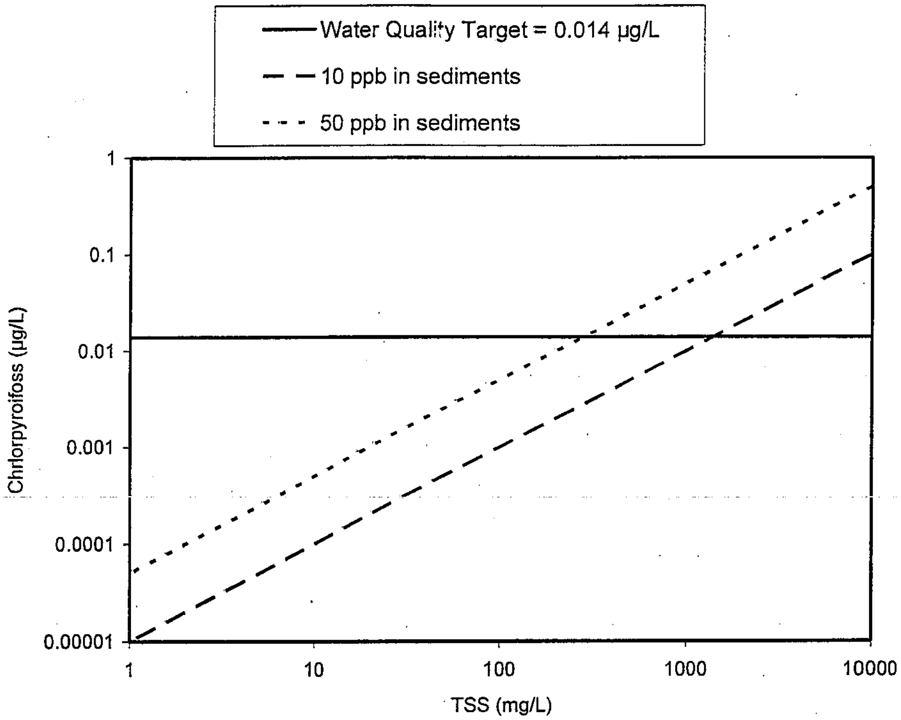


Figure 32. Comparison of how the presence of suspended sediments with 10 µg/kg chlorpyrifos (long dashes) and 50 µg/kg (short dashes) affect water quality compared to the proposed numeric target of 0.014 µg/L (solid line). Note that attainment of the water quality target at all relevant TSS concentrations (up to 2000 mg/L or more) would require sediment with less than 10 µg/kg chlorpyrifos.

Currently, only total concentrations of chlorpyrifos and diazinon are considered in the TTMBM, and there is no distinction between dissolved or particulate fractions. Because the total load of chlorpyrifos and diazinon are calculated by the TTMBM, the sediment associated load to receiving waters is implicitly included in model estimates. The use of total measurements is a conservative utilization of information in that the particle sorbed fraction is likely less toxic than the dissolved fraction. Using the total concentration implicitly assumes that all measured chlorpyrifos and diazinon will equally exert toxicity on aquatic organisms. The transfer between water column and sediment in-stream is not considered in the TTMBM.

6.5 *Degradation and Other Processes*

Degradation of pesticides occurs primarily through the reactions of photolysis and hydrolysis, as well as biodegradation through microbial metabolism. Volatilization is the conversion of a chemical substance from the solid or liquid state to the gaseous or vapor state. This term is often used synonymously with vaporization. Photolysis involves the breakdown of chemicals by the radiant energy of light. Two general modes of photolysis act on pesticides: direct photolysis in which the compound itself absorbs light energy, and indirect or sensitized photolysis by which intermediate compounds, such as hydroxyl radicals, absorb light energy to initiate a breakdown process. Natural conditions that scatter or absorb light affect photolysis rates. Hydrolysis involves a reaction in which a molecular bond is cleaved and a new bond is formed with the hydrogen or hydroxide ion components of a water molecule. Temperature and pH of the water influence this reaction rate. Abiotic or biological oxidation and reduction reactions can also degrade pesticides.

A description of these processes as well as how they are handled in the model is presented below.

6.5.1 Volatilization

Evaporation of water from the reaches is calculated in the DCCMS and used by the TTMBM based on the evaporation rate data multiplied by the estimated water surface area, and is strictly the evaporative loss from the stream surface. Evaporation from the stream surface only removes water from the system thereby increasing the in-stream concentration.

Volatilization of pesticides from soil and water is both a sink (from where it volatilizes) and a source (to the atmosphere, from where it may redeposit) in the watershed. Both diazinon and chlorpyrifos have relatively small Henry's coefficients, and therefore do not tend to volatilize excessively. Dimensionless Henry's coefficients (*H'*) representing the ratio of atmospheric concentration to water concentration range for chlorpyrifos from $1.4 \cdot 10^{-10}$ to $2.7 \cdot 10^{-7}$ (0.0041 to 7.9 $Pa \cdot m^3/mole$) and for diazinon from $2.7 \cdot 10^{-10}$ to $5.6 \cdot 10^{-9}$ (0.011 to 0.14 $Pa \cdot m^3/mole$).

Mackay *et al.* (1997) estimates the half-life volatilization of chlorpyrifos to be nine days for one meter deep streams, which converts to 8.9×10^{-7} m/s. The authors could not find estimates of diazinon volatilization from water. As such, the chlorpyrifos volatilization rate from water is used as the diazinon volatilization rate from water in the TTMBM. This was not expected to have an effect on TTMBM output. Both chlorpyrifos and diazinon have similarly low *H'* values and are considered to be essentially nonvolatile from water. Additionally, the residence time of surface water in the watershed is significantly lower than the volatilization inputs into the TTMBM.

Once volatilized, pesticides may be subject to drift during or following application. Pesticides in drift may enter surface waters directly via atmospheric deposition, or, once deposited in the terrestrial environment, they may be washed off surfaces during rainfall/runoff events. Volatilized chlorpyrifos and diazinon particles can collect in condensed rain droplets that make their way back to surface waters far from the point of application (Hill, 1995). Drift of chlorpyrifos and diazinon is not incorporated into the TTMBM. However, the relatively low vapor pressures of both diazinon and chlorpyrifos are the reason for minimal volatilization from surface waters.

6.5.2 Degradation Processes in Water

Chlorpyrifos is relatively insoluble in water, and hydrolysis and photolysis in the aquatic environment are not considered to be significant degradation processes. Hydrolysis increases significantly under alkaline conditions (USEPA, 1999). Mackay *et al.* (1997) lists the half-life degradation rate in non-sterile water to range from 12 to 27 days. A value in the middle of the range is used in the TTMBM, 16.7 days which equals a first order degradation rate of 4.7×10^{-7} 1/s.

Diazinon is moderately soluble in water. Hydrolysis and microbial breakdown are reportedly the principal degradation processes for diazinon in water, with photolysis potentially significant as well (Ogle, 2004). In water, diazinon is stable at pH 7 and pH 9, but hydrolyzes in non-sterile water at a pH of 5 (USEPA, 1988), with a resulting half-life of 12 to 14 days. For neutral or basic conditions, diazinon half-lives are reported to range from 54.6 to 138 days (Giddings, *et al.,* 2000). For river water of pH 7.4, Mackay *et al.* (1997) lists the half-life of diazinon to be 185 days (first order rate of 4.3×10^{-8} 1/s) which is the value used in the TTMBM.

6.5.3 Processes in Soil/Sediment

The tendency for a pesticide to adhere to particles or organic matter can be estimated from its octanol-water and organic carbon-water partition coefficients (K_{OW} and K_{OC}); higher coefficients correspond to greater propensity to adsorb. The organic carbon partitioning coefficient (K_{OC}) is the most common value used to evaluate a chemical's adsorption onto particles. K_{OC} measures the "strength" with which a compound sorbs to organic material, including organic coating on sediments, plant and animal detritus, and lipids in organisms. The octanol-water partitioning coefficient (K_{OW}) provides a measure of a compound's tendency to partition into non-aqueous or oily phases rather than dissolve in water.

Diazinon binds only moderately to soil and sediment (K_{OW} 2000 and K_{OC} ~1000-1800), and is moderately soluble in water (mean water solubility of 40 mg/L at 20° C) (Ogle, 2004). Diazinon is subject to relatively rapid degradation by microbial decomposition, with half lives in non-sterile soils of 1-5 weeks. On the soil surface, diazinon may be degraded by photolysis (Ogle, 2004). Diazinon degrades under sterile and anaerobic soil conditions by chemical hydrolysis in acidic soils (Giddings, *et al.,* 2000).

Chlorpyrifos is relatively insoluble in water (mean water solubility of 2 mg/L at 25° C), and adsorbs strongly to organic matter (log K_{OW} 4.70; mean K_{OC} 6070) (USEPA, 1999) indicating that chlorpyrifos is more likely than diazinon to become bound to sediment in the environment. Chlorpyrifos adsorbs fairly strongly to soil organic matter, and readily partitions to sediments in surface waters. Microbial metabolism is the principal degradation process, with hydrolysis potentially significant, particularly in alkaline conditions. Photolysis is not a significant degradation process in soil (USEPA, 1999). In experimental soil and surface applications, chlorpyrifos half-lives ranged from 33 to 56 days and 7 to 10 days, respectively (Fontaine *et al.,* 1987).

Soil degradation process and interactions between aquatic sediments and overlying water are not considered in the TTMBM.

6.5.4 Atmospheric Processes

When released to the atmosphere diazinon is readily degraded via photolysis. Both diazinon and chlorpyrifos may react with hydroxyl radicals in the atmosphere. Neither the mass of chlorpyrifos or diazinon are tracked through the atmosphere in the TTMBM.

6.5.5 Bioaccumulation

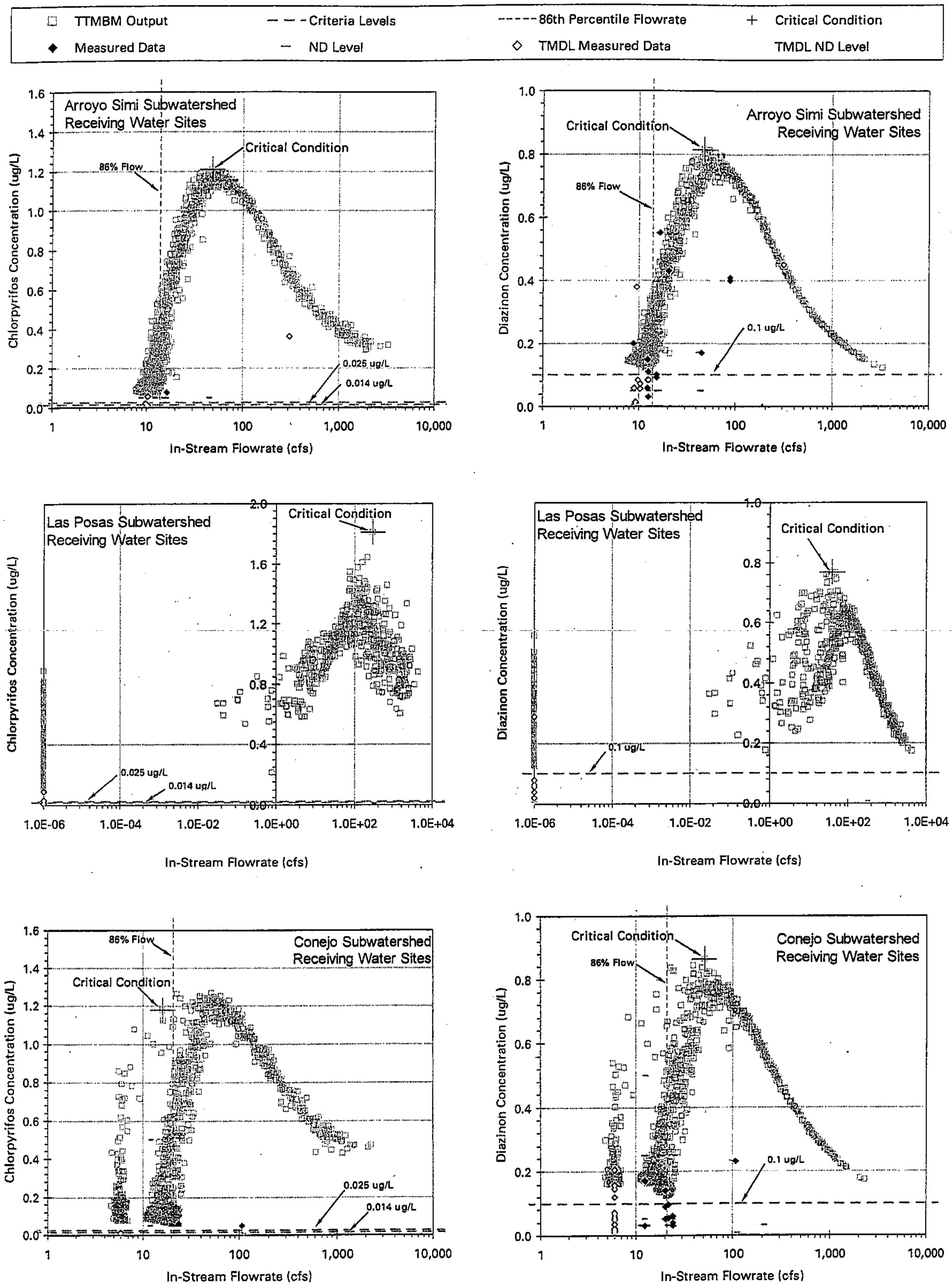
Both chlorpyrifos and diazinon bioaccumulate in freshwater fish, but tissue residues rapidly depurate (within several days of removal from exposure) for both chemicals (Ogle, 2004; USEPA, 1999). As such, it is assumed that reductions in water column concentrations will result in reductions in levels in fish tissue. Bioaccumulation is not explicitly included in the TTMBM.

6.6 *TTMBM Validation*

TTMBM output is compared to all available in-stream measurements of total chlorpyrifos and diazinon for each of the subwatersheds in Figure 33. Because of the conservative approach to model development and the goal of estimating the peak concentrations, the model output (open squares) in-general over predicts the measured data (solid diamonds). Each of the criteria is displayed on the figures, identifying the target levels. The 86th percentile flow for each subwatershed is superimposed on each plot as an estimate of the greatest non-stormwater flowrate. For validation, the TTMBM model output for calculated in-stream loads and concentrations are compared to measured in-stream values. Unfortunately, there are subwatersheds where insufficient in-stream data exist to make judgments of the TTMBM behavior. The following sections discuss TTMBM performance in relation to observed concentrations. Plots comparing available data to model output for each subwatershed are provided in Attachment A.

6.6.1 Arroyo Simi Subwatershed

TTMBM using the 90th percentile prediction intervals overpredicts the measured chlorpyrifos values. Diazinon calculations from the TTMBM match the observed data fairly well. Diazinon concentrations are under-predicted in some instances; however the peak calculated concentration exceeds all measured values. Arroyo Simi receiving water chlorpyrifos or diazinon data for high flow wet weather events is sparse, but the calculated values exceed the available measured values.



TTMBM Output
Criteria Levels
86th Percentile Flowrate
Critical Condition
Measured Data
ND Level
TMDL Measured Data
TMDL ND Level
Arroyo Simi Subwatershed Receiving Water Sites
86% Flow
Critical Condition
0.025 ug/L
0.014 ug/L
Chlorpyrifos Concentration (ug/L)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1
10
100
1,000
10,000
In-Stream Flowrate (cfs)
Arroyo Simi Subwatershed Receiving Water Sites
Critical Condition
86% Flow
0.1 ug/L
Diazinon Concentration (ug/L)
0.0
0.2
0.4
0.6
0.8
1.0
1
10
100
1,000
10,000
In-Stream Flowrate (cfs)
Las Posas Subwatershed Receiving Water Sites
Critical Condition
0.025 ug/L
0.014 ug/L
Chlorpyrifos Concentration (ug/L)
0.0
0.4
0.8
1.2
1.6
2.0
1.0E-06
1.0E-04
1.0E-02
1.0E+00
1.0E+02
1.0E+04
In-Stream Flowrate (cfs)
Las Posas Subwatershed Receiving Water Sites
Critical Condition
0.1 ug/L
Diazinon Concentration (ug/L)
0.0
0.2
0.4
0.6
0.8
1.0
1.0E-06
1.0E-04
1.0E-02
1.0E+00
1.0E+02
1.0E+04
In-Stream Flowrate (cfs)
Conejo Subwatershed Receiving Water Sites
86% Flow
Critical Condition
0.025 ug/L
0.014 ug/L
Chlorpyrifos Concentration (ug/L)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1
10
100
1,000
10,000
In-Stream Flowrate (cfs)
Conejo Subwatershed Receiving Water Sites
Critical Condition
86% Flow
0.1 ug/L
Diazinon Concentration (ug/L)
0.0
0.2
0.4
0.6
0.8
1.0
1
10
100
1,000
10,000
In-Stream Flowrate (cfs)

Continued

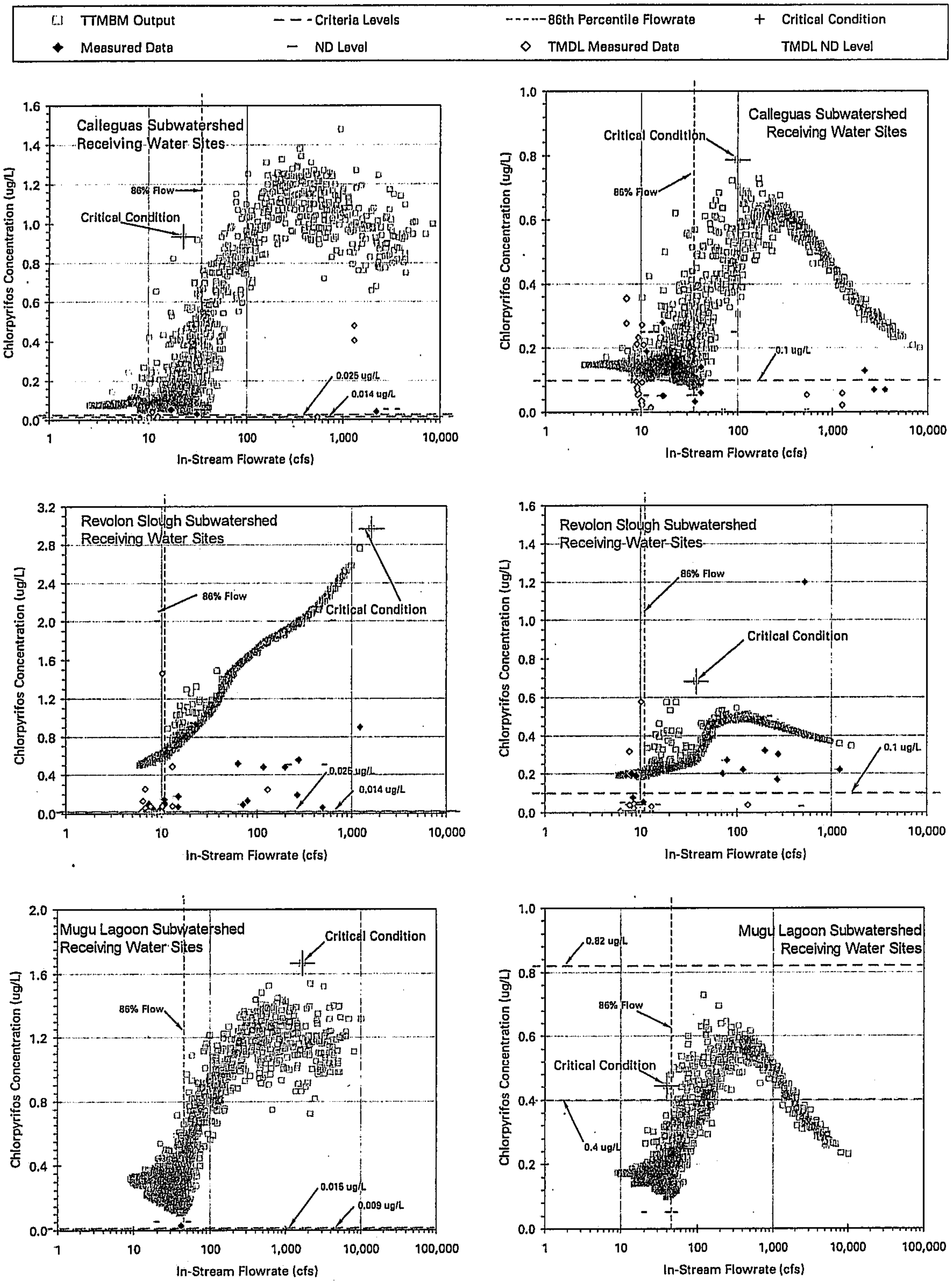


Figure 33. Measured receiving water chlorpyrifos and diazinon concentrations compared to TTMBM output. Note not all figures plotted on the same scale.

6.6.2 Las Posas Subwatershed

The available receiving water data in the Las Posas Subwatershed is more limited than for the Arroyo Simi Subwatershed, only dry weather (i.e. zero subwatershed discharge) chlorpyrifos and diazinon detected value are available for the subwatershed. TTMBM calculated chlorpyrifos and diazinon concentrations match runoff flow patterns and tend to increase substantially during wet-weather. A meaningful comparison of model performance to measured values is not possible due to limited data.

6.6.3 Conejo Subwatershed

The TTMBM over-predicts chlorpyrifos and diazinon loading in dry-weather. There are no available detected measurements for higher flow events. There are too few chlorpyrifos data for a meaningful comparison to TTMBM performance for wet or dry weather conditions. TTMBM matches the trend of available dry weather diazinon data and forms an envelope of peak concentrations.

6.6.4 Calleguas Subwatershed

As with the Conejo Subwatershed TTMBM output over-predicts chlorpyrifos and diazinon dry-weather loads. Wet-weather chlorpyrifos loads are significantly over-predicted. In dry-weather conditions, chlorpyrifos is slightly over predicted and TTMBM output matches trends in observed data. Wet-weather diazinon loads are over-predicted. Diazinon measurements are more scatted than chlorpyrifos during dry-weather, and TTMBM output bounds the measured values in most instances. The dry-weather behavior of most measurements being low with scattered instances of high dry weather concentrations are replicated by the TTMBM. Wet-weather values are over predicted due to the use of the 90th percentile prediction level loading rates. As is the intention, wet-weather concentrations are significantly over predicted by the TTMBM calculations.

6.6.5 Revolon Subwatershed

Chlorpyrifos and diazinon dry-weather loads match the trends of measured loads well, in general over predicting measurements. There are significant scatter in the measured data not reflected in the TTMBM model calculations, however, due to the use of the 90th percentile prediction level loading rates, the TTMBM output typically provides an upper bound to the measurements. A few measurements do exceed the TTMBM calculated values. Wet weather chlorpyrifos concentrations are overpredicted. Trends in diazinon loads are estimated well for wet-weather flows. The TTMBM calculates a nominal concentration of chlorpyrifos and diazinon for a given flow with instances of higher concentrations at flows near the initiation of wet-weather runoff. The data reflect the same behavior of sporadic increase in concentration, but at a lower in-stream flowrate than predicted by the TTMBM. Both chlorpyrifos and diazinon concentrations in general over predicted but match tends of the measured concentrations.

6.6.6 Mugu Lagoon Subwatershed

There are too few chlorpyrifos and diazinon values in the Mugu Lagoon Subwatershed for a meaningful comparison of TTMBM output to measured values. There area no detected diazinon data for the Mugu Lagoon Subwatershed.

6.6.7 Load Apportionment by Subwatershed

In each subwatershed except Revolon Slough, POTW effluent is the major source of both chlorpyrifos and diazinon to the receiving waters for low in-stream flowrates typical of dry weather. As in-stream flowrates increase, agricultural runoff becomes the dominant source of chlorpyrifos and urban runoff becomes the dominant source of diazinon to the receiving waters. In the Revolon Slough Subwatershed, agricultural runoff is the dominant source of both chlorpyrifos and diazinon at all flows according to TTMBM calculations.

6.6.8 Sensitivity Analysis

As discussed in the Source Analysis section, urban and agricultural runoff and POTW effluent provide the bulk of the chlorpyrifos and diazinon loading to the system. Loading of chlorpyrifos and diazinon from urban runoff and POTW effluent are expected to decrease substantially due to the phase-out of urban uses. As such, the TTMBM's sensitivity to urban runoff and POTW effluent is greatly diminished due to the anticipated reductions stemming from the phase-out and is not considered in the sensitivity analysis. The potential atmospheric drift contribution to urban runoff is expected to be dramatically altered due to restrictions on which crops chlorpyrifos and diazinon may be applied to, and re-labeling for application procedures and rates and is not considered in the sensitivity analysis.

As presented in the following section, TMDL and Allocations, the magnitude of required in-stream reductions are between 70 and 99%. Because of the magnitude of reductions, the calculated percent reduction is not sensitive to the exact current or future load in either compartment. To illustrate the insensitivity of the percent reductions required Table 52 lists the change in the required reduction if the actual initial load were 50% greater or less than the TTMBM calculation. For example, if the TTMBM calculated reduction was 99% and subsequently it was determined the current load was 50% less than the calculated load; the actual reduction would need to be 98%. Conversely, if it was determined the current load was 50% greater than the calculated load; the actual reduction would need to be 99.3%.

Due to the magnitude of the reductions, the ultimate answers derived from TTMBM calculations are insensitive to precise current load calculations. As implementation proceeds and loads are reduced in runoff and receiving water there will be an increasing need for model refinement and formal sensitivity analysis to ensure load reductions result in in-stream compliance with numeric targets and allocations.

Table 52. Change in Required Reduction Given a Change in the Calculated Load.

Initial TTMBM Required Reduction (%)	Required Reduction Given Change in Current Load Estimate	
	Current Load 50% Greater	Current Load 50% Less
99	99.3	98
98	98.7	96
95	96.7	90
90	93.3	80
80	86.7	60

6.7 *Conclusions*

Conservation of mass is the basis of the TTMBM water quality model. Flowrates of various reaches in the CCW are calculated by the DCCMS model. By assuming each reach is in steady-state for any given time step, reach outflow and concentration were calculated from algebraic equations. The effect of using a daily time step and the steady-state assumption is to generate a series of daily average snapshots of the conditions likely to exist in the CCW. Both the TTMBM and DCCMS are built on the principles of mass conservation forming a simple, robust, and defensible method of modeling constituent flows through the CCW.

Limitations to the current implementation of the TTMBM include:

- Atmospheric contribution is encapsulated in the agricultural and urban runoff loads of pesticides.
- No measurements of chlorpyrifos and diazinon in the native space runoff in the CCW.
- A linkage between the constituents and TSS and sediments has not been developed.
- A link has not been established between the rate and timing of pesticide use and runoff water quality.

Incorporation of atmospheric drift/direct deposition and wet and dry deposition on the watershed may improve the comparison between TTMBM output and measured in-stream values. Also, estimation of atmospheric deposition loading will allow refined implementation alternatives to address the true source of pesticides to runoff in the CCW. Measurement of chlorpyrifos and diazinon in native space runoff would provide the most direct way of incorporating atmospheric deposition into the TTMBM. Establishing a link between the timing of pesticide application and runoff loading rate may increase the estimation power of the variability in loading by agricultural returns, and if combined with meteorological data may allow estimation of loading by atmospheric deposition.

The current TTMBM utilizes the available information to the extent possible to construct a defensible model constructed under the time constraints of the Toxicity TMDL schedule. In general, the TTMBM output over-estimates chlorpyrifos and diazinon concentrations by design, for estimating potential acute effects. Due to limitations in the available data, there are components of the TTMBM that could be improved. The TTMBM illuminates which sources of the constituents contribute the greatest fraction of in-stream load and under what conditions thus providing decision support for TMDL development. Because of data limitations, the TTMBM output are considered a first-order estimate of actual in-stream conditions. Through continued monitoring and additional investigations, the additional information could greatly improve the predictive capability of the TTMBM.

7 TMDL and Allocations

The loading capacity (LC) for each reach in the CCW, serves as the allowable total maximum daily load of each constituent in the reach. Loading capacity is dependant on in-stream flows and as such is variable. However, by defining a critical condition in the reach, the LC can be calculated by taking the product of the in-stream flow rate at the defined critical condition, the applicable numeric target, and a margin of safety. Equation 6 presents the calculation of the loading capacity.

Equation 6. $$\mathbf{TMDL = LC = Q * C_{NT} * MOS * \mathit{f}}$$

Where:
LC = Loading Capacity (lbs/day)
Q = In-stream Flow at Critical Condition (cubic feet per second)
C_{NT} = Numeric Target Concentration (ug/L)
MOS = Margin of Safety
f = Conversion factor of 0.00539 [(pounds/day)/(ug/L * cfs)]

The LC is allocated to a waste load allocation (WLA) accounting for all identified point sources, a load allocation (LA) accounting for all identified non-point sources, and a background load (BL) consisting of all loads not identified as described in Equation 7.

Equation 7. $$\mathbf{TMDL = LC = WLA + LA + BL}$$

The loading capacity of a waterbody is allocated to known point and non-point sources, and the background load. Allocations to the sources are established to result in the attainment of numeric targets. WLAs and LAs are allocated for:

- Chlorpyrifos: Allocations are set for chlorpyrifos as it is on the 303(d) list in two of the subwatersheds (Revolon and Arroyo Simi); it has been identified as contributing to toxicity in water in at least two of the subwatersheds (Revolon and Arroyo Simi) and to toxicity in sediment in two subwatersheds (Revolon and Calleguas); and it has been detected above numeric targets in receiving water in all six subwatersheds.
- Diazinon: Allocations are set for diazinon as it is the 303(d) list in one of the subwatersheds (Arroyo Simi); it has been identified as contributing to toxicity in water in two of the subwatersheds (Las Posas and Arroyo Simi); and it has been detected above numeric targets in receiving water in five of the subwatersheds (Revolon, Calleguas, Conejo, Las Posas, and Arroyo Simi).

As noted in the Numeric Targets section, the toxicity target in water is set to equal a toxicity unit (TU_c). The toxicity target in sediment is defined as when a sediment sample exhibits toxicity based on the following two criteria: 1) there is a significant difference ($p<0.05$) in mean organism response (e.g., percent survival) between a sample and the control as determined using a separate-variance t-test, and 2) the mean organism response in the toxicity test (expressed as a percent of the laboratory control) was less than the threshold based on the 90th percentile Minimum Significant Difference (MSD) value expressed as a percent of the control value. These toxicity targets can not be divided into portions and allocated to sources. However, an in-stream loading capacity can be applied and is discussed below.

If additional constituents are identified as contributing to water and/or sediment toxicity and these constituents are not appropriately addressed by other TMDLs, waste load and/or load allocations addressing these constituents will need to be developed.

7.1 *Critical Conditions*

The critical condition is defined in this TMDL as the flowrate at which the TTMBM calculated the greatest in-stream diazinon or chlorpyrifos concentration in comparison to the appropriate criterion. Acute criteria are compared to the calculated daily concentrations from the TTMBM, and chronic criteria are compared to a rolling 4-day arithmetic average of the calculated concentrations. The TTMBM calculates estimates of in-stream concentrations of chlorpyrifos and diazinon for conditions that existed between 10/1/90 and 3/31/04 in the CCW. The flow duration curves for the urban and agricultural runoff flows used by the TTMBM are plotted in Figure 34. By inspection, a "knee" is present in each of the flow duration curves occurring at approximately the 86th percentile flowrate. The "knee" corresponds to precipitation driven runoff representing an estimate of the maximum non-storm flowrate. The 86th percentile flows are identified for reference, but are not used in further analysis. In-stream flowrate duration curves are plotted in Figure 35.

The loading capacity at the critical condition was calculated using Equation 6 with the critical condition flowrate equal to **Q** and chronic numeric targets equal to $\mathbf{C_{NT}}$ for in-stream flowrates less than the 86th percentile flow (non-storm conditions) and acute numeric targets equal to $\mathbf{C_{NT}}$ for flows above the 86th percentile flow (storm flow conditions).

Critical conditions for chlorpyrifos and diazinon in water are presented in Table 53 and Table 54, respectively. These tables present TTMBM calculated in-stream flowrates, percentile flow, season, and applicable numeric target at the critical conditions for each subwatershed. Smaller percentile flows correspond to lower in-stream flowrates, with the 86th percentile flow serving as an estimate of the largest non-storm water flowrate. The 99.86th percentile flow is an estimate of the two year return flow typically considered the "bank full" flowrate in many systems.

There currently is no sediment target for chlorpyrifos; however, as discussed in the Numeric Targets section and demonstrated in the Linkage Analysis section, because of chlorpyrifos' affinity for particles, this TMDL makes the simplifying assumption that attainment of the water quality criteria based WLAs and LAs for chlorpyrifos will result in attainment of acceptable chlorpyrifos concentrations in suspended and bottom sediments. Through implementation of the TMDL, the replenishment of chlorpyrifos to the sediment will be greatly curtailed, allowing reduction of current contents.

All receiving water measurements and TTMBM calculations are total chlorpyrifos or diazinon measurements, so monitoring and modeling should be capturing critical runoff and water column sediment associated transport of the constituents. The total of dissolved water concentration and particle associated content of chlorpyrifos and diazinon as measured and calculated by the monitoring and TTMBM output ensuring the discharges to Mugu Lagoon will be controlled through the implementation of the TMDL.

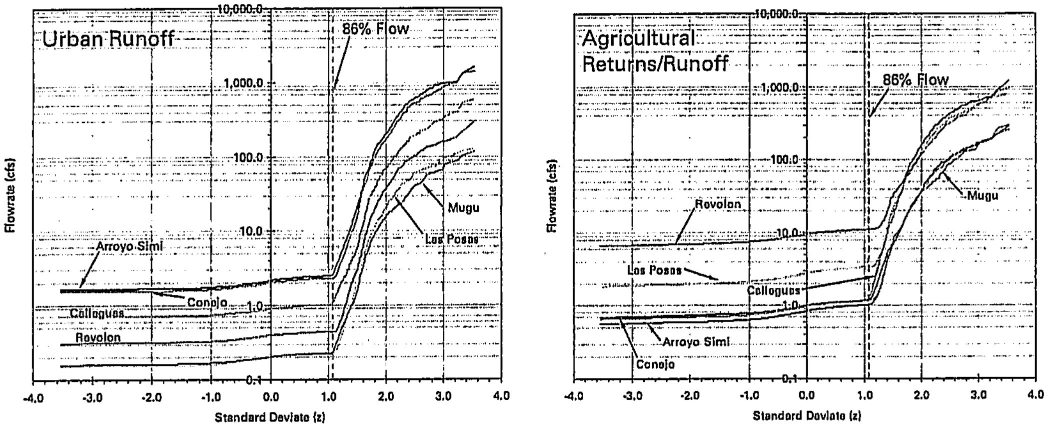


Figure 34. Flow duration curves for urban and agricultural runoff highlighting the 86th percentile flowrate as an estimate of maximum non-stormwater flow.

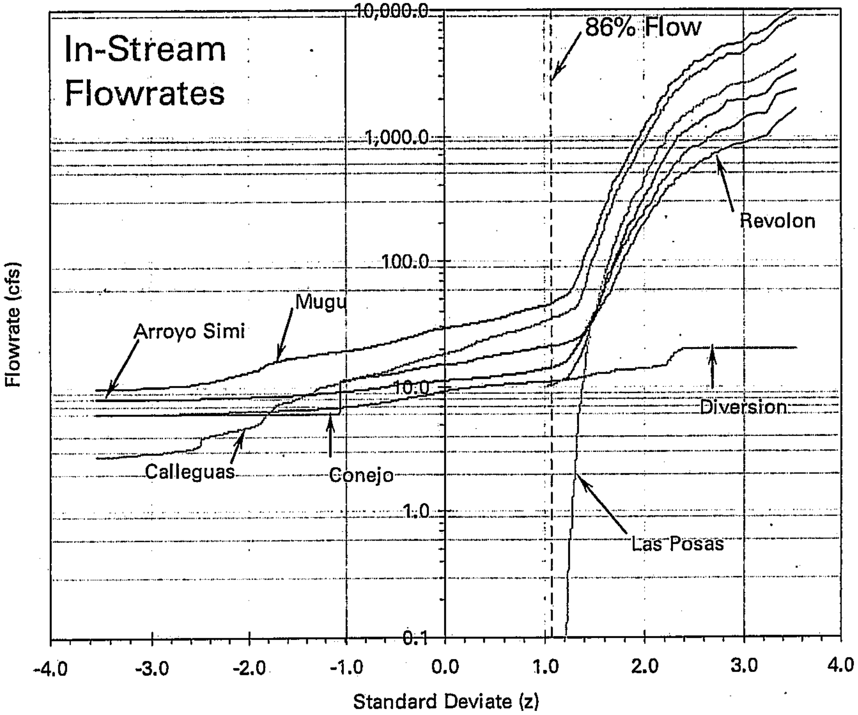


Figure 35. Flow duration curves for in-stream flowrates for each subwatershed in the CCW.

Table 53. Calculated In-Stream Flowrates at Critical Conditions in CCW Subwatersheds for Chlorpyrifos

Subwatershed	Flow (cfs)	Flow Condition	Season	Numeric Target Used
Arroyo Simi	13.7	84th percentile	Dry-Weather	Chronic
Las Posas	0.0[1]	87th percentile	Dry-Weather	Chronic
Conejo	16.4	61th percentile	Dry-Weather	Chronic
Calleguas	29.8	80th percentile	Dry-Weather	Chronic
Revolon Slough	10.5	77th percentile	Dry-Weather	Chronic
Mugu Lagoon	41	79th percentile	Dry-Weather	Chronic

1 Critical condition occurs when stream bed is dry (discharge from subwatershed is 0 cfs), which is the case except during some wet-weather events.

2 Does not include tidal influence as this flow represents freshwater discharge to Mugu Lagoon averaged over entire tidal cycle.

Table 54. Calculated In-Stream Flowrates at Critical Conditions in CCW Subwatersheds for Diazinon

Subwatershed	Flow (cfs)	Flow Condition	Season	Numeric Target Used
Arroyo Simi	40	93th percentile	Wet-Weather	Acute
Las Posas	120	95th percentile	Wet-Weather	Acute
Conejo	44	94th percentile	Wet-Weather	Acute
Calleguas	105	93th percentile	Wet-Weather	Acute
Revolon Slough	38	94th percentile	Wet-Weather	Acute
Mugu Lagoon	37	74th percentile	Dry-Weather	Chronic

1 Does not include tidal influence as this flow represents freshwater discharge to Mugu Lagoon averaged over entire tidal cycle.

7.2 Comparison of Capacity to Current Loads

Table 55 presents estimated current chlorpyrifos loads and the loading capacity for each of the six subwatersheds during the critical condition. Table 56 presents the calculated current diazinon load and the loading capacity for each of the six subwatersheds during the critical condition.

Table 55. Comparison of Current Chlorpyrifos Load to Stream Capacity During Critical Condition

Subwatershed	Criteria[1]	Calculated Load (lb/d)	Capacity (lb/d)	Reduction (%)
Arroyo Simi	Acute	0.31	0.0064	97.9%
Las Posas	Acute	2.80	0.0387	98.6%
Conejo	Chronic	0.10	0.0012	98.8%
Calleguas	Chronic	0.11	0.0017	98.5%
Revolon	Acute	26.2	0.221	99.2%
Mugu Lagoon[2]	Acute	15.0	0.226	99.1%

1 Criteria used in evaluation: CDFG for chlorpyrifos of 0.025 µg/L acute and 0.014 µg/L chronic

2 Does not include tidal influence as this flow represents freshwater discharge to Mugu Lagoon averaged over entire tidal cycle.

Table 56. Comparison of Current Diazinon Load to Stream Capacity During Critical Condition

Subwatershed	Criteria[1]	Calculated Load (lb/d)	Capacity (lb/d)	Reduction (%)
Arroyo Simi	Acute	0.21	0.026	88%
Las Posas	Acute	0.17	0.022	87%
Conejo	Acute	0.24	0.028	88%
Calleguas	Acute	0.43	0.055	87%
Revolon	Acute	0.14	0.021	85%
Mugu Lagoon[2]	Chronic	0.097	0.022	16%

1 Criteria used in evaluation: USEPA for diazinon of 0.1 µg/L acute and chronic

2 Does not include tidal influence as this flow represents freshwater discharge to Mugu Lagoon averaged over entire tidal cycle.

7.3 *Waste Load Allocations and Load Allocations*

7.3.1 Alternatives Considered

Five alternatives for allocating waste load and loads for chlorpyrifos and diazinon were considered to meet in-stream numeric targets:

1. Divide the current load reductions required to meet the LC equally between the dischargers.
2. Estimate the reduction of loads from urban and POTW discharges as a result of the urban use bans of chlorpyrifos and diazinon and allocate the remaining reductions to agriculture.
3. Set WLAs and LAs to vary based on in-stream flows.
4. Allocate load reductions to discharges based on an individual discharge's current proportion of the loading during critical conditions.
5. Set WLAs and LAs equal to the numeric target.

Alternative 1 would divide the load reductions required to meet the LC equally between agriculture, urban dischargers, and POTWs. Alternative 1 was rejected as it would require dischargers to reduce their loads without consideration of their current contribution to in-stream impacts. In addition, this could result in requiring individual dischargers to reduce loads beyond their current contributions (i.e. result in reductions greater than 100%).

Alternative 2 would estimate the load reductions that will result from the cessation of sales of chlorpyrifos and diazinon for urban uses. Current loading estimates would be revised to reflect these load reductions and the remaining reductions would be allocated to agriculture. Alternative 2 was rejected as it is unclear what the effect of ceasing sales of chlorpyrifos and diazinon for urban uses will be on urban and POTW loadings. In addition, the time frame for seeing a response to in-stream loadings is unclear. An overestimation or underestimation of the effect on reducing urban and POTW loadings may result in disproportional high or low allocations of load reductions to these dischargers based on their current contributions to in-stream loadings.

Alternative 3 would set variable WLAs and LAs based on in-stream flow. This alternative was rejected as the variable WLAs and LAs would pose a significant technical challenge to match allowable discharge concentrations to in-stream flow. In addition, stakeholders indicated that it would be easier to set WLAs and LAs to be protective in all conditions so that best management practices could be standardized.

Alternative 4 would allocate load reductions and ultimately WLAs and LAs based on each discharger's current proportion of in-stream loading during critical conditions. Alternative 4 was rejected as LAs would be far below target level and WLAs to urban stormwater discharges would be above targets.

Alternative 5 would set WLAs and LAs equal to the numeric targets set forth in the Numeric Targets section. This is a fairly standard practice for establishing WLAs and LAs. Alternative 5 was the selected alternative because it assigns loads equal to numeric targets which require all dischargers to achieve a standard level of protection. Assigning loads in this manner requires individual discharges to address their current contribution to potential in-stream impacts. Alternative 5 will provide a more conservative approach as indicated in the adopted Sacramento County Urban Creeks Diazinon and Chlorpyrifos TMDL (CVRWQCB, 2004).

7.3.2 Development of Allocations

Waste load allocations (WLAs) set equal to water quality criteria based numeric targets are allocated to point source dischargers, including wastewater treatment plants (POTWs) and urban runoff. Load allocations (LAs) set equal to water quality criteria based numeric targets are allocated to nonpoint source dischargers, in this case agricultural discharges. POTWs, urban runoff, and agricultural discharges will be collectively denoted as dischargers. The source analysis and linkage analysis have demonstrated the contributions of chlorpyrifos and diazinon to receiving waters from each of these dischargers are significant.

The sale of diazinon for non-agricultural uses will cease in December 2004. All sales for legal non-agricultural uses of chlorpyrifos will cease in December 2005. However, the use of remaining residential supplies will likely continue for a number of years after the final phase out of these two pesticides. Importation of products from outside of the United States may contain chlorpyrifos or diazinon residue and may lead to continued discharges to the creek system through urban runoff and POTW dischargers. Urban runoff and POTWs will be assigned WLAs to address potential discharges even though urban use within the CCW is assumed to decrease significantly after December 2005.

7.3.3 Allocations

Table 57 presents the chlorpyrifos and diazinon water quality criteria based numeric target WLAs and LAs concentration requirements for the various dischargers to meet in-stream numeric targets. Table 58 presents the loading reductions required of the various dischargers in the six subwatersheds during the critical condition to meet the water quality numeric target based WLAs and LAs. Figure 36 present chlorpyrifos and diazinon loadings from dischargers during wet and dry weather conditions based on reductions of loadings to meet water quality numeric target based WLAs and LAs. Percent reductions presented in Table 58 are after all iterations had been performed, total reductions are in general higher than required reductions reported in Table 55 or Table 56. Note that the reductions are calculated based on the TTMBM calculations of peak watershed loadings. While the reductions listed are necessary for receiving waters to be in compliance with numeric targets over all conditions, there are dischargers and whole subwatersheds that are currently in compliance under some conditions. Table 59 presents calculated receiving water chlorpyrifos and diazinon conditions post implementation and attainment of the water quality criteria based WLAs and LAs for the CCW discharges. The information in Table 58 and Table 59 is presented to demonstrate the effect of dischargers attaining the water quality criteria based WLAs and LAs.

In addition to the final WLAs and LAs, Table 57 also includes phased limits (the terms "phased" and "interim" are often used interchangeably to refer to non-final WLAs and LAs, the term "phased" is used here in accordance with USEPA convention). The sale of diazinon for non-agricultural uses will cease in December 2004. Non-agricultural uses of chlorpyrifos will cease in December 2005. However, the use of remaining residential supplies will likely continue for a number of years after the final phase out of these two pesticides. Continued use may lead to discharges to the creek through urban runoff and POTW dischargers. Phased LAs for chlorpyrifos and diazinon are set in Table 57 to allow reductions in loadings caused by the phase out of uses, educational programs, studies, and the implementation of appropriate BMPs to occur before incorporating final LAs. The phased acute WLAs and LAs are based on the 99th percentile value of discharge data. The phased chronic WLAs and LAs are based on the 95th percentile value of discharge data. The use of the 95th and 99th percentile values to develop phased limits is consistent with current NPDES permitting methodology. All available discharge data presented in the Source Analysis section were used to create a robust data set to calculate the 99th and 95th percentiles. In instances where sufficient data were not available to calculate phased limits, the highest detected value was used. For POTW dischargers all available discharge data from the POTWs in the CCW, presented in the Source Analysis section, were compiled to create a more robust data set. For urban runoff, all available urban runoff data, presented in the Source Analysis section were used to create a more robust data set. Phased limits are based on the available data and may be revised based on additional water quality data, if appropriate.

Table 57. Chlorpyrifos and Diazinon Waste Load and Load Allocations for Dischargers in the CCW

Waste Load Allocations								
	Chlorpyrifos (ug/L)				**Diazinon (ug/L)**			
POTWs	**Phased[1]**		**Final Acute**	**Final Chronic**	**Phased Acute[2]**	**Phased Chronic[3]**	**Final Acute**	**Final Chronic**
Hill Canyon WWTP	0.030		0.025	0.014	0.567	0.312	0.10	0.10
Simi Valley WQCP	0.030		0.025	0.014	0.567	0.312	0.10	0.10
Moorpark WTP	0.030		0.025	0.014	0.567	0.312	0.10	0.10
Camarillo WRP	0.030		0.025	0.014	0.567	0.312	0.10	0.10
Camrosa WRP	0.030		0.025	0.014	0.567	0.312	0.10	0.10
Urban Stormwater Co-Permittees	**Phased[1]**		**Final Acute**	**Final Chronic**	**Phased Acute[2]**	**Phased Chronic[3]**	**Final Acute**	**Final Chronic**
All Subwatershed	0.45		0.025	0.014	1.73	0.556	0.10	0.10
Load Allocations	**Phased Acute[2]**	**Phased Chronic[3]**	**Final Acute**	**Final Chronic**	**Phased Acute[2]**	**Phased Chronic[3]**	**Final Acute**	**Final Chronic**
All Subwatershed	2.57	0.810	0.025	0.014	0.278	0.138	0.10	0.10

1 Phased limit set at the maximum detected value as there were insufficient detected data to develop 99th or 95th percentile.

2 Phased acute limit set at the 99th percentile.

3 Phased chronic limit set at the 95th percentile.

Table 58. Estimated Chlorpyrifos and Diazinon Reductions in the CCW Necessary to Meet Numeric Target Based Waste Load and Load Allocations During Critical Condition[1]

Subwatershed	Total Reduction[2]		Agricultural Runoff[3]		Urban Runoff[3]		POTW[3]	
	Chlorpyrifos	Diazinon	Chlorpyrifos	Diazinon	Chlorpyrifos	Diazinon	Chlorpyrifos	Diazinon
Arroyo Simi	98%	88%	99.4%	68.3%	99.5%	93.0%	72%	50%
Las Posas	99%	87%	99.6%	69.9%	99.5%	93.0%	NA[4]	NA[4]
Conejo	99%	88%	99.4%	68.4%	99.5%	93.0%	72%	50%
Calleguas	99%	87%	99.6%	70.2%	99.5%	93.0%	72%	50%
Revolon	99%	85%	99.0%	70.6%	99.5%	93.0%	NA[4]	NA[4]
Mugu Lagoon[5]	99%	16%	99.0%	68.2%	99.1%	93.0%	NA[4]	NA[4]

1 Criteria used in evaluation: CDFG for chlorpyrifos of 0.025 µg/L acute and 0.014 µg/L chronic; USEPA for diazinon of 0.1 µg/L for both acute and chronic.

2 Reductions based on comparison of maximum calculated in-stream concentrations of chlorpyrifos and diazinon to the CDFG and USEPA criteria, respectively.

3 Reductions proportional to current load contributions.

4 Not applicable because no POTWs discharge to streams in this subunit.

5 Does not include tidal influence as this flow represents freshwater discharge to Mugu Lagoon averaged over entire tidal cycle.

Table 59. Estimated Chlorpyrifos and Diazinon Receiving Water Concentrations During Critical Condition Post Implementation and Achievement of WLAs and LAs

Subwatershed	Critical Criteria		Percent of Target[1]		Receiving Water	
	Chlorpyrifos	Diazinon	Chlorpyrifos	Diazinon	Chlorpyrifos	Diazinon
Arroyo Simi	Chronic	Acute	-25%	-18%	0.0111	0.0845
Las Posas	Chronic	Acute	-47%	-14%	0.0104	0.0873
Conejo	Chronic	Acute	-13%	-5%	0.0132	0.0949
Calleguas	Chronic	Acute	-72%	-18%	0.0089	0.0845
Revolon	Chronic	Acute	-55%	-15%	0.0040	0.0871
Mugu Lagoon	Acute	Chronic	-67%	-29%	0.0090	0.0680

1 The Percent of Target numbers represent the estimated percent difference between the chlorpyrifos and diazinon targets and concentrations in receiving water post implementation and achievement of WLAs and LAs. Note that predicted receiving water concentrations are below numeric targets.

As mentioned previously, the water and sediment toxicity targets can not be converted into a load and divided into portions to be allocated to sources. Additionally, the loading capacity of a stream with regard to a toxicant causing unknown toxicity in water and/or sediment is inherently unknown and can not be allocated. As such, a toxicity allocation equal to the numeric targets will be set at the base of each of the subwatersheds. The toxicity targets will be implemented as a trigger mechanism for initiation of the TRE/TIE process as outlined in USEPA's *Understanding and Accounting for Method Variability in Whole Effluent Toxicity Applications Under the National Pollutant Discharge Elimination System Program* (2000b) and current NPDES permits held by dischargers to the CCW. Setting allocations equal to the numeric targets at the base of each of the subwatershed will result in "loadings" of toxicity in water and sediment at the numeric targets. This provides a mechanism to address all dischargers contributing to in-stream toxicity as individual dischargers may additively cause an in-stream exceedance of the toxicity targets.

There are currently no sediment targets for chlorpyrifos, and therefore no means to calculate required reductions in sediment. As discussed in the Numeric Targets section and demonstrated in the Linkage Analysis section, because of chlorpyrifos' affinity for particles, this TMDL makes the simplifying assumption that attainment of the water quality criteria based WLAs and LAs for chlorpyrifos will result in attainment of acceptable chlorpyrifos concentrations in suspended and bottom sediments. Future monitoring of sediment toxicity, outlined in the Implementation Plan section, will be the measure for evaluating any additional load reductions and/or the development of sediment WLAs and/or LAs for these constituents. It should be noted that the State Board is currently developing sediment quality guidelines. The development of relevant sediment quality guidelines will be incorporated into the CCW Toxicity TMDL WLAs and LAs, if appropriate.

As described in the Current Conditions section, toxicity associated with chlorpyrifos and/or diazinon can be increased due to the presence of each other or other constituents such as ammonia or triazine herbicides. However, the studies that suggest the potential for increased toxicity used concentrations of chlorpyrifos and diazinon at least twice as high as the concentration based WLAs and LAs (Lindstrom and Lydy, 1997; Belden and Lydy, 2000; Bailey *et al.*, in 2001; Anderson and Lydy, 2002). Due to the possibility of additive or potentiated toxicity, achievement of chlorpyrifos and/or diazinon WLAs and LAs may not result in complete removal of toxicity associated with these constituents. However, at this time there is no evidence to suggest conditions in the CCW warrant an adjustment of WLAs and LAs to consider the possibility of additive or synergistic effects. If future monitoring determines WLAs and LAs do not completely remove toxicity associated with these constituents, these allocations may need to be revised.

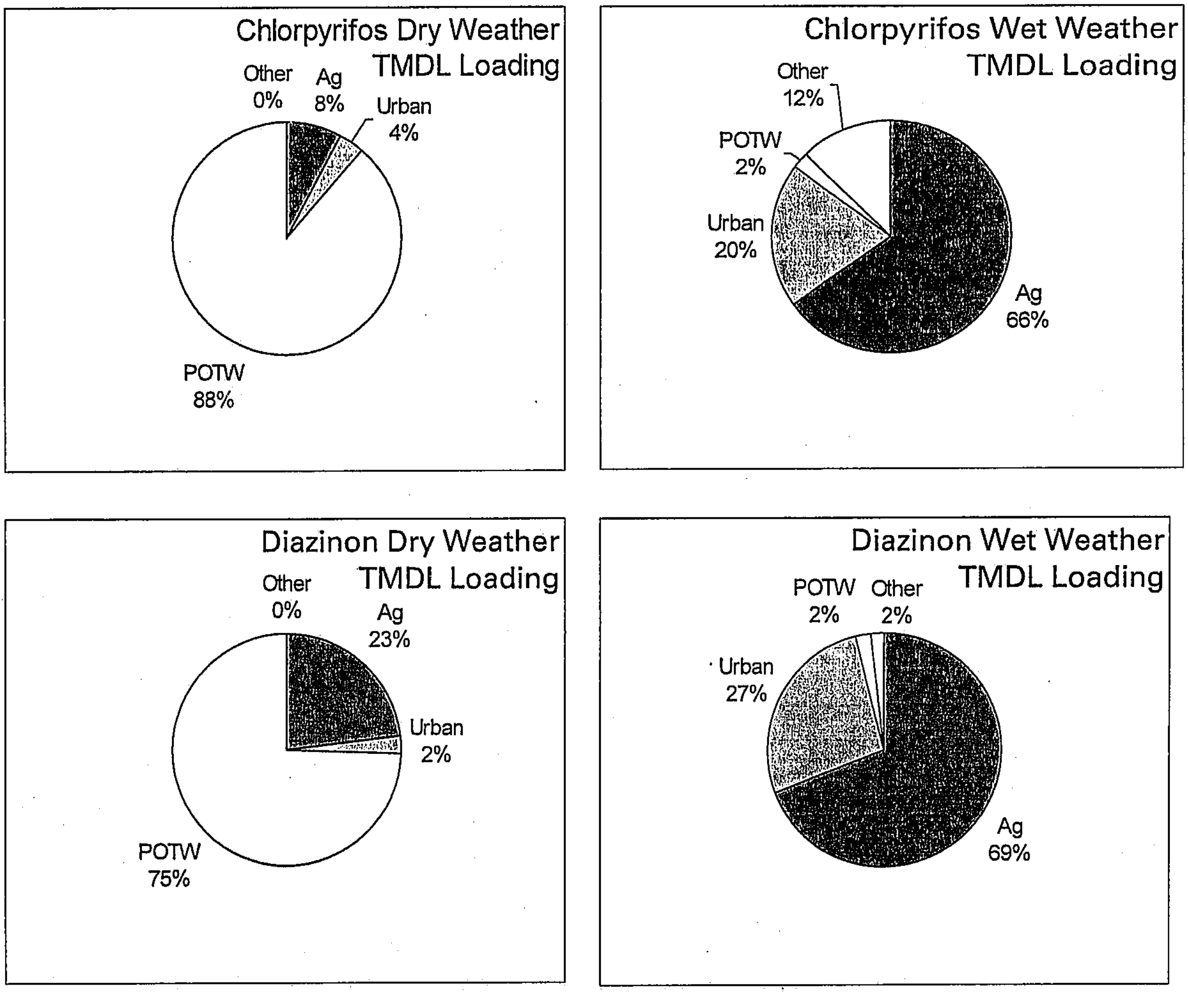


Figure 36. Chlorpyrifos and diazinon loading from various land uses for CCW after complete implementation.

7.3.4 Background Load

Background loading can be allocated to either natural sources and/or sources of loadings directly to a waterbody that are not attributable to a point or nonpoint source. As chlorpyrifos and diazinon are not naturally occurring, a background load would not be applicable under this definition. With regard to loadings that are not attributable to a point or nonpoint source, such as atmospheric and aerial deposition, as discussed in the Source Analysis section the available studies on deposition rates could not be incorporated to determine a specific load of these sources to the CCW. As such, the background load of chlorpyrifos and diazinon is set equal to zero. Potential contributions from background loads are implicitly incorporated into load reductions for identified sources.

7.4 *Margin of Safety (MOS)*

A TMDL analysis involves uncertainty. To address the uncertainty, a TMDL includes a margin of safety, which can be explicit, implicit, or both. The Toxicity TMDL includes an implicit margin of safety by relying on a conservative approach in assignment of water quality criteria based waste load and load allocations. The implicit MOS present in the TMDL is based on this requirement for discharges to meet WLAs and LAs based on water quality numeric targets. This approach follows other chlorpyrifos and diazinon TMDLs developed recently in California such as the USEPA adopted Sacramento County Urban Creeks Diazinon and Chlorpyrifos TMDL (CVRWQCB, 2004) and the Diazinon and Pesticide-Related Toxicity in Bay Area Urban Creeks (SFBRWQCB, 2004). The aforementioned TMDLs do not incorporate an explicit MOS. The following is a list of the conservative actions incorporated into the CCW Toxicity TMDL:

- WLAs for urban stormwater and POTWs are set to the water quality criteria based numeric targets, but use of both constituents is banned in urban areas so the concentrations will likely drop below target levels.
- Implicit in the development of the numeric water quality targets is a margin of safety.
- The WLAs and LAs are set to the water quality criteria based numeric target. Because the contributions to receiving water are dependent on the environmental conditions and behave differently, maximum contribution is a blend of all sources none of which are likely discharging at the target concentration simultaneously.
- Agricultural return flows, urban runoff, and POTWs are the sources of chlorpyrifos and diazinon to the receiving waters in the CCW. Applying the numeric receiving water target to the discharges will ensure the major sources of chlorpyrifos and diazinon to receiving waters are at or below the targets.
- An implicit margin of safety to ensure protection from toxicity due to chlorpyrifos concentrations in sediments exists. As shown in the linkage analysis, attainment of proposed water column target (0.014 ug/L) will ensure attainment of lowest no-effect level of chlorpyrifos in sediments identified in the literature (10 ug/kg).
- The implementation plan describes an adaptive management strategy to incorporate new information, including the State's upcoming sediment quality objectives guidance. When sufficient information exists to establish sediment targets for chlorpyrifos and/or other toxic compounds, those concentrations can be multiplied by the annual sediment flux from the entire watershed and individual sub-watersheds to calculate the assimilative capacity based on sediment concentrations. Thus, it is not expected that sediment quality objectives will produce a more stringent TMDL. Key

information that needs to be developed includes sediment quality objectives for chlorpyrifos and better estimates of sediment transport in the Calleguas Creek Watershed.

7.5 *Seasonal Variation*

Using the TTMBM, a linkage between flows and in-stream water quality was established in each of the subwatersheds. As discussed above, the critical condition was defined as the flowrate at which the TTMBM calculated in-stream diazinon or chlorpyrifos concentration was greatest. The loading capacity at the critical condition was then calculated. The TTMBM was run to ensure the load reductions necessary to meet the loading capacity at the critical condition was protective of all conditions thereby addressing potential issues with seasonal variation.

7.6 *Future Growth*

Ventura County accounts for slightly more than 2% of the state's residents with a population of 753,197 (US Census Bureau, 2000). GIS analysis of the 2000 census data yields a population estimate of 334,000 for the CCW, which equals about 44% of the county population. According to the Southern California Association of Governments (SCAG), growth in Ventura County averaged about 51% per decade from 1900-2000; with growth exceeding 70% in the 1920s, 1950s, and 1960s (Figure 37).

YEAR	POPLN	INCREASE
1900	14,000	--
1910	18,000	28.6%
1920	29,000	61.1%
1930	55,000	89.7%.
1940	70,000	27.3%
1950	115,000	64.3%
1960	199,000	73.0%
1970	376,000	88.9%
1980	529,000	40.7%
1990	669,000	26.5%
2000	753,000	12.6%

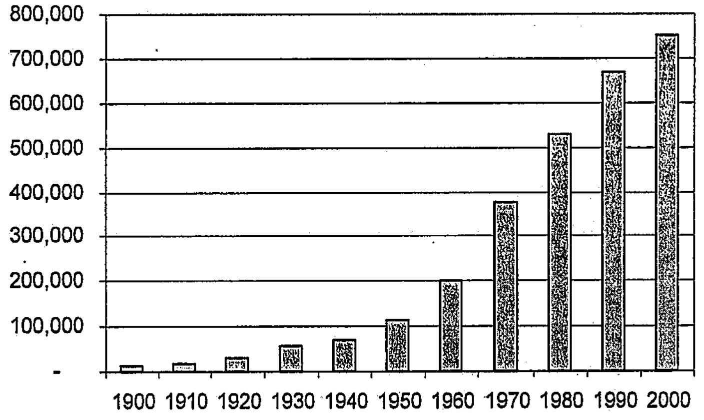


Figure 37. Population growth in Ventura County, 1900-2000 (SCAG, 2004).

Although Moorpark is expected to remain the smallest city as measured by population, it is also expected to have the highest growth rate from 2000-2020 (

Table 60). Both Moorpark and Camarillo are predicted to experience greater than 30% growth in those years. Thousand Oaks is expected to have the lowest growth rate of the CCW cities during that same time period, and is likely to be surpassed by Simi Valley as the most populous city in the watershed by 2020 (SCAG, Minjares, 2004). In general, smaller cities in the watershed are likely to grow faster than larger cities.

Table 60. Growth Projections for CCW Cities and Region, 2000-2020 (SCAG, Minjares, 2004)

City / County / CCW	2000 Popln (July)[1]	2005 Popln (projected)	2010 Popln (projected)	2020 Popln (projected)	% Increase 2000-2010	% Increase 2000-2020
City of Moorpark	31,528	37,611	42,618	43,730	35%	39%
City of Camarillo	57,478	63,179	67,507	76,842	17%	34%
City of Simi Valley	112,190	125,456	131,198	140,902	17%	26%
City of Thousand Oaks	117,418	126,272	129,992	132,925	11%	13%
Ventura County	758,054	821,045	865,149	929,181	14%	23%
CCW[2]	336,121	364,051	383,607	411,999	14%	23%

1 Projected values for June 2000. Actual census values from April 2000 were slightly lower (Ventura County population was 753,197).

2 Values in this row represent a rough estimate, calculated as 44% of the value for Ventura County (based upon the fact that current CCW population is approximately 44% of Ventura County total population).

7.6.1 Growth Management Efforts

Ventura County has been actively involved in growth management for several decades and continues to implement a range of growth management measures such as: urban growth boundaries, ballot-initiative approved zoning, and encouragement of higher density and mixed-use development. The Save Open Space and Agricultural Resources initiative (SOAR) that was passed in 1998 is one such growth management policy. Ventura County's SOAR initiative aims to preserve farmland, open-space and rural areas by establishing a City Urban Restriction Boundary beyond which urban development is controlled (Figure 38). County voter approval is required before any land located outside the City Urban Restriction Boundary can be developed for non-agricultural purposes.

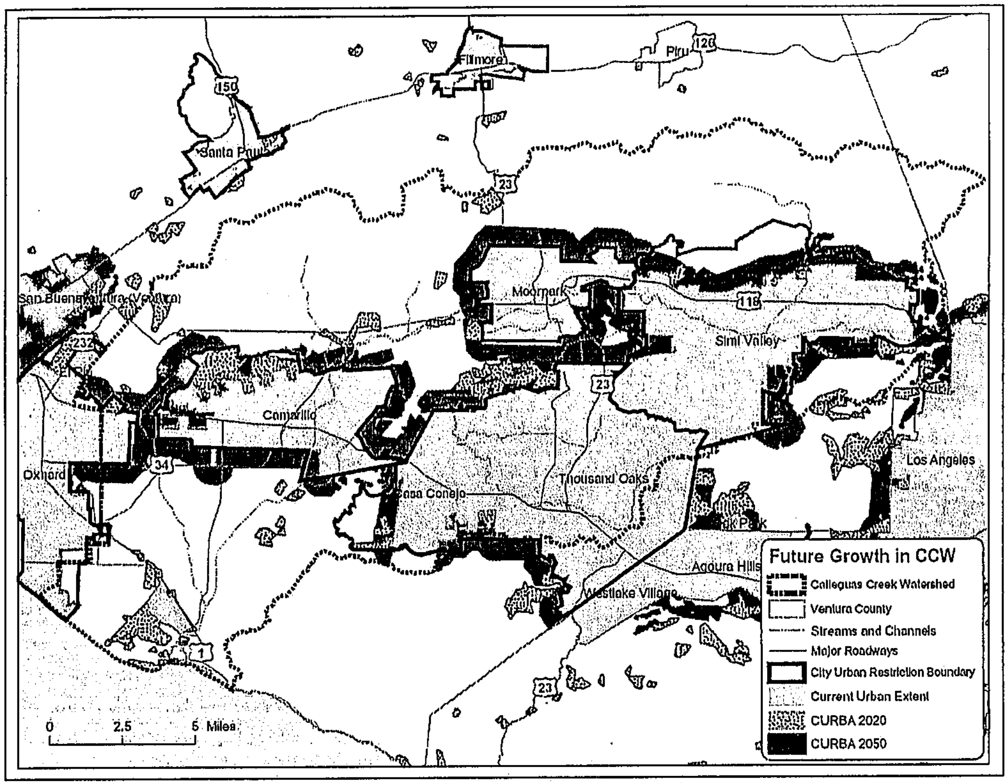


Figure 38. Urban growth in Ventura County (Ventura County CURB, California Urban and Biodiversity Analysis).

The results of California Urban and Biodiversity Analysis (CURBA) for lands within the CCW for the years 2020 and 2050 are also shown in Figure 38 (Landis et al, 1998). CURBA uses an urban growth model to predict future land-use scenarios, and a habitat loss and fragmentation analysis model to estimate the effects of various land use policies upon biodiversity (only results from the urban growth model are considered here). The urban growth model calculates future urbanization probabilities for all undeveloped sites in a given area, according to such factors as: proximity to highways, proximity to city boundaries, site slope, and site development constraints. The CURBA results shown here seem to have been heavily influenced by the "development constraints" variable, as evidenced by the fact that predicted growth is highly correlated with the City Urban Restriction Boundaries established by the SOAR initiative. Since SOAR is due to expire in 2020, it does not provide permanent protection for open space or farmland.

7.6.2 Effects of Growth on Chlorpyrifos and Diazinon Loading

The phase out of chlorpyrifos and diazinon for urban uses will be completed on December 31, 2005. This phase out is expected to reduce loadings from urban and POTWs significantly by 2007. Use of diazinon in agriculture has declined considerably between 1998 and 2003. Conversely, chlorpyrifos use in agriculture has remained relatively stable over the same period. However, as outlined in the Source Analysis section, use modifications for chlorpyrifos have been approved by the USEPA, but not yet approved by DPR. Use modifications for diazinon are currently under negotiations between the manufacturer and the USEPA. Use modifications will change application practices for growers and will likely take effect before the implementation of this TMDL is complete. The phase out of these pesticides in urban environment and the change in use patterns in the agricultural environment will result in a marked decrease in the use of these. Consequently, future growth will not result in increased use or discharge of these pesticides. In addition the WLAs and LAs are set equal to numeric targets which will allow them to appropriately address the potential impact of future growth on the presence of these pesticides in the environment.

The phase out of chlorpyrifos and diazinon as well as population growth will cause an increase in the use of replacement pesticides (e.g. pyrethroids) in the urban environment and may have an impact on water and/or sediment toxicity. Additionally, population growth may affect an increase in the levels of chlorpyrifos and diazinon loading in the CCW from imported products which contain residues of these pesticides. As part of the Implementation Plan the potential for replacement pesticides to cause water and/or sediment toxicity will be investigated through monitoring.

Regardless of the available pesticides, population growth will likely result in greater pesticide loads to POTW influent and urban dischargers. The load will likely increase proportionally to the population increase assuming future domestic water and pesticide load per capita remain stable. Under these assumptions, the volume of wastewater discharged by POTWs would also increase proportionally to population growth. Where impairments do not currently exist, increased flows from POTWs and urban discharges should not result in impairments. However, these assumptions do not take into account two factors 1) market and regulatory forces which dictate the pesticides available to urban users are not predictable over a long time period and 2) the potential of unknown future pesticides to cause water and/or sediment toxicity. As such, a cautious approach should be taken when anticipating the effect of future growth on pesticide loadings and subsequent environmental impact.

Agriculture is currently working through new regulatory processes which will result in changes in pesticide use patterns and likely reduce pesticide loads to the CCW. Conversely, urban users will not necessarily be required to go through similar regulatory processes requiring changes in pesticide use patterns. This suggests that pesticide loads from urban dischargers will increase with future growth. Therefore, the implementation of this TMDL needs to take into account the future use of other pesticides and the potential for this use to contribute to toxicity. To address the potential continued impact from urban uses of pesticides an education program outlining the harmful effects of pesticides, proper use techniques, pesticide alternatives, and integrated pest management will be completed as part of the Implementation Plan. As the potential impact of replacement pesticides is unknown, the unknown toxicity WLAs and LAs set equal to the numeric target will be protective regardless of future growth.

8 Implementation Plan

California Water Code section 13360 precludes the Regional Board from specifying the method of compliance with waste discharge requirements; however California Water Code section 13242 requires that the Basin Plan include an implementation plan to describe the nature of actions to be taken and a time schedule for action. This section describes the proposed implementation plan to meet numeric targets for chlorpyrifos, diazinon and toxicity in the CCW. The Implementation Plan includes the following elements:

- Source control activities to reduce urban sources of pesticides;
- Implementation and evaluation of agricultural best management practices (BMPs) in the watershed;
- Monitoring for diazinon, chlorpyrifos, and toxicity in water and sediment throughout the watershed.

If additional constituents are identified as contributing to water and/or sediment toxicity and these constituents are not appropriately addressed by other TMDLs, an implementation plan to address these constituents will be developed.

8.1 *Waste Load Allocation Implementation*

This section provides a discussion of the application of the final WLAs for MS4s and POTWs, the method for determining compliance with the final WLAs, implementation actions that will be undertaken to achieve the allocations, and the implementation schedule. The final WLAs, listed in Table 57, will be included in NPDES permits in accordance with the compliance schedules provided in the Implementation Schedule section (Table 63), subject to the following condition:

> WLAs may be revised prior to the dates they are placed into permits and/or prior to the dates of final WLA achievement. Any revisions to these WLAs are to be based on the collection of additional information as described in the Special Studies and Monitoring Plan Section.

8.1.1 MS4s

A group concentration-based WLA has been developed for the municipal separate storm sewer system (MS4). USEPA regulation allows allocations for NPDES-regulated stormwater discharges from multiple point sources to be expressed as a single categorical WLA when the data and information are insufficient to assign each source or outfall individual WLAs (40 CFR 130). The grouped allocation will apply to all NPDES-regulated municipal stormwater discharges in the CCW.

MS4 WLAs will be incorporated into the NPDES permit as receiving water limits measured in-stream at the base of each subwatershed and will be achieved through the implementation of BMPs as outlined in this section. Compliance will be determined through the measurement of in-stream water quality and sediment at the base of each of the subwatersheds. To facilitate measuring compliance in all six of the subwatersheds, additional monitoring locations will be needed in four of the subwatersheds (Mugu, Conejo, Las Posas, and Arroyo Simi).

The toxicity numeric targets will be implemented as a trigger mechanism for initiation of the TRE/TIE process as outlined in USEPA's *Understanding and Accounting for Method Variability in Whole Effluent Toxicity Applications Under the National Pollutant Discharge Elimination System Program* (2000b) and current NPDES permits held by dischargers to the CCW.

8.1.2 POTWs

WLAs established for the three major POTWs in this TMDL will be implemented through NPDES permit limits. The proposed permit limits will be applied as end-of-pipe concentration-based effluent limits for POTWs. Compliance will be determined through monitoring of final effluent discharge as defined in the NPDES permit.

The toxicity numeric target will be implemented as a trigger mechanism for initiation of the TRE/TIE process as outlined in USEPA's *Understanding and Accounting for Method Variability in Whole Effluent Toxicity Applications Under the National Pollutant Discharge Elimination System Program* (2000b) and current NPDES permits held by dischargers to the CCW.

The following implementation actions will be taken by Ventura County Stormwater Copermittees and POTWs located in the CCW:

- Plan, develop, and implement an urban pesticides public education program;
- Plan, develop, and implement urban pesticide education and chlorpyrifos and diazinon collection program;
- Study diazinon and chlorpyrifos replacement pesticides for use in the urban environment; and,
- Conduct environmental monitoring as outlined in the Monitoring Plan and NPDES Permits.

As discussed above, additional implementation actions may be necessary, if results of monitoring indicate the phase out of urban uses of chlorpyrifos and diazinon has not adequately addressed related beneficial use impairments.

As discussed in the Numeric Targets and Allocations sections and as demonstrated in the Linkage Analysis section, it is assumed that WLAs for chlorpyrifos will address associated sediment toxicity. However, the State Board is currently developing sediment quality guidelines. The development of relevant sediment quality guidelines will be incorporated into CCW Toxicity TMDL WLAs, if appropriate. The USEPA diazinon criteria may be revised after incorporating comments and additional data submitted by March 30, 2004 as part of the criteria development process. As a result, any revisions to the diazinon water quality criteria will be incorporated into the CCW Toxicity TMDL WLAs, if appropriate.

The sale of diazinon for non-agricultural uses will cease in December 2004. Non-agricultural uses of chlorpyrifos will cease in December 2005. However, the use of remaining residential supplies will likely continue for a number of years after the final phase out of these two pesticides. Continued use may lead to discharges to the creek through urban runoff and POTW dischargers. As the ultimate step to reduce/eliminate the discharge of these pollutants in urban environments, banning use, has already occurred, the phased allocations shown in Table 57 in the allocations section and the implementation schedule presented in the Implementation Schedule section (Table 63) provide sufficient time to allow the pesticide bans and education programs to reduce concentrations in urban runoff and POTW dischargers to or below the WLAs. In addition, it allows time for completion of monitoring to verify the appropriateness of WLAs.

8.2 *Load Allocation Implementation*

LAs for chlorpyrifos and diazinon, presented in Table 57, will be implemented in a manner consistent with the Porter-Cologne Water Quality Control Act. Through Porter-Cologne and the State's Nonpoint Source

Pollution Control Program (NPSPCP), nonpoint source pollution (i.e. Load Allocations) is addressed through the following five key elements of the Policy for the Implementation and Enforcement of the NPSPCP (NPSPCP Implementation Policy):

1. A NPS control implementation program's ultimate purpose must be explicitly stated and at a minimum address NPS pollution control in a manner that achieves and maintains water quality objectives.
2. The NPS pollution control implementation program shall include a description of the management practices (MPs) and other program elements expected to be implemented, along with an evaluation program that ensures proper implementation and verification.
3. The implementation program shall include a time schedule and quantifiable milestones, should the RWQCB so require.
4. The implementation program shall include sufficient feedback mechanisms so that the RWQCB, dischargers, and the public can determine if the implementation program is achieving its stated purpose(s), or whether additional or different MPs or other actions are required.
5. Each RWQCB shall make clear, in advance, the potential consequences for failure to achieve an NPS implementation program's objectives, emphasizing that it is the responsibility of individual dischargers to take all necessary implementation actions to meet water quality requirements.

Under the NPSPCP Implementation Policy, the RWQCBs must regulate all nonpoint sources of pollution, using the administrative permitting authorities provided by the Porter-Cologne Act. One of the permitting authorities available to the LARWQCB is the adoption of a Conditional Waiver from Waste Discharge Requirements. The LARWQCB is currently in the process of developing and adopting a Conditional Waiver for Irrigated Lands (Conditional Waiver Program) to implement the state's NPSMP. Once adopted, the Conditional Waiver Program can be used to ensure implementation of allocations and meeting of numeric targets contained in this TMDL. However, until this program is adopted by the Regional Board, allocations can be implemented directly through a stand alone Basin Plan Amendment that is also consistent with the State's NPSPCP and includes all of the implementation provisions contained herein. In either case, reasonable assurance will be provided that the agricultural controls necessary to meet the LAs will be implemented.

Compliance with LAs will be measured at the monitoring sites approved by the Executive Officer of the Regional Board through the monitoring program developed as part of the Conditional Waiver, or through a monitoring program that is required as part of the Basin Plan Amendment in case the Conditional Waiver Program is not adopted in a timely manner consistent with the TMDL implementation schedule. In either case, monitoring shall be consistent with the Monitoring Plan section of this TMDL. The toxicity numeric target will be implemented in-stream as a trigger mechanism for the initiation of the TRE/TIE process. LAs are based on the available data and may be revised based on additional water quality data, if appropriate.

Studies are currently being conducted to assess the extent of BMP implementation and provide information on the effectiveness of BMPs for agriculture. This information will be used to develop an Agricultural Water Quality Management Plan that will guide the implementation of agricultural BMPs in the CCW. Then, an agricultural education program will be developed to inform growers of the recommended BMPs and the management plan. The Association of Water Agencies of Ventura County and the Ventura County Farm Bureau are actively working on outreach to local growers to educate them on the upcoming requirements from TMDLs and the proposed Conditional Waiver Program.

Replacement of chlorpyrifos and diazinon with other pesticides is not explicitly recommended in this implementation plan as replacement pesticides may pose similar toxicity risks to aquatic life. Rather, the implementation of BMPs should help control the mobilization and discharge of pesticides to receiving waters. Since BMPs have the potential to control discharges of other constituents of interest, such as nutrients and organochlorine pesticides, the implementation of BMPs will be coordinated to achieve the maximum benefit for all constituents of concern. However, if BMPs prove insufficient the only alternative may to replace chlorpyrifos and diazinon.

The phased allocations presented in Table 57 in the Allocations Section and the implementation schedule, shown in Table 63, will provide sufficient time to:

- Allow for the adoption and implementation of the Conditional Waiver Program by agricultural dischargers throughout the CCW;
- Allow for development of an Agricultural Water Quality Management Plan as part of either the Conditional Waiver Program or the Calleguas Creek WMP;
- Allow pesticide bans to reduce concentrations in urban runoff and POTW dischargers;
- Allow label changes for agricultural chlorpyrifos and diazinon products to reduce concentrations in agricultural dischargers;
- Allow for the completion of monitoring to verify the appropriateness of LAs;
- Complete studies to determine the most appropriate BMPs given crop type, pesticide, site specific conditions, as well as the critical condition defined in the development of the LAs;
- Implement appropriate BMPs and monitor to evaluate effect on in-stream water and sediment quality; and,
- Implement adaptive management strategies to employ additional BMPs or revise existing BMPs to met LAs.

As discussed above, implementation of LAs will be conducted over a sufficient period of time to allow for adoption of the Conditional Waiver Program by the Regional Board, as well as coordination with special studies and implementation actions resulting from other TMDL Implementation Plans (Nutrient, Historic Pesticides and PCBs, Metals, Bacteria, Sediment, etc.). As compliance with the chlorpyrifos, diazinon, and toxicity targets are determined in-stream, there is the potential for compliance with the targets without attainment of LAs. As such, LAs may be revised prior to the final LA achievement dates. Any revisions to these LAs are to be based on the collection of additional information as described in the Special Studies and Monitoring Plan sections of the Implementation Plan.

As discussed in the Numeric Targets and Allocations sections and as demonstrated in the Linkage Analysis section, it is assumed that LAs for chlorpyrifos will address associated sediment toxicity. However, the State Board is currently developing sediment quality guidelines. The development of relevant sediment quality guidelines will be incorporated into CCW Toxicity TMDL LAs, if appropriate. The USEPA diazinon criteria may be revised after incorporating comments and additional data submitted by March 30, 2004 as part of the criteria development process. As a result, any revisions to the diazinon water quality criteria will be incorporated into the CCW Toxicity TMDL LAs, if appropriate.

The implementation schedule is designed to parallel, where appropriate, the Nutrient TMDL and Organochlorine Pesticides and PCBs TMDL Implementation Plans. Additional TMDL Implementation Plans may be developed before 2012, for the Metals, Bacteria, and Sediment TMDLs. The implementation schedule for this TMDL may be revised, if appropriate, when the Metals, Bacteria, and Sediment TMDLs are completed.

8.3 *Special Studies*

Several special studies are planned to improve understanding of key aspects related to achievement of WLAs and LAs for the Toxicity TMDL.

8.3.1 Special Study #1 - Monitoring of Sediment Concentrations by Land Use Type

The purpose of this special study will be the identification of sediment concentrations of OP pesticides from representative land uses. The study will be conducted over the course of one year and will include monitoring in urban, agriculture, and native land areas. Once completed, this special study will provide general understanding of overall processes and contributions related to fate and transport of OPs in the CCW. The relevant analytical parameters will be added to the study required for the OCs TMDL.

8.3.2 Special Study #2 - Calculation of Sediment Transport Rates

Under the OCs TMDL, sediment transport rates will be developed for the CCW. The results of this study could be used to evaluate sediment toxicity and sediment loadings for chlorpyrifos in the CCW.

8.3.3 Special Study #3 - Determination of Site Specific Chlorpyrifos and/or Diazinon Criteria

The purpose of this optional special study would be to determine if alternative chlorpyrifos and/or diazinon numeric targets and/or allocations are applicable in various reaches of the CCW given site specific conditions not considered in the original criteria document. The special study could consider averaging periods, resident species, a multi-indicator approach (toxicity assays in conjunction with biological assessments), or the effect of sediment bound chlorpyrifos and diazinon on the toxicity exhibited in water and/or sediment. Possible changes in numeric targets and/or allocations will consider potential affects on sediment toxicity associated with these constituents.

This is an optional special study to be conducted if desired by the stakeholders or determined to be necessary by the Executive Officer.

8.4 *Reevaluation of WLAs and LAs*

A number of provisions in this TMDL could provide information that could result in revisions to the TMDL. Additionally, the development of sediment quality criteria and other water quality criteria revisions may require the reevaluation of this TMDL. For these reasons, the Implementation Plan includes this provision for reevaluating the TMDL to consider state and/or EPA developed sediment toxicity and chemistry criteria, revised methodology for calculating chronic water toxicity, revised water quality objectives/criteria, and the results of implementation studies, if appropriate.

8.5 *Monitoring Plan*

The Monitoring Plan is designed to monitor and evaluate the implementation of this TMDL and refine the understanding of current chlorpyrifos and diazinon loads as well as to continue efforts to identify the cause(s) of remaining or future toxicity in water and sediment. The information presented in this section is intended to be a brief overview of the goals of the Calleguas Creek Watershed TMDL Monitoring Program (CCWTMP) included as Attachment B. The CCWTMP is intended to parallel efforts of the CCW Nutrients TMDL and Organochlorine Pesticides and PCBs TMDL implementation plans.

Monitoring conducted through the forthcoming Conditional Waiver Program may meet part of the needs of the CCWTMP. To the extent monitoring required by the Toxicity TMDL Implementation Plan parallels monitoring required by the Conditional Waiver Program, it shall be coordinated with Conditional Waiver Program monitoring conducted by individuals and groups subject to the terms and conditions of the waiver. The goals of the CCWTMP include:

1. To determine compliance with chlorpyrifos, diazinon, and toxicity numeric targets at receiving water monitoring stations generally located at the base of the subwatersheds and at POTW discharges.
2. To determine compliance with waste load and load allocations for chlorpyrifos, diazinon, and toxicity generally located at the base of the subwatersheds and at POTW discharges.
3. To evaluate presence of sediment toxicity at sediment monitoring stations located in Mugu Lagoon (Reach 1), Lower Calleguas Creek (Reach 2), Calleguas Creek (Reach 3), Revolon Slough (Reach 4), and Conejo Creek (Reach 9A).
4. To identify causes of unknown toxicity and/or potential additive and/or synergistic effects.
5. To generate additional land use runoff data to increase the resolution of current loadings.
6. To monitor the effect of diazinon and chlorpyrifos replacement pesticides on water quality with regard to toxicity.
7. To monitor the effect of implementation actions by urban, POTW, and agricultural dischargers on in-stream water and sediment quality.
8. To implement the CCWTMP in a manner consistent with other TMDL implementation plans and regulatory actions within the CCW.

Current loading estimates are based on limited data. Due to the nature of the data set, assumptions were made about loadings from the various dischargers. The collection of data through the CCWTMP will increase the resolution of current loadings and may indicate the need to refine the WLAs and LAs.

8.5.1 Compliance Monitoring

Monitoring will begin within one year of the effective date of the CCW Toxicity TMDL. In-stream water column samples will be collected quarterly for analysis of water column toxicity, general water quality constituents (GWQC), and targeted organic constituents (including chlorpyrifos and diazinon). In-stream water column samples will generally be collected at the base of each of the subwatersheds (Table 61) until numeric targets are consistently met at these points. At such a time as numeric targets are consistently met at the base of a subwatershed, an additional site or sites within the subwatershed will be considered for monitoring to ensure numeric targets are met throughout the subwatershed.

Additional samples will be collected concurrently at representative agricultural and urban runoff discharge sites as well as at POTWs in each of the subwatersheds and analyzed for GWQC and targeted organic constituents (including chlorpyrifos and diazinon). The location of the land use stations will be determined before initiation of the CCWTMP. TIEs will be initiated on toxic samples as outlined in the Follow-up Toxicity Testing section of the CCWTMP. For organic constituents, environmentally relevant detection limits will be used (i.e. detection limits lower than applicable target), if available at a commercial laboratory. All efforts will be made to include at least two wet weather-sampling events during the wet season (October through April) during a targeted storm event.

Streambed sediment samples will be collected twice a year for analysis of sediment toxicity, general sediment quality constituents (GSQC), and targeted organic constituents (including chlorpyrifos) as presented in Table 61. Sediment samples in Mugu Lagoon will be collected once a year for similar analysis. An annual frequency was selected for Mugu Lagoon sediment sampling due to the relatively slow sedimentation rates in the lagoon in comparison to sample collection depths as discussed in the Sample Collection section of the CCWTMP. TIEs will be initiated on toxic samples as outlined in the Follow-up Toxicity Testing section of the CCWTMP. Fish tissue samples will be collected twice a year in the Revolon Slough subwatershed for analysis of chlorpyrifos. These samples will be used to assess changes in fish tissue concentration as a result of achievement of chlorpyrifos waste load and load allocations.

Table 61. Compliance Sampling Station Locations

Subwatershed	Station ID	Station Location	Sample Media		
			Water	Sediment	Fish Tissue[1]
Mugu Lagoon	01_11_BR	11th Street Bridge	T, OP, OC		OC[2]
	01_BPT_1	Located Near Entrance to Lagoon		T, OP, OC	
	01_BPT_3	Located In The Eastern Arm of the Lagoon		T, OP, OC	
	01_BPT_6	Located In The Eastern Part of the Western Arm		T, OP, OC	
	01_BPT_9	Located Near 17th Street in far side of Western Arm		T, OP, OC	
	01_BPT_15	Located In Central Part of the Lagoon		T, OP, OC	
	01_SG_74	Located In Central Part of the Lagoon In Mudflat Area		T, OP, OC	
Revolon Slough	04_WOOD	Revolon Slough East Side Of Wood Road	T, OP, OC	T, OP, OC	OP, OC
Calleguas	03_CAMAR	Calleguas Creek At University Drive	T, OP, OC	T, OP, OC	OC
	03D_CAMR	Camrosa Water Reclamation Plant	OP, OC		
	9AD_CAMA	Camarillo Water Reclamation Plant	OP, OC		
Conejo	9B_ADOLF	Conejo Creek at Adolfo Road	T, OP, OC	OC	OC
	10D_HILL	Hill Canyon Wastewater Treatment Plant	OP, OC		
Las Posas	06_SOMIS	Arroyo Las Posas off Somis Road	T, OP, OC	OC	OC
	06D_MOOR	Ventura County Wastewater Treatment Plant	OP, OC		
Arroyo Simi	07_HITCH	Arroyo Simi East Of Hitch Boulevard	T, OP, OC	OC	OC
	07D_SIMI	Simi Valley Water Quality Control Plant	OP, OC		

T Toxicity, triazine, and pyrethroid samples will be collected
OP Organophosphate samples will be collected
OC Organochlorine Pesticides and PCBs samples will be collected

[1] Attempts will be made to collect fish tissue samples in the same location as water and sediment samples. However, samples may be collected elsewhere if no fish are found at pre-established sample stations.

[2] Fish tissue sampling locations in Mugu will be determined in conjunction with biologists prior to sample collection.

8.5.2 Toxicity Investigation

Monitoring will begin within one year of the effective date of the CCW Toxicity TMDL. In-stream water column samples will be collected at select sampling stations where the cause(s) of water toxicity have not been identified (Table 62). The sampling schedule for toxicity investigation monitoring occurs during months in which toxicity of unknown causes was observed in previous studies. The CCWTMP will contain provisions to revise the monitoring schedule if it does not adequately characterize toxicity of unknown cause(s). Toxicity investigation samples will be analyzed for water column toxicity, general water quality constituents (GWQC), and targeted organic constituents. TIEs will be initiated on toxic samples as outlined in the Follow-up Toxicity Testing section of the CCWTMP. For organic constituents, environmentally relevant detection limits will be used, if available at a commercial laboratory. As with compliance monitoring, all efforts will be made to include at least two wet weather water sampling events during the wet season (October through April) during a targeted storm event.

Streambed sediment samples will be collected twice a year at select sampling stations where the cause(s) of sediment toxicity have not been identified (Table 62). Streambed sediment will be analyzed for sediment toxicity, general sediment quality constituents (GSQC), and targeted organic constituents. TIEs will be initiated on toxic samples as outlined in the Follow-up Toxicity Testing section of the CCWTMP.

Table 62. Toxicity Investigation Sampling Station Locations

Subwatershed	Station ID	Station Location	Sample Media	
			Water	Sediment
Calleguas	02_PCH	Calleguas Creek Northeast Side of Highway 1 Bridge		X
	9A_HOWAR	Conejo Creek at Howard Road Bridge		X
Conejo	10_GATE	Conejo Creek Hill Canyon below North Fork of Conejo Creek	X	
	13_BELT	Above Confluence with Conejo Creek North Fork	X	

8.5.3 Reporting and Modification of CCWTMP

A Monitoring Report will be prepared annually within three months after the completion of the final event of the sampling year. An adaptive management approach to the CCWTMP will be adopted as it may be necessary to modify aspects of the CCWTMP. Results of sampling carried out through the CCWTMP and other programs within the CCW may be used to modify this plan, as appropriate. These modifications will be summarized in the annual report. Possible modifications could include, but are not limited to the, following:

- The inclusion of additional land use stations to accurately characterize loadings;
- The removal of land use stations if it is determined they are duplicative (*i.e.,* a land use site in one subwatershed accurately characterize the land use in other subwatersheds);
- The inclusion of additional in-stream sampling stations;
- Discontinuation of analysis of sediment fractions;
- The addition of analysis for constituents identified as contributing to toxicity; and,
- The elimination of analysis for constituents no longer identified in land use and/or in-stream samples.

If a coordinated and comprehensive monitoring plan is developed and meets the goals of this monitoring plan that plan should be considered as a replacement for the CCWTMP.

8.6 *Implementation Schedule*

Table 63 presents the overall implementation schedule for the Calleguas Creek Watershed Toxicity TMDL. A concerted effort was made to incorporate ongoing efforts in the CCW with the overall implementation schedule. For instance, two studies assessing agricultural BMPs in Ventura County were initiated in the fall of 2003 and are expected to be completed in 2006.

Since the ultimate step to reduce/eliminate the discharge of diazinon and chlorpyrifos from urban areas, banning use, has already occurred, the implementation schedule presented in Table 63 provides sufficient time to allow implementation measures and the ban to reduce concentrations in the CCW. In addition, time is allotted for the completion of special studies and the reevaluation of the TMDL, if necessary.

Table 63. Overall Implementation Schedule for Calleguas Creek Watershed Toxicity TMDL

	Implementation Action[1]	Responsible Party	Tentative Date
1	Effective date of phased chlorpyrifos and diazinon waste load allocations.[2]	POTWs and MS4 Copermittees	Effective date[1]
2	Effective date of phased chlorpyrifos and diazinon load allocations.[2]	Agricultural Dischargers	Effective date[1]
3	Implement Calleguas Creek Watershed Toxicity Monitoring Program.	POTWs, MS4 Copermittees, and Agricultural Dischargers	Within 1 year of effective date
4	Conduct a study to investigate the pesticides that will replace diazinon and chlorpyrifos in the urban environment, their potential impact on receiving waters, and potential control measures.	POTWs and MS4 Copermittees	Within 2 years of effective date
5	Special Study #1 – Complete monitoring of sediment concentrations by source/land use type through special study required in the OCs TMDL Implementation Plan.	Agricultural Dischargers and MS4 Copermittees	Within 2 years of effective date
6	Develop and implement collection program for diazinon and chlorpyrifos and an educational program. Collection and education could occur through existing programs such as household hazardous waste collection events.	POTWs and MS4 Copermittees	Within 3 years of effective date
7	Development of an Agricultural Water Quality Management Plan in conjunction with the Conditional Waiver for Irrigated Lands, or (if the Conditional Waiver is not adopted in a timely manner) the development of an Agricultural Water Quality Management Plan as part of the Calleguas Creek WMP.	Agricultural Dischargers	Within a 3 years of effective date
8	Identify the most appropriate BMPs given crop type, pesticide, site specific conditions, as well as the critical condition defined in the development of the LAs.	Agricultural Dischargers	Within 2 years of effective date
9	Implement educational program on BMPs identified in the Agricultural Water Quality Management Plan.	Agricultural Dischargers	Within 3 years of effective date
10	Special Study #2 – Consider findings of sediment transport rates in CCW developed through OCs TMDL Implementation Plan.	Agricultural Dischargers and MS4 Copermittees	Within 5 years of effective date
11	Begin implementation of BMPs.	Agricultural Dischargers	Within 3 years of effective date
12	Evaluate effectiveness of BMPs.	Agricultural Dischargers	Within 5 years of effective date
13	Based on the results of Implementation Actions 1 - 12 and if sediment guidelines are promulgated or water quality criteria are revised, and/or if targets are achieved without attainment of WLAs or LAs, reevaluate the TMDLs and WLAs and LAs, if necessary.	Agricultural Dischargers and MS4 Copermittees	Within 2 years of the submittal of information necessary to reevaluate the TMDL
14	Achievement of Final WLAs	POTWs and MS4 Copermittees	2008
15	Achievement of Final LAs	Agricultural Dischargers	2018

1 The Regional Board regulatory programs addressing all discharges in effect at the time this implementation task is due may contain requirements substantially similar to the requirements of this implementation task. If such requirements are in place in another regulatory program, including other TMDLs, the Executive Officer may revise or eliminate this implementation task to coordinate this TMDL implementation plan with other regulatory programs.

2 Phased WLAs and LAs are effective immediately upon TMDL adoption. WLAs will be placed in POTW NPDES permits as effluent limits. WLAs will be placed in stormwater NPDES permits as in-stream limits. LAs will be implemented using applicable regulatory mechanisms.

8.7 *Adaptive Management*

Implementation of the CCW Toxicity TMDL will operate within an adaptive management framework where compliance monitoring, special studies, and stakeholder interaction guide the process as it develops through time. Compliance monitoring will generate information critical for measuring progress toward achievement of WLAs and LAs, and may suggest the need for revision of those allocations in some instances. Additionally, data from ongoing monitoring could reveal necessary adjustments to the implementation timeline and may serve to initiate reevaluation when appropriate. Special studies will increase understanding of specific conditions/processes in the watershed, allowing for more accurate prediction of results expected from various implementation efforts. Thus, adaptive management allows this TMDL to become an ongoing and dynamic process, rather than a static document.

Leadership of the adaptive management program will involve individuals from a range of groups. The LARWQCB will oversee compliance monitoring and any potential need for reevaluation of this TMDL. Various members or stakeholder groups may contribute time and expertise to special studies. The VCWPD has significant resources and personnel dedicated to improving the understanding of sediment transport in watersheds of the region, including the CCW. United Water is involved in a program to monitor effects upon water quality from various agricultural land uses, which will likely generate information beneficial for the efficacy of the Implementation Plan. Many stakeholders have been working together since 1996 toward the development of a Watershed Management Plan for Calleguas Creek. The purpose of the Watershed Management Plan is to develop a strategy to address a variety of needs in the watershed: flood control, erosion and sedimentation, water quality, water resources, and habitat. When developed, this plan will identify mechanisms for addressing the water quality issues within the watershed, including 303(d)-listed pollutants. As such, the plan will serve as the ultimate implementation plan for all of the TMDLs within the watershed.

8.8 *Economic Analysis of Implementation*

Water Code Section 13000 requires the State and Regional Boards to regulate so as to achieve the highest water quality which is reasonable, based on consideration of economics and other public interest factors. Water Code Section 13141 requires that prior to the implementation of any agricultural water quality control program; an estimate of the total cost of the program and identification of potential sources of financing shall be included in any applicable regional water quality control plan. An analysis of the impacts of implementing these TMDLs with respect to costs, benefits, and other public interests factors is presented below.

The WLA Implementation Plan focuses on education, collection of unused products, water conservation, and monitoring to refine the state of knowledge with regard to current and potential future conditions. A study and a combined education and chlorpyrifos and diazinon collection program will be specifically be completed as part of the WLA Implementation Plan. Table 64 summarizes the goals of the education/collection program and study as well as estimated costs.

Table 64. Waste Load Allocation Implementation Plan Actions and Cost Estimates

Implementation Action and Goals	Estimated Cost
Develop and implement urban educational and collection program. The goals of this program are: 1. Provide information on: • The ban and restrictions on use of chlorpyrifos and diazinon. • The harmful effects of chlorpyrifos and diazinon and the potential effects of replacement products on the environment. • The proper use and disposal of pesticides. • Alternative pest control techniques including integrated pest management. • Methods for reducing urban water use and runoff. • Collect a portion of the remaining chlorpyrifos and diazinon stocks held by domestic users. 2. Assess effectiveness of program.	$150,000/year for a minimum of three years
Study diazinon and chlorpyrifos replacement pesticides for use in the urban environment. The goal of this study is to investigate the pesticides that will replace diazinon and chlorpyrifos in the urban environment, their potential impact on the beneficial uses in receiving waters, and potential control measures.	$30,000

The LA Implementation Plan focuses on education, water conservation, and implementation of BMPs. Table 65 summarizes the goals of the programs and studies as well as estimated costs. Table 65 summarizes the estimated unit costs and watershed wide costs associated with implementing various BMPs. Currently it is unclear which BMPs have been implemented in the CCW or the extent to which those BMPs have been implemented. Because of this, in developing the estimated cost for implementing BMPs it was assumed that 1) no BMPs are implemented in the CCW and 2) all BMPs would be required on all agricultural lands applying diazinon or chlorpyrifos. Cost estimates were developed by selecting the least and most expensive options by category for the low and high cost estimates, respectively. The total acreage considered was determined by averaging the total acres to which chlorpyrifos and diazinon were applied to between 1998 and 2003 based on PUR data. The range of estimates is likely high given the broad assumptions used.

Table 65. Load Allocation Implementation Plan Actions and Cost Estimates

Implementation Action and Goals	Estimated Cost
Develop and implement an Agricultural Water Quality Management Plan. The goal of this action is develop a management plan to address identified water quality impairments and meet water quality objectives.	$700,000
Identify appropriate BMPs and the extent to which BMPs are currently implemented in the CCW. The goal of this action is to complete studies to determine the most appropriate BMPs for the CCW given crop type, pesticide, site specific conditions, as well as the critical conditions as well as the current BMPs utilized in the CCW and the extent to which they are currently implemented.	This work is currently being conducted and will not require additional funding.
Develop and implement agricultural BMP education program. The goals of this program are to: 1. Provide information on: • BMPs identified in the aforementioned studies as well as other BMPs deemed to be effective at reducing runoff to waterbodies given crop type, pesticide, site specific conditions, as well as the critical conditions. • The restrictions on use of chlorpyrifos and diazinon. • The harmful effects of chlorpyrifos and diazinon and the potential effects of replacement products. • The proper use and disposal of pesticides. • Alternative pest control techniques including integrated pest management. • Methods for reducing water use and runoff. 2. Assess effectiveness of program.	$75,000/year for a minimum of three years
Implement BMPs. The goal of this action is to implement BMPs to address diazinon, chlorpyrifos, and toxicity of unknown causes and to assess the effectiveness of BMPs.	$3,300,000 – 140,000,000

Table 66. Estimated Costs for Applicable Agricultural Best Management Practices (BMPs) for Reducing Pesticide Loading[1,2]

Agricultural BMP	Units	Cost Range Per Unit		Cost Range For Watershed (note acreage and how defined)	
		Low	High	Low	High
Conservation Tillage					
No Till	acre	-$11.50	$5.70	-$227,800	$112,900
Mulch Till	acre	$11.50	$22.90	$227,800	$453,600
Contour Farming	acre	$9.20	$114.60	$96,600	$1,203,300
Contour Orchard and Other Fruit Area	acre	$114.60	$149.00	$1,203,300	$1,564,500
Crop Residue Use					
Chopping and Chopping Waste	acre	$28.70	$68.80	$568,500	$1,362,800
Mulching using min. Tillage	acre	$11.50	$28.70	$227,800	$568,500
Filter Strip					
Filter Strip (10-20 ft wide)	acre	$430	$14,326	$80,500	$2,682,500
Filter Strip (20-40 ft wide)	acre	$430	$14,326	$161,000	$5,364,900
Filter Strip (40-60 ft wide)	acre	$430	$14,326	$321,900	$10,729,900
Buffer Strip (20-30 ft wide)	acre	$487	$1,948	$182,400	$729,600
Landscaping (20-30 ft wide)	acre	$516	$4,011	$193,100	$1,502,200
Grassed Waterway	acre	$430	$14,326	$403,400	$13,412,300
Hillside Bench	acre	$40	$2,120	$421,050	$22,262,100
Irrigation Systems					
Irrigation System: Sprinkler	acre	$401	$1,261	$7,945,000	$24,971,950
Irrigation System: Trickle					
Microspray System	acre	$974	$3,667	$19,296,050	$72,643,900
Drip Irrigation	acre	$2,120	$4,126	$41,996,900	$91,723,850
Irrigation System					
Tailwater Recovery	each	$5,157	$28,652	NC	NC
Irrigation Water Management	acre	$57	$28,652	$1,135,000	$17,025,000
Runoff Management system					
Sediment Basin	each	$802	$1,150,000	NC	NC
Infiltration Trench	per foot	$17	$86	NC	NC
Sediment Trap, Box Inlet	each	$212	$974	NC	NC
			Total[3]	**$3,300,000**	**$140,000,000**

NC Not calculated as there was not a clear method for estimating the total units needed.

1 From: Calleguas Creek Watershed Erosion and Sediment Control Plan for Mugu Lagoon (NRCS, 1995).

2 Costs adjusted from 1995 to 2000 using Engineering News Record Construction Cost Index.

3 The total for the Low Cost Range determined by selecting the least expensive BMP from each subgroup. The total for the High Cost Range determined by selecting the most expensive BMP from each subgroup.

9 References

Abrol, S., Augustenborg, C., Madden, C., Suffet, M. 2003. Development of a TMDL for Organochlorine Pesticides for the Calleguas Creek Watershed. Prepared for the Los Angeles Regional Water Quality Control Board. Contract No. 01-172-140-0. September 2003.

Anghera, Michelle. 2004. Preliminary data report emailed to Heather Kirschmann of Larry Walker Associates on May 27, 2004.

Alameda County. 2001. Runoff of Diazinon form Paved Plots and Test Sites: Summary of Results. Alameda County Flood Control and Water Conservation District.

Anderson, B.S., Vlaming, V. DE, Larsen, K., Deanovic, L.S., Birosik, S., Smith, D.J., Hunt J.W., Phillips B.M., Tjeerdema R.S. 2002. Causes of Ambient Toxicity in the Calleguas Creek Watershed of Southern California. *Environmental Monitoring and Assessment.* 78, 131-151.

Anderson, B.S. 2004. Moss Landing Marine Laboratory. Personal communication with C. Minton, November 30, 2004.

Anderson, T. D. and Lydy, M. J. 2002. Increased toxicity to invertebrates associated with a mixture of atrazine and organophosphate insecticides. Environ. Tox. and Chem. V21, No. 7, 1507–1514.

Approach to Water Pollution Reduction. Water Science and Technology Board, Division on Earth and Life Studies. National Academy Press, Washington, DC.

Bailey, H.C., DiGiorgio, C., Kroll, K., Miller, J.L., Hinton, D.E., Starrett, G. 1996. Development of Procedures for Identifying Pesticide Toxicity in Ambient Waters: Carbofuran, Diazinon, Chlorpyrifos. Environ. Tox. and Chem. V15, No. 6, 837–845.

Bailey, H. C., Elphick, J. R., Krassoi, R., Lovell, A. 2001. Joint Acute Toxicity of Diazinon and Ammonia to Ceriodaphnia dubia. Environ. Tox. and Chem. V20, No. 12, 2877–2882.

Callaghan, A., G. Hirthe, et al. 2001. "Effect of Short-Term Exposure to Chlorpyrifos on Developmental Parameters and Biochemical Biomarkers in Chironomus riparius Meigen." Ecotoxicology and Environmental Safety 50(1): 19-24.

California Department of Fish and Game (CDFG). 2000. Water Quality Criteria for Diazinon and Chlorpyrifos. California Department of Fish and Game Administrative Report 00-3. 65pp.

California Department of Water Resources (DWR). 2000. Land use survey GIS data. Website visited April 2004: http://www.landwateruse.water.ca.gov/basicdata/landuse/landusesurvey.cfm.

California Resources Agency. 1997. CWIS Mugu Lagoon. California Environmental Resources Evaluation System (CERES). Website visited January 2001: http://ceres.ca.gov/wetlands/geo_info/so_cal/mugu_lagoon.html

Central Valley Regional Water Quality Control Board (CVRWQCB). 2001. Diazinon and Chlorpyrifos Target Analysis – Draft.

Central Valley Regional Water Quality Control Board (CVRWQCB). 2004. Total Maximum Daily Load (TMDL) Report for the Pesticides Diazinon and Chlorpyrifos in: Arcade Creek, Elder Creek, Elk Grove Creek, Morrison Creek, and Chicken Ranch and Strong Ranch Sloughs Sacramento County, California – Final Staff Report.

Central Valley Regional Water Quality Control Board (CVRWQCB). 2005. Amendments to the Water Quality Control Plan for the Sacramento River and San Joaquin River Basins for the Control of Diazinon and Chlorpyrifos Runoff into the Lower San Joaquin River. Peer Review Draft Staff Report. February 2005.

City of Camarillo. 1997 – 2000. Camarillo Wastewater Treatment Plant NPDES Annual Reports.

City of Thousand Oaks. 1997 – 2001. Olsen Road and Hill Canyon Wastewater Treatment Facility NPDES Annual Reports.

Code of Federal Regulations (CFR). 2000. 40 Code of Federal Regulations Part 130 (TMDL Rule).

Granade, Steve. 2003. Environmental Engineer, Naval Base Ventura County. steve.granade@navy.mil. Personal communication with C. Minton, August 4, 2003.

Grigorian, Grigor. 2001. Personal communication with A. Cooper. January 18, 2001.

Helsel, D.R. and T.A. Cohn. 1988. Estimation of Descriptive Statistics for Multiply Censored Water Quality Data, Water Resour. Res. Vol. 24, No. 12, pp. 1997-2004.

Helsel, D.R. 1990. Less than obvious: Statistical treatment of data below the detection limit. Environ. Sci. Technol., Vol. 24, No. 12., pp. 1766-1774.

Helsel D.R. and R.M. Hirsch. 1992. Statistical Methods in Water Resources, Elsevier Science B.V., Amsterdam.

Landis, J. D. PhD, Chair of the City and Regional Planning at the University of California, Berkeley (with Juan Pablo Monzon, Michael Reilly, and Chris Cogan). 1998. Development and Pilot Application of the California Urban and Biodiversity Analysis Model, forthcoming in Computers, Environment, and Urban Systems, http://gis.esri.com/library/userconf/proc98/PROCEED/TO600/PAP571/P571.htm

Keller, A.A., Y. Zheng, and T.H. Robinson.2004. Determining Critical Water Chemistry Conditions for Inorganic Nitrogen in Dry, Semi-Urbanized Watersheds. J. American Water Res. Assoc., V 40, n 3, pp, 721-735.

Larry Walker Associates (LWA). 2000. Calleguas Creek Characterization Study. Results of the Coordinated Water Quality Monitoring Program, Surface Water Element.

Larry Walker Associates (LWA). 2004a. Calleguas Creek Watershed Database. Accessed December 6, 2004.

Larry Walker Associates (LWA). 2004b. Progress Report on Efforts to Address Salts on the Calleguas Creek Watershed, submitted to Calleguas Creek Watershed Management Plan, pp. 105, June 30, 2004.

Los Angeles Regional Water Quality Control Board (LARWQCB). 1996. Water Quality Assessment and Documentation. 1996.

Los Angeles Regional Water Quality Control Board (LARWQCB). 1998. Public Notice – Biennial Listing of Impaired Surface Waters – Pursuant to the Clean Water Act Section, Section 303(d). March 24, 1998.

Los Angeles Regional Water Quality Control Board (LARWQCB). 2002a. Draft Staff Report – 2002 Update: Clean Water Act Section 305(b) Report and Section 303(d) List of Impaired Waters – LA Region. January 29, 2002.

Los Angeles Regional Water Quality Control Board (LARWQCB). 2002b. Total Maximum Daily Loads for Nitrogen Compounds and Related Effects Calleguas Creek, Tributaries, and Mugu Lagoon – Staff Report.

Los Angeles Regional Water Quality Control Board (LARWQCB). 2003. 2002 Clean Water Act Section 303(d) List of Water Quality Limited Segments.

McIntyre, Sam. 2004. Pesticide Advisor, Somis Ag Management Inc. sompacag@aol.com . Personal communication with M. Casterline, May 2004.

Mackay, D., W.Y. Shiu, K.C. Ma.1997. Illustrated handbook of physical-chemical properties and environment fate for organic chemicals, CRC Press, Lewis Publishers, Boca Raton, FL

Majewski, M.S., D.S. Baston. 2002. Atmospheric Transport of Pesticides in the Sacramento, California, Metropolitan Area, 1996-1997. USGS Report 02-4100.

Javier Minjares, Southern California Association of Governments, Population Growth by City for SCAG Region for 2000-2030 (pre-website release of population projections), minjares@scag.ca.gov.

Mount, D.I. and T.J. Norberg. 1984. A several life-cycle cladoceran toxicity test. Environ Chem. 3:425-434.

National Research Council (NRC). 2001. Assessing the TMDL Approach to Water Quality Management. Committee to Assess the Scientific Basis of the Total Maximum Daily Load Approach to Water Pollution Reduction. Water Science and Technology Board, Division on Earth and Life Studies. National Academy Press, Washington, DC.

Natural Resources Conservation Service (NRCS). 1995. Calleguas Creek Watershed Erosion and Sediment Control Plan for Mugu Lagoon.

Neter, J., W. Wasserman, and M.H. Kutner. 1990. Applied Linear Statistical Models Regression, Analysis of Variance, and Experimental Design, 3rd Ed., Irwin, Homewood, IL.

Oris, J.T., Winner, R.W., and Moore, M.V. 1991. A four-day survival and reproduction test for Ceriodaphnia dubia, Environ. Toxicol. Chem. 10, 217-224.

Ross, L. 2002. Department of Pesticide Regulation, personal communication.

San Francisco Bay Regional Water Quality Control Board (SFBRWQCB). 2004. Diazinon and Pesticide-Related Toxicity in Bay Area Urban Creeks Water Quality Attainment Strategy and Total Maximum Daily Load – Final Project Report.

Schimmel, S.C., B.D. Melzian, D.E. Campbell, C.J. Strobel, S.J. Benyi, J.S. Rosen, H.W. Buffum, and N.I. Rubinstein. 1994. Statistical Summary EMAP-Estuaries Virginian Province - 1991. EPA /620/R-94/005.

Southern California Association of Governments (SCAG). 2004. Urban land use GIS data. Website visited June 2004: http://rtmisweb.scag.ca.gov/data_gis/ .

State Water Resources Control Board (SWRCB). 1996. Marine Bioassay Project – Eighth Report – Refinement and Implementation of Four Effluent Toxicity Testing Methods Using Indigenous Marine Species. July 1996.

State Water Resources Control Board (SWRCB). 1997. Proposed Decision Regarding Application 29408 and Wastewater Change Petition No. 6 of the City of Thousand Oaks and Availability of Unappropriated Water for Applications 29816, 29819, 29581, 29959, 300317, 30092, and 30194--Arroyo Conejo, Conejo Creek, and Calleguas Creek in Ventura County. Sacramento, California. August 1997.

State Water Resources Control Board (SWRCB). 1998. Sediment Chemistry, Toxicity, and Benthic Community Conditions in Selected Water Bodies of the Load Angeles Region. August 1998.

State Water Resources Control Board (SWRCB). 2000. Policy for Implementation of Toxics Standards for Inland Surface Waters, Enclosed Bays, and Estuaries of California (SIP). May 2000.

State Water Resources Control Board (SWRCB). 2004a. State Mussel Watch Program (SMWP) website visited August 2004: http://www.swrcb.ca.gov/programs/smw/index.html.

State Water Resources Control Board (SWRCB). 2004b. Toxic Substances Monitoring Program (TSMP) website visited August 2004: http://www.swrcb.ca.gov/programs/smw/index.html.

State Water Resources Control Board (SWRCB). 2004c. Water Quality Control Policy For Developing California's Clean Water Act Section 303(D) List. September 30th, 2004.

Stow, C.A. and M.E. Borsuk. 2003. Assessing TMDL Effectiveness Using Flow-Adjusted Concentrations: A Case Study of the Neuse River, North Carolina, Environ Sci. Technol., V 37, 2043-2050.

Summerfelt, Robert. Toxicity of Pesticides Adsorbed to Suspended Sediment to Larval Fish in the Cedar River. 2001 Leopold Center Progress Reports, Volume 10 (2001). Leopold Center for Sustainable Agriculture.

Tchobanoglous, G. and Schroeder, E. 1985. Water Quality: Characteristics, Modeling, Modification, Addison-Wesley Publishing Company, Reading, MA.

Tetra Tech. 2000. Final Phase 1 Remedial Investigation Technical Memorandum. Naval Air Weapons Station, Point Mugu, California.

Tetra Tech. 2003. Draft Ecological Risk Assessment Addendum for Installation Restoration Program Sites 5 and 11. Naval Base Ventura County, Point Mugu Site, California.

Thursby, G.B. and C.E. Schlekat. 1993. Statistical analysis of 10-day solid phase toxicity data for amphipods. Abstract, 14th Annual Meeting, Society of Environmental Toxicology and Chemistry.

Thompson, B., Anderson, B., Hunt, J., Taberski, K., Phillips, B. 1997. Relationship Between Sediment Toxicity and Contamination in San Francisco Bay. Prepared for the San Francisco Estuary Institute.

United States Census Bureau (USCB). Website visited May 2004: http://www.census.gov/population/projections/state/stpjpop.txt

United States Geological Survey (USGS). 2004. Letter from Chris Ingersoll (USGS) to Lenwood Hall (University of Maryland). Subject line: Diazinon toxicity data for Gammarus fasciatus reported in Johnson and Finley (1980) and in Mayer and Ellersieck (1986).

United States Department of Health and Human Services (USDHHS). 1996. Toxicological Profile for Diazinon.

United States Environmental Protection Agency (USEPA). 1980. Ambient Water Quality Criteria for DDT. Office of Water Regulations and Standards. EPA 440/5-80-038.

United States Environmental Protection Agency (USEPA). 1985. Guidelines for Deriving Numeric National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses. Office of Research and Development PB85-227049.

United States Environmental Protection Agency (USEPA). 1986. Ambient Water Quality Criteria for Chlorpyrifos – 1986. Office of Water 440/5-005.

United States Environmental Protection Agency (USEPA). 1991. Technical Support Document for Water Quality Based Toxics Control. EPA/505/2-90-001

United States Environmental Protection Agency (USEPA). 1999. Reregistration Eligibility Science Chapter for Chlorpyrifos, Fate and Environmental Risk Assessment Chapter. US Environmental Protection Agency, Washington, D.C. October, 1999; revised June 2000

United States Environmental Protection Agency (USEPA). 2000a. Draft Ambient Aquatic Life Water Quality Criteria for Diazinon. Office of Water Draft.

United States Environmental Protection Agency (USEPA). 2000b. Chlorpyrifos Revised Risk Assessment and Agreement with Registrants. US Environmental Protection Agency, Washington, D.C.

United States Environmental Protection Agency (USEPA). 2001a. Diazinon Revised Risk Assessment and Agreement with Registrants. US Environmental Protection Agency, Washington, D.C.

United States Environmental Protection Agency (USEPA). 2002a. Methods for Measuring the Acute Toxicity of Effluents and Receiving Waters to Freshwater Marine Organisms. Fifth Edition. October.

United States Environmental Protection Agency (USEPA). 2002b. Total Maximum Daily Loads for Toxic Pollutants – San Diego Creek and Newport Bay, California. US Environmental Protection Agency, Region 9. Established June 14, 2002.

Ventura County. Website visited May 2004: http://www.countyofventura.org/visitor/visitor.asp

Ventura County Flood Control District. 1998. Ventura Countywide Stormwater Quality Management Program. Annual Report.

Ventura County Flood Control District. 1999. Ventura Countywide Stormwater Quality Management Program. Annual Report.

Ventura County Flood Control District. 2000. Ventura Countywide Stormwater Quality Management Program. Annual Report.

Ventura County Flood Control District. 2001. Ventura Countywide Stormwater Quality Management Program. Annual Report.

Ventura County Flood Control District. 2002. Ventura Countywide Stormwater Quality Management Program. Annual Report.

Ventura County Flood Control District. 2003. Ventura Countywide Stormwater Quality Management Program. Annual Report.

Wilen, C.A. 2001. Survey of Residential Pesticide Use and Sales in the San Diego Creek Watershed of Orange County, California. University of California Statewide Integrated Pest Management Project, University Cooperative Extension.

Wu, Jigang; Laird, David. 2004. Interactions Of Chlorpyrifos With Colloidal Materials In Aqueous Systems. Journal Of Environmental Quality. 33(5):1765-1770.

Young, T. 2002, Department of Civil and Environmental Engineering, University of California, Davis, personal communication with M. Mysliwiec.

Zabik, J.M., Seiber, J.N. 1993. Atmospheric transport of organophosphate pesticides from California's Central Valley to the Sierra Nevada mountains. J Environ Qua1 22(1):80-90.

Appendix I. Mugu Lagoon Data Summary Discussion

Introduction

Calleguas Creek Reach 1 (Mugu Lagoon) is currently on the 303(d) list for sediment toxicity. The listing is based on data collected through the California State Water Resources Board's Bay Protection and Toxic Cleanup Program (BPTCP) in 1993. The purpose of this Appendix is to summarize available sediment toxicity and sediment chemistry data for the Lagoon collected since 1993 in an effort to determine the persistence of sediment toxicity, identify potential causes of observed toxicity, and to help guide future monitoring activities to support development of the toxicity TMDL.

Summary of Existing Toxicity Data for Mugu Lagoon

Research was conducted to identify sediment toxicity data collected for Mugu Lagoon since the testing performed by the BPTCP in 1993. A summary of the existing toxicity data evaluated is provided in Table 1 and summarized in detail in this Appendix. As indicated in Table 1, additional tests were conducted by the BPTCP in 1997; the Naval Air Weapons Station (NAWS) conducted testing as part of the Phase I Remedial Investigation (RI); the Naval Base Ventura County (NBVC) performed testing as a validation to testing conducted for the NAWS RI; and Michelle Anghera collected sediment toxicity and chemistry data for a graduate degree while at UCLA. Each of these studies is discussed below. Because of several differences in methodologies among these studies (e.g. sample collection, test methods) the studies are not directly comparable and therefore only a qualitative analysis of these studies could be performed.

BPTCP

In addition to the tests conducted in 1993 that are the basis for the 303(d) listing for Reach 1, the BPTCP performed sediment toxicity tests in April 1994 and February 1997. As indicated in Table 2 several stations monitored in Mugu Lagoon demonstrated significant toxicity when compared to control organisms; these sites are also plotted in Figure 1 according to percent survival.

Sediment samples were also analyzed for PAHs, pesticides, metals, and total PCBs. As discussed in the following section, sediment concentration results were used to evaluate the relationship between sediment chemistry and biological impacts. Sediment samples were collected as grab samples to a desired depth of 10 cm. Once collected, overlying water was removed and the top 2 cm of surficial sediment was sub-sampled from the grab.

Table 1. Toxicity Studies Conducted in Mugu Lagoon

Agency	Study	Dates	Locations	Species Tested (acute unless otherwise noted)	Sediment Chemistry Collected
SWRCB	BPTCP	April 1994; February 1997	Mugu/Entrance; West Mugu Lagoon; Central Mugu Lagoon; East Mugu Lagoon	Amphipod *Eohaustorius* Amphipod *Rhepoxynius*	Yes, analyzed for PAHs, pesticides, metals, and total PCBs.
NAWS Pt. Mugu	Phase I Remedial Investigation	February 1994	Sites 2, 4, and 5	Amphipod *Ampelisca* Amphipod *Eohaustorius* (chronic) Polychaete *Neanthes* (chronic)	No, sediment samples were analyzed as part of the study but were not collected simultaneously with toxicity samples.
NBVC Pt. Mugu	Ecological Risk Assessment	December 1997	Site 11	Amphipod *Ampelisca*	Yes, co-located with toxicity samples and analyzed for PAHs, pesticides, and metals.
UCLA	Graduate study performed by Michelle Anghera	February 2001	Four sites each on two tidal creeks (four adjacent to NBVC reference sites); 6 sites in the lagoon mudflat	Amphipod *Eohaustorius*	Yes, analyzed for metals, pesticides, PCBs, and PAHs.

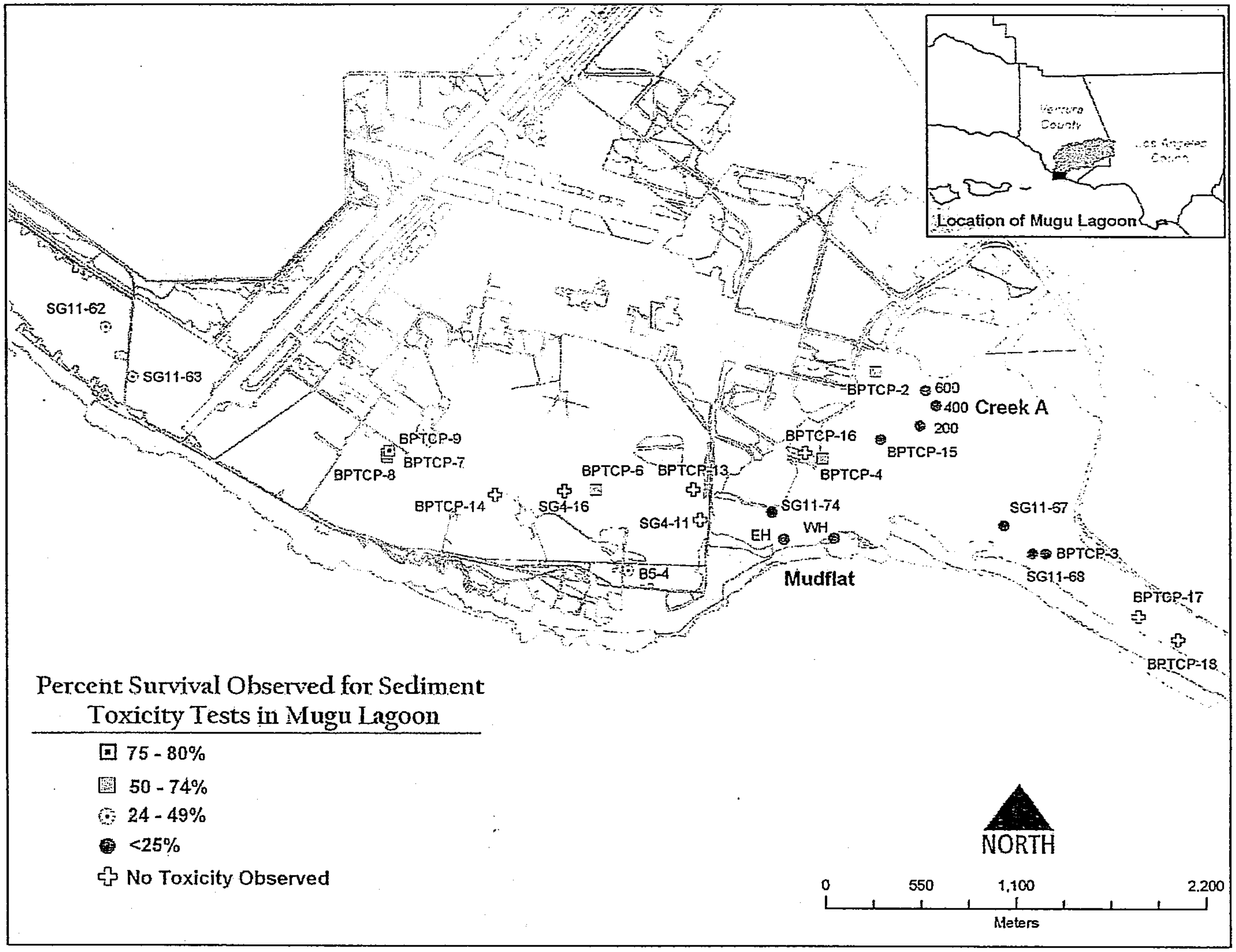


Figure 1. Mugu Lagoon Sediment Toxicity Results

Table 2. Summary of BPTCP Sediment Toxicity Testing

Station	Date	*Eohaustorius estuarius* Mean % Survival	*Rhepoxynius abronius* Mean % Survival
Mugu Lagoon	1/12/93	**66***	N/A
Mugu/Entrance	1/12/93	N/A	**14***
Mugu/Main Lagoon	1/12/93	N/A	**68***
Mugu/Western Arm	1/12/93	N/A	**64***
Mugu/Entrance – Rep 1	4/14/94	N/A	51*
Mugu/Entrance – Rep 2	4/14/94	N/A	69*
Mugu/Entrance – Rep 3	4/14/94	N/A	78*
West Mugu Lagoon – A1	2/6/97	87	N/A
West Mugu Lagoon – A2	2/6/97	89	N/A
Central Mugu Lagoon – B1	2/6/97	17*	N/A
Central Mugu Lagoon – B2	2/6/97	85	N/A
East Mugu Lagoon – C1	2/6/97	78	N/A
East Mugu Lagoon – C2	2/6/97	84	N/A

N/A= Not Analyzed

Bold = Basis for 303(d) listing

* = significantly different from the control at the 95% confidence level and less than the threshold based on the 90th percentile Minimum Significant Difference (MSD)

NAWS and NBVC Studies

Sediment samples were collected and analyzed for toxicity in 1994 under the Phase I Remedial Investigation (RI) for the NAWS at Point Mugu. Samples were collected at stations within Sites 2, 4, and 5. Site 2 is located at the southern end of South Mugu Road which transects the entire site; Site 4 is just North of the Lagoon; and Site 5 is located on the southern side of the western arm of Mugu Lagoon. As shown in Table 3, with the exception of lower survival of *Ampelisca* (42%) observed at Site 5 and *Eohaustorius* (59% and 55%) at Site 2 amphipod (*Ampelisca and Eohaustorius*) survival and reburial did not show significant differences when compared to control organisms. Polychaete (*Neanthes*) survival was not impacted at any sites and growth was effected only at one Site 2 location. Samples collected at Site 2 represented low marsh and mudflat sediments. Coordinates were not available for this site location and therefore could not be plotted on Figure 1. Because sediment concentrations of phenanthrene, DDT, chlordane, dieldrin, PCBs, and cadmium exceeded sediment screening values (i.e. minimal effects–low values (ERLs)) and toxicity was observed during the 1994 investigation, a validation study was conducted in 1997.

The validation study compared sediment chemistry and toxicity at several locations within Site 11 to reference sites adjacent to Site 11. Site 11 includes Mugu Lagoon and all of the drainage ditches in the installation. Reference sites were utilized in this study to account for potential effects from upstream sources and/or effects of sediment texture on the results of the bioassays. Toxicity results showed that Site 11 sites were not statistically different from the reference sites. Site 11 sites and reference sites where less than 50% survival was observed are plotted on Figure 1 and percent survival for all Site 11 sites and reference sites is shown graphically in Figure 2. Additionally, there were no strong trends or correlations between amphipod survival percentages and sediment parameters such as percent fines, percent moisture, sulfides, or ammonia (Tetra Tech, 2000).

Table 3. Summary of Navy Toxicity Data Collected for the RI and ERA

Station	Date	*Ampelisca*	*Eohaustorius estuarius*		*Neanthes*	
		Mean % Survival	Mean % Survival	Mean % reburial	Mean % Survival	Mean weight (mg)
Site 2 (SG2-1)	Feb-1994	82	N/A	N/A	92	0.5*
Control 101/102	Feb-1994	88/92	--	--	--	--
Control 35/36	Feb-1994	--	--	--	96/80	0.84/0.54
Site 2 (SG11-7)	Feb-1994	N/A	59*	96	96	0.83
	Feb-1994	N/A	55*	93	92	0.47
Control 203	Feb-1994	--	98	96	--	--
Control 200/201	Feb-1994	--	--	--	100/100	0.49/0.41
Site 4 (SG4-11)	Feb-1994	83[a]	N/A	N/A	80[b]	1.92[b]
Site 4 (SG4-16)	Feb-1994	81[a]	N/A	N/A	88[b]	0.41[b]
Site 5 (B5-4)	Feb-1994	42*[a]	N/A	N/A	80	0.7
Control 64/65	Feb-1994	--	--	--	32/96	0.56/0.9
Site 11 (SG11-69)[b]	Dec-1997	64	N/A	N/A	N/A	N/A
Site 11 (SG11-70)[b]	Dec-1997	51	N/A	N/A	N/A	N/A
Site 11 (SG11-71)[b]	Dec-1997	78	N/A	N/A	N/A	N/A
Site 11 (SG11-72)[b]	Dec-1997	91	N/A	N/A	N/A	N/A
Site 11 (SG11-73)[b]	Dec-1997	71	N/A	N/A	N/A	N/A
Site 11 (SG11-74)[b]	Dec-1997	14	N/A	N/A	N/A	N/A
Site 11 (SG11-75)[b]	Dec-1997	89	N/A	N/A	N/A	N/A
Site 11 (SG11-76)[b]	Dec-1997	61	N/A	N/A	N/A	N/A
Reference Area						
SG11-61[b]	Dec-1997	68	N/A	N/A	N/A	N/A
SG11-62[b]	Dec-1997	44	N/A	N/A	N/A	N/A
SG11-63[b]	Dec-1997	39	N/A	N/A	N/A	N/A
SG11-64[b]	Dec-1997	58	N/A	N/A	N/A	N/A
SG11-65[b]	Dec-1997	56	N/A	N/A	N/A	N/A
SG11-66[b]	Dec-1997	65	N/A	N/A	N/A	N/A
SG11-67[b]	Dec-1997	14	N/A	N/A	N/A	N/A
SG11-68[b]	Dec-1997	10	N/A	N/A	N/A	N/A

* = significantly different from the controls at the 95% confidence level.

[a] Corresponding controls are Control 101 and Control 102. [b] Control data not provided.

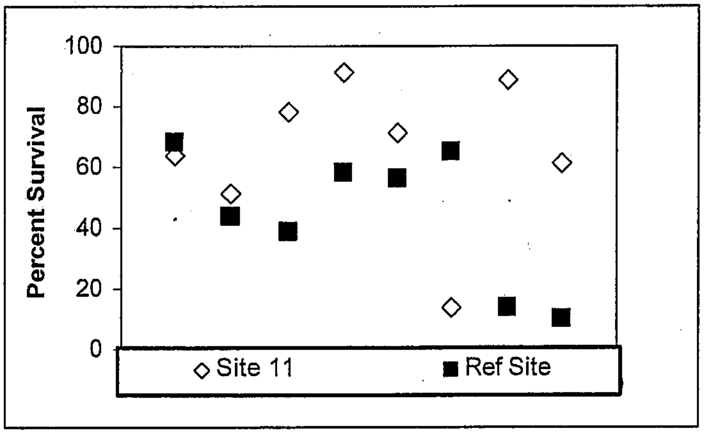


Figure 2. ***Ampelisca*** **Percent Survival at Site 11 Sites and Reference Sites**

Sediment samples were analyzed for pesticides, PCBs, total metals, and phenols. Sediment samples for chemical analysis were not collected at the same locations (co-located) for toxicity samples during the 1994 remedial investigation but co-located toxicity and sediment samples were collected for the additional testing that was conducted in 1997. Although toxicity was not observed relative to reference sites, samples from both the study sites and reference sites showed toxicity at some locations. However, based on the results provided in the study reports (Tetra Tech 2000, 2003) it was not possible to determine which sites showed toxicity when compared to test control organisms. As discussed in the following section sediment chemistry results were compared to toxicity benchmark values to assess possible causes of observed sediment toxicity at these sites.

Collection of sediment samples for these studies differed from the BPTCP and UCLA studies in that sediment was collected at a depth from 0 – 0.5 feet, therefore representing a deeper core sample than the surficial samples collected from the top 2 centimeters in the other studies.

UCLA Study

Sediment toxicity tests were performed on sediment samples collected from four sites in each of two tidal creeks (Creek A and Creek C) located within the central marsh at 0, 200, 400, and 600 meters from the creek mouths. Additionally, in the mudflat area sites were sampled at 0, 100, and 200 meters along two transect lines. One transect was at the mean low tide line and the other at the mean high tide. Benthic and sediment cores (22 cm^2, 6 cm deep) were collected and one liter of aerobic sediment was collected within 30 cm of the cores for toxicity, chemistry (metals, pesticides, PCBs, and PAHs), porewater salinity, dissolved ammonia, and pH measurements. The oxygenated layer of sediment was collected in order to minimize factors that may impact toxicity and contaminant results due to oxidation of anoxic sediments. The sediment was collected by scraping the surface sediment down to the anaerobic layer (1-2 cm).

Results are provided in Table 4 and indicate low survival of organisms at several locations; however, the study report did not provide information regarding the statistical significance of these differences from controls. These results are compared to sediment chemistry concentrations in the following section. Sites where less than 50% survival was observed are plotted on Figure 1.

Table 4. Summary of Toxicity Data Collected by UCLA

Station	Date	*Eohaustorius* Mean % Survival
Creek A (A0)	Feb-2001	66.3
Creek A (A200)	Feb-2001	9.2
Creek A (A400)	Feb-2001	0
Creek A (A600)	Feb-2001	0
Creek C (C0)	Feb-2001	67.5
Creek C (C200)	Feb-2001	51.9
Creek C (C400)	Feb-2001	80
Creek C (C600)	Feb-2001	62.5
Mudflat EH	Feb-2001	28.8
Mudflat EL	Feb-2001	55
Mudflat MH	Feb-2001	60
Mudflat WL	Feb-2001	68.8
Mudflat WH	Feb-2001	21.3

Evaluation of Existing Toxicity Data

For each of the studies in which sediment chemical analysis was performed, sediment chemical concentrations were compared to published guideline values including minimal effects-low (ERL), effects range-median (ERM), and the probable effects level (PEL). The guideline values used were derived from a wide variety of studies on invertebrates and marine and estuarine sediments, including the National Oceanic and Atmospheric Association database. It should be noted that these values were developed as informal, interpretive tools. The guidelines are not promulgated as regulatory criteria or standards, and are not intended as cleanup or remediation targets, discharge attainment targets, or as pass-fail criteria for dredged material disposal decisions or any other regulatory purpose.

Evaluations performed for BPTCP, NBVC study, and UCLA study results all utilized the same ERL and ERM values as listed in Table 5. PEL values provided in Table 5 were used by the BPTCP but not the other studies, for purposes of this evaluation other study results were compared to the PEL values used by the BPTCP.

Table 5. Sediment Screening Levels

CONSTITUENT	PEL	ERL	ERM
Total PCB (ug/kg – dry weight)	188.79	22.70	180.0
PAH (ug/kg – dry weight)			
Acenaphthene	88.90	16.00	500.0
Acenaphthylene	127.89	44.00	640.0
Anthracene	245.00	85.30	1100.0
Fluorene	144.35	19.00	540.0
2-methylnapthalene	201.28	70.00	670.0
Naphthalene	390.64	160.00	2100.0
Phenanthrene	543.53	240.00	1500.0
Total LMW-PAHs	1442.00	552.00	3160.0
Benz(a)anthracene	692.53	261.00	1600.0
Benzo(a)pyrene	763.22	430.00	1600.0
Chrysene	845.98	384.00	2800.0
Dibenz(a,h)anthracene	134.61	63.40	260.0
Fluoranthene	1493.54	600.00	5100.0
Pyrene	1397.60	665.00	2600.0
Total HMW-PAHs	6676.14	1700.00	9600.0
Total PAHs	16770.54	4022.00	44792.0
Pesticides (ug/kg - dry weight)			
p,p'DDE	374.17	2.20	27.0
p,p'DDT	4.77		
Total DDT	51.70	1.58	100.0/g.o.c.
Lindane	0.99		
Chlordane	4.79	2.00	6.0
Dieldrin	4.30		8.0
Endrin			45.0
Metals (mg/kg - dry weight)			
Arsenic	41.60	8.20	70.0
Antimony		2.00	25.0
Cadmium	4.21	1.20	9.6
Chromium	160.40	81.00	370.0
Copper	108.20	34.00	270.0
Lead	112.18	46.70	218.0
Mercury	0.70	0.15	0.7
Nickel	42.80	20.90	51.6
Silver	1.77	1.00	3.7
Zinc	271.00	150.00	410.0

The ERL represents the lower 10th percentile of ranked data where chemical concentration was associated with an effect; concentrations below the ERL are rarely expected to cause adverse biological effects to invertebrates. The ERM expresses the 50th percentile of ranked data and the level above which effects are expected to occur. Therefore, effects are occasionally expected to occur when chemical concentrations fall between the ERL and ERM. ERM quotients (ERM-Q) can be calculated to allow for a simple comparison between observed chemical concentrations and guideline values developed for that chemical. To derive an ERM-Q the concentration of each chemical is divided by its respective ERM value to get a quotient. In addition, quotient values for multiple chemicals can be averaged to get a mean ERM-Q to screen samples for potential effects of chemical mixtures. Quotient values greater than 1 indicate that the chemical in that sample exceeded its guideline value, and is likely to be associated with biological effects.

A discussion of the relationship between observed toxicity and measured sediment concentrations for each study is provided below.

BPTCP

As indicated in Table 6, there is not enough corresponding sediment data to interpret potential causes of toxicity for the samples in which toxicity was observed with the exception of the Mugu/Entrance and Central Mugu Lagoon-B1 stations. No sediment concentrations were above screening values at the Mugu Entrance station. At the Central Lagoon station elevated concentrations of total chlordane and total PCBs were observed. Additionally, at some sites samples were significantly toxic using a t-test but were not toxic relative to the MSD value (see Table 2). For these sites sediment chemistry indicates that some biological effect may potentially be caused by total chlordane and total PCBs, and additionally zinc for the East Mugu Lagoon – C1 station. The BPTCP reported that chemical and biological results at Mugu Lagoon sites were variable. Although individual pesticides sometimes exceeded guideline values ERM quotients were low (BPTCP, 1998).

NAWs and NBVC

In sediment samples collected for the IR in 1994, concentrations of phenanthrene, DDT, chlordane, dieldrin, PCBs, and cadmium exceeded ERLs. However, because sediment samples collected for the IR in 1994 for toxicity were not collected at the same sites and times as sediment samples for chemical analysis, meaningful evaluation of the relationship between chemical concentrations and the toxicity observed could not be performed.

As mentioned previously, sediment samples collected under the validation study in 1997 were not significantly toxic when compared to reference site results. The report available for these data did not indicate toxicity relative to control organisms but only compared toxicity at regular sites to results from reference sites. However, in an effort to identify potential causes of sediment toxicity, tests with survival less than 50% were evaluated against sediment chemistry results and sediment biological effects values.

Table 6. Sediment Chemistry and Toxicity Comparison for BPTCP Data

Site	*Eohaustorius* toxicity (yes/no)	*Rhepoxynius* toxicity (yes/no)	Sediment Toxicity Benchmark Evaluation[a]			
			Zinc	Total Chlordane	Dieldrin[b]	Total PCBs
Mugu Lagoon	Yes	NA	NA	NA	NA	NA
Mugu/Entrance	Yes	Yes	<ERL	<ERL	<ERM	<ERL
Mugu/Main Lagoon	NA	Yes	NA	NA	NA	NA
Mugu/Western Arm	NA	Yes	NA	NA	NA	NA
West Mugu Lagoon – A1	NA	No[c]	<ERL	>ERL <ERM	<ERM	>ERL <ERM
West Mugu Lagoon – A2	NA	No[c]	<ERL	>ERL <ERM	<ERM	>ERL <ERM
Central Mugu Lagoon – B1	NA	Yes	<ERL	>ERM	<ERM	>ERL <ERM
Central Mugu Lagoon – B2	NA	No[c]	NA	>ERM	<ERM	>ERL <ERM
East Mugu Lagoon – C1	NA	No[c]	>ERL <ERM	>ERM	<ERM	>ERL <ERM
East Mugu Lagoon – C2	NA	No[c]	<ERL	>ERM	<ERM	>ERL <ERM

[a] Below the ERL biological effects not expected; between the ERL and ERM biological effects expected; effects expected above the ERM.

[b] Evaluated with ERM value only because an ERL is not available.

[c] Was toxic with t-test but not relative to the MSD value.

Sediment samples collected during the validation study were analyzed for pesticides, PAHs, and metals. Table 7 includes the constituents that were detected above ERL, ERM, or PEL values. All other constituents were not detected above these screening values. Some constituents; archlors, gamma-BHC, and chlordane; were not included in the table because detection limits were above the screening values so an accurate evaluation of these constituents could not be performed. As indicated in Table 7, sediment values for DDE (at 2 sites), cadmium (at 1 site), copper (at 1 site), lead (at 1 site), nickel (at 4 sites), and zinc (at 1 site) were between the ERL and ERM for sites with survival rates less than 50%. DDD (at 3 sites) and DDT (at 2 sites) concentrations were above PELs for sites with less than 50% survival. To further compare sediment concentrations to mortality the data were ranked according to percent survival. This comparison indicated that no distinct patterns between chemistry and toxicity were discernable from these data.

It is important to note that trace metals toxicity is dependant on general sediment quality data (e.g. acid volatile sulfide, organic carbon, percent fines). Comparison of the metals analyzed during the validation study to sediment quality parameters indicated a strong trend between concentration and percent moisture.

UCLA

Information regarding the significance of toxicity compared to control organisms was not provided in the draft report (Anghera, 2003), however several tests had low survival percentages. Complete mortality was observed at two sites on Creek A; total DDT, copper, cadmium, and arsenic (1 site only) sediment concentrations at these sites were between ERL and ERM values indicating possible biological effects associated with these constituents. At one site on Creek A 9.2 percent survival was observed and total DDT and cadmium sediment concentrations were between the ERL and ERM for this sample. Two high tide mudflat samples demonstrated low survival 28.8 percent and 21.3 percent and total DDT and cadmium sediment concentrations were between the ERL and ERM for both sites and copper at one site. Although some screening values were exceeded all ERM-Q values were below 1.

Conclusions

Based on evaluation of existing sediment data identified for Mugu Lagoon, significant toxicity to amphipods has been observed at several locations. None of the referenced studies conducted TIEs as such no constituents could be identified as contributing to the toxicity observed in these samples. However, in the interest of identifying potential causes of observed toxicity to assist in future monitoring efforts, the comparison of available sediment chemistry data collected at these same sites indicated several possible constituents that may be responsible for the observed toxicity. Also, a more in-depth analysis involving sediment quality characteristics would be required to determine potential metals toxicity. Following is a summary of these constituents for each of the studies included in this evaluation.

BPTCP: total chlordane, total PCBs, and zinc
NAWS & NBVC: DDD, DDT, DDE, cadmium, copper, lead, nickel, and zinc
UCLA: DDT, copper, cadmium, and arsenic

In addition, based on the results of the reviewed studies it was possible to identify constituents that were not detected above screening values and therefore provide some evidence that these constituents may not need to be addressed. PAHs were analyzed during all studies but were not detected in any study above sediment screening values. No pesticides for which screening values were available exceeded these values except DDT, DDD, DDE, and total chlordane; however, dieldrin, gamma-BHC, chlordane, and several archlors analyzed by the NBVC validation study had detection limits above screening values. Other metals that were analyzed and not detected above screening values include antimony, chromium, mercury, and silver.

Table 7. Sediment Chemistry and Toxicity Comparison for NAWs and NBVC Studies

Sample Location	Sample Date	Amphipod (*Ampelisca*) Survival (%)	DDD	DDE	DDT	Arsenic	Cadmium	Copper	Lead	Nickel	Zinc
Effects Range-Low (ERL)				2.2		8.2	1.2	34	46.7	20.9	150
Effects Range-Median (ERM)				27		70	9.6	270	218	51.6	410
Probable Effect Level (PEL)			7.81	374.2	4.77	41.6	4.21	108.2	112.2	42.8	271
SG11-68	Dec-97	10	**J 18**	***57***	**30**	4.1	<0.52	14.7	6.5	16.7	44.2
SG11-67	Dec-97	14	J 1.9	*9.6*	J 1.7	5.9	<0.73	18.5	8.3	*22*	56.5
SG11-74	Dec-97	14	**11**	***42***	**9.9**	5.9	<0.83	19.2	9.6	*22*	67.3
SG11-63	Dec-97	39	**J 11**	***41***	< 14	5.1	*J 1.7*	*42.3*	32.1	*36.8*	*152*
SG11-62	Dec-97	44	1.2	*7.6*	J 0.48	7.8	<0.38	28.1	*168*	*28*	98.2
SG11-70	Dec-97	51	5.7	*14*	J 2.6	*10.9*	*J 1.5*	*36.2*	12.8	*34.2*	91.2
SG11-65	Dec-97	56	J 2.7	*18*	J 4.2	*16.6*	**7**	32.2	11.9	***63.3***	107
SG11-64	Dec-97	58	J 6.4	***64***	**J 6.2**	*8.7*	*J 1.9*	*37*	22.7	*34*	128
SG11-76	Dec-97	61	J 0.76	< 0.58	< 0.58	5	<1.1	24.9	10.5	*24.8*	76.8
SG11-69	Dec-97	64	J 4.3	***36***	J 3.8	7.4	*J1.3*	26.3	17.3	*28.6*	84.7
SG11-66	Dec-97	65	J 3.2	*14*	J 2.9	4.3	<0.44	12.5	6.7	14.3	39.7
SG11-61	Dec-97	68	< 1.3	< 1.3	<1.3	7.2	<0.57	*38.5*	41	*J 30.8*	95.9
SG11-73	Dec-97	71	J 2.1	*12*	J 1.5	5.5	<0.75	18.3	9.1	*21.4*	59
SG11-71	Dec-97	78	7.1	***33***	**J 5.3**	7.3	<0.87	24	12.1	*25.1*	74.2
SG11-75	Dec-97	89	< 9.4	***29***	< 9.4	4.3	<0.44	15.7	8.2	19.2	53.8
SG11-72	Dec-97	91	**J 9**	***37***	**J 6.4**	7	*J 1.2*	*39.7*	12.2	*37.9*	89.4

Bold data are higher than the PEL
Italicized data are between the ERL and the ERM
< = below detection limit

Table 8. Sediment Chemistry and Toxicity Comparison for UCLA Data[a]

Site		Metals (mg/kg)				Organics (mg/kg)		ERM-Q	Amphipod Mean Survival (%)
		Arsenic	Silver	Cadmium	Copper	DDT	Total DDT		
ERL		8.2	1.0	1.2	34.0	NA	1.58	NA	NA
ERM		70.0	3.7	9.6	270.0	4.7[b]	46.1		
Creek A	A0	5.4 (0.8)	0.23 (0.1)	1.1 (0.1)	24.6 (4.5)	0.0 (0.0)	55.1 (4.2)	0.3	66.3 (6.1)
	A200	7.2 (0.6)	0.2 (0.0)	1.2 (0.1)	31.9 (3.4)	4.3 (0.8)	126.7 (10.9)	0.5	9.2 (9.2)
	A400	7.7	0.1	1.2	34.7	4.0	121.1	0.5	0.0
	A600	8.4	0.2	1.7	44.6	4.4	64.1	0.4	0.0
	Total[c]	7.2 (0.6)	0.2 (0.0)	1.3 (0.1)	34.0 (0.1)	3.2 (1.1)	91.8 (18.7)	0.4 (0.0)	20.7 (14.1)
Creek C	C0	5.7	0.2	0.5	15.9	0.0	26.8	0.2	67.5
	C200	8.1 (1.7)	0.2 (0.1)	0.7 (0.1)	17.8 (3.2)	1.5 (0.6)	46.7 (5.1)	0.2	51.9 (10.9)
	C400	11.5	0.3	1.4	39.5	0.0	29.6	0.3	80.0
	C600	5.6	0.2	0.7	16.2	0.0	19.8	0.1	62.5
	Total[c]	7.7 (1.4)	0.2 (0.0)	0.8 (0.2)	22.4 (5.7)	0.4 (0.4)	30.7 (5.7)	0.2 (0.0)	72.6 (14.1)
Mudflat	EH	6.1 (0.4)	0.3 (0.1)	1.4 (0.2)	31.4 (1.7)	0.0 (0.0)	67.3 (3.5)	0.3	28.8 (3.5)
	EL	6.0	0.1	1.2	31.8	0.0	66.7	0.3	55.0
	MH	6.8	0.3	1.1	31.8	na	0.0	0.2	60.0
	WL	5.4	0.2	0.9	24.8	0.0	31.3	0.2	68.8
	WH	7.3	0.2	1.4	35.8	0.0	83.4	0.4	21.3
	Total[c]	6.3 (0.3)	0.2 (0.0)	1.2 (0.1)	31.1 (1.8)	0.0	49.8 (15.1)	0.3 (0.0)	41.6 (11.5)

[a] Values in parentheses are standard error (SE)
[b] Probable Effect Level (PEL)
[c] Total value for each area (n=4) calculated from the average value for each site within each area

References

Anghera, Michelle. 2004. Preliminary data report emailed to Heather Kirschmann of Larry Walker Associates on May 27, 2004.

California State Water Resources Control Board Division of Water Quality Bay Protection and Toxic Cleanup Program; California Department of Fish and Game Marine Pollution Studies Laboratory; University of California, Santa Cruz Institute of Marine Sciences; and San Jose State University Moss Landing Marine Laboratories. 1998. Sediment Chemistry, Toxicity, and Benthic Community Conditions in Selected Water Bodies of the Los Angeles Region. Final Report. August.

Tetra Tech. 2003. Draft Ecological Risk Assessment Addendum for Installation Restoration Program Sites 5 and 11. Naval Base Ventura County, Point Mugu Site, California. April.

Tetra Tech. 2000. Final Phase 1 Remedial Investigation Technical Memorandum. Naval Air Weapons Station, Point Mugu, California. March.

Appendix II. Land Use in the Calleguas Creek Watershed by Subcategory

Name (class1,subclass1)	Acres in CCW	% of CCW	Acres of Utilized Land	% of Utilized Land
native veg	103,689.95	47.1%	--	--
urban	52,723.13	24.0%	52,723.13	47.1%
lemons	17,647.92	8.0%	17,647.92	15.8%
avocados	7,913.95	3.6%	7,913.95	7.1%
strawberries	5,261.21	2.4%	5,261.21	4.7%
peppers	3,048.93	1.4%	3,048.93	2.7%
beans(green)	2,938.90	1.3%	2,938.90	2.6%
celery	2,643.34	1.2%	2,643.34	2.4%
no data	2,491.16	1.1%	--	--
misc truck	2,307.12	1.0%	2,307.12	2.1%
flowers,nursery,xmas tree	2,295.47	1.0%	2,295.47	2.1%
onions, garlic	1,520.59	0.7%	1,520.59	1.4%
turf farms	1,424.69	0.6%	1,424.69	1.3%
golf course	1,276.71	0.6%	1,276.71	1.1%
lawn area, irr	1,132.84	0.5%	1,132.84	1.0%
mixed(4)	1,091.30	0.5%	1,091.30	1.0%
lettuce	1,039.00	0.5%	1,039.00	0.9%
citrus (misc)	846.87	0.4%	846.87	0.8%
melon,squash,cuc	818.42	0.4%	818.42	0.7%
riparian	815.14	0.4%	--	--
oranges	676.46	0.3%	676.46	0.6%
corn (field and sweet)	650.51	0.3%	650.51	0.6%
truck crops (misc)	626.95	0.3%	626.95	0.6%
water	610.72	0.3%	--	--
broccoli	512.11	0.2%	512.11	0.5%
misc field	482.23	0.2%	482.23	0.4%
cabbage	464.71	0.2%	464.71	0.4%
barley	373.14	0.2%	373.14	0.3%
tomatoes	346.09	0.2%	346.09	0.3%
mixed pasture	340.96	0.2%	340.96	0.3%
livestock feed lots	321.04	0.1%	321.04	0.3%
barren	290.32	0.1%	--	--
bush berries	244.12	0.1%	244.12	0.2%
cole crops	217.13	0.1%	217.13	0.2%
cauliflower	177.42	0.1%	177.42	0.2%
spinach	119.46	0.1%	119.46	0.1%
grain (misc)	105.67	0.0%	105.67	0.1%
sudan	73.79	0.0%	73.79	0.1%
artichoke	66.99	0.0%	66.99	0.1%
idle	121.63	0.1%	--	--
carrots	53.97	0.0%	53.97	0.0%
vinyard	41.14	0.0%	41.14	0.0%
farmsteads	38.42	0.0%	38.42	0.0%
pasture (misc)	27.52	0.0%	27.52	0.0%
pistachios	11.61	0.0%	11.61	0.0%
poultry	9.75	0.0%	9.75	0.0%
grapefruit	9.68	0.0%	9.68	0.0%
walnuts	8.19	0.0%	8.19	0.0%
misc subtropical fruit	6.63	0.0%	6.63	0.0%
wheat	5.76	0.0%	5.76	0.0%
cemetery, irr	5.47	0.0%	5.47	0.0%
total =	**219,966.22**	**100.0%**	**111,947.30**	**100.0%**

January 15, 2005

Attachment A to the Calleguas Creek Watershed
Toxicity TMDL

Toxicity TMDL Linkage Analysis for the Calleguas Creek Watershed

Submitted to:
Calleguas Creek Watershed Management Plan

LARRY
WALKER
ASSOCIATES

INTRODUCTION

In a preliminary analysis performed for the Source Analysis (LWA 2004a), compounds likely to impose toxicity include ammonia and organophosphate (OP) pesticides. To assist the development of the Toxicity TMDL for the Calleguas Creek Watershed (CCW), a numerical model is employed to estimate loading, movement, and effects of reductions of constituents thought to impose toxicity on the receiving waters in the watershed. As discussed in the Toxicity TMDL Modeling Approach (LWA 2004c), the Toxicity TMDL will not exclude other compounds, but will focus primarily on OP pesticides, as there is an adopted TMDL for Nitrogen Compounds, and a TMDL for Historic Pesticides and PCBs is in development. The following is a description of the Toxicity TMDL Mass Balance Model (TTMBM) developed to provide decision support of source loading and implementation effectiveness for the Toxicity TMDL.

SCOPE OF THE TOXICITY TMDL MASS BALANCE MODEL

The National Research Council (NRC, 2001) provides some guidance for determining the appropriate level of complexity for modeling efforts in support of TMDL development: "There is a common belief that the expected realism in the model can compensate for a lack of data, and the complexity of the model gives the impression of credibility. Starting with simple analyses and iteratively expanding data collection and modeling as the need arises is the best approach." Following the recommendation of the NRC, the first step in the TTMBM development is a review and critical evaluation of the available OP pesticide data collected in the CCW.

Discussions of the TTMBM development and applicability require a preface describing data and time constraints. The TTMBM uses the available information to determine source loadings and contributions to receiving waters in the CCW. Currently, there are no data available describing the quality of native space (undeveloped, vacant, open space) runoff, however, if drift and atmospheric deposition are important processes, there will be a significant contribution from the native space to the receiving waters. If scavenging from the atmosphere by precipitation is an important process in the CCW, the data analysis will indicate a runoff problem, when in-fact there would be an air pollution problem. Groundwater contribution to the receiving waters may be a significant fraction of flow during dry-weather, however there are no available detected data describing the concentrations of OP pesticides in the groundwater basins of the CCW. An estimate of groundwater contribution is included in the TTMBM. There are entire subwatersheds in the CCW without in-stream data or with extremely limited data on OP pesticides. The TTMBM developed herein represents the most complete model possible based on available information. Continued monitoring and future model refinement are recommended.

Chlorpyrifos is known to readily partition to the organic fraction/coating of sediment. Except for a limited number of samples, available sediment data is limited to samples collected in the late 80's and early 90's. Water column data only exist from mid 90's to present. Sediment data are being collected as part of the current TMDL effort but data from a sufficient number of events are not currently available to perform the analysis. Consequently, sediment partitioning is not currently included as a mechanism in the TTMBM. Once recent sediment data become available, the model may be expanded to incorporate partitioning effects to account for phase transfer.

The time frame for model development is an important consideration for any modeling investigation. A sophisticated hydrologic model simulation using HSPF is now available for the CCW, however the calibration of HSPF was finalized after the TTMBM was developed. Output from a model such as HSPF would be required for flow inputs to alternate water quality models such as WASP. The time available for the CCW Toxicity TMDL development is less than the time that would be required to use a canned model such as WASP.

Limited data set size and scatter has a great influence on the model development and validation. A summary of data available in the CCW by TTMBM Subwatershed is presented in Table 1. The number of chlorpyrifos and diazinon samples collected by runoff or receiving water type and the percent detected are listed in the Table. Also listed in the Table is the percent of samples where the constituent was either detected or non-detected at a detection level sufficiently low to evaluate compliance with water quality objectives. Detection levels for the majority of chlorpyrifos samples are too high to be environmentally relevant. Environmentally relevant detection levels for diazinon are utilized on a far greater percentage of samples than chlorpyrifos.

Data summaries for receiving water data that could be used for validation are listed in Table 2. To further limit the usefulness of the data, several subwatersheds only have detected data corresponding to dry-weather sampling, meaning the wet-weather performance of the model is unverifiable for several subwatersheds. A minimum of 3 unique detected data and more than 20% of data detected are needed to perform the statistical analysis of the data. Statistics generated from data sets with less than 40% detected values should be considered estimates and are subject to error. Nearly all runoff or receiving water data sets available contain less than 40% detected values.

Because of limited available data, grab and composite samples are treated in the analyses as being equivalent and equally representative of conditions in the CCW. Estimated and qualified data are used below in the analysis as normal detected values. Both uses of the data may introduce errors into the analysis, as grab samples may not be equivalent to composite samples and may not be representative of the source. Estimated values, while being a better estimate of the true sample value than the reporting limit, may not reflect the true value accurately.

In the simplified reality of the TTMBM, it is assumed that the receiving water data are representative of surface waters in the entire subwatershed. A related simplifying assumption is that it is assumed that the agricultural runoff and urban characterization sites are representative of all like land uses everywhere across the CCW.

An analysis of pesticide use reports (PUR) conducted for the Source Assessment (LWA, 2004a) yielded agriculture and urban uses as the predominant source of OP pesticides applied to the watershed. A link between the application rates of OP pesticides to runoff water quality was not established for the TTMBM. There are currently too few data for a temporal analysis of runoff water quality.

CCW is a small flashy watershed, so the storm-runoff model that is the heart of the Dynamic Calleguas Creek Modeling System (DCCMS), which is detailed in LWA 2004d, works well to estimate runoff and in-stream flows.

An explicit margin of safety (MOS) cannot be determined for the TTMBM, as there is insufficient receiving water data to fully characterize the performance of the model.

Many of the above qualifications on the TTMBM can be removed through continuing monitoring efforts using environmentally relevant detection limits.

Table 1: Chlorpyrifos and Diazinon Data Summaries by Source Type in CCW.

	Clorpyrifos		Diazinon	
Source	n	Detected	n	Detected
Agricultural Runoff	75	37.3%	66	22.7%
Urban Runoff (1)	47	10.6%	50	54.0%
Pumped Groundwater	4	0.0%	4	0.0%
Effluent Discharge	18	5.6%	19	36.8%
Receiving Water	213	25.8%	239	45.2%

(1) Samples from out-of-watershed characterization site.
(2) Samples from in-watershed characterization sites/
(3) Combination of (1) and (2)
(4) Includes the samples from Urban and Agriculture; and Agriculture and Open Space.
(5) Includes the samples Residential, Commercial, and Industrial runoff.

Table 2: Chlorpyrifos and Diazinon Summary Statistics for Receiving Waters in the CCW by Toxicity TMDL Modeling Subwatershed.

	Chlorpyrifos			Diazinon		
TMDL Reach	n	Detected	Percentile @ 0.014 μg/L	n	Detected	Percentile @ 0.1 μg/L
Arroyo Simi	39	12.8%	NC (1)	42	50.0%	73.9%
Las Posas	10	30.0%	79.8%	10	60.0%	80.6%
Conejo Creek	55	5.5%	NC	73	39.7%	90.6%
Calleguas Creek	52	19.2%	NC	57	56.1%	78.3%
Revolon Slough	54	61.1%	23.0%	54	37.0%	79.7%
Mugu Lagoon	3	33.3%	NC	3	0.0%	NC

(1) Not Calculated: Statistical analysis requires a minimum of three unique data point and greater than 20% detected to calculate distribution. Distributions calculated with less than 40% detected data should be considered estimates.
(2) Neglecting 6 early data points with detection limits of 2 ug/L allows a sufficient number of detected values (20.5%) to estimate the probability distribution.

MODELING APPROACH OVERVIEW

The framework for the CCW Toxicity TMDL modeling effort is a spreadsheet-based mass balance water quality model. The newly developed model dubbed the Toxicity TMDL Mass Balance Model (TTMBM) represents a preliminary modeling effort to track selected constituents through the CCW. The TTMBM utilizes the flowrate calculations and precipitation data processing of the Dynamic Calleguas Creek Modeling System (DCCMS) developed in support of the Calleguas Creek Salts TMDL (LWA 2004d).

To model the desired constituents in the CCW, the entire watershed is divided into 6 subwatersheds based on the major drainages within the watershed, specifically: Arroyo Simi, Conejo and Calleguas Creeks, Revolon Slough, and Mugu Lagoon. The subwatersheds are displayed in Figure 1. General information about each of the TTMBM subwatersheds including: TMDL Reaches circumscribed by the subwatershed boundaries, listing of publicly owned treatment works (POTW) are encompassed, and general size parameters are listed in Table 3. Each subwatershed is considered a single complete-mix computational element for determining in-stream flow and calculating the water quality due to processes present along stream reaches circumscribed by the sub-watersheds.

Table 3: Toxicity TMDL Mass Balance Model Subwatershed Description.

Subwatershed	TMDL Reaches	POTWs	Area		Perimeter mi.
			acres	sq. mi.	
Arroyo Simi	7, 8	Simi Valley WQCP Moorpark WRP	82,951	129.6	66.5
Las Posas	Upper 6	---	21,570	33.7	31.2
Conejo Creek	9B, 10, 11, 12, 13	Hill Canyon WWTP Olsen Rd. (1)	46,812	73.1	49.5
Calleguas Creek	2, 3, 6, 9A	Camarillo WRP Camrosa WRP	17,239	26.9	35.5
Revolon Slough	4, 5	---	39,466	61.7	47.3
Mugu Lagoon	1	---	11,924	18.6	32.0

(1) Olsen Rd decommissioned in 2002, all flow currently diverted to Hill Canyon.

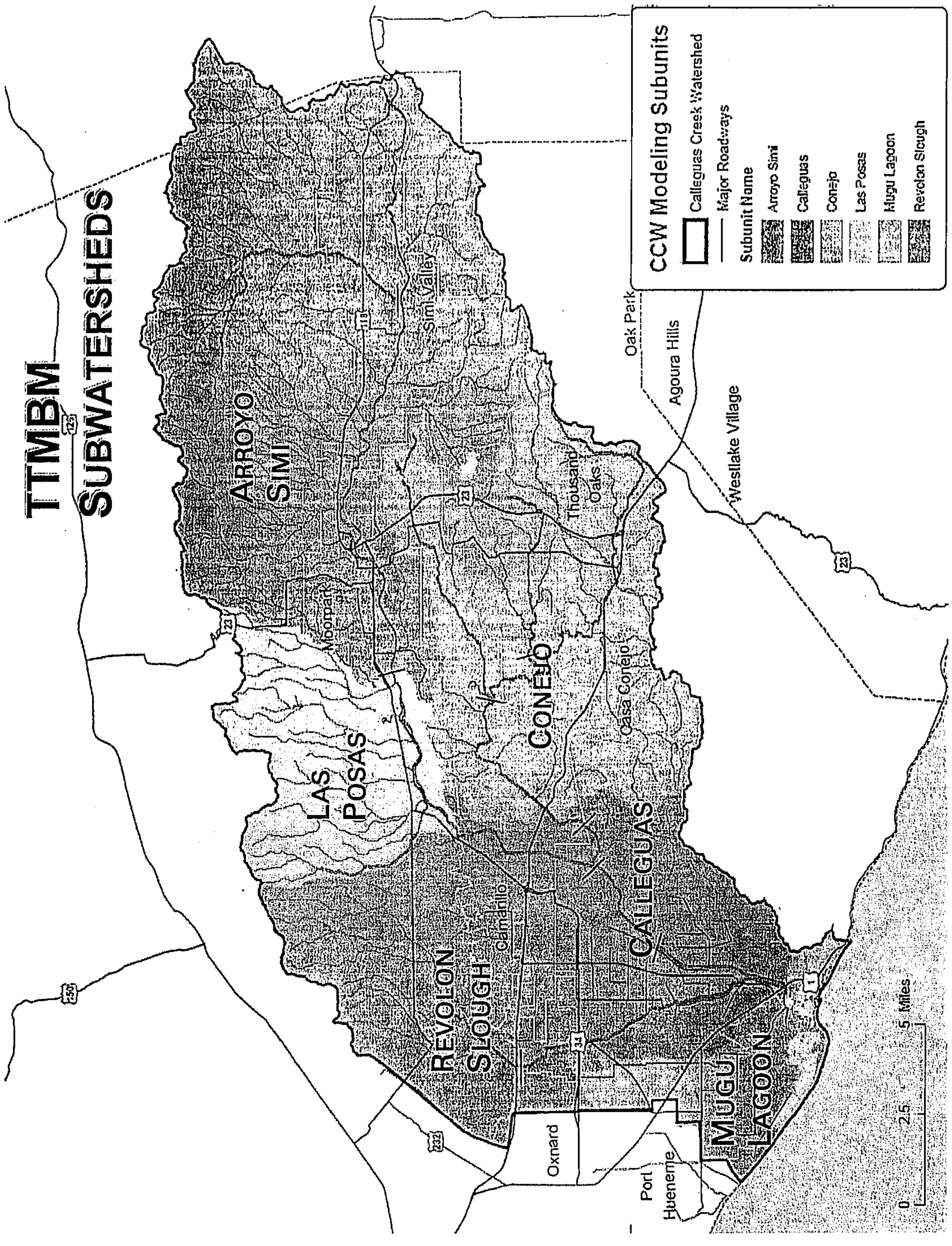


Figure 1: Subwatershed Definition Sketch for the Toxicity TMDL Modeling Effort.

Length scales for the receiving waters in the CCW are listed in Table 4. Manning's equation is used to calculate in-stream depth at any desired flowrate using the depths in Table 4, and the nominal flowrate of the reach. The stream width is assumed to remain constant. Only volatilization is affected by the stream width. By assuming a constant width will underestimate volatilization during high flow events, conservatively overestimating in-stream concentrations.

Table 4: Nominal Receiving Water Characteristic Dimensions.

Subwatershed	Length		Width (ft)	Depth (ft)	Surface Area (ft^2)
	(ft)	(mi)			
Arroyo Simi	96,307	18.2	40.0	0.55	3,853,954
Las Posas	29,779	5.6	29.7	0.43	731,296
Conejo Creek	130,258	24.7	17.0	0.67	707,801
Calleguas Creek	50,635	9.6	97.4	2.54	2,350,128
Revolon Slough	88,704	16.8	50.0	0.50	4,435,200
Mugu Lagoon	38,438	7.3	55.5	2.65	880,994

Land-use patterns for each of the TTMBM subwatersheds are listed in Table 5. In the Table, the areas of native (undeveloped), agricultural, and urban land uses are listed in terms of percentages of the subwatershed, percentages of the total land use in the entire CCW, and the actual areas in acres and square miles for each subwatershed. The calculations are based on the Department of Water Resources (DWR) 2000 land use GIS data. Based on the information in Table 5, the Arroyo Simi subwatershed encompasses a total of 82,951 acres (129.6 sq. mi.), and is 72.6% covered by undeveloped native land which is 55.8% of the total native land in the entire CCW. Arroyo Simi and Conejo Creek subwatersheds each contain just under 40% of the total urban area in the watershed. Revolon Slough is covered by over 65% agricultural lands and contains nearly half of all the land in the CCW used for agricultural purposes.

Crop penetration for each TTMBM subwatershed is listed in Table 6. Because the analysis performed for the Interim Source Assessment (LWA 2004a) revealed a large portion of the total chlorpyrifos and diazinon agricultural use is on lemon, strawberry, broccoli, corn, beans, onions and garlic, and lettuce they are explicitly separated from general citrus, nut, truck, field, and grain crops. In the Arroyo Simi Subwatershed, 35.1% of the agricultural land is used for lemon groves, however the Arroyo Simi groves only account for 6.1% of the total lemon grove area in the entire CCW. The Las Posas and Revolon Slough Subwatersheds together account for over 75% of the land used for lemon groves. In the whole CCW, over 50% of the lemon groves, over 50% of the strawberry fields, and over 60% of the broccoli fields are located in the Revolon Slough Subwatershed. Together, lemons, strawberries, and broccoli crops account for over 90% of the agricultural chlorpyrifos use. Application to beans and onions account for 63% of the agricultural diazinon use. Revolon Slough Subwatershed accounts for over 70% of the beans and over 60% of the onion and garlic plantings in the whole watershed.

Table 5: Land Use in each TTMBM Subwatershed.

Subwatershed	Land Use	Percent of Sub-watershed	Percent of Land Use in CCW	Area (1)	
				Acres	Sq. mi.
Arroyo Simi	Native	72.6	55.8	60,243	94.1
	Agriculture	3.6	5.2	2,958	4.6
	Urban	23.8	35.8	19,749	30.9
	Total	100.0	37.7	82,951	129.6
Las Posas	Native	41.8	8.4	9,018	14.1
	Agriculture	54.5	20.6	11,751	18.4
	Urban	3.7	1.5	800	1.3
	Total	100.0	9.8	21,570	33.7
Conejo Creek	Native	47.3	20.5	22,165	34.6
	Agriculture	7.8	6.4	3,657	5.7
	Urban	44.8	38.1	20,990	32.8
	Total	100.0	21.3	46,812	73.1
Calleguas Creek	Native	42.4	6.8	7,315	11.4
	Agriculture	40.2	12.2	6,926	10.8
	Urban	17.4	5.4	2,998	4.7
	Total	100.0	7.8	17,239	26.9
Revolon Slough	Native	12.6	4.6	4,965	7.8
	Agriculture	66.5	46.1	26,260	41.0
	Urban	20.9	14.9	8,240	12.9
	Total	100.0	17.9	39,466	61.7
Mugu Lagoon	Native	35.1	3.9	4,187	6.5
	Agriculture	45.1	9.4	5,374	8.4
	Urban	19.8	4.3	2,363	3.7
	Total	100.0	5.4	11,924	18.6
Whole CCW	Native	49.1	100.0	107,894	168.6
	Agriculture	25.9	100.0	56,926	88.9
	Urban	25.1	100.0	55,141	86.2
	Total	100.0	100.0	219,961	343.7

(1) As per Department of Water Resources, 2000

Table 6: Crop Penetration in each TTMBM Subwatershed.

Subwatershed	Crop[(1)]	Percent of Ag in Sub-watershed	Percent of Crop in Whole CCW	Area Acres	Area Sq. mi.
Arroyo Simi	Lemon	35.1	6.1	1,039	1.6
	Strawberry	1.2	0.7	37	0.1
	Broccoli	1.8	7.4	54	0.1
	Corn	0.0	0.0	0	0.0
	Beans	0.0	0.0	0	0.0
	Onion and garlic	5.4	10.4	158	0.2
	Lettuce	0.0	0.0	0	0.0
	Other Citrus and Nuts	35.3	11.0	1,044	1.6
	Other Truck, Field, and Grain	16.4	3.3	486	0.8
	Pasture and Livestock	4.8	19.1	141	0.2
	Vineyard and Turf	0.0	0.0	0	0.0
	Idle	0.0	0.0	0	0.0
Las Posas	Lemon	38.7	26.5	4,543	7.1
	Strawberry	0.2	0.3	19	0.0
	Broccoli	0.6	9.8	71	0.1
	Corn	0.0	0.0	0	0.0
	Beans	0.0	0.0	0	0.0
	Onion and garlic	0.7	5.8	88	0.1
	Lettuce	0.2	2.0	21	0.0
	Other Citrus and Nuts	44.6	55.3	5,239	8.2
	Other Truck, Field, and Grain	10.9	8.6	1,284	2.0
	Pasture and Livestock	3.7	58.5	431	0.7
	Vineyard and Turf	0.0	0.0	0	0.0
	Idle	0.5	45.2	55	0.1

Continued

Table 6 continued

Subwatershed	Crop[1]	Percent of Ag in Sub-watershed	Percent of Crop in Whole CCW	Area Acres	Area Sq. mi.
Conejo	Lemon	33.7	7.2	1,232	1.9
	Strawberry	0.0	0.0	0	0.0
	Broccoli	0.0	0.0	0	0.0
	Corn	1.6	8.9	58	0.1
	Beans	0.0	0.0	0	0.0
	Onion and garlic	0.0	0.0	0	0.0
	Lettuce	2.6	9.2	96	0.1
	Other Citrus and Nuts	18.7	7.2	682	1.1
	Other Truck, Field, and Grain	41.6	10.2	1,521	2.4
	Pasture and Livestock	1.0	4.8	36	0.1
	Vineyard and Turf	0.0	0.0	0	0.0
	Idle	0.9	26.3	32	0.1
Calleguas	Lemon	18.6	7.5	1,292	2.0
	Strawberry	16.1	20.0	1,117	1.7
	Broccoli	2.0	19.4	141	0.2
	Corn	5.7	60.7	395	0.6
	Beans	4.5	9.3	313	0.5
	Onion and garlic	2.9	13.4	204	0.3
	Lettuce	4.2	28.1	292	0.5
	Other Citrus and Nuts	9.2	6.7	639	1.0
	Other Truck, Field, and Grain	35.8	16.7	2,479	3.9
	Pasture and Livestock	0.2	1.7	13	0.0
	Vineyard and Turf	0.6	2.4	41	0.1
	Idle	0.0	0.0	0	0.0

Continued

Table 6 continued

Subwatershed	Crop [1]	Percent of Ag in Sub-watershed	Percent of Crop in Whole CCW	Area	
				Acres	Sq. mi.
Revolon Slough	Lemon	32.7	50.1	8,575	13.4
	Strawberry	11.0	51.8	2,889	4.5
	Broccoli	1.8	63.5	463	0.7
	Corn	0.8	30.3	197	0.3
	Beans	9.2	72.1	2,422	3.8
	Onion and garlic	3.7	63.3	962	1.5
	Lettuce	2.2	55.1	572	0.9
	Other Citrus and Nuts	6.7	18.7	1,769	2.8
	Other Truck, Field, and Grain	29.1	51.4	7,642	11.9
	Pasture and Livestock	0.3	10.2	76	0.1
	Vineyard and Turf	2.5	37.9	658	1.0
	Idle	0.1	28.5	35	0.1
Mugu Lagoon	Lemon	8.0	2.5	432	0.7
	Strawberry	28.1	27.1	1,511	2.4
	Broccoli	0.0	0.0	0	0.0
	Corn	0.0	0.0	0	0.0
	Beans	11.6	18.6	624	1.0
	Onion and garlic	2.0	7.1	108	0.2
	Lettuce	1.1	5.6	58	0.1
	Other Citrus and Nuts	1.9	1.1	100	0.2
	Other Truck, Field, and Grain	27.2	9.8	1,460	2.3
	Pasture and Livestock	0.8	5.7	42	0.1
	Vineyard and Turf	19.3	59.8	1,039	1.6
	Idle	0.0	0.0	0	0.0

(1) As per Department of Water Resources, 2000

WATER SOURCES AND OP PESTICIDE LOADING TO THE WATERSHED

Precipitation, deep aquifer transfers, and imported water are all major sources of water to the watershed.

Precipitation

Areal precipitation values for a subwatershed are calculated by using the percent of subwatershed area listed in to form a weighted average of the precipitation measurements recorded at the local gages. All precipitation information is post-processed from the DCCMS to match the TTMBM subwatersheds.

Table 7: Precipitation Station General Statistics. See Figure 2 for Station Location within the CCW.

Station ID	Start Date	End Date	Average Annual (in) (1)	Max Daily Precip (in)
128	1/21/1943	2/26/2004	15.20	5.74
141	10/18/1948	3/2/2004	14.58	5.54
154	10/11/1947	3/2/2004	14.71	4.88
169	12/5/1956	3/2/2004	16.24	5.52
177	1/5/1957	3/2/2004	12.71	5.02
187	1/27/1956	2/26/2004	33.20	6.05
188	1/21/1956	3/2/2004	14.97	6.58
189	1/21/1956	2/3/2004	16.01	5.14
190	11/14/1955	2/3/2004	15.31	5.02
191	11/14/1955	2/3/2004	17.47	5.25
192	11/14/1955	2/4/2004	14.04	5.07
193	12/4/1980	2/4/2004	29.26	4.9
194	11/14/1955	2/3/2004	12.93	5.27
196	11/6/1977	2/4/2004	20.23	5.1
206	11/4/1960	2/6/2004	17.23	4.31
219	10/28/1964	2/26/2004	14.43	4.2
223	10/13/1946	1/28/2004	12.07	4.77
227	9/19/1966	2/4/2004	28.49	4.75
234	10/4/1968	2/4/2004	30.50	4.7
238	11/5/1970	2/3/2004	20.85	8.7
239	12/4/1972	9/29/2002	16.46	4.98
242	10/25/1971	2/3/2004	43.16	5.61
250	10/20/1976	2/3/2004	19.68	4.76
259	10/1/1981	1/3/2004	14.07	4.46
263	10/17/1984	2/3/2004	11.87	3.77
3	10/21/1902	7/12/1992	13.22	4.6
49	1/16/1929	1/28/2004	13.68	4.7

(1) Average based on annual precipitation for period of record for individual precipitation stations.

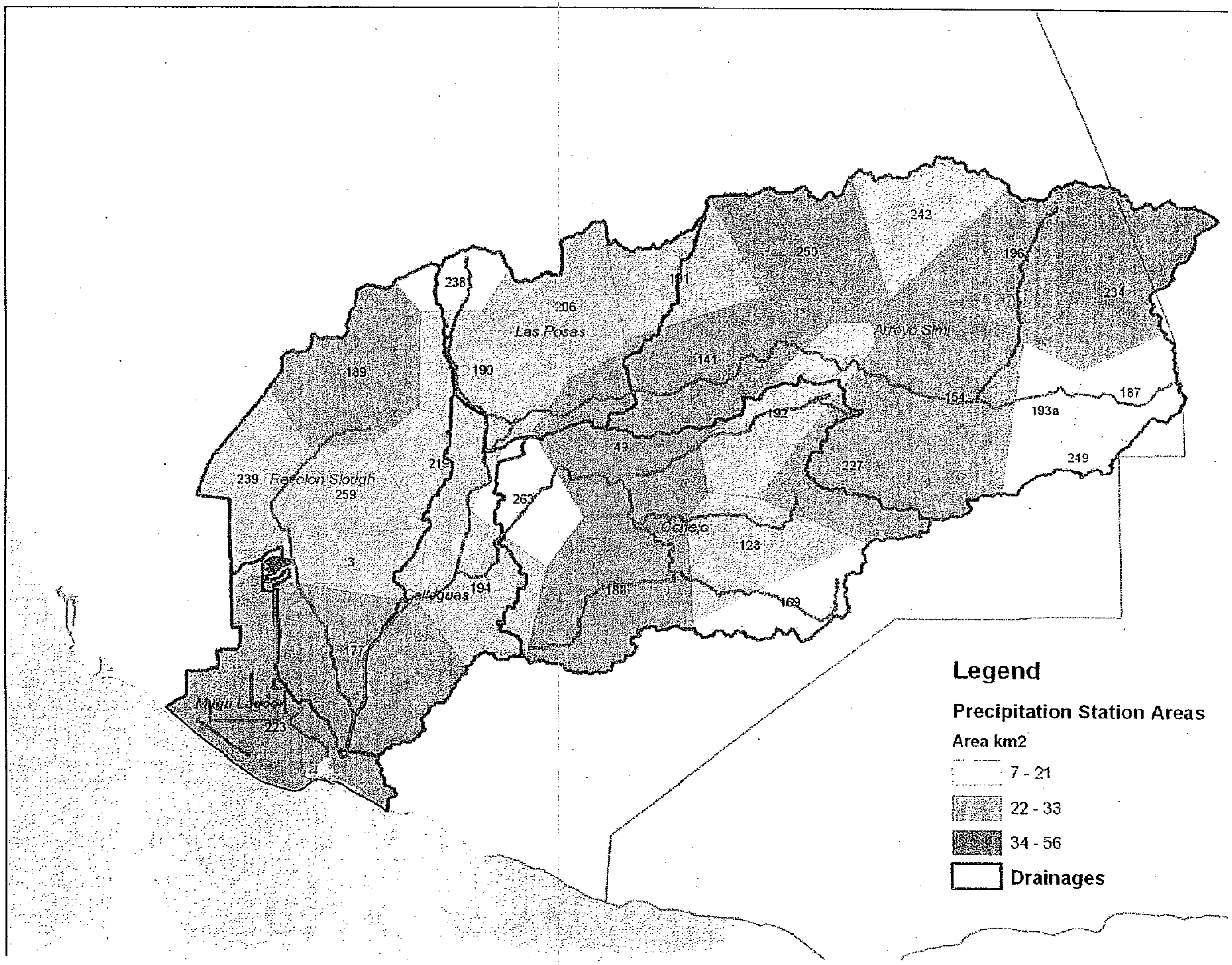


Figure 2: Relation of Precipitation Stations to CCW Toxicity TMDL Mass Balance Model Subwatersheds.

Table 8: Subwatershed Percent Coverage by Precipitation Stations.

Subwatershed	Precipitation Station	Percent of Subwatershed
Arroyo Simi	154	15.61
	187	6.73
	192	2.94
	193a	5.89
	196	12.81
	227	8.25
	234	11.66
	242	8.01
	141	10.63
	191	4.10
	250	11.57
	49	1.71
Las Posas	141	1.22
	190	27.35
	191	15.65
	206	32.29
	219	1.08
	238	9.6
	263	0.4
	49	12.39
Conejo Creek	141	0.50
	192	12.22
	227	10.14
	49	16.41
	128	16.19
	169	9.75
	188	24.75
	194	1.98
	263	7.91

Continued

Table 8: Continued

Subwatershed	Precipitation Station	Percent of Subwatershed
Calleguas	177	32.77
	190	2.27
	194	38.52
	219	14.3
	223	3.15
	263	5.07
	3	3.72 (1)
Revolon Slough	177	15.81
	189	24.92
	190	4.49
	219	8.32
	223	2.47
	238	2.02
	239	15.67
	259	26.29 (1)
	3	
Mugu Lagoon	177	15.57
	223	80.2
	239	1.58
	3	2.76 (1)

(1) Data for Station 3 used prior to 10/1/1990, data for Station 259 used post 10/1/1990.

Precipitation driven flows are calculated in the DCCMS by the rational method (Chow et al., 1988). The fraction of the total subwatershed area comprising the various land use types similar to the list in Table 5 are used to form a weighted average precipitation driven runoff. Runoff from urban, agricultural, and open space land-use areas are calculated separately. Characteristic water quality may be assigned to each land use type to reflect concentrations of constituents in the respective runoff.

Atmospheric Deposition

Wet and dry deposition of OP pesticides are known to be a source of constituents to wet and dry weather runoff. The TTMBM implicitly includes atmospheric deposition in the estimates of OP pesticide loading from wet and dry weather runoff for each land use type. While allowing calculation of receiving water quality, the method will not attribute the true source of constituents. Wet and dry weather monitoring stations should be installed around the CCW in a strategic manner to test the true level of atmospheric deposition contribution to agricultural, urban, and native space runoff.

Direct measurements of pesticide deposition in urban areas have not been measured. Estimates have been determined using ambient concentrations and assumed deposition rates, but the determined rates carry a high degree of uncertainty and may be unrealistic (Ross, 2002).

A study conducted by Dow AgroSciences (1998) at Orestimba Creek around agricultural sites in Stanislaus County, CA involved surface water monitoring for a year. The researchers found that some concentration peaks detected for several OP pesticides could be associated with specific pesticide application events, and that the most probable transport process could be determined. For chlorpyrifos, nine of thirteen attributable concentration peaks were a result of drift from the application site. For diazinon, five of fourteen attributable peaks were a result of drift from the application site (SRWP, 2000).

Majewski and Baston (2002) conducted ambient air quality monitoring for OP pesticides in the Sacramento urban area and nearby agricultural areas during the period 1996-1997. Of 17 pesticides monitored during the study, chlorpyrifos, diazinon, and trifluralin accounted for 24 percent of the agricultural and 76 percent of the non-agricultural/urban pesticides used during the two-year study period. Molinate and thiobencarb offer the clearest example of pesticides used in agriculture that drift into urban areas, because they are used exclusively in rice cultivation, but were measured in the Sacramento urban area (Majewski and Baston, 2002).

The Southern California Coastal Water Research Project (SCCWRP) is beginning a study to determine the impact of atmospheric deposition of pesticides transported from sources within the airshed to waterbodies of interest in selected regions of Southern California. Results from the study will help quantify deposition pesticide deposition rates in urban areas.

There is no clear path to incorporate the finding of the above studies into the CCW to determine the local deposition rate of OP pesticides for modeling purposes. Monitoring of wet and dry deposition rates of OP pesticides would provide the clearest information to incorporate the atmospheric contribution to the runoff water quality.

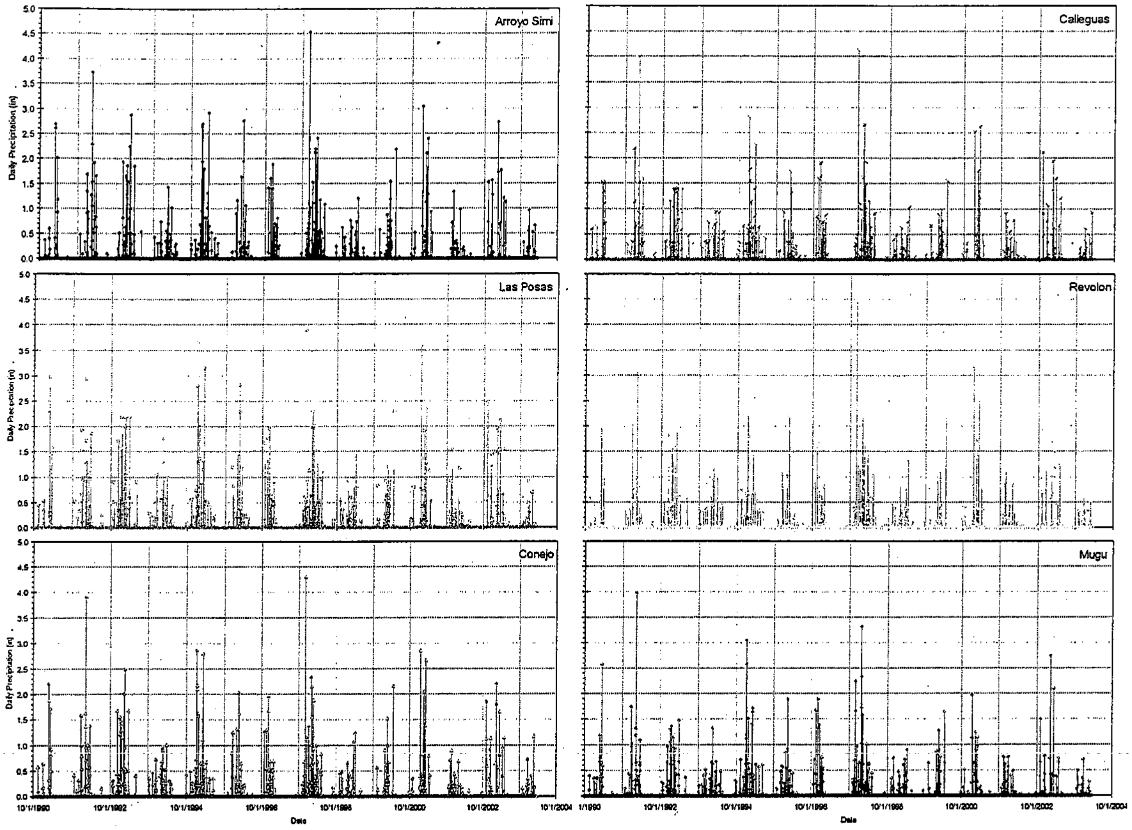


Figure 3: Daily Precipitation Over the TTMBM Subwatersheds from Oct 1, 1990 to March 1, 2004.

Imported Water Supplies

Imported water from the State Water Project and Freeman Diversion are accountable for essentially all the imported water to the CCW. Deep groundwater wells drawing water from the lower confined aquifer underlying the CCW are producing water from the Fox Canyon Aquifer which is replenished with water from outside the watershed. There is no direct linkage between the Imported Water Supplies and the TTMBM.

As there is no evidence to the contrary, it is assumed in the TTMBM development that there is no chlorpyrifos or diazinon in any imported water source.

COMPUTATIONAL ELEMENT

Each computational element balances the inflow and outflow of water and mass with conservation equations to calculate changes in in-stream flow and concentration across a subwatershed. The computational elements used by the TTMBM to model conditions in the CCW are displayed in Figure 1. Over each time step, the stream reach within any subwatershed is assumed to behave as a complete-mix system in equilibrium. Because of the relatively short reach length, stream geometry, and daily time step; flows can be considered in equilibrium on a daily basis, so long as the routing of peak flows is not of critical importance. Assuming that each subwatershed behaves as a complete-mix reactor implies that the in-stream concentration is constant at all locations within a subwatershed (Tchobanoglous and Schroeder, 1985). Because the concentration is modeled as constant for the entire subwatershed, all withdrawals from the reach, including the discharge to the downstream reach will have the same concentration by definition. A schematic of the computational element is displayed in Figure 4. Each input and output considered is represented in Figure 4 with an arrow pointing into the reach for additions, and pointing out from the reach to represent withdrawals. In Figure 4, flows from upstream reaches enter from the right and flow to downstream reaches exit to the left. Details of the flows are discussed in subsequent subsections. Scour and deposition, sorption and desorption, and sediment content are not currently included in the TTMBM, but may be incorporated when paired sediment and water column data are available.

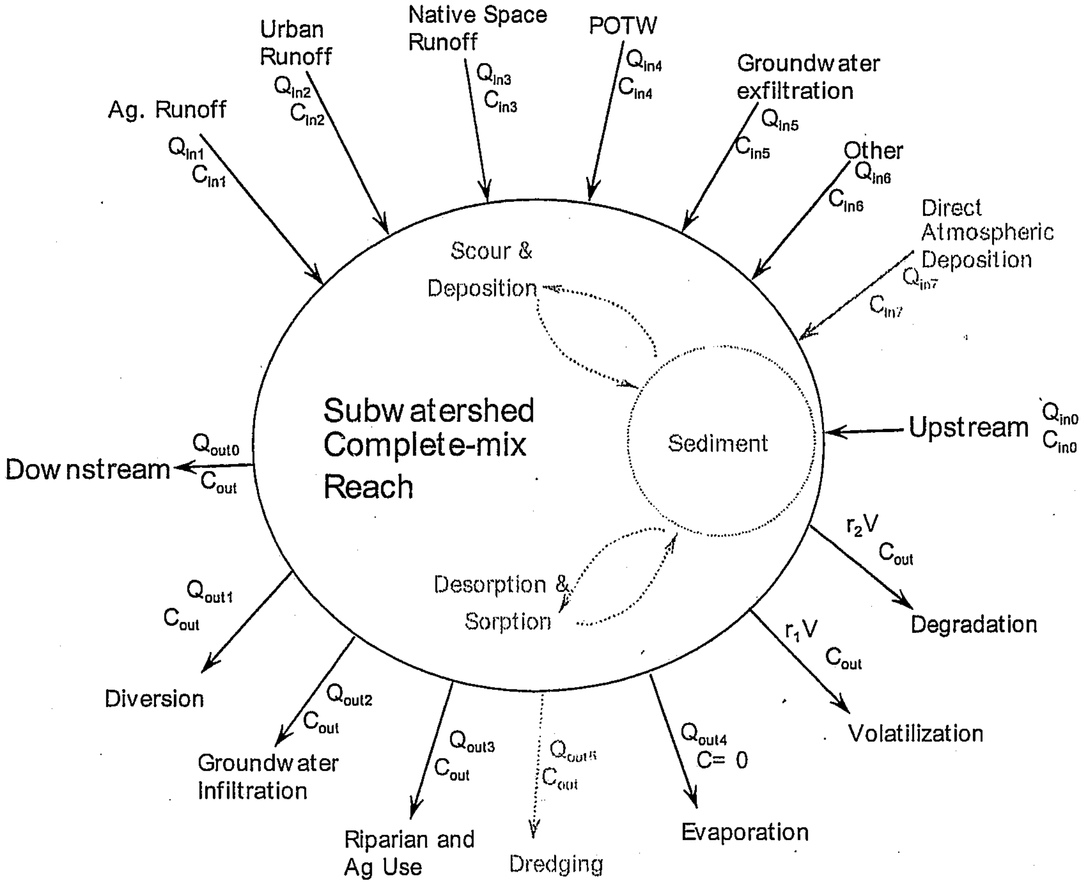


Figure 4: Schematic of Inputs and Outputs for a General Computational Element used in the CCMS Mass Balance Model to Estimate Water Flow and Quality within Surface Water Reaches. Direct Atmospheric Deposition, Sediment Interaction, and Dredging are Not Included in the Current Version of the TTMBM.

Mass Balance Calculations

To calculate the stream discharge flow and in-stream concentration for a computational element, all inflow rates and concentrations must be specified along with all other of the outflow rates. Normally, the outflow to the downstream reach will be calculated with the conservation of flow equation. If all inflow rates and concentrations, and all outflow rates except the downstream discharge rate are known, the in-stream concentration and downstream discharge may be calculated. Because of the complete-mix assumption, the concentration in the outflows will equal the in-stream concentration, except in the case of evaporation (Tchobanoglous and Schroeder, 1985), where only water is assumed to be removed from the system by evaporation implying that the concentration of constituents in evaporated water is equal to zero. The general conservation law is captured in Equation (1).

$$\text{accumulation} = \text{in} - \text{out} + \text{generation} \qquad (1)$$

Each of the daily time steps is assumed to be in steady-state. By making the steady-state assumption the ability to model peak flood routing is lost; however because of the relatively small size of the CCW, a smaller time step than one day would be required to capture a flood wave moving through the watershed. The steady assumption specifies no accumulation of flow or mass in the surface water within a subwatershed, simplifying the mass balance equation by setting the left hand side of Equation (1) to zero, in effect requiring the sum of the inputs to equal the sum of the outputs plus and generation within the subwatersheds (Tchobanoglous and Schroeder, 1985), resulting in Equation (2). The mass loading of a constituent may be represented by Equation (3), where $Q_{in}C_{in}$ is the sum total of mass loads to the subwatershed, $Q_{out}C_{out}$ is the sum total of loads leaving the subwatershed, and rV is the generation of constituents within the subwatershed, where r is the reaction rate and V is the in-stream volume of water.

$$\text{in} = \text{out} - \text{generation} \qquad (2)$$

$$\sum Q_{in}C_{in} = \sum Q_{out}C_{out} - \sum rV \qquad (3)$$

A first order reaction is represented in Equation (3) by replacing the rate, r, with kC_{out}., where k is the first order reaction rate in 1/s and C_{out} is the in-stream concentration within the subwatershed. If k is a negative value, the reaction will represent degradation of the constituent. Volatilization is represented in Equation (3) by replacing rV with $-K_L a C_{out} h A_{surface}$, where K_L is the liquid-film transfer rate (ft/s), a is the ratio of the surface area to the volume (1/ft), h is the nominal stream depth (ft), C_{out} is the in-stream concentration, and $A_{surface}$ is the surface area of the stream within the subwatershed, and the term is negative because constituents are volatilizing from the water surface. The form of the volatilization term is derived assuming a zero atmospheric concentration above and around the stream. For most slightly soluble constituents, the transfer rate $K_L a$ is essentially the total mass transfer rate K divided by the depth, h, allowing the volatilization to be represented by $KC_{out}A_{surface}$.

The sum of all inflows (reference Figure 4) is set equal to the sum of all outflows forming the flow balance for each subwatershed and is defined by Equation (4). Flows discharged downstream from the computational element may be calculated using algebra to solve Equation (4) for the flowrate leaving the subwatershed, Q_{out0}., yielding Equation (5).

$$Q_{in0} + Q_{in1} + Q_{in2} + Q_{in3} + Q_{in4} + Q_{in5} + Q_{in6} = Q_{out0} + Q_{out1} + Q_{out2} + Q_{out3} + Q_{out4} \qquad (4)$$

$$Q_{out0} = Q_{in0} + Q_{in1} + Q_{in2} + Q_{in3} + Q_{in4} + Q_{in5} + Q_{in6} - Q_{out1} - Q_{out2} - Q_{out3} - Q_{out4} \quad (5)$$

The constituent concentration within the subwatershed may be calculated by inserting the mass loadings indicated in Figure 4 into the conservation of mass equation, Equation (2), while recalling that the concentrations are equal for all outflows, except evaporation which by definition equals zero. The conservation of mass equation for a computational element is given by Equation (6). Rearranging Equation (6) for the outflow concentration yields Equation (7).

$$\begin{aligned} &C_{in0}Q_{in0} + C_{in1}Q_{in1} + C_{in2}Q_{in2} + C_{in3}Q_{in3} + C_{in4}Q_{in4} + C_{in5}Q_{in5} + C_{in6}Q_{in6} \\ &= C_{out}Q_{out0} + C_{out}Q_{out1} + C_{out}Q_{out2} + C_{out}Q_{out3} + (0)Q_{out4} - kVC_{out} - KA_{surface}C_{out} \end{aligned} \quad (6)$$

$$C_{out} = \frac{C_{in0}Q_{in0} + C_{in1}Q_{in1} + C_{in2}Q_{in2} + C_{in3}Q_{in3} + C_{in4}Q_{in4} + C_{in5}Q_{in5} + C_{in6}Q_{in6}}{Q_{out0} + Q_{out1} + Q_{out2} + Q_{out3} - kV - KA_{surface}} \quad (7)$$

In general, the derived equations listed above will hold for each of the subwatersheds in the CCW, but not all flows will be present for each reach and if not present would be set to zero. Derivations of the individual flows are presented in the following sections.

The in-stream volume and surface area required for the degradation and volatilization calculations are determined from the information in Table 4 and adjusted to different flowrates via Manning's Equation.

Upstream Subwatersheds

Inflow and mass loading from the upstream subwatershed are added as inputs to the computational element. If the sub-watershed is located at the top of a stream's drainage, there will be no upstream subwatershed and the TTMBM will assign a 0.0 for the flow and mass loading. If multiple upstream subwatersheds contribute to the computational element, the sum of the upstream outflows and sum of the mass loadings are inserted in Q_{in0} and $C_{in0}Q_{in0}$. A definition sketch of the case where multiple upstream reaches contribute to the computational element is displayed in Figure 5. The inflow to the computational element is a simple sum of the flowrates from the upstream reaches, as indicated in Equation (8).

$$Q_{in0} = Q_{out0\,A} + Q_{out0\,B} \quad (8)$$

The inflow of mass and concentration of the inflow are calculated in Equation (9), which may be rearranged into Equation (10) for calculating the concentration in the inflow.

$$C_{in0}Q_{in0} = C_A Q_{out0\,A} + C_B\, Q_{out0\,B} \quad (9)$$

$$C_{in0} = \frac{C_A Q_{out0\,A} + C_B\, Q_{out0\,B}}{Q_{in0}} \quad (10)$$

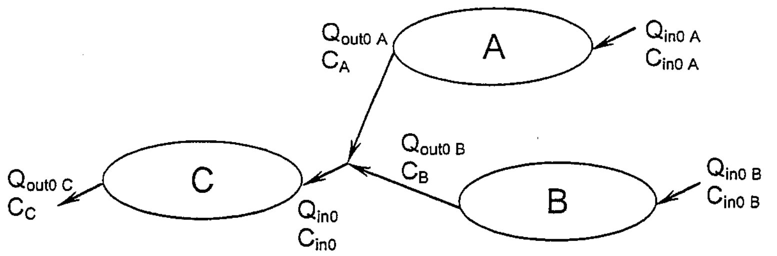


Figure 5: Schematic of Case where Two Upstream Subwatersheds, A and B, Contribute to the Inflow of a Computational Element, C.

Subwatershed Inflows of Constituents

Possible inflows include: agriculture returns, urban runoff, native (open space) runoff, publicly owned treatment works (POTWs), groundwater exfiltration, and any other flows. Each computational element includes provisions to include a generation component, which would be necessary if the constituents were being generated chemio-physio-biologically in the reach. The generation component is set to zero as no reactions producing OP Pesticides are assumed to occur in the CCW surface waters, i.e. no degradation products are tracked.

Agriculture Returns to Computational Elements

Agricultural runoff flowrate is calculated via the rational method within the DCCMS. Dry weather runoff is calculated using an average flow per unit area of agriculture land. Wet weather runoff is calculated similarly to the dry-weather agricultural runoff, except the precipitation over the subwatershed is multiplied by a runoff coefficient and fraction of agricultural land use to determine the runoff flowrate. Provisions are included in the DCCMS model to mimic tailing of runoff following precipitation events. For the CCW, only large rain events will cause appreciable, increased in-stream flow for more than one day. Flow duration curves for agricultural return and runoff flowrates calculated from DCCMS output are plotted in Figure 6. In general, Revolon Slough Subwatershed produces the greatest amount of agricultural runoff, followed by the Las Posas Subwatershed. Both watersheds contain significant agricultural activities as is evidenced in the land use Table 5. The 86th percentile level is called out on Figure 6 as an estimate of the maximum non-stormwater agricultural runoff flows. The Revolon Slough subwatershed contains the bulk of the agricultural runoff data.

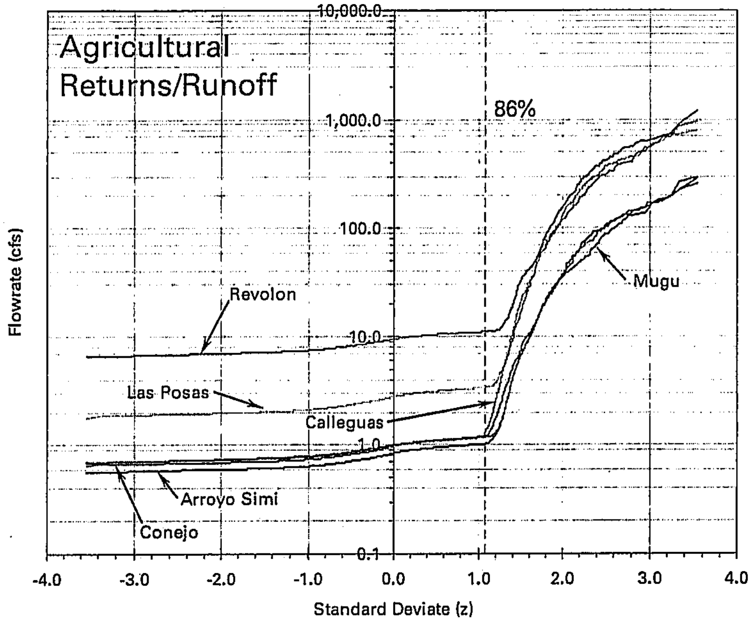


Figure 6: Flow Duration Curves of Agricultural Returns and Runoff for the TTMBM Subwatersheds.

Data from all agricultural runoff sites across the entire CCW are aggregated to determine characteristic concentrations of OP pesticides in the return flows. Regression on order statistics (ROS), used throughout the TTMBM development, utilizes the non-detected data in an analysis to estimate the distribution of the concentrations. The concentration log-normal probability distributions for chlorpyrifos and diazinon are plotted in Figure 7. Superimposed on the Figure are the 95th probability level, and the probabilities associated with the in-stream water quality criteria. The probability distribution functions (PDFs) corresponding to the distribution lines are included in the plots. The PDFs illustrate how plotting by the standard deviate allows a straight line to correspond to a "bell curve" shaped normal distribution.

Assuming that any individual sample is representative of agricultural runoff from any given location in the CCW, the concentration measurements may be paired with the DCCMS calculated agricultural runoff flows. Specifically, the calculated agricultural runoff flowrate for the entire Revolon Slough Subwatershed is used to calculate the load from agricultural runoff to Revolon Slough. Ideally, the specific land use, area drained, and actual flowrate corresponding to the sample times and locations would be used to scale-up the sampling information to reflect loadings of similar areas in the subwatersheds. Furthermore, it would be best to have sufficient sampling to cover the range of crop types and farming practices. However, the required detail and numbers of sampling do not exist at the current time and a complete analysis is not possible. The greatest error would potentially occur using the selected methodology if each sample represented drainage from a different crop type. The method utilized here would not be in great error if each sampling location drained a representative mix of crops and agricultural practices.

Using the Revolon Slough Subwatershed-wide agricultural runoff flowrate to calculate the load and to act as the abscissa, Figure 8 is a plot of the OP pesticide loading from agricultural areas. In an analysis inspired by Stow and Borsuk (2003), a power curve was used as a regression for the data. A power relationship describes the increase in loading for increasing runoff flowrate, because concentrations increase as flowrates increase. For instance, if concentration doubled with doubling flowrate, the load would increase by a factor of 4, or a 2.0 power relationship. Chlorpyrifos load is seen in Figure 8 to increase with slightly greater than a 1.3 power of flowrate indicating concentrations in agricultural runoff increase with increasing runoff flowrate. Diazinon loading increases with essentially a 1.0 power reflecting diazinon concentrations remaining relatively constant with increasing runoff flowrate, so that increasing runoff load is solely a function of the increasing flowrate.

The relationships defining the agricultural runoff load of constituents as a function of runoff flowrate displayed in Figure 8 are the input parameters to the TTMBM. Given the agricultural runoff flowrate in cfs, Equations (11) and (12) are used in the TTMBM to determine the agricultural runoff chlorpyrifos and diazinon loads in lb/d, respectively.

$$\mathrm{Load}_{\mathrm{ag\,runoff}}^{\mathrm{chlorpyrifos}} = 0.00231 \cdot Q_{\mathrm{ag\,runoff}}^{1.310} \tag{11}$$

$$\mathrm{Load}_{\mathrm{ag\,runoff}}^{\mathrm{diazinon}} = 0.00127 \cdot Q_{\mathrm{ag\,runoff}}^{1.052} \tag{12}$$

Both Equations (11) and (12) correspond to the upper 90th percentile prediction interval of the regression. Because the acute conditions are the important conditions to model, the upper prediction interval is used in the TTMBM to estimate peak loads and concentrations of OP pesticides in the CCW. Appendix A is a summary of TTMBM results using the regression equations instead of the prediction interval to determine the average loads and concentrations found in the CCW.

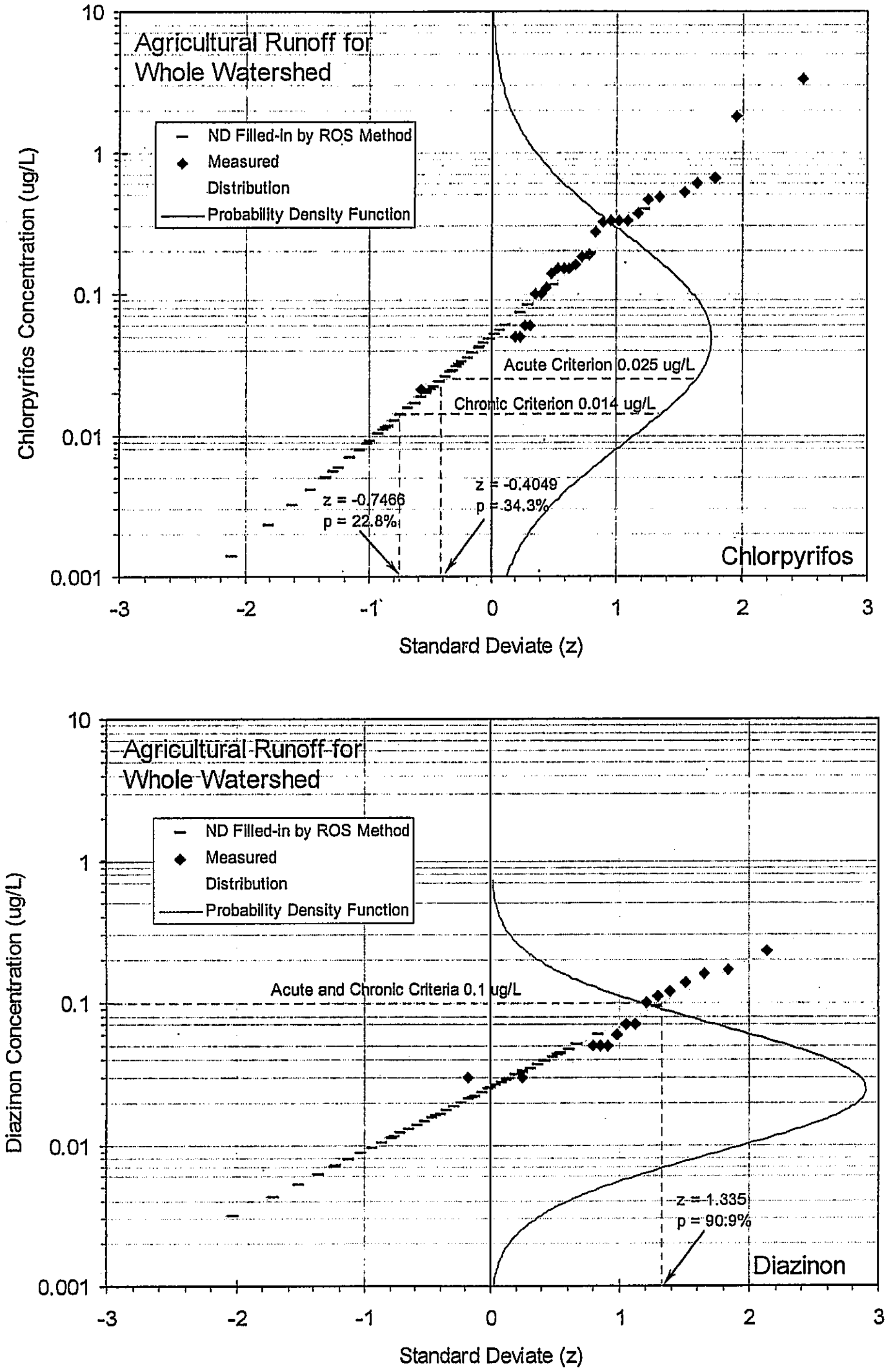


Figure 7: Agricultural Runoff Chlorpyrifos and Diazinon Concentration Log-Normal Probability Distributions.

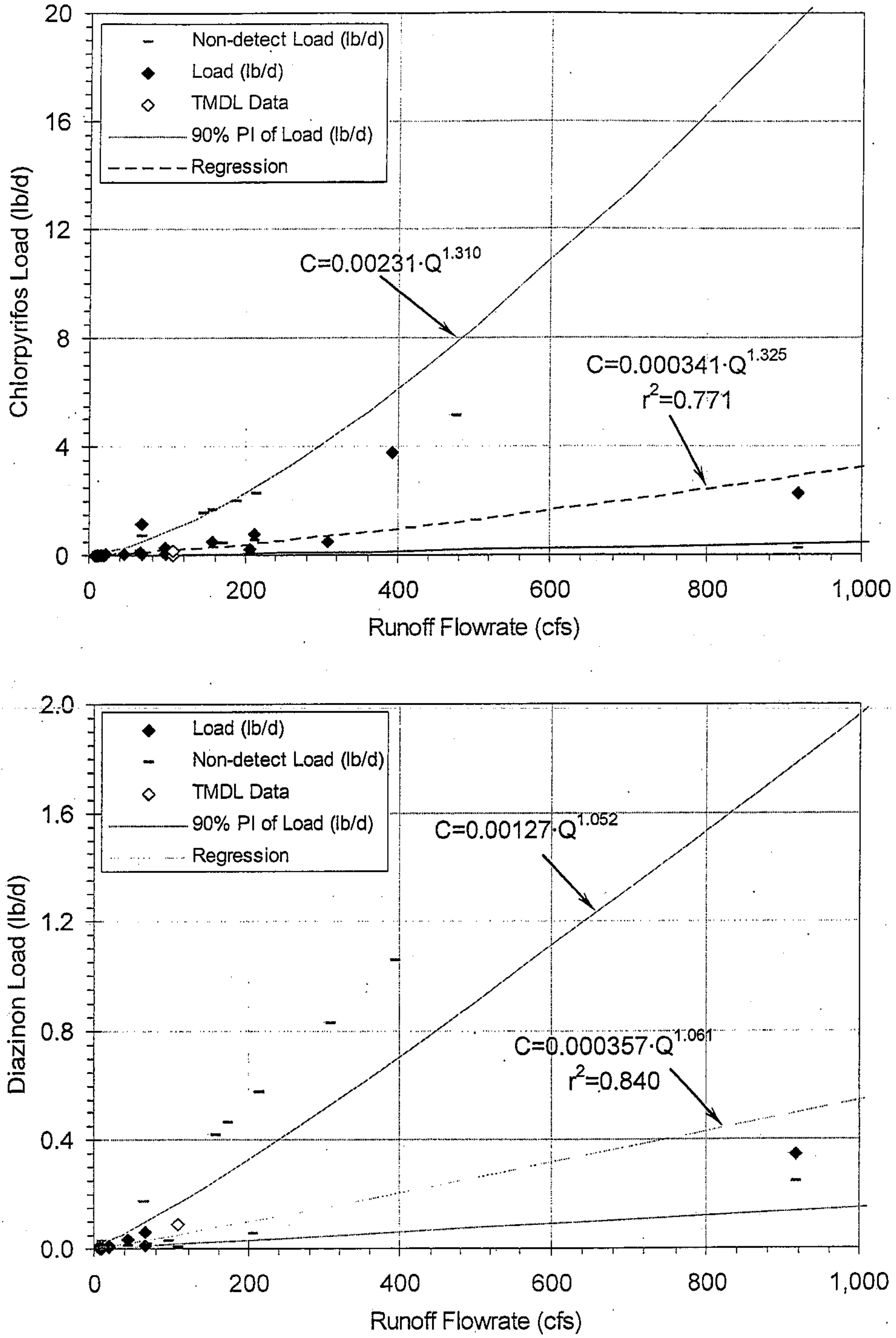


Figure 8: OP Pesticide Load as a Function of Agricultural Runoff Flowrate.

Urban Runoff to Computational Elements

To the extent possible, urban runoff has been analyzed akin to the agricultural runoff. Many of the details discussed above apply to the urban runoff, but have not been repeated in the interest of brevity.

Urban runoff is calculated as a mix of runoff from residential, commercial, and industrial land uses. Urban runoff flowrate is calculated via the rational method within the DCCMS. Dry weather runoff is calculated using an average flow per urban area. Wet weather runoff is calculated similarly to the dry-weather urban runoff, except the precipitation over the subwatershed multiplied by a runoff coefficient is used to determine the runoff flowrate and provisions are included in the model to mimic tailing of the runoff. The flow duration curves of daily urban runoff in the CCW for the period 10/1/1990 to 3/1/2004 are plotted in Figure 9. The Arroyo Simi and Conejo Subwatersheds produce the greatest amount of urban runoff as they contain significant urbanized areas as reported in Table 5. The 86th percentile flows are called out on Figure 9 as an estimate of the maximum non-stormwater urban runoff flows.

OP pesticide data for urban runoff were collected at selected characterization sites, while all sites are located in Ventura County, not all sites are located in the CCW. The underlying assumption is that the selected characterization sites are representative of all urban sites in the CCW. Probability plots of available chlorpyrifos and diazinon data are presented in Figure 10. Only 5 of 47 chlorpyrifos data were detected, so a distribution plot could not be calculated. The probability plot of diazinon reveals the concentrations in urban runoff exceed receiving water quality objectives approximately 30% of the time.

The loading of chlorpyrifos and diazinon given an urban runoff flowrate is presented in Figure 11. Equations (13) and (14), given an urban runoff flowrate in cfs, a urban runoff load is calculated in lb/d for chlorpyrifos and diazinon, respectively.

$$\mathrm{Load}_{\mathrm{urban\ runoff}}^{\mathrm{chlorpyrifos}} = 0.0224 \cdot ln\left(Q_{\mathrm{urban\ runoff}}\right)^{2.230} \tag{13}$$

$$\mathrm{Load}_{\mathrm{urban\ runoff}}^{\mathrm{diazinon}} = 0.00811 \cdot ln\left(Q_{\mathrm{urban\ runoff}}\right)^{2.667} \tag{14}$$

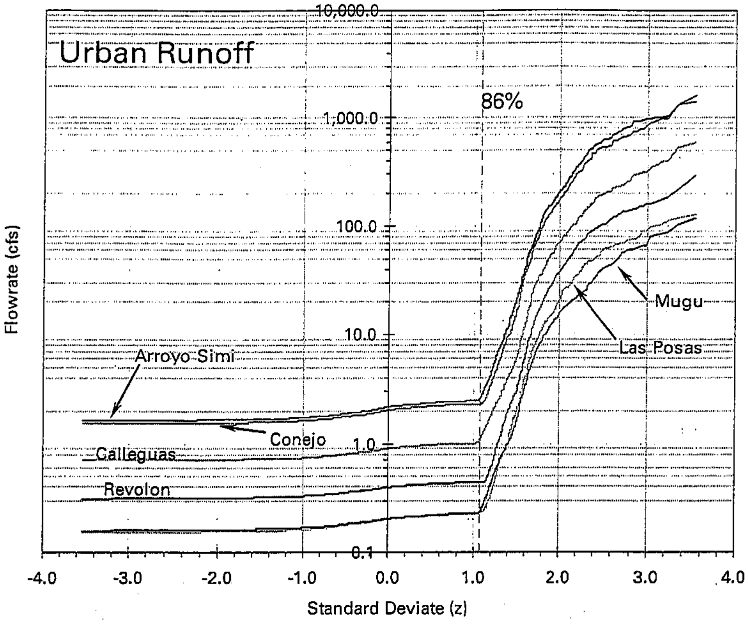


Figure 9: Urban Runoff Flowrate Distributions by TTMBM Subwatershed.

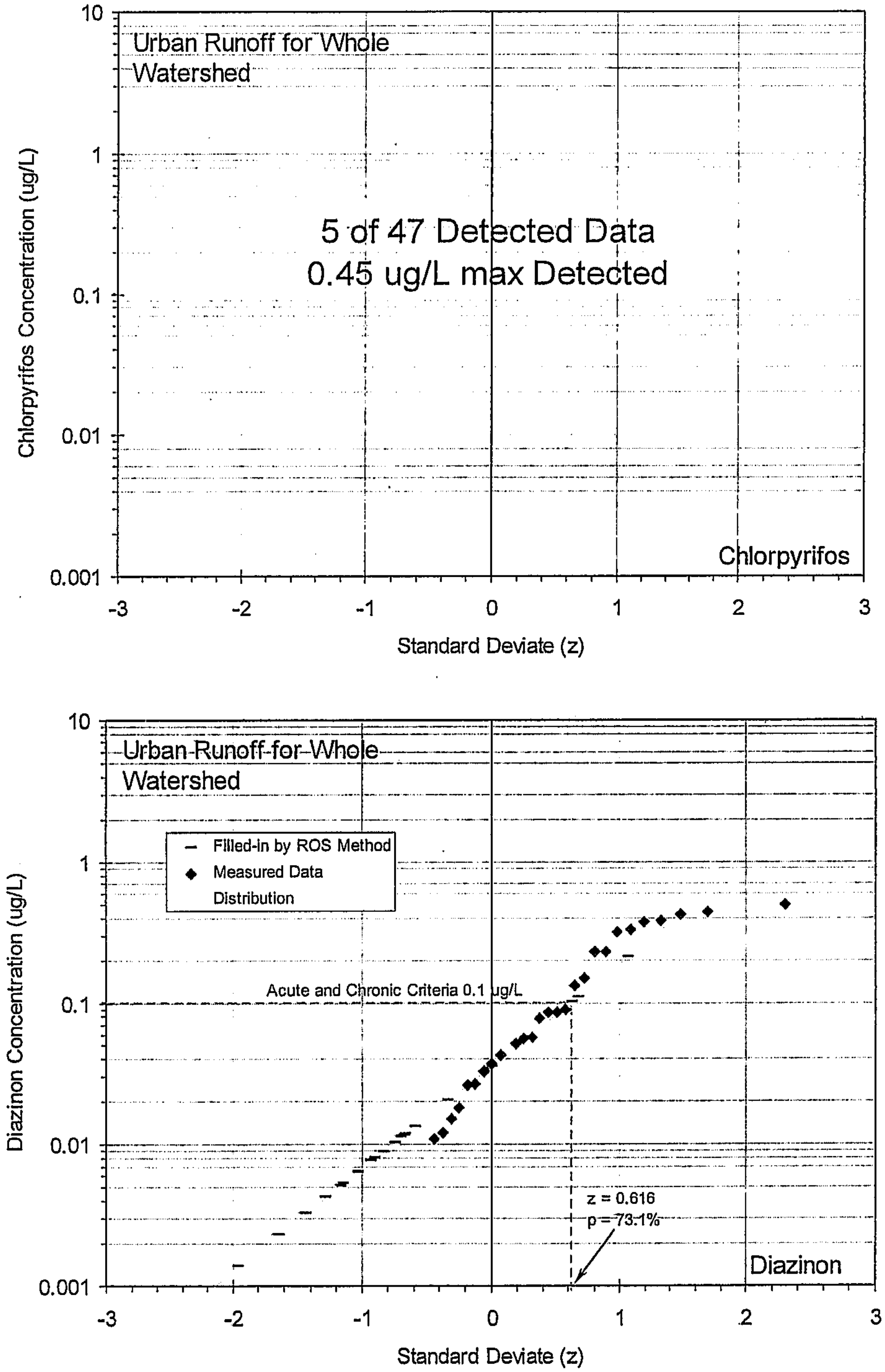


Figure 10: Distributions of Chlorpyrifos and Diazinon Concentrations Sampled from Urban Runoff. Data from all Urban Characterization Sites Combined. ND Filled-in Values Represent the Calculated Estimate of the Non-Detected Values via the ROS Method and Do Not Correspond to Physical Measurements.

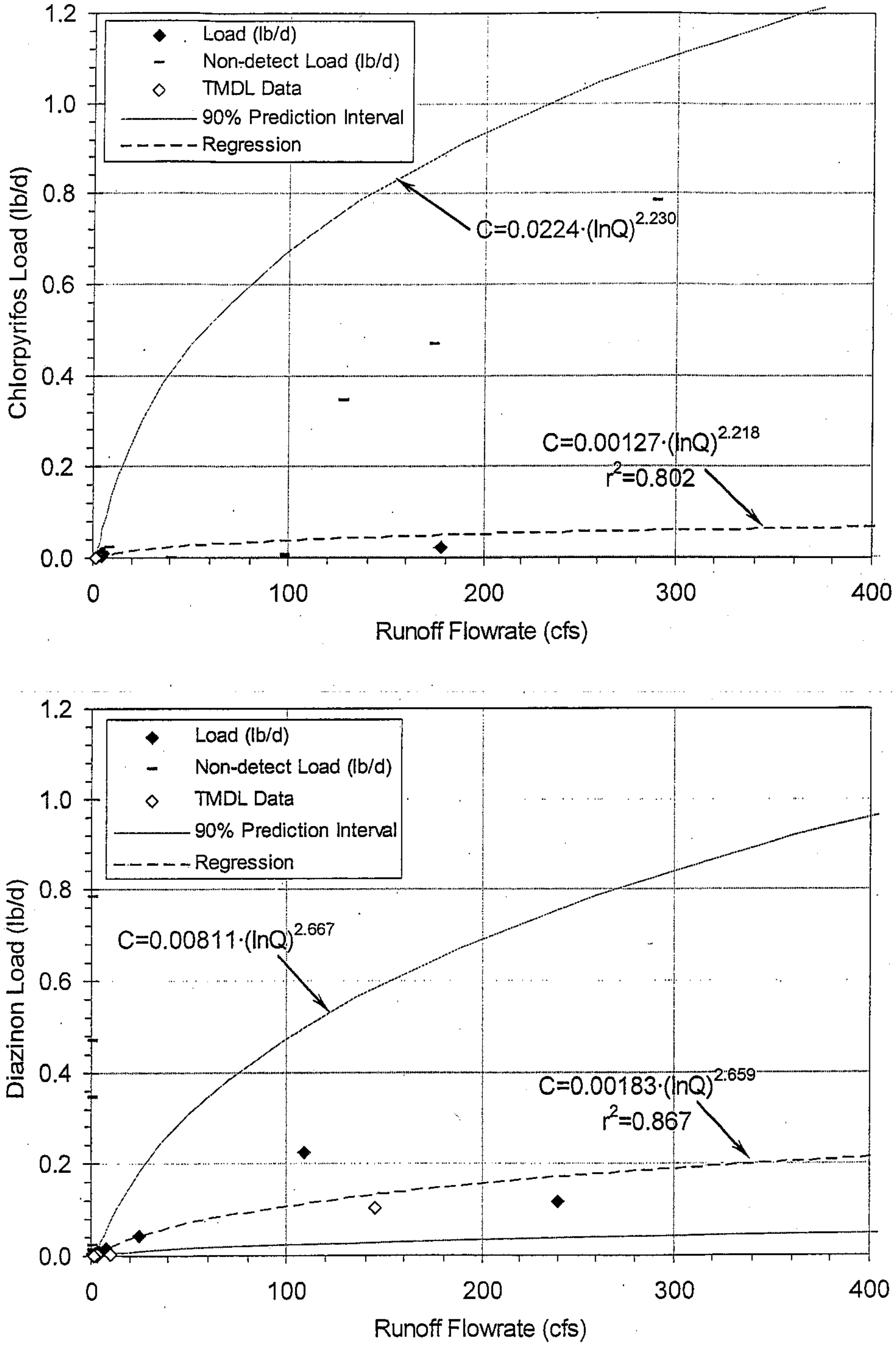


Figure 11: Chlorpyrifos and Diazinon Load Estimated for Urban Runoff.

Native (Open Space) Runoff to Computational Elements

The runoff from native areas of vacant, undeveloped, open space is calculated in a manner similar to urban runoff. Wet-weather runoff flows are calculated similarly to the urban runoff. No information is currently available describing the native runoff OP pesticide concentration or loads in the CCW. The loading of OP pesticides to the receiving waters would provide an indication of drift, and wet and dry deposition. To date, there are no data quantifying pesticides in runoff from natural space in the CCW.

The DCCMS calculated flowrates for native flowrates are presented in Figure 12. Arroyo Simi and Conejo Subwatersheds yield the greatest native runoff, as would be expected as the two subwatersheds contain the majority of native area in the CCW. Currently, the load of chlorpyrifos and diazinon are set to zero in native space runoff.

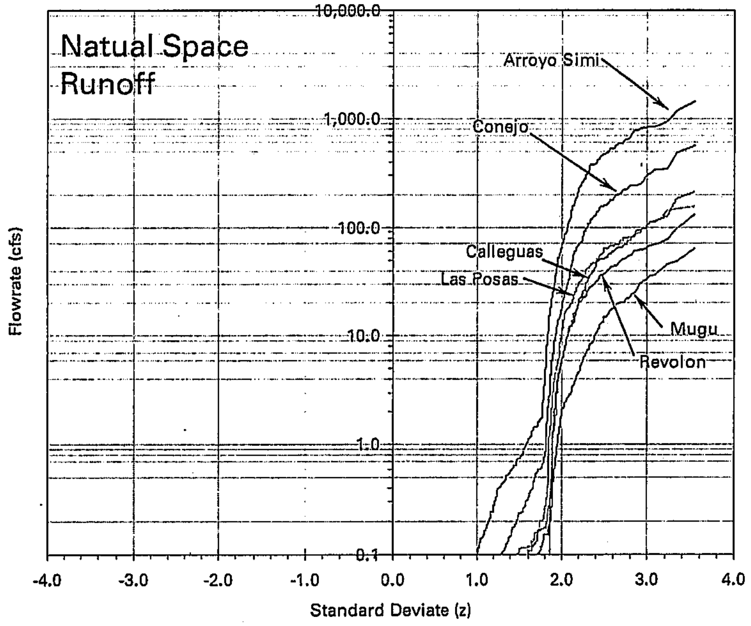


Figure 12: Flow Duration Curves for Native Runoff Flowrates.

POTW Inflows to Computational Elements

Only the subwatersheds containing wastewater treatment plants that discharge to surface waters will have non-zero Q_{in4} and C_{in4}. The flow duration curves of the DCCMS calculated POTW effluent flowrates are plotted in Figure 13.

For the DCCMS, effluent monitoring data from the treatment plants are used to develop statistical descriptions of the effluent flowrate. On review and analysis of flow data from the Simi Valley, Hill Canyon, and Camarillo POTWs there was an observed pattern of monthly variations in flowrates. Because the variations in flowrate could not be conclusively linked to external variables, separate distributions for flowrates from each POTW were calculated from the available data for each month of the year. Flowrates from POTWs are generally higher after precipitation. Insufficient data from the Moorpark POTW precluded performing a similar analysis for that treatment plant. The details of the analysis are included in the DCCMS documentation.

All available data for OP pesticides in POTW effluent are listed in Table 9. A maximum of four samples are available for each treatment plant. The combined chlorpyrifos and diazinon data are plotted in Figure 14.

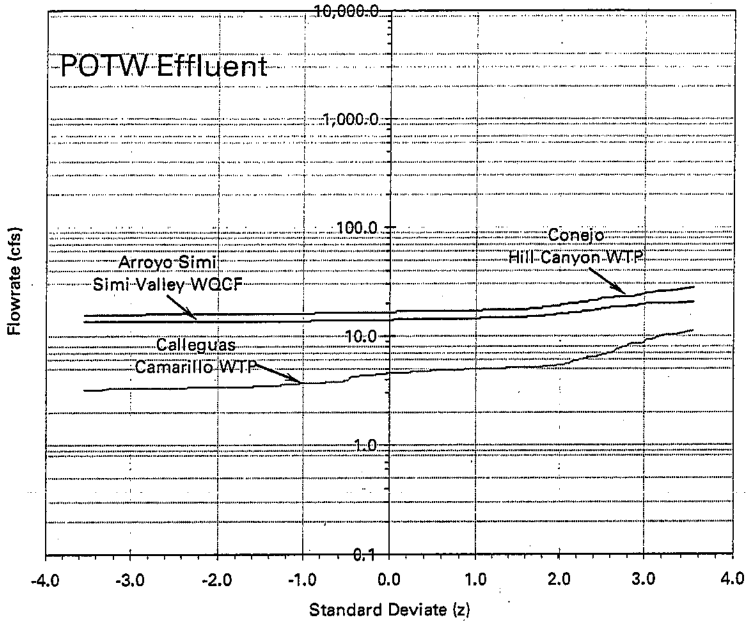


Figure 13: Flow Duration Curves for the POTWs in the CCW.

Because so few data exist characterizing each POTW effluent, the concentrations of chlorpyrifos and diazinon are set in the TTMBM to the chronic water quality criteria of 0.014 μg/L, and 0.1 μg/L, respectively. The values used in the TTMBM are listed in Table 10 as an order of magnitude guide for POTW contribution. While a constant concentration is used for each POTW, the DCCMS calculated effluent flowrates are used to determine the loading for chlorpyrifos and diazinon to the surface waters in the CCW.

Table 9: Chlorpyrifos and Diazinon Detected Values for POTW Discharge in the CCW.

	Chlorpyrifos			Diazinon		
POTW	n	Detected	Detected Values µg/L	n	Detected	Detected Values µg/L
Simi Valley	4	0%	---	4	75%	0.025 0.025 0.14
Moorpark	2	0%	---	3	67%	0.11 0.17
Olsen Rd. (1)	4	25%	0.03	4	0%	---
Hill Canyon	4	0%	---	4	50%	0.09 0.25
Camarillo	4	0%	---	4	0%	---
Camrosa	0	---	---	0	---	---

(1) Olsen Rd decommissioned in 2002, all flow currently diverted to Hill Canyon.

Table 10: Chlorpyrifos and Diazinon Nominal Loadings for POTW Discharges in the CCW.

	Chlorpyrifos			Diazinon		
POTW	Flowrate (cfs)	Conc. (µg/L)	Load (lb/d)	Flowrate (cfs)	Conc. (µg/L)	Load (lb/d)
Simi Valley	14.1	0.014	0.00106	14.1	0.1	0.0076
Moorpark (1)	2	0.014	0.00015	2	0.1	0.0011
Olsen Rd. (2)	0	---	---	0	---	---
Hill Canyon	16.7	0.014	0.00126	16.7	0.1	0.0090
Camarillo	4.6	0.014	0.00035	4.6	0.1	0.0025
Camrosa (3)	0	---	---	0	---	---

(1) In general, Moorpark does not discharge to surface waters of the United States and is not included in the TTMBM.

(2) Olsen Rd decommissioned in 2002, and is not included in the TTMBM.

(3) In general, Camrosa does not discharge to surface waters of the United States and is not included in the TTMBM.

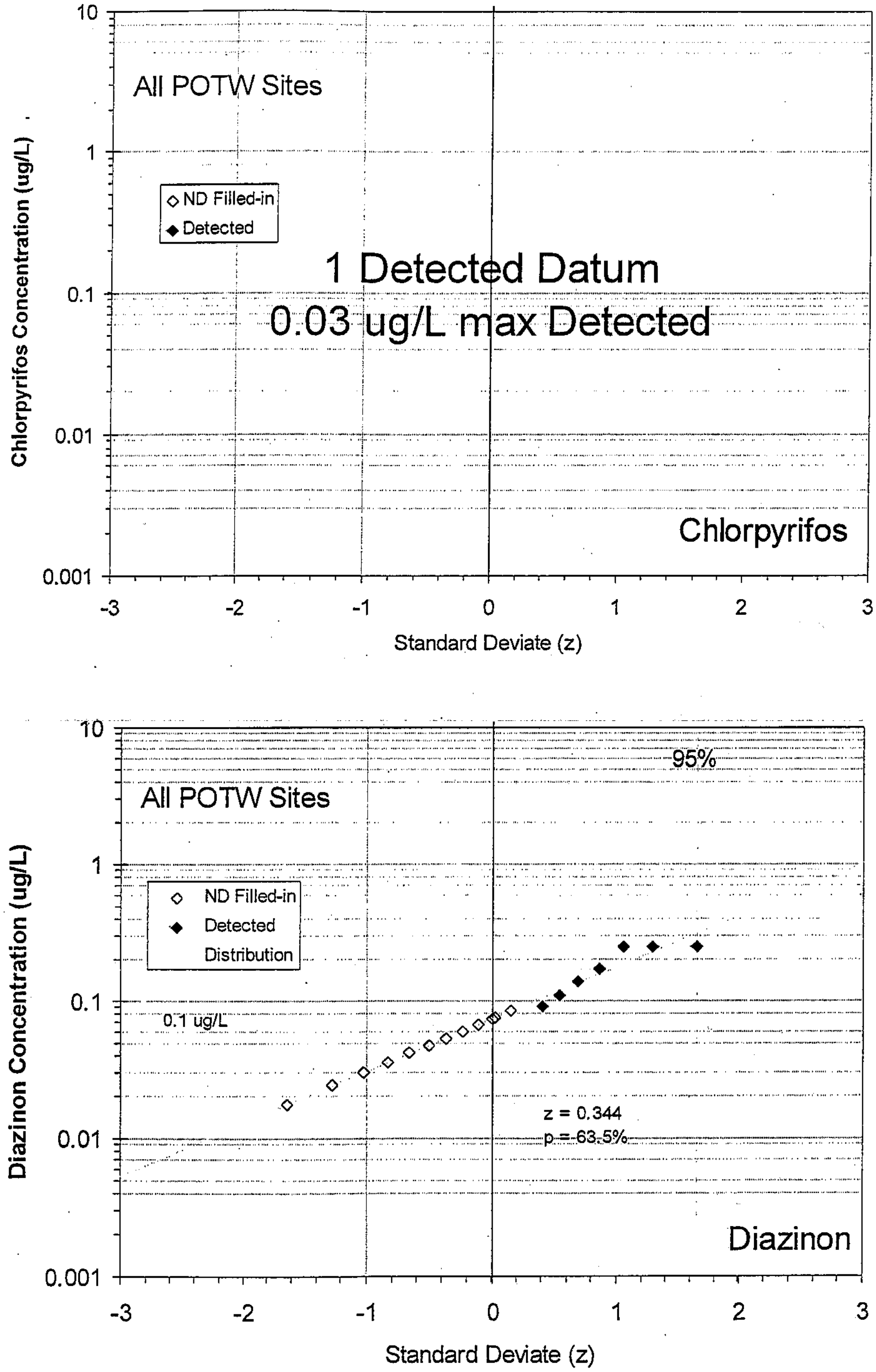


Figure 14: Distributions of Chlorpyrifos and Diazinon Concentrations Sampled from POTW Treated Effluent. Data from all CCW POTWs Combined. ND Filled-in Values Represent the Calculated Estimate of the Non-Detected Values via the ROS Method and Do Not Correspond to Physical Measurements.

Groundwater Inputs to Computational Elements

Groundwater exfiltration and groundwater dewatering discharges are included under the general heading of groundwater inputs to computational elements. Currently, the only dewatering wells included in the model are located in the Simi Valley area of the watershed. The groundwater flows in the Simi Valley are largely due to continuous pumping to lower the groundwater table. From a modeling perspective, the dewatering well discharges affect the CCW system in an equivalent manner to the natural exfiltration of groundwater providing baseflow to the stream.

Analysis of available data revealed that dry-season groundwater exfiltration rates are related to the previous wet-season total precipitation. A relationship between annual precipitation and groundwater exfiltration has been developed for the Upper Arroyo Simi, Conejo Creek, and Calleguas Creek sections of the CCW (LWA 2004d). For dates between April 1st and September 30th for a given water year, the cumulative precipitation for the water year is used to calculate groundwater exfiltration using the developed relationships. For dates between October 1st and March 31st, a weighted average between the total precipitation in the previous water year and the cumulative precipitation for the current water year are used in the calculations. Flow duration curves for groundwater exfiltration are presented as Figure 15.

Groundwater well water quality data were reviewed to develop updated estimates of exfiltration water quality. Dewatering well discharge water quality measurements have not revealed chlorpyrifos or diazinon in the Arroyo Simi groundwater. There is little information available on OP pesticide concentrations in the groundwater in other areas of the CCW. Average groundwater concentrations were input into the TTMBM on a trial and error basis to increase dry-weather in-stream loadings to match measured values. Estimated groundwater concentrations are 0.001 µg/L of chlorpyrifos and 0.002 µg/L of diazinon. For the current model, it is assumed that there are no OP pesticides present in the groundwater baseflow contribution to the surface water streams. Groundwater exfiltration as implemented in the TTMBM will serve to dilute the receiving water concentrations of OP pesticides.

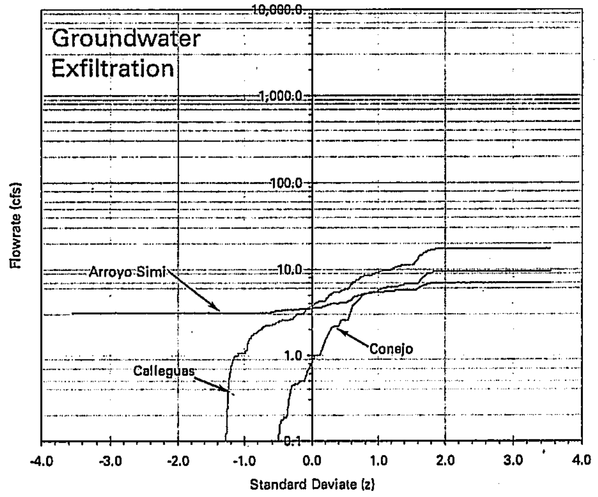


Figure 15: Flow Duration Curves of Groundwater Exfiltration by TTMBM Subwatershed.

Other Inflows to Computational Elements

Other processes possibly included in the future will account for management practices and diversions resulting from the implementation of control strategies. Other inflows are reserved for the implementation of potential control strategies. In the Conejo Subwatershed, State Import Water will be used to replenish the North and South Forks of the Arroyo Conejo once the Hill Canyon WTP effluent is removed from the stream as part of the salts implementation plan. The replenishment flows would be added to the TTMBM under the other flows catagory. State Import Water is assumed to contain no OP pesticides.

In-stream Generation within Computational Elements

No in-stream processes are included that generate chlorpyrifos or diazinon. Currently, TTMBM does not include desorption for sediment, so no phase transfer is included in the model. Degradation products are not tracked in the TTMBM, so no other species are generated. The description of the degradation and volatilization reactions is included in the In-stream Degradation Section.

Subwatershed Outflows

Possible withdrawals or outflows from the CCW reaches include groundwater infiltration and diversions, agricultural use, and evaporation. First order degradation (combination of microbial and hydrolysis reactions) and volatilization from the surface waters are included in the TTMBM for both chlorpyrifos and diazinon. Because of the complete-mix assumption, the concentration in each of the outflows is equal to the concentration calculated in the reach that is discharged to downstream subwatersheds.

Groundwater Infiltration from Computational Elements

The groundwater infiltration rate for the Northern CCW is 1.1 cfs/reach mile, and in the Conejo Creek region the rate is 0.3 cfs/reach mile. To ensure the Arroyo Las Posas goes dry during dry-weather, the rate of infiltration may be increased in the Las Posas Subwatershed up to five times the nominal value. The infiltration rate is checked internally by the DCCMS to ensure negative flowrates are not produced if the streambed becomes dry. Infiltration removes a load of the constituents from the stream. The groundwater infiltration flows are plotted in Figure 16.

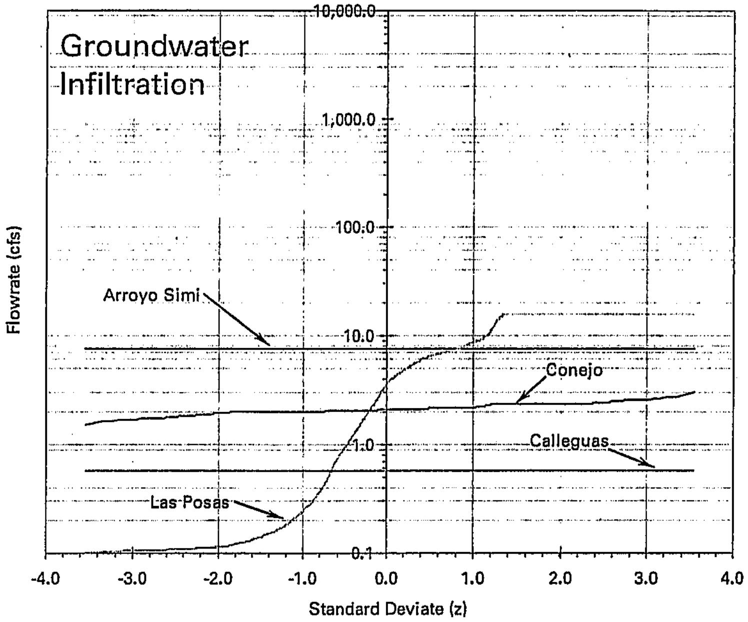


Figure 16: Flow Duration Curves of Groundwater Infiltration for the CCW.

Riparian Vegetation Demand from Computational Elements

Natural stream draw-down for riparian habitat support and agricultural withdrawals are accounted for in the Riparian Vegetation Demand. In the DCCMS calculations, the rate of riparian vegetation consumption is modified by the ratio of the daily evaporation to the annual average evaporation, as in Equation (15).

$$\text{Riparian ET} = \text{Riparian ET}_{\text{steady}} \frac{\text{daily evap (in/d)}}{0.164\,\text{(in/d)}} \qquad (15)$$

The calculated lost flow is checked against the available flow to ensure that a negative flowrate for the subwatershed does not result from including the riparian consumptive loss. All riparian use flows are plotted in Figure 17. Water is drawn from the streams to satisfy the evapotranspiration demand of riparian vegetation. Because the water is drawn from the stream before evaporating, constituents are carried from the stream to the root-zone. Constituents may accumulate in the root zone and would be subject to leaching back into the stream with baseflow, however, the back leaching is not currently included in the model. Once the Conejo Creek Diversion began operation, there was a significant drop of water available for stream-side use, as is evidenced by the off-scale jump the Conejo flows take for the percentage of time the diversion has been in operation.

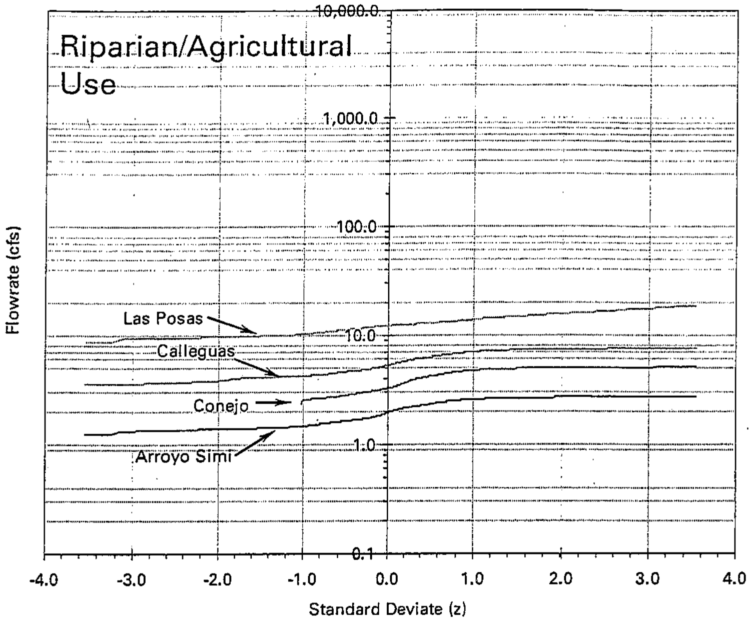


Figure 17: Flow Duration Curves for Riparian and Agricultural Use.

Evaporation from Computational Elements

Daily evapotranspiration values for coastal and inland areas of the CCW were developed in LWA 2004c. The variability within each month of the year of available daily evaporation is used to perturb the daily evaporation values calculated in LWA 2004c. Regression of historic evaporation against daily maximum temperatures in Camarillo or Oxnard would provide a mechanism for forming a daily estimate based on daily watershed conditions rather than rely on a constant value.

Evaporation from the reaches is calculated from the evaporation rate data multiplied by the estimated water surface area, and so is strictly the evaporative loss from the stream surface. The calculated lost flow from evaporation is checked against the available flow in the subwatershed to ensure that a negative flowrate does not result from including the evaporation loss.

Mugu Lagoon, Revolon Slough, and Calleguas Subwatersheds are calculated using the coastal areas evaporation rates in Figure 18. Evaporation from surface waters in Conejo, Las Posas, and Arroyo Simi Subwatershed is calculated using the interior valley information in Figure 18. The evaporative rates for the CCW are plotted in Figure 19.

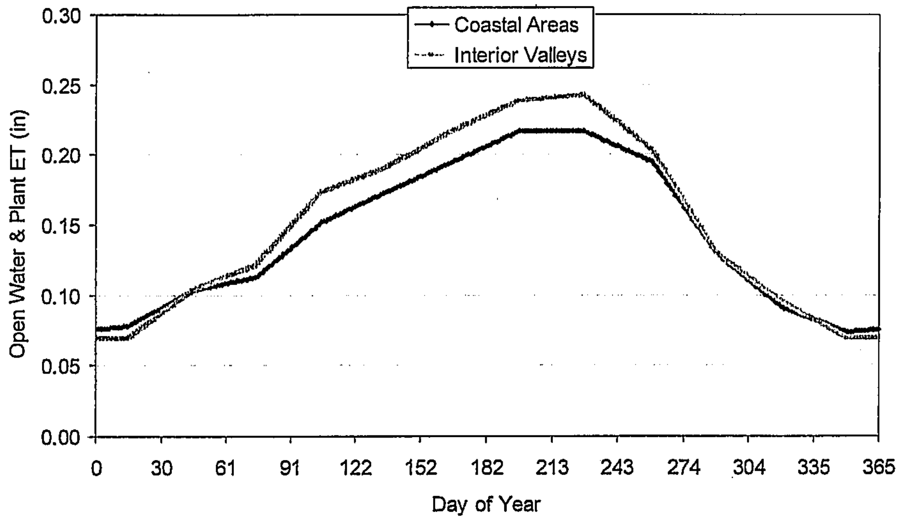


Figure 18: Base evapotranspiration from coastal and inland areas of the CCW.

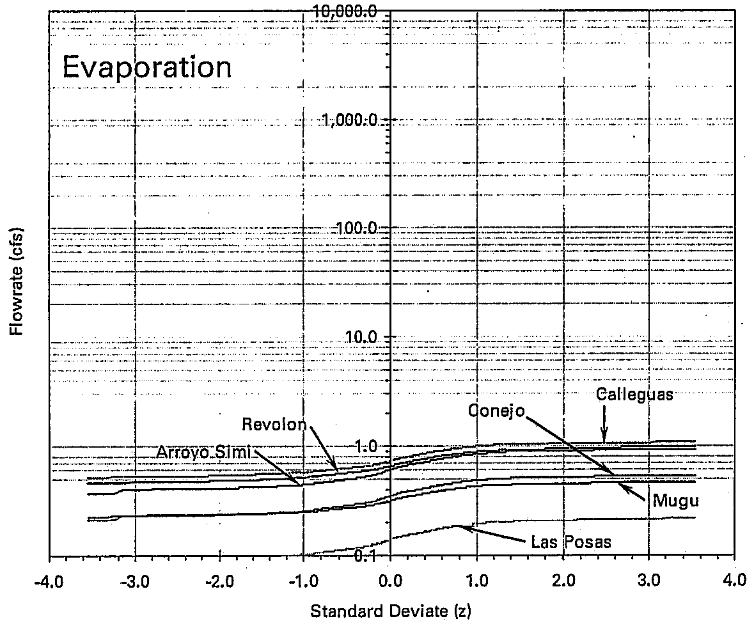


Figure 19: Flow Duration Curves for Evaporation from Receiving Waters in the CCW.

In-stream Consumption within Computational Elements

First order degradation rates are included in each of the constituent mass balances to account for microbial degradation and hydrolysis. Volatilization is included in each mass balance. The rates are small in comparison to the hydrologic movement through the watershed, so the degradation and volatilization do not greatly affect loadings in receiving waters.

Downstream Subwatersheds

The calculated outflow and mass load are used as input to the next most downstream computational element. As above, the reach discharge to downstream subwatersheds and outflow concentrations are calculated by Equations (16), and (17), respectively:

$$Q_{out0} = Q_{in0} + Q_{in1} + Q_{in2} + Q_{in3} + Q_{in4} + Q_{in5} + Q_{in6} - Q_{out1} - Q_{out2} - Q_{out3} \tag{16}$$

$$C = \frac{C_{in0}Q_{in0} + C_{in1}Q_{in1} + C_{in2}Q_{in2} + C_{in3}Q_{in3} + C_{in4}Q_{in4} + C_{in5}Q_{in5} + C_{in6}Q_{in6}}{Q_{out0} + Q_{out1} + Q_{out2} - kV - KA_{surface}} \tag{17}$$

TTMBM VALIDATION

The loads to the receiving waters in the CCW are calibrated above using available data and information. For validation, the TTMBM model output for calculated in-stream loads and concentrations are compared to measured in-stream values. The flowrate range of 0-25 cfs highlights typical dry-weather conditions, whereas the flowrates greater than approximately 25 cfs reveal wet-weather behavior. Additionally, the different scales give two views on the scatter and data availability. Unfortunately, there are subwatersheds where insufficient in-stream data exist to make strong judgments of the TTMBM behavior.

In each of the loading plots, the available data are represented by solid diamond shapes. For samples collected with no detected chlorpyrifos or diazinon, the detection level is used with the receiving water flow to estimate a corresponding non-detected load. The only meaning attributable to the non-detect load is that the actual receiving water load would be some value less than the value plotted. The TTMBM calculated loads are plotted as open squares, and the agricultural contribution to the load are plotted as plus symbols. The difference between the total and agricultural contribution is the total urban contribution which is composed of urban runoff and POTW flows. The TTMBM calculated concentrations are compared to the measured in-stream concentrations for each subwatershed.

Inspection of the following plots reveals that the measured in-stream concentrations of chlorpyrifos and diazinon can vary by more than two orders of magnitude for any given set of runoff conditions. By using the 90th percentile prediction interval to estimate loading to the receiving waters, the TTMBM is designed to estimate the high end of concentrations for any given flow condition. Calculated concentrations of chlorpyrifos and diazinon for each of the TTMBM subwatersheds are presented in Figure 20. The available measured concentrations are superimposed on the plots.

Appendix A contains Figures similar to the validation presented below for the conditions of using the regression functions for estimating the discharge chlorpyrifos and diazinon loads. Using the regression is essentially utilizing the 50th percentile prediction interval.

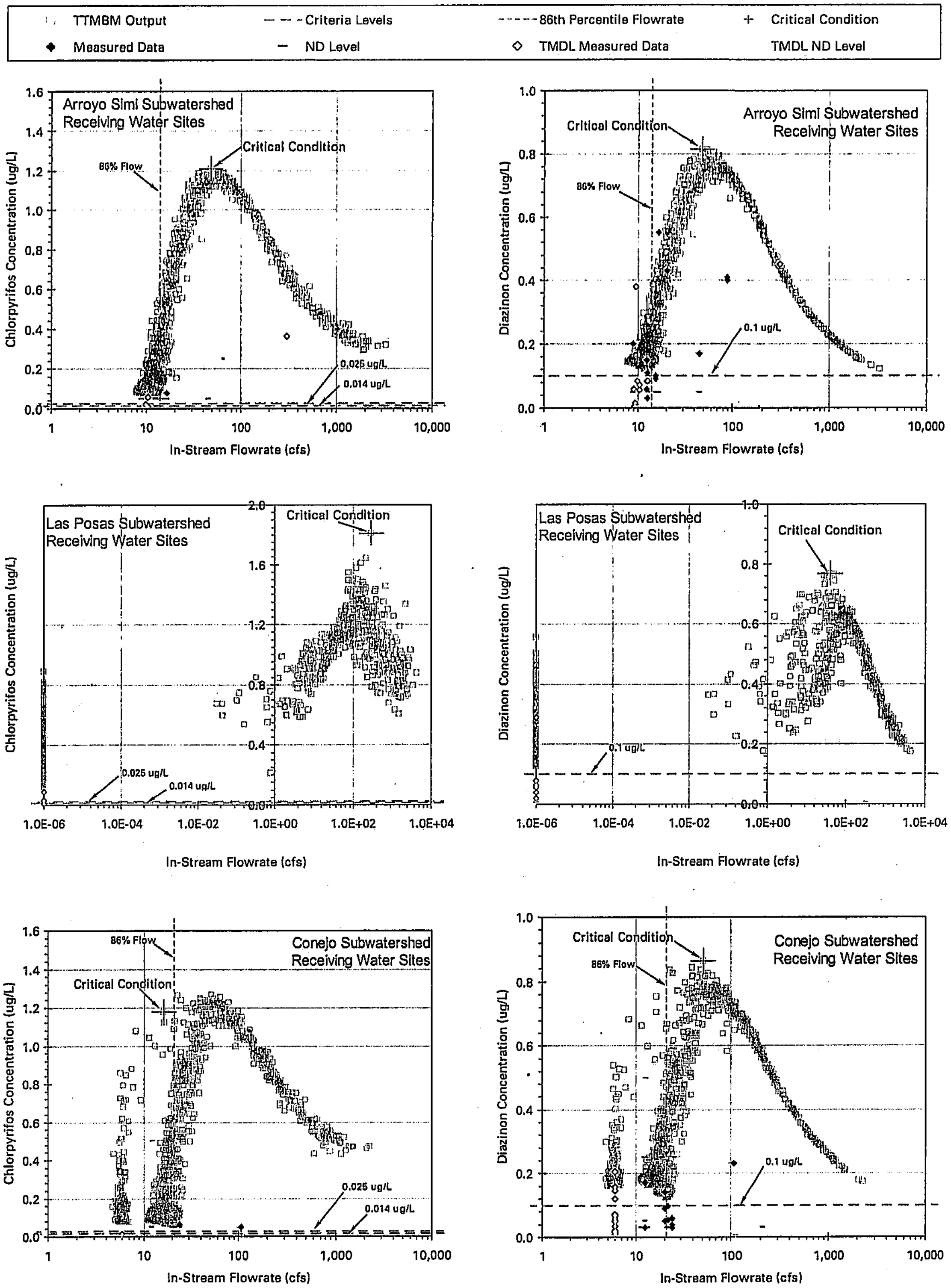


Figure 20 Continued

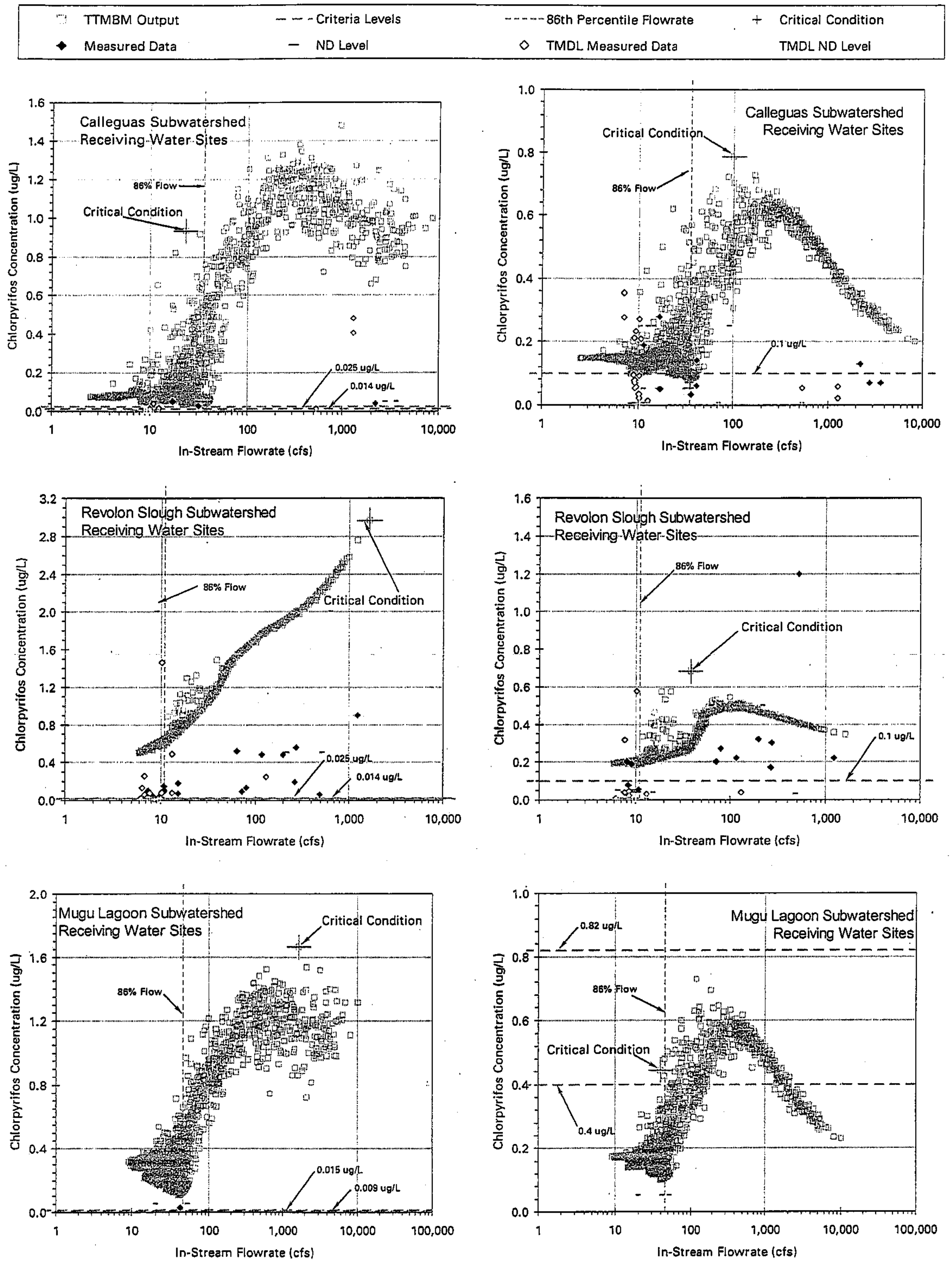


Figure 20: Measured Receiving Water Chlorpyrifos and Diazinon Concentrations Compared to TTMBM Output. Note not all Figures Plotted o the Same Scale.

Arroyo Simi Subwatershed

The pesticide loads are plotted in Figure 21. The comparison between the TTMBM calculated and measured concentrations is plotted as Figure 22. TTMBM output over-predicts the measured chlorpyrifos. Diazinon calculations from the TTMBM match the observed data fairly well. There are no Arroyo Simi receiving water chlorpyrifos or diazinon samples for higher flow wet weather events, so a comparison is not possible. The TTMBM Runoff Model calculates relatively constant concentrations of chlorpyrifos and diazinon, in the Arroyo Simi Subwatershed with slightly elevated values during wet-weather events.

Las Posas Subwatershed

The pesticide loads are plotted in Figure 23. The comparison between the TTMBM calculated and measured concentrations is plotted as Figure 24. The available receiving water data in the Las Posas Subwatershed is more limited than for the Arroyo Simi Subwatershed. A meaningful comparison of model performance to measured values is not possible.

Conejo Subwatershed

The pesticide loads are plotted in Figure 25. The comparison between the TTMBM calculated and measured concentrations is plotted as Figure 26. The TTMBM in general over-predicts chlorpyrifos loading and diazinon. There are no available measurements for higher flow events. There are too few chlorpyrifos data for a meaningful comparison to TTMBM performance for wet or dry weather conditions. Concentration comparisons for diazinon are fair, however available data only represent dry-weather, so a wet-weather comparison is not possible.

Calleguas Subwatershed

The pesticide loads are plotted in Figure 27. The comparison between the TTMBM calculated and measured concentrations is plotted as Figure 28. As with the Conejo Subwatershed TTMBM output over-predicts chlorpyrifos and diazinon loads. Wet-weather chlorpyrifos loads are significantly over-predicted. Wet-weather diazinon loads are slightly over-estimated but match the data well. Chlorpyrifos and diazinon concentrations match well, but there are some measured diazinon concentrations significantly higher than the TTMBM.

Revolon Subwatershed

The pesticide loads are plotted in Figure 29. The comparison between the TTMBM calculated and measured concentrations is plotted as Figure 30. Chlorpyrifos and diazinon dry-weather loads match the trends of measured loads well. There are significant scatter in the measured data that are not reflected in the TTMBM model calculations. Wet weather chlorpyrifos loads match quite well to the trend of the measured data. Chlorpyrifos loads are significantly over estimated. Diazinon loads are over-estimated by the TTMBM for wet-weather flows. Chlorpyrifos concentrations in general match well, but diazinon concentrations are estimated as relatively constant, where the measured concentrations are quite variable.

Mugu Lagoon Subwatershed

The pesticide loads are plotted in Figure 31. The comparison between the TTMBM calculated and measured concentrations is plotted as Figure 32. There are too few chlorpyrifos and diazinon values in the Mugu Lagoon Subwatershed for a meaningful comparison of TTMBM output to measured values. Concentration comparisons are similar to other subwatersheds.

Load Apportionment by Subwatershed

To facilitate scenario development, the in-stream load of chlorpyrifos and diazinon are apportioned to POTW, agricultural runoff, and urban runoff as a function of in-stream flowrate for each subwatershed in Figure 33 to Figure 38. In each subwatershed except Revolon Slough, POTW effluent is the major source of both chlorpyrifos and diazinon to the receiving waters for low in-stream flowrates typical of dry weather. As in-stream flowrates increase, agricultural runoff becomes the dominant source of chlorpyrifos and urban runoff becomes the dominant source of diazinon to the receiving waters. In the Revolon Slough Subwatershed, agricultural runoff is the dominant source of both chlorpyrifos and diazinon at all flows according to TTMBM calculations.

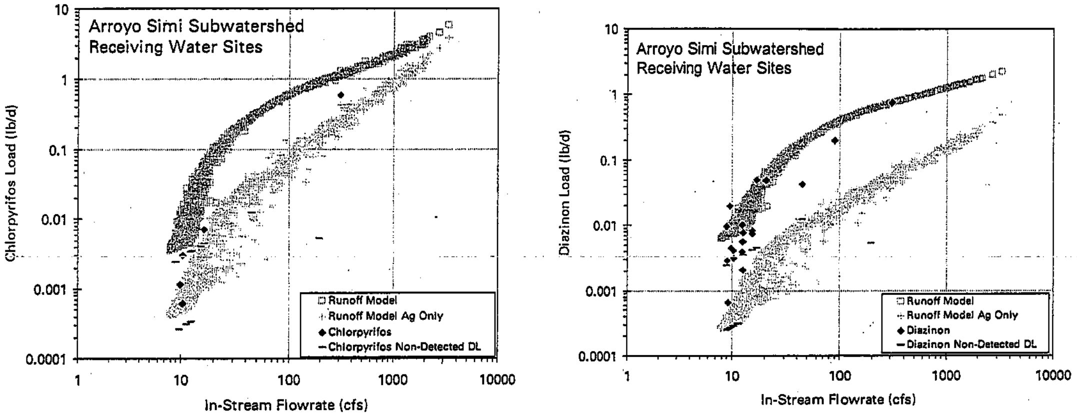


Figure 21: Chlorpyrifos and Diazinon Load in the Arroyo Simi Subwatershed.

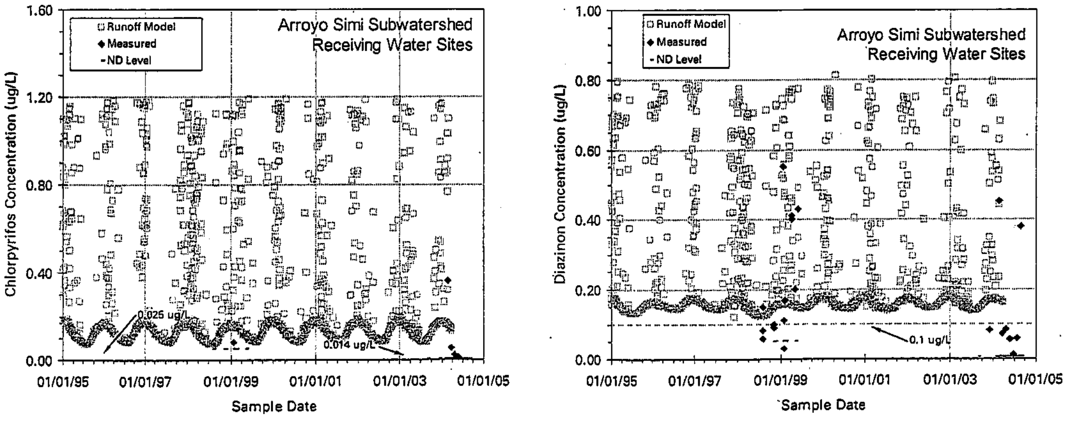


Figure 22: Chlorpyrifos and Diazinon Concentrations in the Arroyo Simi Subwatershed.

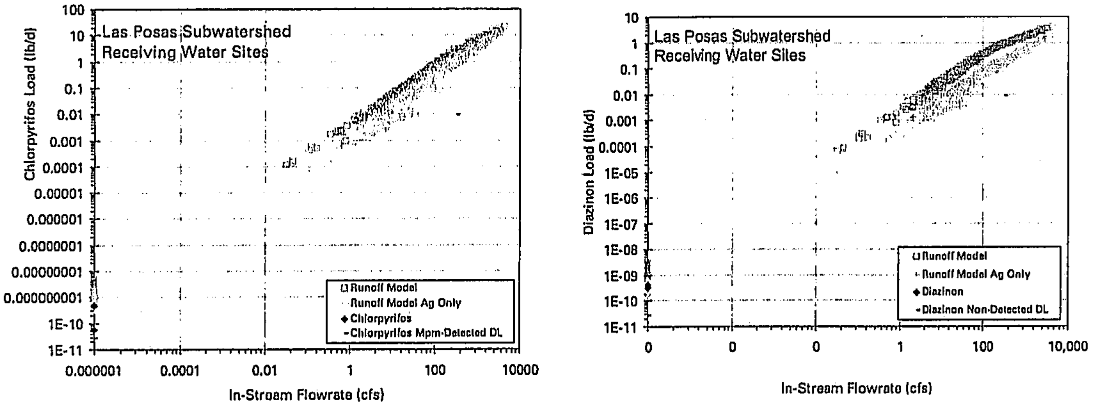


Figure 23: Chlorpyrifos and Diazinon Load in the Las Posas Subwatershed.

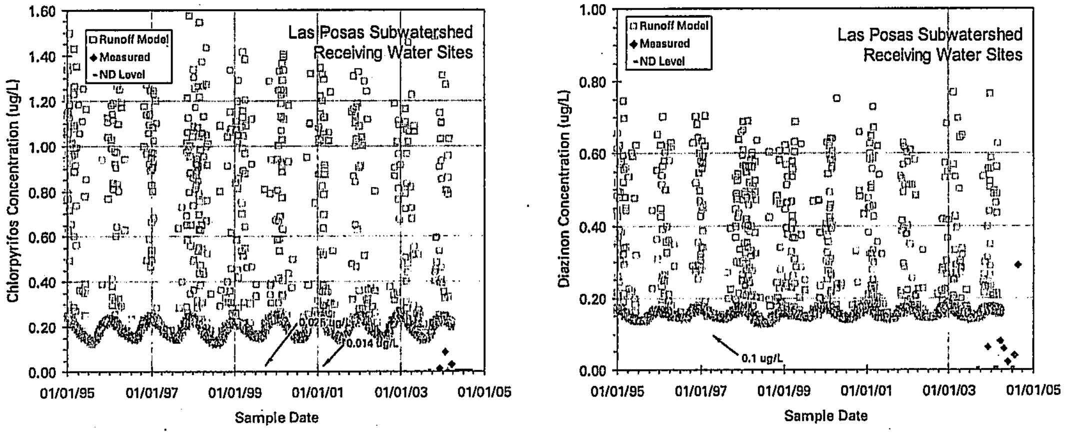


Figure 24: Chlorpyrifos and Diazinon Concentrations in the Las Posas Subwatershed.

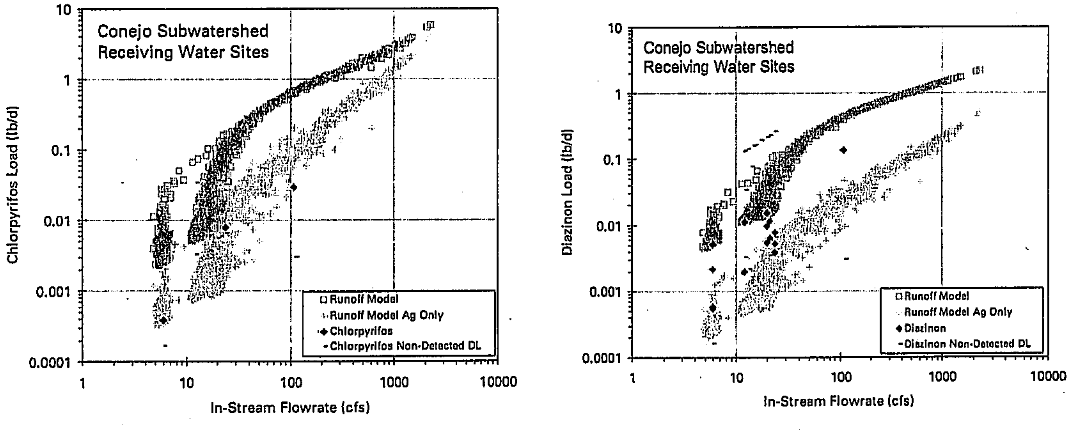


Figure 25: Chlorpyrifos and Diazinon Load in Conejo Subwatershed.

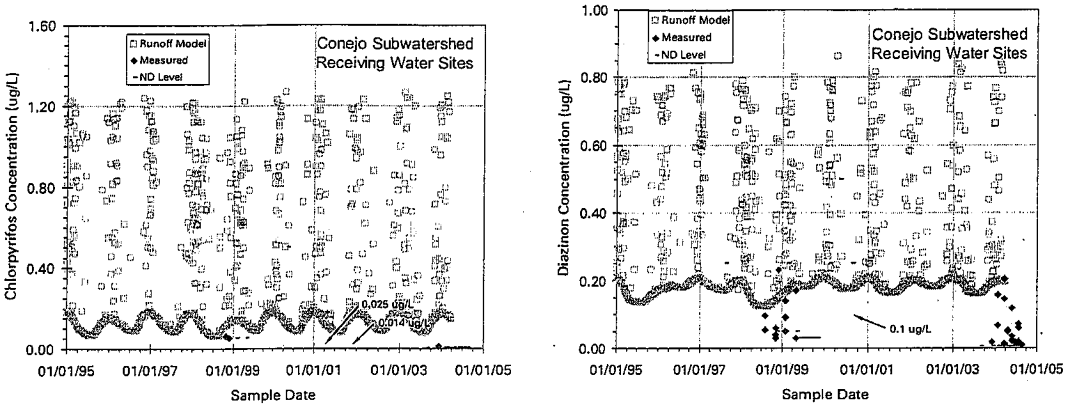


Figure 26: Chlorpyrifos and Diazinon Concentration in the Conejo Subwatershed.

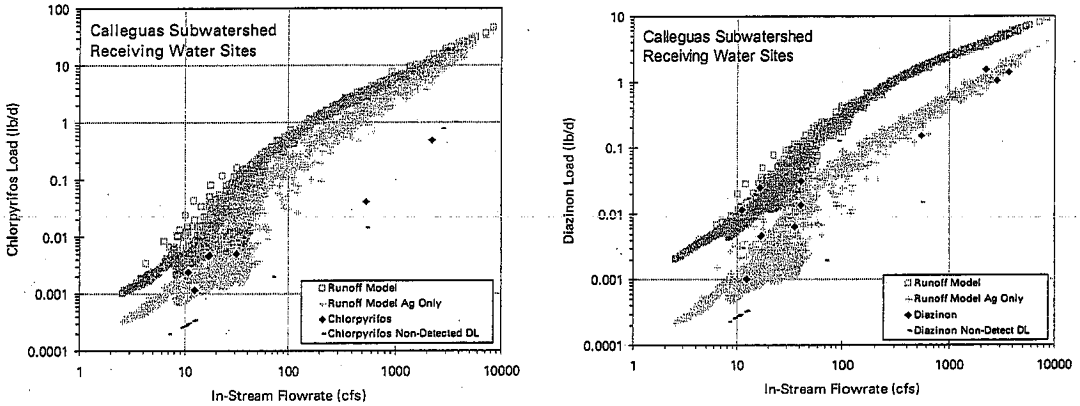


Figure 27: Chlorpyrifos and Diazinon Load in the Calleguas Subwatershed.

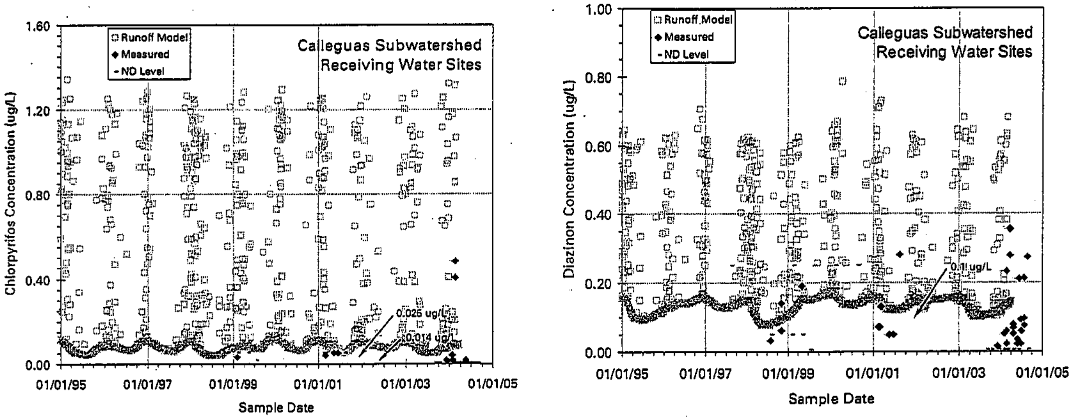


Figure 28: Chlorpyrifos and Diazinon Concentrations in the Calleguas Subwatershed.

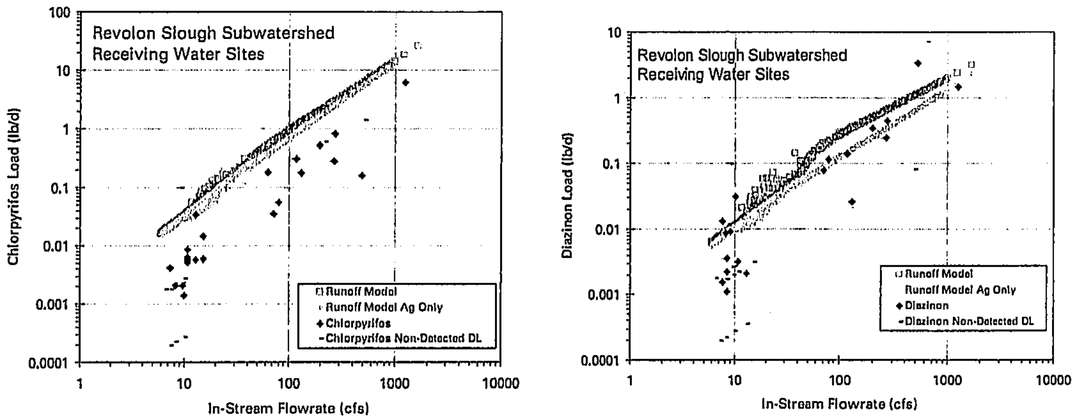


Figure 29: Chlorpyrifos and Diazinon Load in the Revolon Slough Subwatershed.

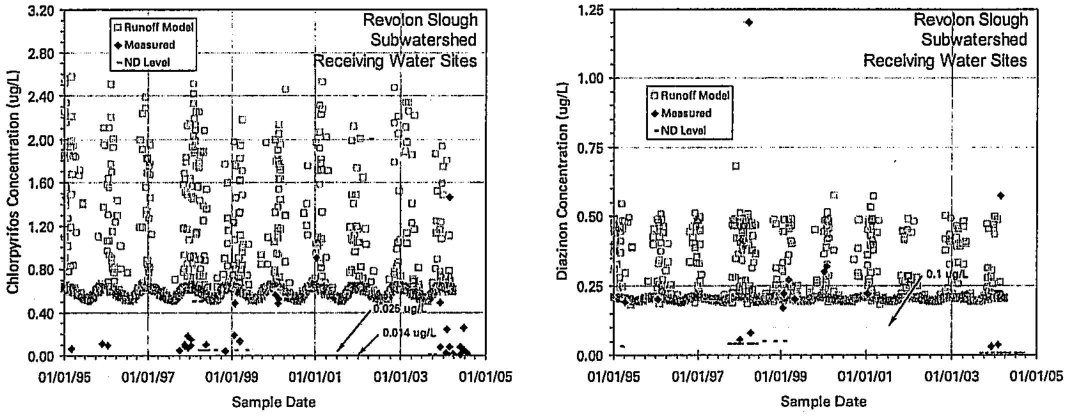


Figure 30: Chlorpyrifos and Diazinon Concentrations in Revolon Slough Subwatershed.

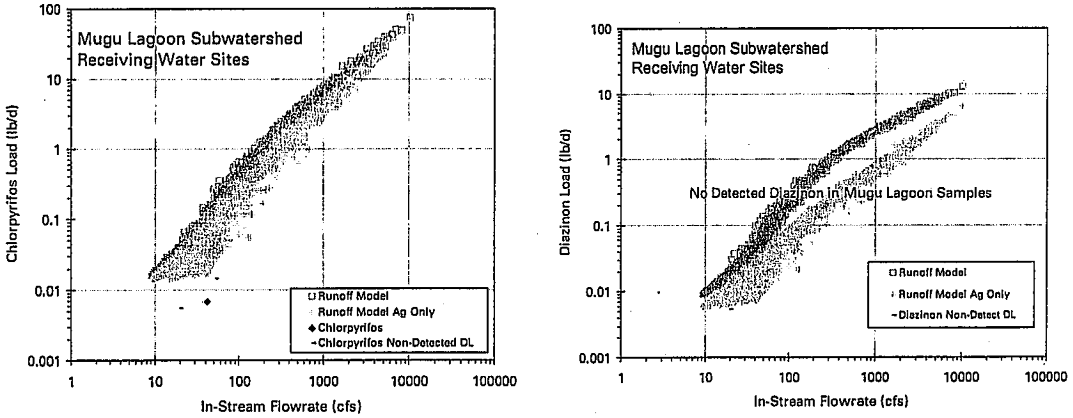


Figure 31: Chlorpyrifos and Diazinon Loads in the Mugu Lagoon Subwatershed.

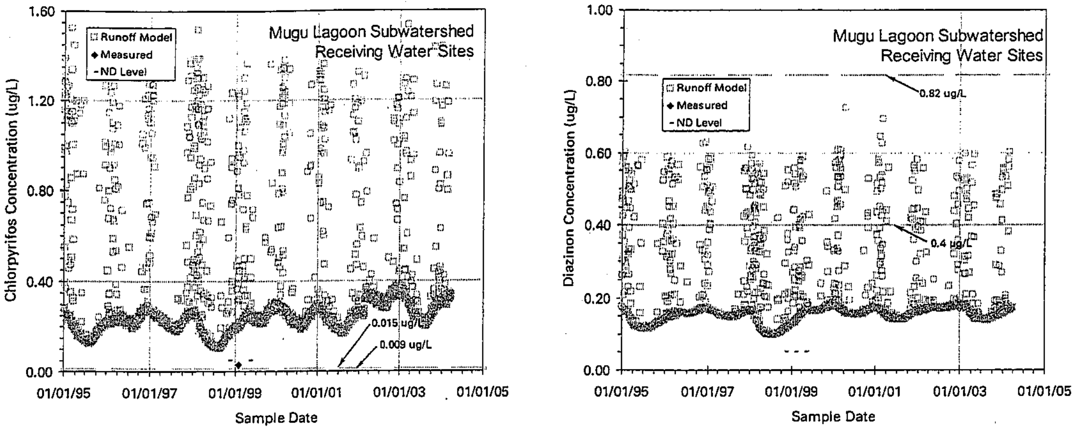


Figure 32: Chlorpyrifos and Diazinon Concentrations in the Mugu Lagoon Subwatershed.

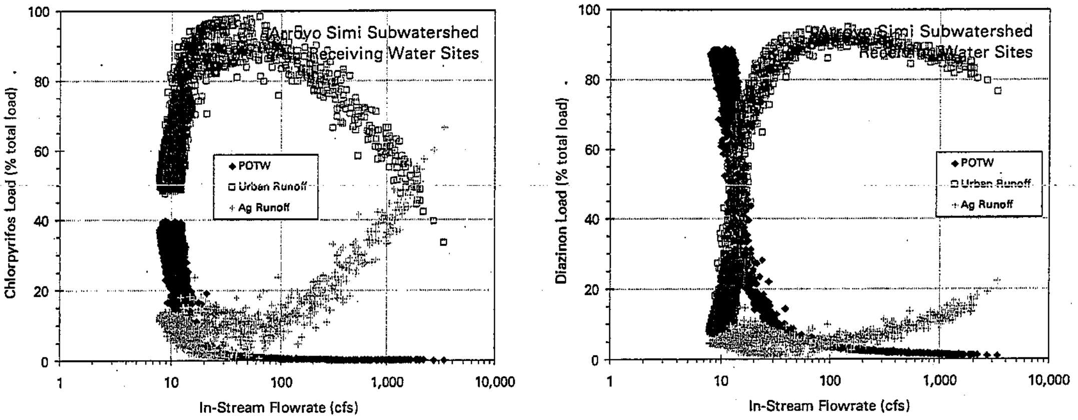


Figure 33: Chlorpyrifos and Diazinon Load Apportionment Arroyo Simi Subwatershed.

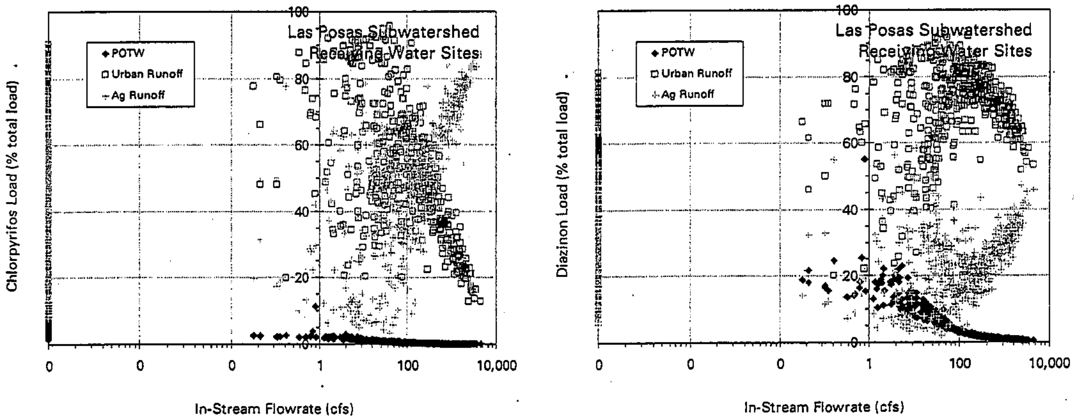


Figure 34: Chlorpyrifos and Diazinon Load Apportionment for Las Posas Subwatershed.

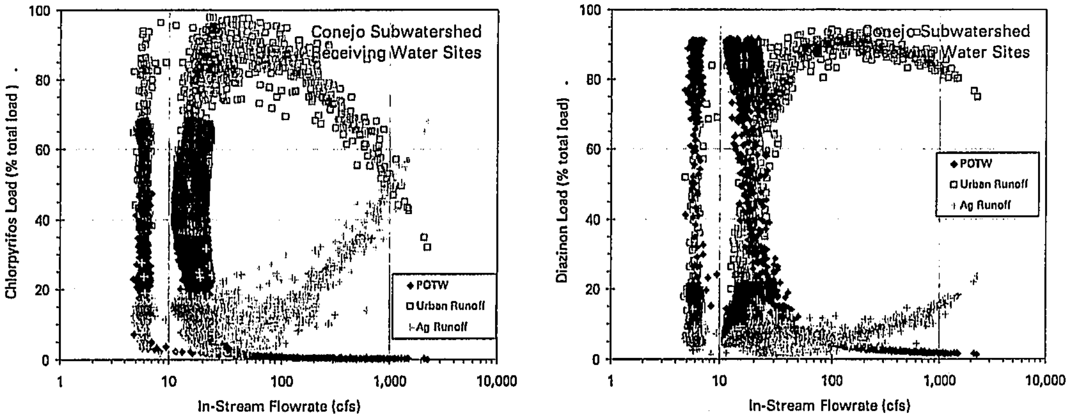


Figure 35: Chlorpyrifos and Diazinon Load Apportionment for Conejo Subwatershed.

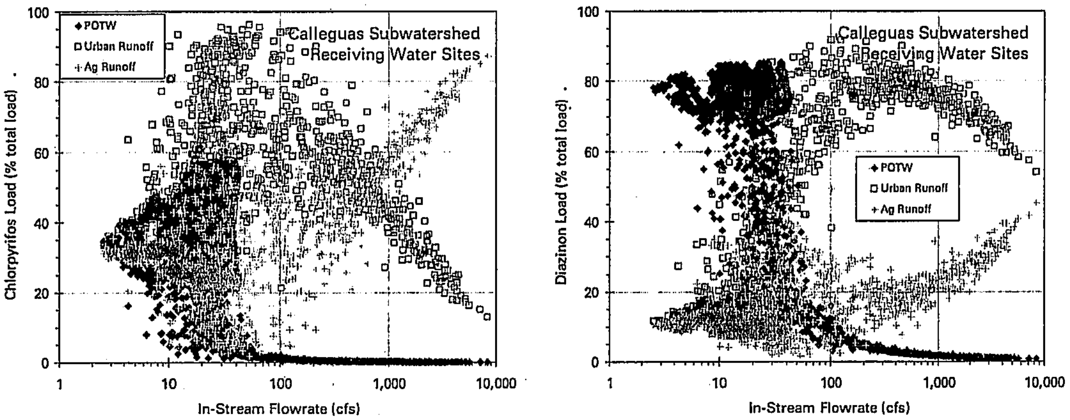


Figure 36: Chlorpyrifos and Diazinon Load Apportionment for Calleguas Subwatershed.

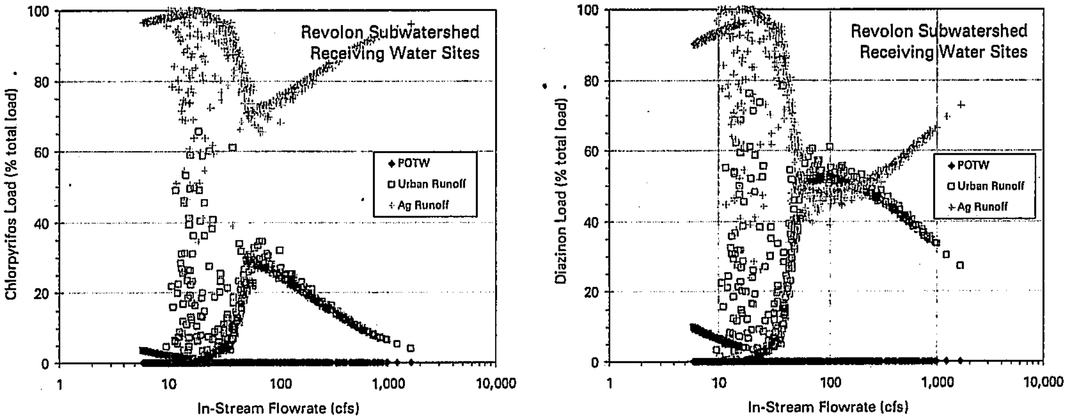


Figure 37: Chlorpyrifos and Diazinon Load Apportionment for Revolon Slough Subwatershed.

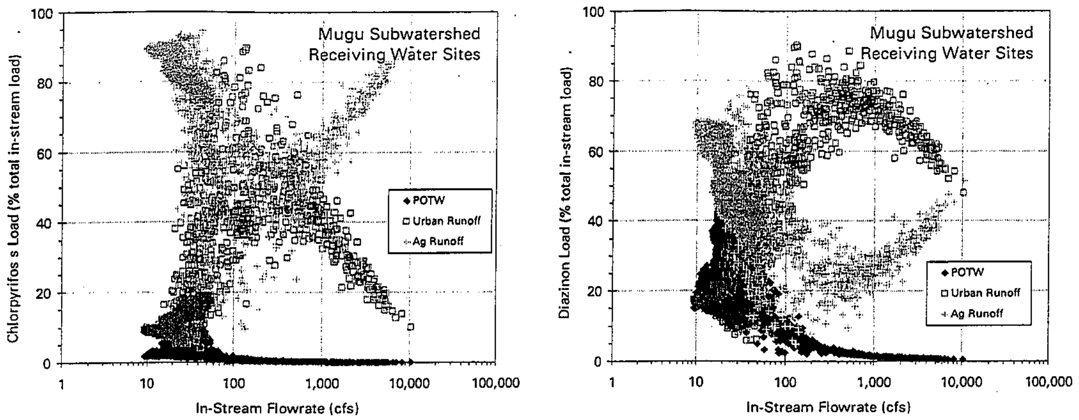


Figure 38: Chlorpyrifos and Diazinon Load Apportionment in Mugu Lagoon Subwatershed.

CRITICAL CONDITIONS

The critical conditions for diazinon and chlorpyrifos include both dry and wet conditions, however the exact quantification of those conditions needs further analysis. During dry weather, specific events appear to lead to high loadings in the receiving water. A linkage between flows, use and runoff quality has not yet been established and it may not be possible to determine the connection. However, it is likely that peak dry weather concentrations and loads will occur during periods of maximum source flows. Additional analysis will be conducted to identify this period and determine whether any other linkages exist that can be used to clarify dry weather critical conditions.

During wet weather events, concentrations of chlorpyrifos are typically much greater than nominal dry weather values. In-stream diazinon concentrations are typically observed to be greater during wet-weather events than for dry-weather. Consequently, wet weather is also a critical condition for these pesticides. Higher concentrations appear to be driven by larger storm events. The larger amount of discharge of these pesticides during storm events does not appear to be diluted significantly by runoff from native spaces. Therefore, all storm events are potentially of concern. Wet weather wasteload and load allocations will be defined for wet weather conditions to account for this critical condition.

MARGIN OF SAFETY (MOS)

A TMDL analysis involves uncertainty. To address the uncertainty, a TMDL is to include a margin of safety, which can be explicit, implicit, or both. Conservative assumptions are incorporated throughout the development of the linkage analysis and calculation of the required reductions. The analysis includes an implicit margin of safety by relying on a generally conservative approach through the entire development. The implicit MOS based on conservative analysis and requiring receiving water targets for the major sources follows the approach of other chlorpyrifos and diazinon TMDLs developed recently in California (SFBRWQCB 2004, CVRWQCB 2004) The following is a list of the conservative assumptions made during the development of the TTMBM and calculations of required reductions: .

- All runoff data were used in regression calculations potentially biasing the results high in comparison to present conditions.
- Loading equations are based on the 90% prediction interval of the load vs. runoff flowrate regressions. Calculations of discharge quality effectively estimate the 95th percentile measurement.
- Total measurements of chlorpyrifos and diazinon implicitly include and incorporate sediment associated loading to the receiving waters.
- WLAs to urban stormwater and POTWs are set to the numeric target, but use of both constituents is banned in urban areas so the concentrations should drop below target levels.
- Implicit in the development of the numeric water quality targets is a margin of safety.
- The WLAs and LAs are set to the numeric water column target. Because the contributions to receiving water are dependent on the environmental conditions and behave differently, maximum contribution is a blend of all sources none of which are discharging at the target concentration simultaneously.
- Agricultural return flows, urban runoff, and POTWs are the dominant sources of chlorpyrifos and diazinon to the receiving waters in the CCW. Applying the numeric receiving water target to the discharges will ensure the major sources of chlorpyrifos and diazinon to receiving waters are at or below the targets.

Basing the loading equations on the 90% prediction level of the regression captures a large portion of the observed variability in the discharge data, thereby calculating the receiving water quality based on the peak loadings for a given set of conditions. The TTMBM output, in general, over-predicts the in-stream concentrations. Required reductions based on the TTMBM output are a conservative estimate of the required reductions necessary to achieve numeric targets in-stream and as such are an implicit MOS. By requiring a limit of the receiving water numeric target for all controllable discharges results in the maximum TTMBM calculated receiving water concentrations under the target by 5 to 72%.

SENSITIVITY ANALYSIS

Because the TTMBM suffers from significant data limitations, a formal sensitivity analysis is not performed at the current time. It is anticipated that the TTMBM will be updated when additional data are available and the update will potentially alter the rates of loading used in the model. Any sensitivity analysis performed now would be invalidated when the model is updated with additional data. For example, it is possible that the rate of urban loading should be a super-linear function of runoff flowrate, instead of the sub-linear and linear rates assumed for the current version of TTMBM. If runoff loading is found to be super-linear, the model will be much more sensitive to perturbations of the loading rate than for linear loading rates.

Urban runoff, POTW effluent, and agricultural returns provide the bulk of the OP pesticide loading to the system. Loading of chlorpyrifos and diazinon from urban runoff and POTW effluent to the watershed are expected to decrease substantially due to implementation of the restrictions. Model sensitivity to urban runoff and POTW effluent is neutered do to the anticipated reductions stemming from the bans on use. The potential atmospheric drift contribution to urban runoff is expected to be dramatically altered due to restrictions on which crops chlorpyrifos and diazinon may be applied to, and re-labeling for application procedures and allowable dose applied. Because the magnitude of reductions required in both the agricultural returns and the receiving waters, the calculated percent required reduction is not sensitive to the exact load in either compartment. To illustrate the insensitivity of percent required reduction, Table 11 lists the change in the required reduction if the actual initial load is found to be either 50% greater or less than the TTMBM calculation. If the TTMBM calculated required reduction is 99%, the required reduction would be 99.3% if the initial load is found to be 50% greater than TTMBM calculations. Also, for a 99% required reduction, even after the loads are reduced by 50%, there is still a need for a 98% reduction. Due to the magnitude of the required reductions, the ultimate answers derived from TTMBM calculations are insensitive to precise load calculations, as the implementation proceeds there will be an increasing need for model refinement and formal sensitivity analysis.

Table 11: Change in Required Reduction Given a Change in the Calculated Load.

Initial Required Reduction (%)	Required Reduction Given Change in Load	
	50% Greater	50% Less
99	99.3	98
98	98.7	96
95	96.7	90
90	93.3	80
80	86.7	60

SCENARIO INVESTIGATIONS

To perform implementation scenario investigations, changes affecting flows should be input into a new DCCMS scenario to determine CCW flows for the new scenario. The new flows would be copied into the TTMBM spreadsheet. Finally, estimates of loading modifications would be used to change the TTMBM input values.

IMPROVEMENTS REMAINING

In general, the TTMBM output under-estimates the OP pesticide concentrations. Currently, atmospheric contribution is encapsulated in the agricultural and urban runoff loads of pesticides. There are no measurements of OP pesticides in the native space runoff in the CCW. Measurement of OP pesticide native space runoff would provide the most direct way of incorporating atmospheric deposition into the TTMBM. Incorporation of atmospheric drift/direct deposition and wet and dry deposition on the watershed may improve the comparison between TTMBM output and measured in-stream values. Chlorpyrifos is known to have a high affinity for the organic fraction of sediment. As current TMDL data become available, a linkage will be investigated between the constituents and TSS, Sediments, etc. Incorporation of the pesticide use information into the model to the extent possible will provide a means to relax the assumption that each agricultural runoff sample is representative of all agricultural runoff across the entire CCW. Specifically, determining if a link can be established between the rate and timing of pesticide use and runoff water quality will ideally account for a large portion of the variability in the observed measurements.

When improvements are made to the DCCMS, the applicable results should be carried over to the Toxicity TMDL model.

Because of the TTMBM structure, adding additional constituents essentially requires additional columns to be inserted into the spreadsheet based model, and addition of the appropriate runoff loading parameters.

As discussed in the Scope of the Toxicity TMDL Mass Balance Model section, continued monitoring for OP pesticides in the CCW using environmentally relevant detection limits would greatly benefit any subsequent modeling effort. Each additional piece of information listed above will likely increase the resolution of apportioning loads under wider range of conditions. Due to the application-runoff nature of OP pesticide loading to the receiving water, an extremely detailed model would be required to exactly match the variability of the observed data. A detailed model would require more data to develop, calibrate, and validate as well as consume time and monetary resources. For the purposes of TMDL development, it is unclear that the increased level of detail is necessary. If the expected range of variability around the TTMBM model output were know (i.e "error bars" for a range of in-stream flowrates), through additional data gathering, sufficient information would exist to develop wasteload and load allocations that would be protective of all beneficial uses in each of the receiving waters.

CONCLUSIONS

Conservation of mass is the basis of the TTMBM water quality model. Flowrates of various water streams in the CCW are calculated by the DCCMS model. By assuming that each reach is steady for any given time step, reach outflow and concentration may be calculated from algebraic equations. The effect of using a daily time step and the steady-state assumption is to generate a series of daily average snapshots of the conditions likely to exist in the CCW. Both the TTMBM and DCCMS are built on the principles of mass conservation forming a simple, robust, and defensible method of modeling constituent flows through the CCW.

The current development of the TTMBM represents utilizing the available information to the extent possible to construct a defensible model. Due to limitations in the available data, there are components of the TTMBM that could be improved. Currently, the TTMBM illuminates which sources of the constituents contribute the greatest fraction of in-stream load, and under what conditions. Because of data limitations, the TTMBM output should be considered estimates of field conditions. Through continued monitoring and additional investigations, the additional information could greatly improve the predictive capability of the TTMBM.

REFERENCES

Chow, V.T., D.R. Maidment, and L.W. Mays (1988), Applied Hydrology, McGraw-Hill Publishing Company, New York, NY.

Dow AgroSciences LLC (1998). A monitoring study to characterize chlorpyrifos concentration patterns and ecological risk in an agriculturally dominated tributary of the San Joaquin River. Study ID ENV96055.

Larry Walker Associates (LWA, 2004a). *Source Analysis Calleguas Creek Watershed Toxicity TMDL*. Interim Draft Report submitted to the Calleguas Creek Watershed Management Plan, 2004.

Larry Walker Associates (LWA, 2004b). *Toxicity TMDL Conceptual Model for the Calleguas Creek Watershed.* Draft Report submitted to the Calleguas Creek Watershed Management Plan, 2004. 22 pp.

Larry Walker Associates (LWA, 2004c). *Toxicity TMDL Modeling Approach for the Calleguas Creek Watershed.* Interim Draft Report submitted to the Calleguas Creek Watershed Management Plan, 2004. 17 pp.

Larry Walker Associates (LWA 2004d), *Progress Report on Efforts to Address Salts on the Calleguas Creek Watershed*, submitted to Calleguas Creek Watershed Management Plan, pp. 105, June 30, 2004.

Larry Walker Associates (LWA 2003), "Precipitation Water Quality", Technical Memorandum to WQ/WR Stakeholder Group, December 30, 2003.

Majewski, M.S., D.S. Baston (2002), Atmospheric Transport of Pesticides in the Sacramento, California, Metropolitan Area, 1996-1997. USGS Report 02-4100.

National Research Council (NRC, 2001). *Assessing the TMDL Approach to Water Quality Management*. Committee to Assess the Scientific Basis of the Total Maximum Daily Load Approach to Water Pollution Reduction. Water Science and Technology Board, Division on Earth and Life Studies. National Academy Press, Washington, DC.

Ross, L., (2002), Department of Pesticide Regulation, personal communication.

SRWP OP Pesticide Focus Group (SRWP, 2000), Sacramento and Feather Rivers OP Pesticide Management Plan, Identification and Evaluation of OP Pesticide, Management Practices for Orchard Dormant Sprays, November 7, 2000

Stow, C.A. and M.E. Borsuk (2003), "Assessing TMDL Effectiveness Using Flow-Adjusted Concentrations: A Case Study of the Neuse River, North Carolina, *Environ Sci. Technol.*, V 37, 2043-2050.

Tchobanoglous and Schroeder (1985), Water Quality: Characteristics, Modeling, Modification, Addison-Wesley Publishing Company, Reading, MA.

Young, T. (2002), Department of Civil and Environmental Engineering, University of California, Davis, personal communication.

CONVERSIONS

Area

$0.004047 \frac{km^2}{acre}$

Volume

$7.481 \frac{gal}{ft^3}$

Flow

$1.008 \frac{acre \cdot in/hr}{cfs}$

$0.0013813 \frac{cfs}{acre \cdot ft/yr}$

$0.5042 \frac{cfs}{acre \cdot ft/d}$

$1.547 \frac{cfs}{MGD}$

Mass Loading

$5.394 \frac{lb/d}{cfs \cdot mg/L}$

$0.005394 \frac{lb/d}{cfs \cdot \mu g/L}$

APPENDIX A: TTMBM USING NOMINAL REGRESSION RESULTS

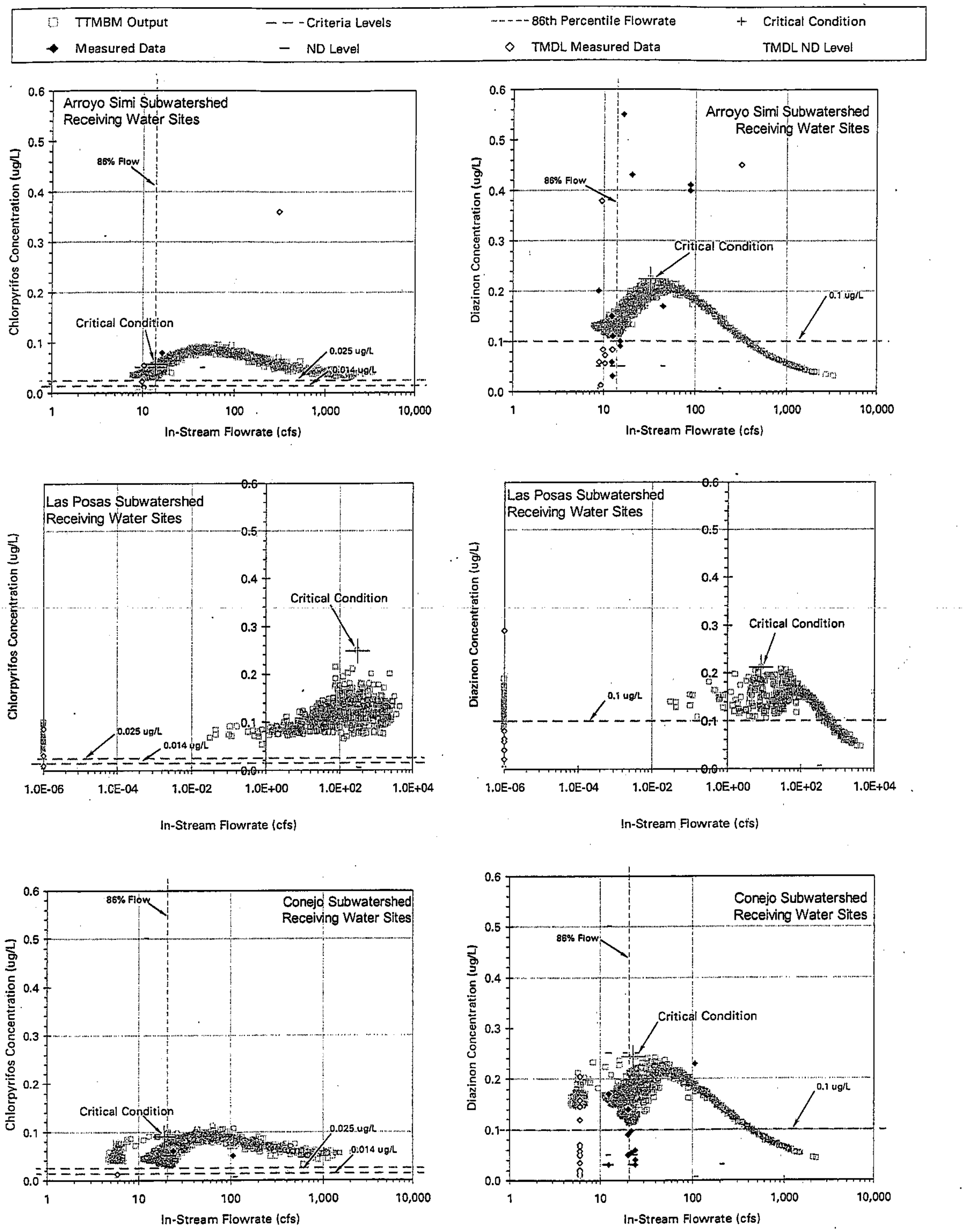


Figure 39 Continued

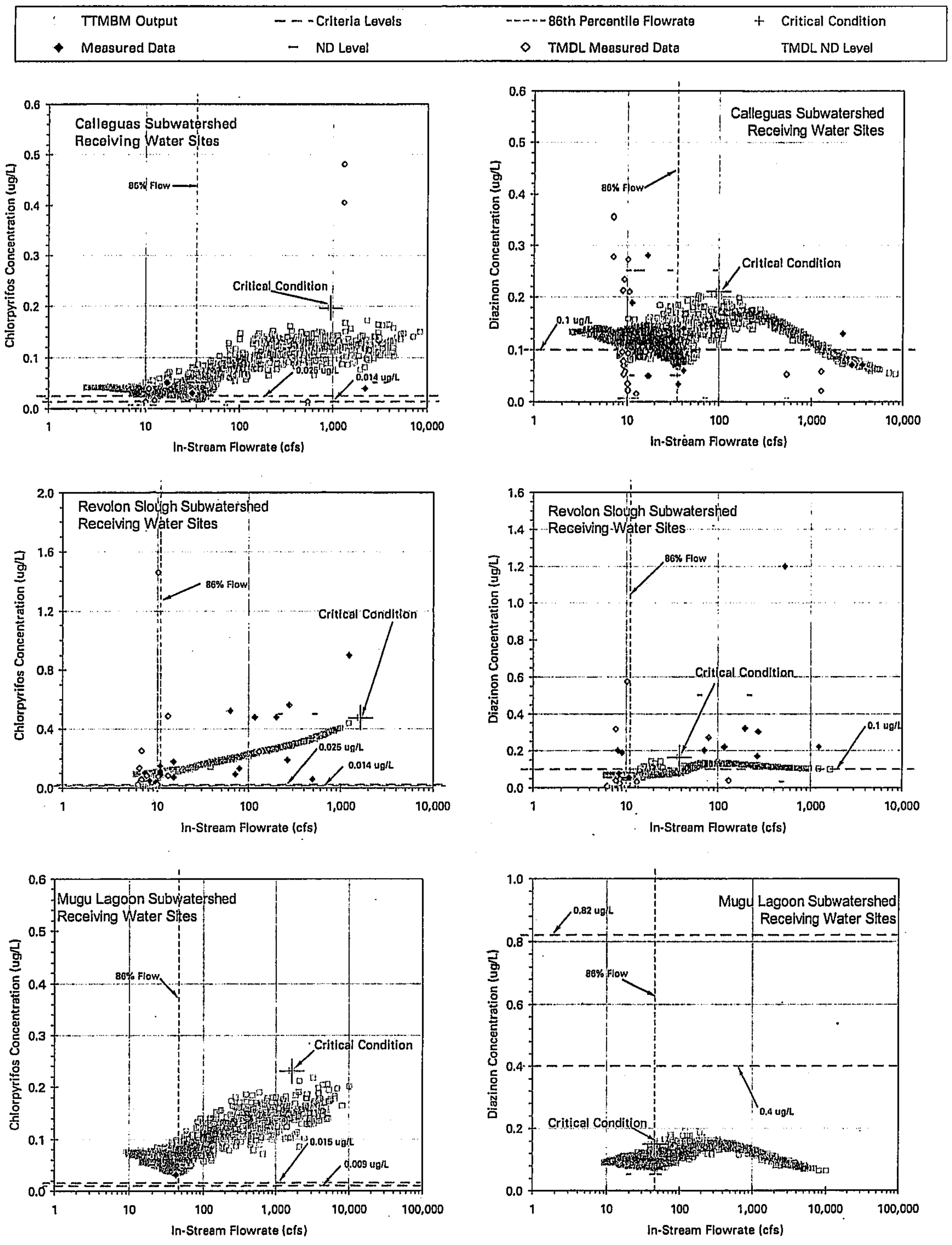
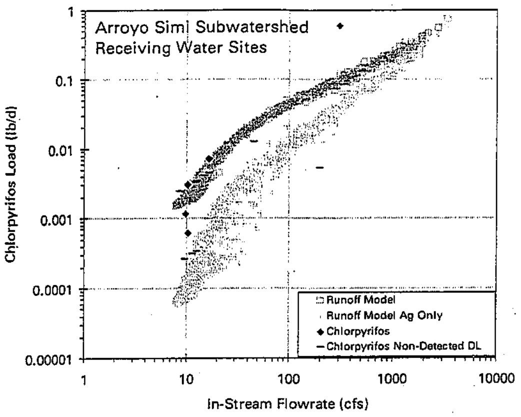
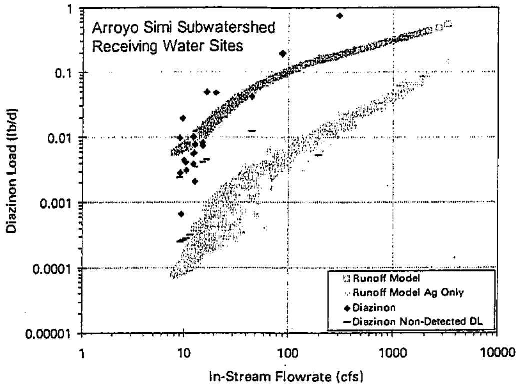
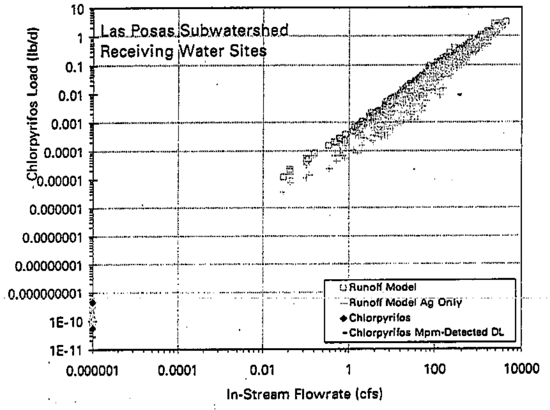
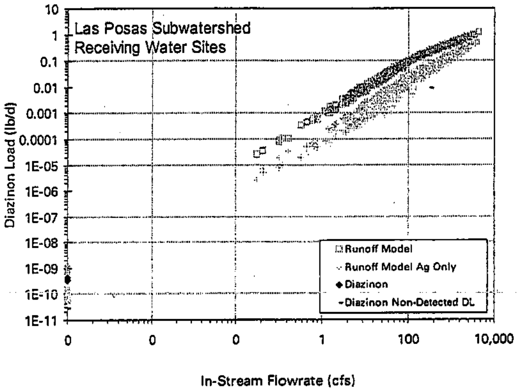


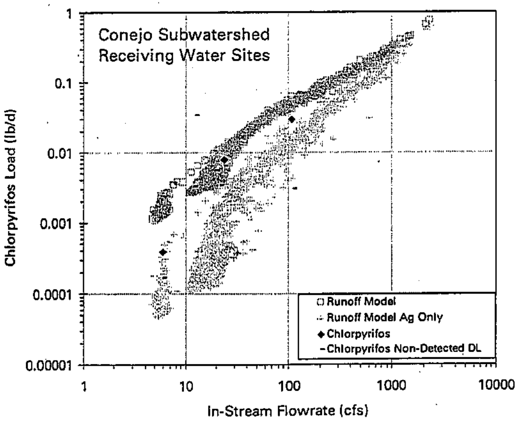
Figure 39: Chlorpyrifos and Diazinon Concentrations as a function of receiving water flowrates. Discharge loads calculated via regression.

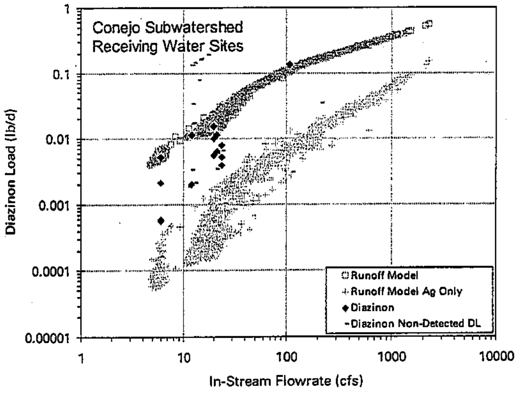

Arroyo Simi Subwatershed
Receiving Water Sites
Chlorpyrifos Load (lb/d)
1
0.1
0.01
0.001
0.0001
0.00001
1
10
100
1000
10000
In-Stream Flowrate (cfs)
Runoff Model
Runoff Model Ag Only
Chlorpyrifos
Chlorpyrifos Non-Detected DL


Arroyo Simi Subwatershed
Receiving Water Sites
Diazinon Load (lb/d)
1
0.1
0.01
0.001
0.0001
0.00001
1
10
100
1000
10000
In-Stream Flowrate (cfs)
Runoff Model
Runoff Model Ag Only
Diazinon
Diazinon Non-Detected DL


Las Posas Subwatershed
Receiving Water Sites
Chlorpyrifos Load (lb/d)
10
1
0.1
0.01
0.001
0.0001
0.00001
0.000001
0.0000001
0.00000001
0.000000001
1E-10
1E-11
0.000001
0.0001
0.01
1
100
10000
In-Stream Flowrate (cfs)
Runoff Model
Runoff Model Ag Only
Chlorpyrifos
Chlorpyrifos Mpm-Detected DL


Las Posas Subwatershed
Receiving Water Sites
Diazinon Load (lb/d)
10
1
0.1
0.01
0.001
0.0001
1E-05
1E-06
1E-07
1E-08
1E-09
1E-10
1E-11
0
0
0
1
100
10,000
In-Stream Flowrate (cfs)
Runoff Model
Runoff Model Ag Only
Diazinon
Diazinon Non-Detected DL


Conejo Subwatershed
Receiving Water Sites
Chlorpyrifos Load (lb/d)
1
0.1
0.01
0.001
0.0001
0.00001
1
10
100
1000
10000
In-Stream Flowrate (cfs)
Runoff Model
Runoff Model Ag Only
Chlorpyrifos
Chlorpyrifos Non-Detected DL


Conejo Subwatershed
Receiving Water Sites
Diazinon Load (lb/d)
1
0.1
0.01
0.001
0.0001
0.00001
1
10
100
1000
10000
In-Stream Flowrate (cfs)
Runoff Model
Runoff Model Ag Only
Diazinon
Diazinon Non-Detected DL

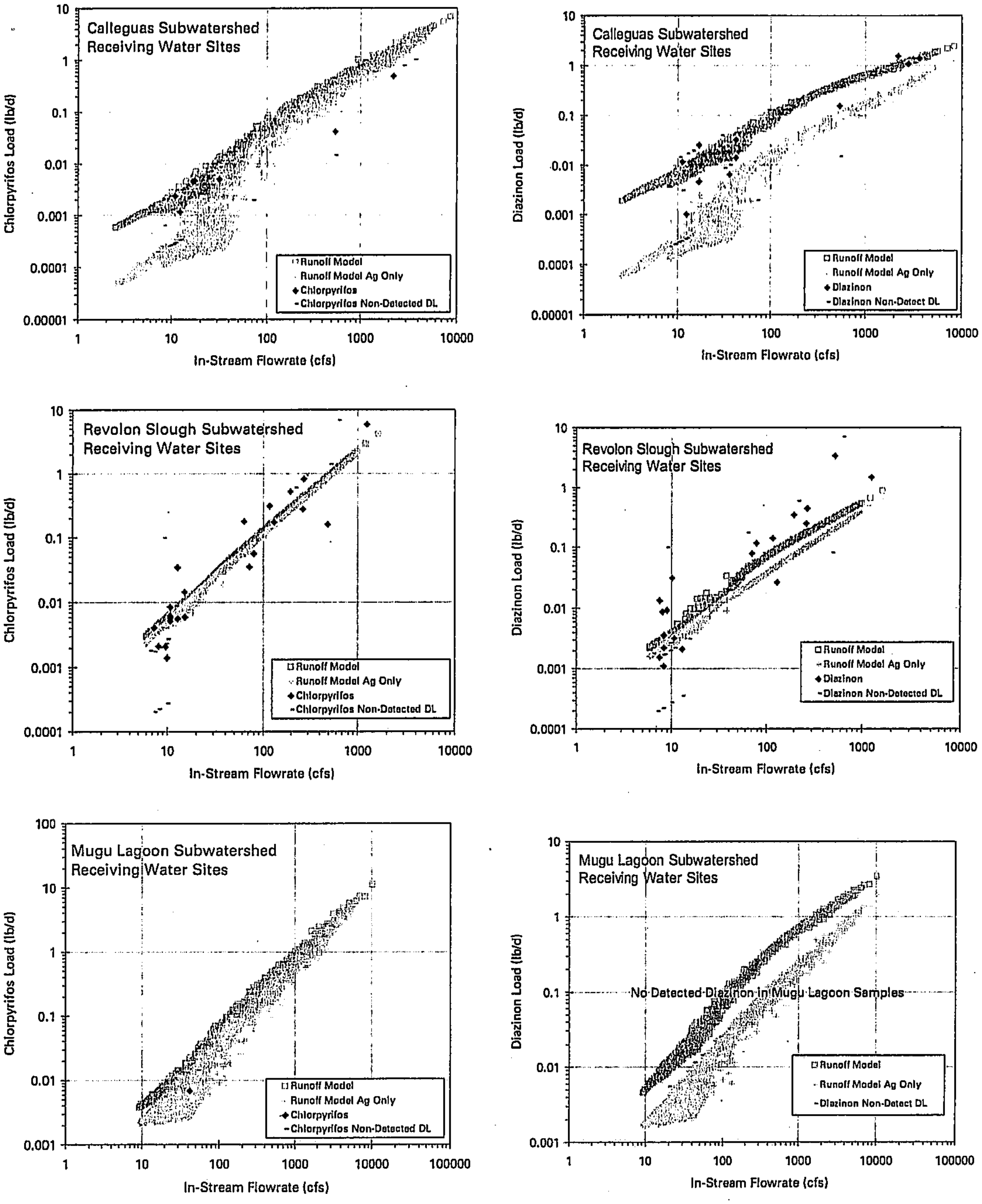


Figure 40: Chlorpyrifos and Diazinon Load as a Function of Flowrate and Compared to Receiving Water Data.

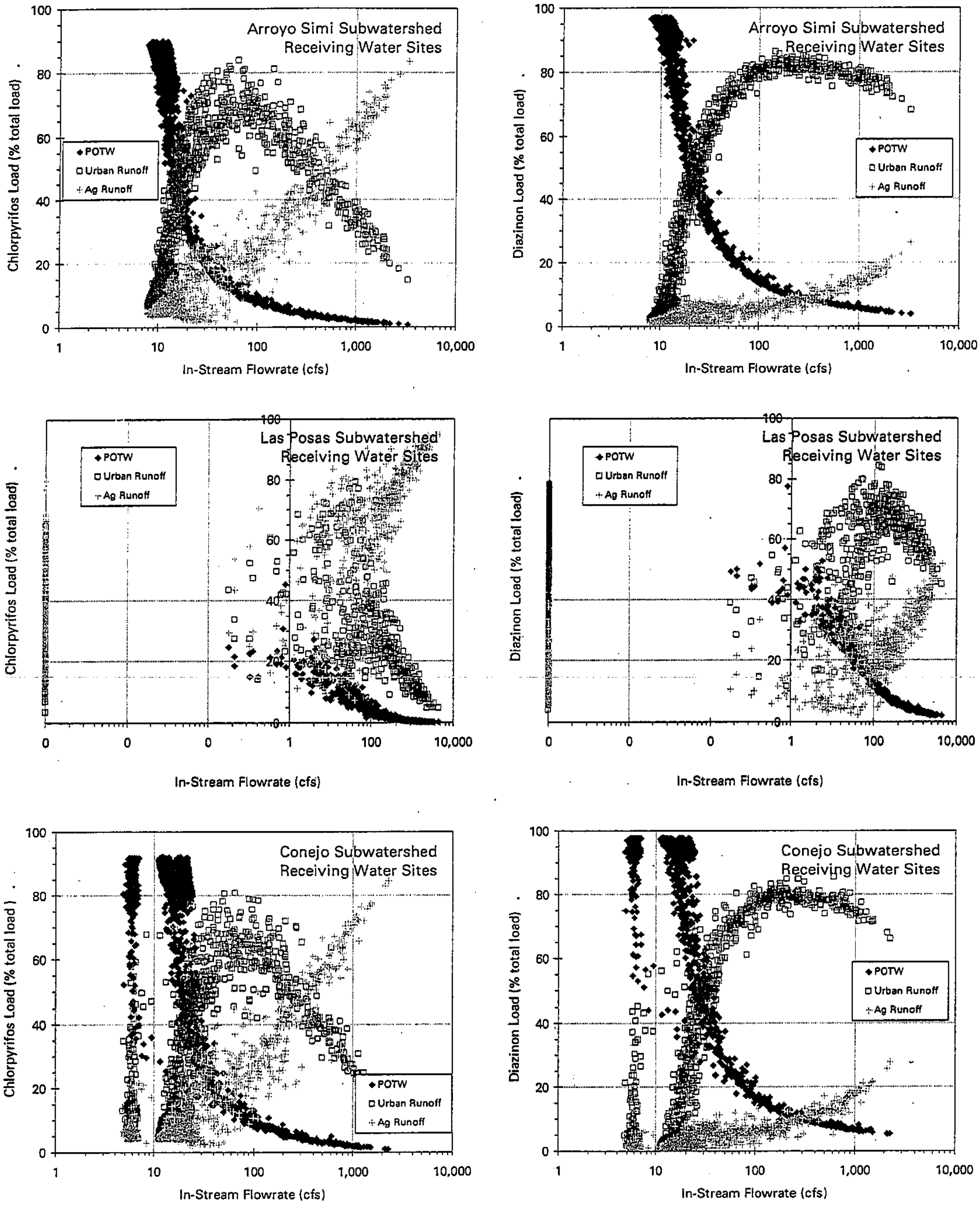


Figure 41 Continued

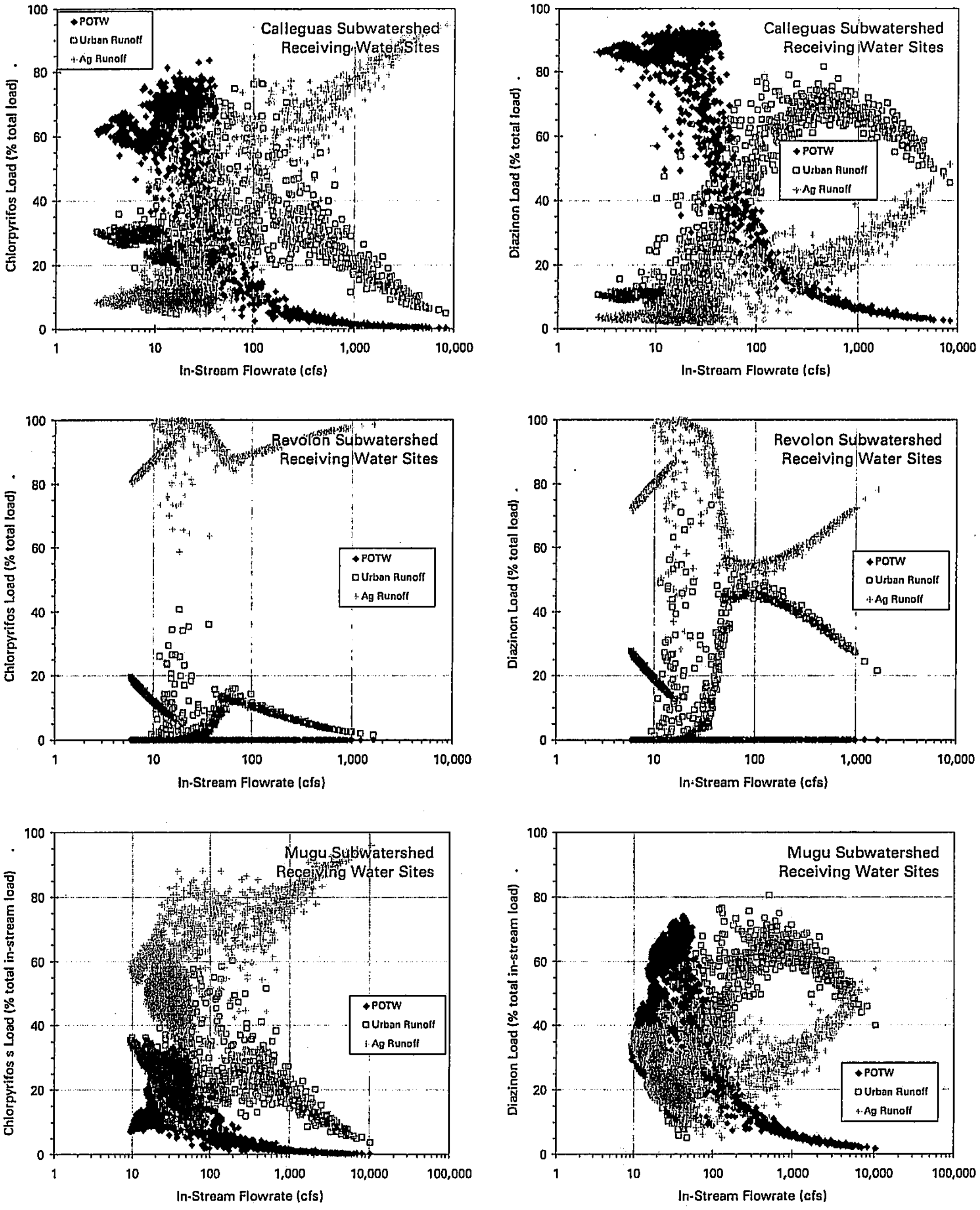


Figure 41: Apportionment of in-stream load using regression discharge loading equations.

April 2005

Attachment B to the Calleguas Creek Watershed Toxicity TMDL Technical Report

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Calleguas Creek Watershed Toxicity TMDL and OCs TMDL Monitoring Program

Table of Contents

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List of Acronyms

ug/L	Micrograms per liter
cm	Centimeters
CCW	Calleguas Creek Watershed
CCWTMP	Calleguas Creek Watershed Total Maximum Daily Load Monitoring Program
CDFG	California Department of Fish and Game
COCs	Chains of Custody
GSQC	General Sediment Quality Constituents
GWQC	General Water Quality Constituents
LA	Load Allocation
MS/MSD	Matrix Spike/Matrix Spike Duplicate
NPDES	National Pollutant Discharge Elimination System
OC	Organochlorine
OP	Organophosphate
POTW	Publicly Owned Treatment Works
PPT	Part Per Thousand
QA/QC	Quality Assurance/Quality Control
QPF	Quantity of Precipitation Forecast
TIE	Toxicity Identification Evaluation
TMDL	Total Maximum Daily Load
TSS	Total Suspended Solids
TUc	Toxic Unit Chronic
USEPA	US Environmental Protection Agency
USGS	US Geological Survey
WLA	Waste Load Allocation

Introduction

The Calleguas Creek Watershed Total Maximum Daily Load Monitoring Program (CCWTMP) was developed as part of the Calleguas Creek Watershed Toxicity TMDL (Toxicity TMDL) and the Organochlorine Pesticides and PCBs TMDL (OCs TMDL) Implementation Plans. The CCWTMP is designed to monitor and evaluate the implementation of the Toxicity and OCs TMDLs and refine the understanding of current loads as well as to continue efforts to identify the cause(s) of remaining or future unknown toxicity. The CCWTMP is intended to parallel efforts of the CCW Nutrients TMDL. Monitoring conducted through the forthcoming Conditional Waiver for Irrigated Lands (Conditional Waiver Program) may meet part of the needs of the CCWTMP. To the extent monitoring required by the Implementation Plans parallel monitoring required by the Conditional Waiver Program, it shall be coordinated. The goals of the CCWTMP include:

1. To determine compliance with OCs pesticides and PCBs (collectively referred to as OCs), chlorpyrifos, diazinon, and toxicity numeric targets at receiving water monitoring stations at the base of the subwatersheds and at Publicly Owned Treatment Works (POTW) discharges.
2. To determine compliance with waste load and load allocations for OCs, chlorpyrifos, diazinon, and toxicity at the base of the subwatersheds and at POTW discharges.
3. To evaluate the presence of sediment toxicity at sediment monitoring stations located in Mugu Lagoon (Reach 1), Lower Calleguas Creek (Reach 2), Calleguas Creek (Reach 3), Revolon Slough (Reach 4), and Conejo Creek (Reach 9A).
4. To identify causes of unknown toxicity and/or potential additive and/or synergistic effects.
5. To generate additional land use runoff data to increase the resolution of current loadings.
6. To monitor the effect of diazinon and chlorpyrifos replacement pesticides on water quality with regard to toxicity.
7. To monitor the effect of implementation actions by urban, POTW, and agricultural dischargers on in-stream fish tissue, water, and sediment quality.
8. To implement the CCWTMP in a manner consistent with other TMDL implementation plans and regulatory actions within the CCW.

Current loading estimates and load reduction estimates are based on limited data. Due to the nature of the data set, assumptions were made about loadings from the various discharges. The collection of data through the CCWTMP will increase the resolution of current loadings and may indicate the need to refine the waste load allocations (WLAs) and load allocations (LAs).

Background

The 303(d) listings addressed by the Toxicity TMDL include water column and sediment toxicity, organophosphate (OP) pesticides in water, and chlorpyrifos in fish tissue (Figure 1). The 303(d) listings addressed by the OCs TMDL include water column, sediment, and fish tissue listings associated with OC pesticides and PCBs (Figure 2). Through various monitoring programs, the presence of water and sediment toxicity as well as chlorpyrifos, diazinon, and OC concentrations above criteria were identified in reaches not on the 303(d) list. Table 1 presents all of the reaches addressed by the Toxicity TMDL and OCs TMDL.

Table 1. Calleguas Creek Watershed Reaches Addressed by Toxicity TMDL and/or OCs TMDL

	Reach	Water Column Toxicity	Sediment Toxicity	Chlorpyrifos and/or Diazinon in Water	OCs in Water, Sediment, and/or Fish Tissue[1]
1	Mugu Lagoon		X[2]		X[2]
2	Calleguas Creek Lower		X[2]		X[2]
3	Calleguas Creek Upper	X	X	X	X
4	Revolon Slough	X[2]	X	X[2]	X[2]
5	Beardsley Channel	X[2]		X[2]	X[2]
6	Arroyo Las Posas	X		X	X[2]
7	Arroyo Simi	X		X[2]	X
8	Tapo Canyon			X	X
9A	Conejo Creek	X	X	X	X[2]
9B	Conejo Creek Main Stem	X[2]		X	X[2]
10	Hill Canyon	X[2]		X	X[2]
11	Arroyo Santa Rosa	X[2]		X	X[2]
13	Conejo Creek South Fork	X[2]			X[2]

[1] OCs addressed in the OCs TMDL include: DDT (DDE and DDD), PCBs, dacthal, aldrin, chlordane, dieldrin, endosulfan, endrin, heptachlor, heptachlor epoxide, hexachlorocyclohexane (HCH, including lindane), and toxaphene.

[2] Identified as impaired on the 2002 303(d) list.

Data presented in the Toxicity TMDL identified chlorpyrifos, diazinon, and ammonia as constituents causing acute toxicity (mortality) in water in various reaches. The triazine herbicides atrazine, prometryn, and simazine have been detected in toxic samples and have the potential to potentiate (increase) toxicity of OP pesticides, but have not observed to potentiate toxicity or cause toxicity on their own. Toxicity of unknown cause(s) continues to exist as toxicant(s) have not been identified at all times toxicity has been observed.

Chlorpyrifos and ammonia have been identified as constituents causing acute toxicity (mortality) in sediment in various reaches. The triazine herbicide prometryn has been detected in toxic samples and has the potential to potentiate toxicity, but was not observed to potentiate toxicity or cause toxicity on its own. In addition, toxicity of unknown cause(s) continues to exist as the toxicant(s) causing toxicity have not been identified in all reaches at all times toxicity has been observed.

Agricultural runoff is the largest source of OCs to surface waters of the CCW, although urban runoff and POTWs also contribute. POTW discharges and agricultural and urban runoff are the largest sources of chlorpyrifos and diazinon to waterbodies in the CCW. Urban use of diazinon and chlorpyrifos are unlikely to be a long-term source to the CCW as neither of these pesticides will be sold for non-agricultural uses as of December 31, 2005. However, as estimated in the Toxicity TMDL, stockpiles of chlorpyrifos and diazinon for urban uses will likely continued to be applied until depleted around 2005 and 2007, respectively.

POTW and urban discharges were assigned WLAs and agricultural discharges were assigned LAs to address the potential impacts of chlorpyrifos, diazinon, and OC loadings to waterbodies. WLAs and LAs were assigned to the various discharges based on their location in subwatersheds in the CCW. Figure 1 and Figure 2 contain outlines of the six subwatersheds designated in each TMDL.

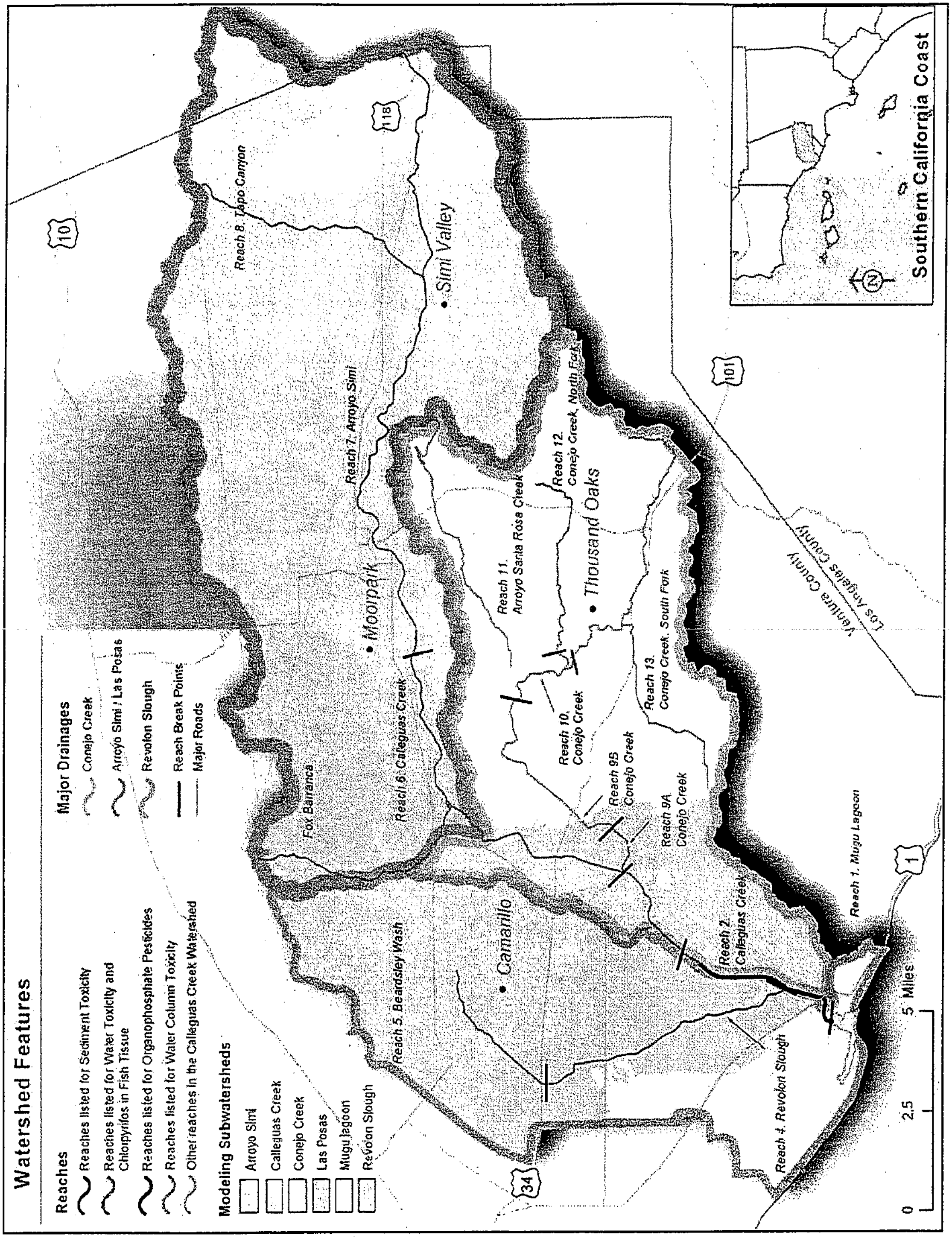


Figure 1. Reaches in the Calleguas Creek Watershed listed on the 2002 303(d) List for water or sediment toxicity, chlorpyrifos in fish tissue, and/or organophosphate pesticides.

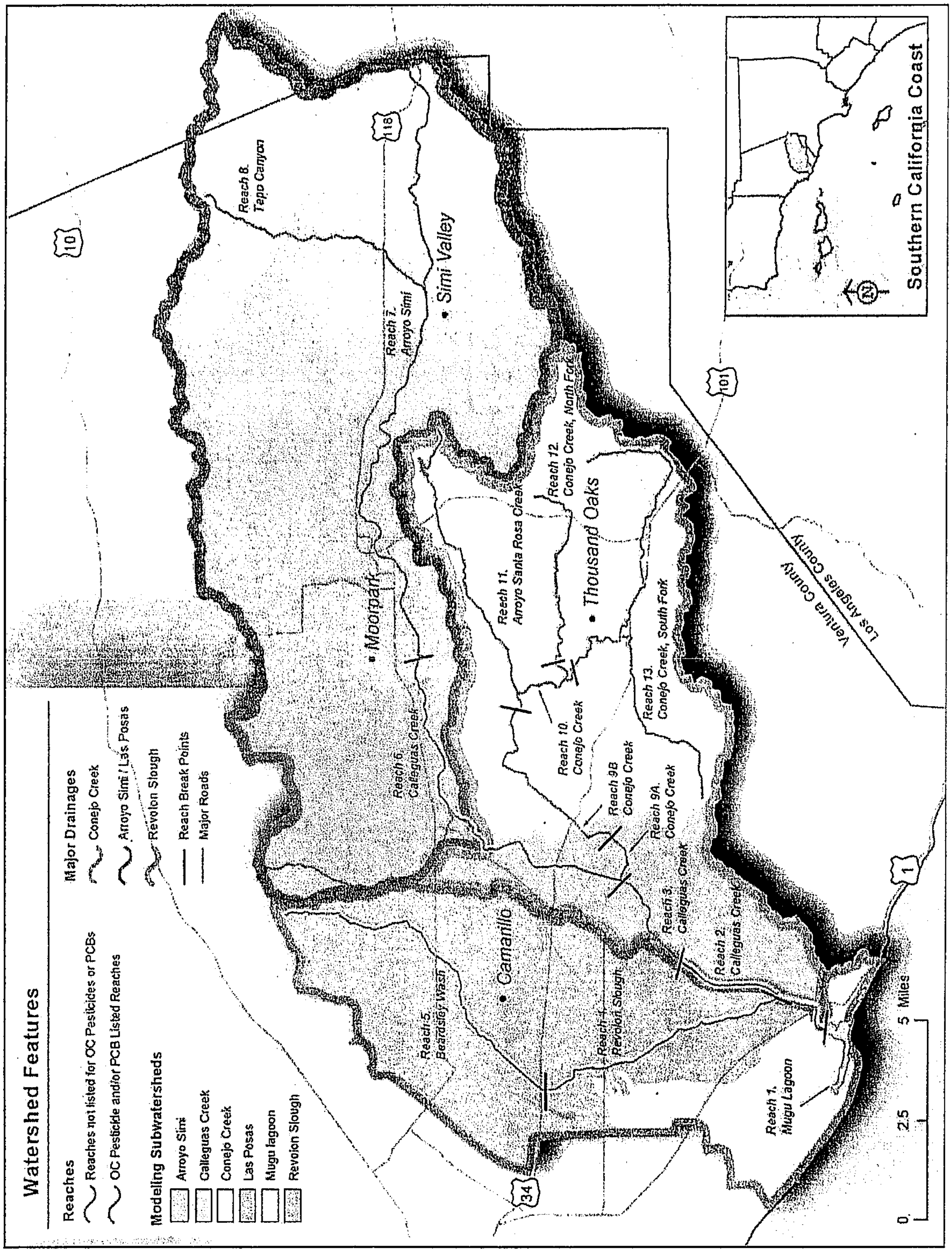


Figure 2. Reaches in the Calleguas Creek Watershed listed on the 2002 303(d) List for organochlorine pesticides and/or PCBs in water, sediment, and/or fish tissue.

Approach

Compliance monitoring for constituents associated with the Toxicity TMDL will begin within one year of the effective date of the Toxicity TMDL. Compliance monitoring for constituents associated with the OCs TMDL will begin within one year of the effective date the OCs TMDL. For compliance monitoring, in-stream water column samples will be collected quarterly for analysis of water column toxicity, general water quality constituents (GWQC), and target organic constituents. Target organic constituents for the OCs TMDL include the OCs listed as a footnote in Table 1. Target organic constituents for the Toxicity TMDL include chlorpyrifos and diazinon, triazine herbicides, and pyrethroid insecticides. Triazine herbicides are included because the potential exists for toxicity caused by chlorpyrifos and diazinon to be increased in their presence (Anderson and Lydy, 2002). Although pyrethroids are not on the 303(d) list and have not been identified as contributing to toxicity in the CCW, they have been identified as contributing to sediment toxicity elsewhere in California as the use of this group of pesticides increases (Weston *et al.*, in press).

In-stream water column samples will generally be collected at the base of each of the subwatersheds. Additional samples will generally be collected concurrently at representative agricultural and urban runoff discharge sites as well as at POTWs in each of the subwatersheds and analyzed for selected GWQC and target organic constituents. The locations of compliance monitoring sampling stations are discussed in the Sampling Stations section. Toxicity identification evaluations (TIEs) will be conducted on toxic samples as outlined in the Follow-up Toxicity Testing section. For organic constituents, environmentally relevant detection limits will be used. Detection limits will be the lower of either the allocations or the numeric targets presented in the TMDLs, if attainable at a commercial laboratory.

Toxicity investigation monitoring will begin within one year of the effective date of the Toxicity TMDL. For toxicity investigation monitoring, in-stream water column samples will be collected at select sampling stations where the cause(s) of water toxicity have not been identified. The locations of toxicity investigation sampling stations are discussed in the Sampling Stations section. The sampling schedule for toxicity investigation monitoring occurs during months in which toxicity of unknown causes was observed in previous studies. The monitoring schedule will be revised if it does not adequately characterize toxicity of unknown cause(s). These samples will be analyzed for water column toxicity, and GWQC and target organic constituents. TIEs will be conducted on toxic samples as outlined in the Follow-up Toxicity Testing section.

Streambed sediment samples will be collected twice a year for analysis of sediment toxicity, general sediment quality constituents (GSQC), and target organic constituents. Sediment samples in Mugu Lagoon will be collected once a year for similar analysis. An annual frequency was selected for Mugu Lagoon sediment sampling due to the relatively slow sedimentation rates in the lagoon. Streambed sediment samples collected for compliance monitoring will be collected in all subwatersheds. Streambed sediment samples collected for toxicity investigation will be collected in reaches of the CCW where the cause(s) of sediment toxicity have not been identified. The locations of compliance monitoring and toxicity investigation monitoring sampling stations are discussed in the Sampling Stations section. TIEs will be conducted on toxic samples as outlined in the Follow-up Toxicity Testing section.

All efforts will be made to include two additional wet weather water sampling events for both compliance and toxicity investigation monitoring during targeted storm events between October and May. Wet weather sampling conditions are discussed in the Sampling Schedule section.

Sampling Stations

Compliance Monitoring Sampling Stations

Table 2 lists the in-stream compliance monitoring sampling stations and identifies the media sampled and constituents analyzed. Figure 3 shows the general locations of the in-stream sampling stations, not including Mugu Lagoon. Figure 4 shows the general locations of the in-stream sampling stations in Mugu Lagoon.

Compliance monitoring sampling stations are generally located at the base of each of the six subwatersheds and at POTWs. In the case of the Revolon Slough and Calleguas Subwatersheds, compliance monitoring sampling stations will be located upstream of the base of the subwatersheds as 1) these locations are not tidally influenced and 2) the majority of the data addressing toxicity in these subwatersheds have been collected at the upstream locations. Compliance monitoring sampling stations for sediment toxicity are located in the Revolon Slough and Calleguas Subwatersheds. In the case of the Mugu Lagoon Subwatershed, compliance with water targets will be measured at the base of the upstream subwatersheds to the lagoon and compliance with sediment targets will be measured at several stations throughout the lagoon. At such a time as numeric targets are consistently met at the base of a subwatershed, an additional site or sites within the subwatershed will be considered for monitoring to ensure numeric targets are met throughout the subwatershed.

Agricultural and urban runoff land use sampling stations will be selected within one year of the effective date of the Toxicity and/or OCs TMDL, whichever occurs first. At least one agricultural and urban runoff land use sampling station will be located in each subwatershed, unless this is determined unnecessary. For example, a particular land use type may not discharge to a receiving water body in a particular subwatershed making it unnecessary to sample this land use. Land use sampling stations will be located at a point where water from a representative group of similar land uses discharges to one of the reaches listed in Table 1. Land use sampling stations will coincide with current and previous sampling programs in the CCW, where available. The number and location of land use stations may be revised if it is determined that alternative locations are needed or the number of stations needed to appropriately characterize these discharges may be modified.

The water and sediment compliance monitoring sampling stations generally coincide with current and previous sampling programs in the CCW. Current or previously used sampling stations were selected whenever practical to save time and resources, and to provide historical data. Appendix 1 presents detailed descriptions of and directions to the sampling stations identified in this plan.

Table 2. Compliance Monitoring Sampling Station Locations and Constituents

Subwatershed	Station ID	Station Location	Sample Media		
			Water	Sediment	Fish Tissue[1]
Mugu Lagoon	01_11_BR	11th Street Bridge	T, OP, OC		OC[2]
	01_BPT_1	Located near entrance to lagoon after Calleguas Creek and Revolon Slough join, south of Oxnard Drain #2 discharge, formerly site BPTCP-1.		T, OP, OC	
	01_BPT_3	Located in the eastern arm of the lagoon, formerly site BPTCP-3.		T, OP, OC	
	01_BPT_6	Located in the eastern part of the western arm of the lagoon, formerly site BPTCP-6.		T, OP, OC	
	01_BPT_9	Located near 17th street in far side of western arm of the lagoon, east of Oxnard Drain #3 discharge, formerly site BPTCP-9.		T, OP, OC	
	01_BPT_15	Located in central part of the lagoon, formerly site BPTCP-15.		T, OP, OC	
	01_SG_74	Located in central part of the lagoon in mudflat area, south of Oxnard Drain #7 discharge, formerly site SG11-74.		T, OP, OC	
Revolon Slough	04_WOOD	Revolon Slough East Side of Wood Road	T, OP, OC	T, OP, OC	OP, OC
Calleguas	03_CAMAR	Calleguas Creek at University Drive	T, OP, OC	T, OP, OC	OC
	03D_CAMR	Camrosa Water Reclamation Plant	OP, OC		
	9AD_CAMA	Camarillo Water Reclamation Plant	OP, OC		
Conejo	9B_ADOLF	Conejo Creek at Adolfo Road	T, OP, OC	OC	OC
	10D_HILL	Hill Canyon Wastewater Treatment Plant	OP, OC		
Las Posas	06_SOMIS	Arroyo Las Posas off Somis Road	T, OP, OC	OC	OC
	06D_MOOR	Ventura County Wastewater Treatment Plant	OP, OC		
Arroyo Simi	07_HITCH	Arroyo Simi East of Hitch Boulevard	T, OP, OC	OC	OC
	07D_SIMI	Simi Valley Water Quality Control Plant	OP, OC		

T Toxicity, triazine, and pyrethroid samples will be collected OP Organophosphate samples will be collected

OC Organochlorine Pesticides and PCBs samples will be collected

1 Attempts will be made to collect fish tissue samples in the same location as water and sediment samples. However, samples may be collected elsewhere if no fish are found at pre-established sample stations.

2 Fish tissue sampling locations in Mugu will be determined in conjunction with biologists prior to sample collection.

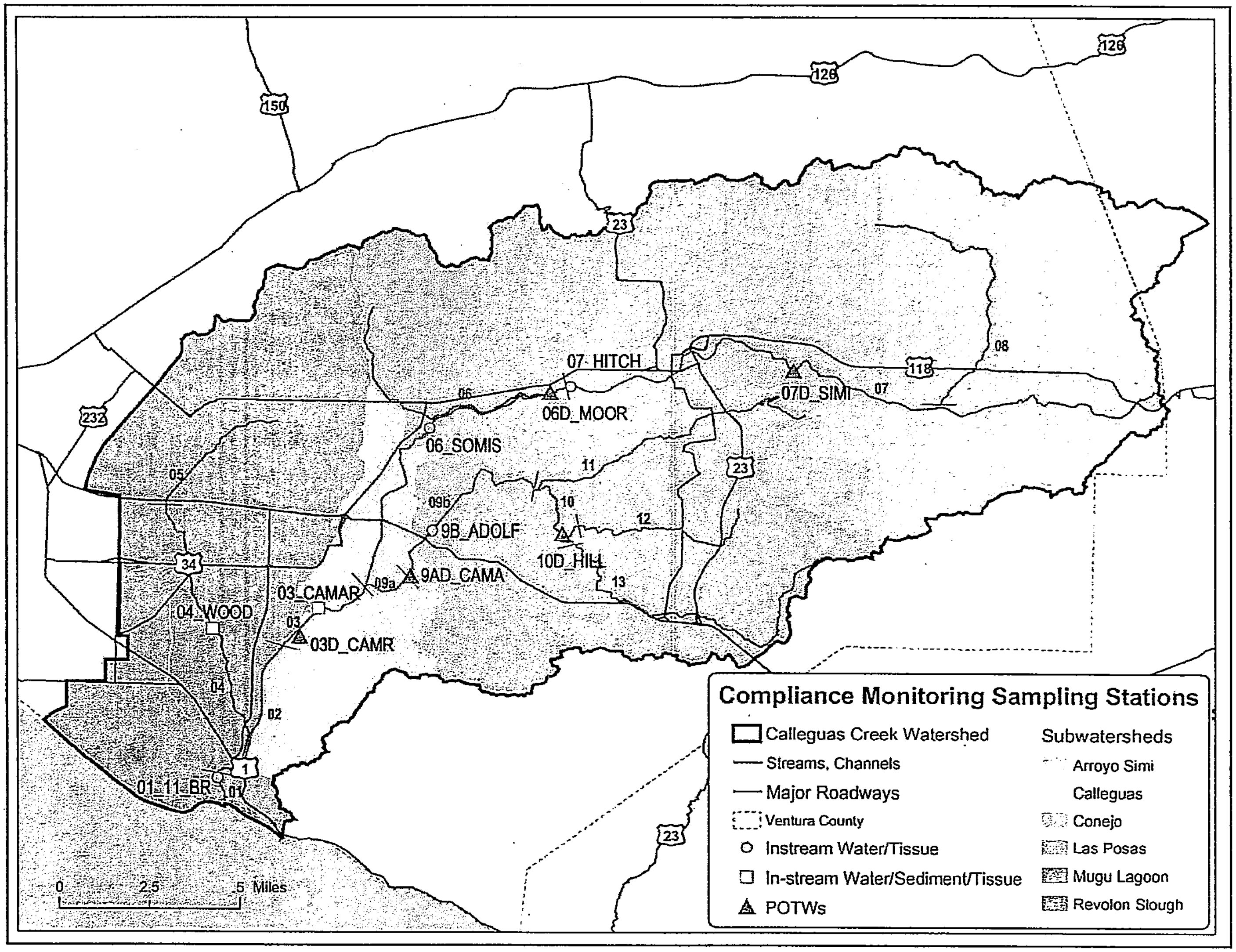


Figure 3. Compliance monitoring sampling stations for the CCW Toxicity TMDL and OCs TMDL.

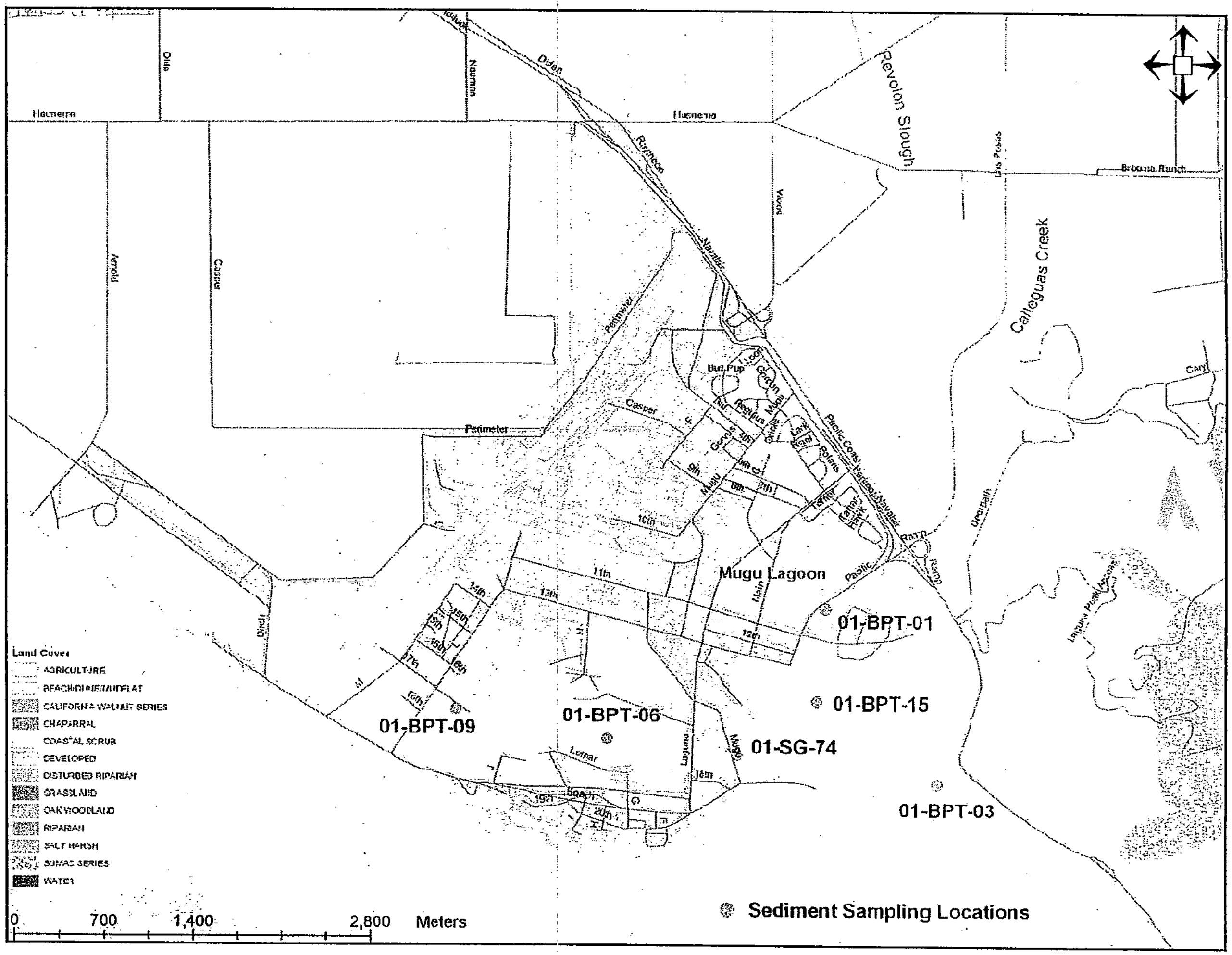


Figure 4. Compliance monitoring sampling stations in Mugu Lagoon for the CCW Toxicity TMDL and OCs TMDL.

Toxicity Investigation Sampling Stations

Table 3 lists the toxicity investigation sampling stations and identifies the media that will be sampled. Figure 5 shows the general locations of the sampling stations in the CCW. The water and sediment toxicity investigation sampling stations generally coincide with current and previous sampling programs in the CCW. Current or previously used sampling stations were selected whenever practical to save time and resources, and to provide historical data. Appendix 1 presents detailed descriptions of and directions to the sampling stations.

Table 3. Toxicity Investigation Sampling Station Locations

Subwatershed	Station ID	Station Location	Sample Media	
			Water	Sediment
Calleguas	02_PCH	Calleguas Creek Northeast Side of Highway 1 Bridge		X
	9A_HOWAR	Conejo Creek at Howard Road Bridge		X
Conejo	10_GATE	Conejo Creek Hill Canyon Below North Fork of Conejo Creek	X	
	13_BELT	Above Confluence with Conejo Creek North Fork	X	

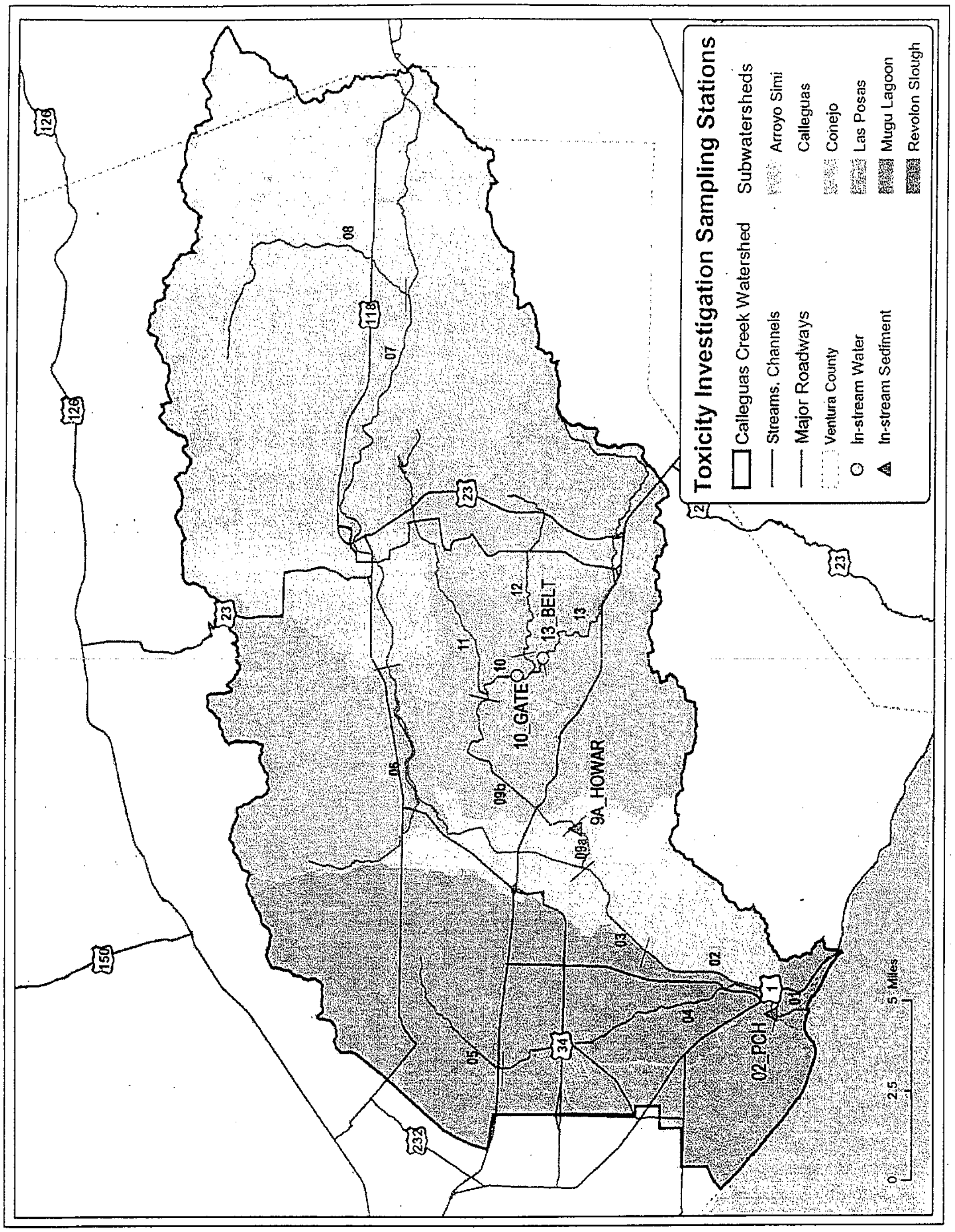


Figure 5. Toxicity Investigation sampling stations for the CCW Toxicity TMDL.

Sampling Schedule

Table 4 presents the sampling schedule. Dates will be finalized during coordination with other monitoring efforts (NPDES Stormwater Permit monitoring, CCW Nutrients TMDL, and any agricultural water quality monitoring program) in order to minimize duplication of effort and to develop a representative data set. All efforts will be made to include two additional wet weather water sampling events between October and April during targeted storm events, as described below. Dry weather water column samples shall be collected quarterly. The sampling schedule for toxicity investigation monitoring occurs during months in which toxicity of unknown causes was observed in previous studies. Streambed sediment samples will be collected twice a year for analysis of sediment toxicity, general sediment quality constituents (GSQC), and target organic constituents. Sediment samples in Mugu Lagoon will be collected once a year for similar analysis. An annual frequency was selected for Mugu Lagoon sediment sampling due to the relatively slow sedimentation rates in the lagoon in comparison to sample collection depths as discussed in the Sample Collection section. The monitoring schedule will be revised if it does not appropriately characterize conditions in the watershed.

Table 4. Compliance and Toxicity Investigation Monitoring Schedules

Subwatershed	Station ID	Station Type	Month[1]			
			Feb	May	Aug	Nov
Mugu Lagoon	01_11_BR	C	W	W	W	W
	01_BPT_1	C			S	
	01_BPT_3	C			S	
	01_BPT_6	C			S	
	01_BPT_9	C			S	
	01_BPT_15	C			S	
	01_SG_74	C			S	
	TBD	C		T		T
Revolon	04_WOOD	C	W	W, S, T	W	W, S, T
Calleguas	02_PCH	I		T, S		S, T
	03_CAMAR	C	W	W, S, T	W	W, S, T
	9A_HOWAR	I		S		S
Conejo	9B_ADOLF	C	W	W, S, T	W	W, S, T
	10_GATE	I	W		W	W
	13_BELT	I	W		W	
Las Posas	06_SOMIS	C	W	W, S, T	W	W, S, T
Arroyo Simi	07_HITCH	C	W	W, S, T	W	W, S, T

Station Type: C indicates compliance station; I indicates toxicity investigation station;
Media Type: W indicates water sample; S indicates sediment sample; T indicates tissue sample
TBD Fish tissue sampling locations in Mugu will be determined in conjunction with biologists prior to sample collection.
1 All attempts will be made to include two wet weather sampling events during the wet season (October through April).

Should measurable precipitation occur during the seven days prior to a scheduled dry weather event, the sampling event shall be rescheduled to allow for at least seven days without measurable precipitation prior to sampling. All efforts will be made to collect two wet weather samples during the wet season (October through April). Wet weather water samples shall be collected during a targeted storm event, defined as a storm that produces at least 0.5 inches of precipitation.

Sufficient precipitation is needed to produce runoff, mobilize constituents of interest, and increase stream flow. The decision to sample a storm event shall be made in consultation with weather forecasting information services and after a quantity of precipitation forecast (QPF) has been determined. Peak flows shall be targeted, to the extent practicable. Should measurable precipitation occur in the three days prior to a wet event, the sampling event shall be rescheduled to allow for at least three days without measurable precipitation prior to sampling. Sediment samples collected during the wet season shall be collected as dry weather samples (i.e. no measurable precipitation seven days prior to sampling).

Coordination of Sampling Programs

As mentioned previously, extensive sampling of receiving waters and land use sites already occurs in the CCW. Table 5 presents a list of the required monitoring programs in the watershed as well as the type of sites monitored in the program and the frequency of sample collection. POTWs conduct sampling for water column toxicity and OC pesticides and PCBs in their effluent and at two receiving water sites. The frequency of sample collection varies from semiannual to monthly and from effluent to receiving water based on the constituent. Additionally, frequency requirements for sample collection vary between POTWs. The POTWs do not conduct wet weather sampling. Because the Camrosa WRP and Ventura County WWTP rarely discharge to the CCW these two POTWs do not conduct regular monitoring for the constituents of interest for these two TMDLs.

The Ventura County NPDES Stormwater Co-Permittees sample for water column toxicity as well as OP and OC pesticides at two receiving water sites and two agricultural sites in the CCW. A total of six events are conducted annually which include at least three targeting wet weather events. The Agricultural Conditional Waiver Program has not been adopted by the Regional Board. Once adopted conditional waiver permit holders will be required to sample for several pesticides (including diazinon, chlorpyrifos, and some OC pesticides) as well as toxicity. Toxicity will only be collected once a year while all other constituents will be collected quarterly. Two wet events are required. The number of stations in the CCW will not be determined until monitoring plans are submitted to meet conditional waiver program requirements.

To the extent practicable CCWTMP monitoring will coordinate with these programs and other monitoring programs in the watershed.

Table 5. Required Monitoring Programs in CCW

Program	Number of Sites in the CCW			Annual Frequency of Sample Collection
	Receiving Water	Ag	POTW	
Agriculture Conditional Waiver Program	TBD	TBD		1 – 4 events per year
Camarillo WRP NPDES Permit	2		1	2 – 12 events per year[1]
Camrosa WRP NPDES Permit	2		1	2 – 12 events per year[1]
Hill Canyon WWTP NPDES Permit	2		1	2 – 12 events per year[1]
Ventura County WWTP NPDES Permit	2		1	2 – 12 events per year[1]
Simi Valley WQCP NPDES Permit	2		1	2 – 12 events per year[1]
VC NPDES Stormwater Permit	2	2		6 events per year

TBD To be determined – Monitoring stations for the agricultural waiver program have not been selected at this time.

[1] The frequency of sampling for constituents of interest varies between semiannually and monthly.

Parameters to be Monitored

Table 6 lists the constituents for which analysis will be conducted, analytical methods and the expected detection limits, and holding times for each constituent. Additional constituents will be added to Table 6 if potential toxicants not currently on this table are identified.

Wet weather water column samples will be filtered, after which the sediment and aqueous fractions will be analyzed separately for target organic constituents. The sediment fraction will be sieved into two grain size fractions (2mm-63um and less than 63um), after which the whole sample as well as the two grain size fractions will be analyzed separately. Measurements of general water quality constituents (GWQC) will be conducted on the whole sample. Streambed sediment samples will be sieved into two grain size fractions (2mm-63um and less than 63um), after which the whole sample as well as two grain size categories will be analyzed separately for target organic constituents. Measurements of general sediment quality constituents (GSQC) will be conducted on the whole sample. The various fractions (aqueous and sediment and the two grain size fractions) are considered to develop an understanding of how target organic constituents are transported through the watershed. This information can be used to assess the potential effectiveness of best management practices given the association of target organic constituents with the different grain size fractions. There might not be a need to continue this type of fractionation indefinitely if a relationship between target organic concentrations and grain size fractions is developed.

Table 6. Constituents, Methods, Detection Limits, and Holding Times

Constituent	Analytical Method	Detection Limit	Holding Time
Aquatic Toxicity			
Chronic (~ 7 day) *Ceriodaphnia dubia*[1]	EPA/821/R-02/013 1002.0	N/A	36 hours
Sediment Toxicity			
Chronic (10 day) *Hyalella azteca* bulk sediment	EPA 600/R-99/064 100.1	N/A	14 days[2]
Chronic (10 day) *Eohaustorius estuarius*[3] bulk sediment	EPA 600/R-94/025	N/A	14 days[2]
Chronic (10 day) *Hyalella azteca* porewater	EPA 600/R-99/064 100.1	N/A	14 days[2]
Chronic (10 day) *Eohaustorius estuarius*[3] porewater	EPA 600/R-94/025	N/A	14 days[2]
Fish Tissue			
Percent Lipids	Gravimetric/Bligh and Dyer	NA	1 year if frozen
OC Pesticides and PCBs	EPA 8270	0.001 ug/wet g	1 year if frozen
OP Pesticides	EPA 8270	0.005 ug/wet g	1 year if frozen
General Water Quality Constituents (GWQC)			
Total Ammonia	SM4500-NH_3	0.01 mg/L	28 days
Hardness	SM 2340-B	1 mg/L	180 days
Total Suspended Solids (TSS)	SM 2540-D	0.1 mg/L	7 days
Flow, pH, Temperature, Dissolved Oxygen, Conductivity, Salinity	Field Measurement	IR	N/A
Organic Constituents in Water			
OC Pesticides and PCBs	EPA 608/625	1 – 10 ng/L	7/40 days[5]
OP Pesticides	EPA 614/625	5 – 10 ng/L	7/40 days[5]
Pyrethroids and Triazines	Modified EPA 625[4]	5 ng/L	7/40 days[5]
General Sediment Quality Constituents (GSQC)			
Total Ammonia	SM4500-NH3 F	0.01 mg/L	28 days
Percent Moisture	EPA160.3	0.1 Percent	1 year[6]
Grain Size Analysis	SM2560B	0.02 µm	6 months
Total Organic Carbon (TOC)	EPA 415.1	0.012 mg/L	28 days
***Organic Constituents in Sediment* (measured in whole sample, <63um, and between 2mm and 63um fractions**			
OC Pesticides and PCBs	EPA 8081/8082	1 – 10 ng/dry g	1 year[6]
OP Pesticides	EPA 8141/8270	5 – 10 ng/dry g	1 year[6]
Pyrethroids and Triazines	Modified 8270[4]	5 ng/dry g	1 year[6]
Additional Constituents for Mugu Lagoon Sediment			
Acid Volatile Sulfides	SM 4500-Sulfide	0.5 ppm	6 months
Simultaneously Extractable Metals (SEM)	EPA200.8	0.05-1 ppb	180 days, Hg 6months

1 If sample salinity exceeds 1 PPT *Americamysis bahia* (formerly *Mysidopsis bahia*) will be used to conduct toxicity testing.
2 No longer than 8 weeks
3 If sample salinity exceeds 15 PPT *Eohaustorius estuarius* will be used to conduct toxicity testing.
4 Analytical methods for Pyrethroids and Triazines have not been standardized and are analyzed based on modified EPA methods.
5 7/40 = 7 days to extract and 40 days from extraction to analysis.
6 One year if frozen, otherwise 14/40 days
IR – Instrument resolution; N/A – Not applicable; N/M – Analytical methods for Pyrethroids have not been standardized.

Ambient samples of water and sediment will be tested in the laboratory for toxicity to aquatic life to provide an indication of the conditions that exist in the natural environment. Standard test species and test procedures shall be used to provide reliable results. Toxicity is deemed to occur when test species are adversely affected by exposure to ambient water, bulk sediment, or sediment porewater. Adverse effects may include impaired growth or reproduction, abnormalities, and/or death of test species. Effects may occur rapidly (acute toxicity) or may occur over a longer period (chronic toxicity).

Selection of appropriate analytical methods and laboratory selection are fundamentally important steps in constructing a monitoring program. All analyses shall meet data quality objectives, as stated in the Quality Assurance Project Plan (QAPP) for Calleguas Creek TMDL Work Plan Monitoring (LWA, 2003), and be otherwise qualified in conformity with USEPA QA/QC guidance. The choice of analytical method may change if a different method is found to give better results (better QA/QC results and/or a more suitable detection limit). The laboratory conducting water and sediment chemical analyses (with the exception of field measurements) will be selected within a year after the effective date of either the Toxicity TMDL or the OCs TMDL. The selected laboratory will be certified by the California Department of Health Services – Environmental Laboratory Accreditation Program to perform all analyses, and in conformance with USEPA and California (DHS-ELAP) requirements, unless it is determined by project staff that an uncertified lab is more qualified for a particular analysis. The laboratory conducting water and sediment toxicity analyses will be selected within a year after the effective date of the Toxicity TMDL. The laboratory conducting toxicity analyses will have proven experience in water and sediment toxicity testing as well as conducting all phases of the TIE procedures.

The United States Geological Survey (USGS) has identified various issues with the current methodology for collecting and analyzing water samples for total suspended sediment (TSS) using method SM 2540 D. The issue with the method for analyzing samples using the TSS analytical method is that it does not produce representative results in samples that contain greater than 25 percent sand-size material (Gray *et al.*, 2000). The suggested alternative method of analysis to determine the amount of suspended sediments in a sample (Gray *et al.*, 2000) is the sediment concentration (SC) method (ASTM, 2002). The primary issue with the TSS analytical method is that it is performed on a portion of the sample which may not be representative of the whole sample, whereas, the SC analytical method is performed on the whole sample. However, suspended sediment data generated using the SC method is not necessarily directly comparable to suspended sediment data generated using the TSS method. As such, conducting statistical analysis using historic TSS data and SC data may not be possible. It may be necessary to run analysis using both methods to develop a correlation between the two.

Additionally, the currently used grab method for collecting TSS samples is likely inadequate for characterizing suspended sediments during storm conditions in the CCW. During these conditions it may be appropriate to have a location in the watershed where depth and width integrated samples are collected to properly characterize the volume, grain size, and chemical concentrations associated with suspended sediments moving through the CCW. The US Navy is currently collecting depth and width integrated samples just downstream of where Calleguas Creek and Revolon Slough enter Mugu Lagoon. Before the CCWTMP is implemented it will be determined if 1) if this issue should be addressed by this monitoring program or if it is more appropriately addressed by the sediment transport/quality special study required in the TMDL Implementation Plans and 2) if it is determined to be appropriate for this monitoring program to address the issue of how suspended sediment concentrations will be measured and where an appropriate sampling station could be located for collecting depth and width integrated samples during storm conditions.

Toxicity Testing Procedures

For the CCWTMP, standard test species will be used for toxicity testing. *Ceriodaphnia dubia* will be used for the aquatic toxicity testing. *Hyalella azteca* will be used for the bulk sediment and porewater toxicity testing. *Eohaustorius estuarius* will be used for aquatic, bulk sediment, and porewater toxicity at sampling locations where salinity levels adversely affect the other test species. *Americamysis bahia* (formerly *Mysidopsis bahia*) will be used to conduct aquatic toxicity testing if sample salinity exceeds 1 part per thousand (PPT) but is less than 15 PPT. Water and toxicity testing will be conducted according to current EPA guidelines. These species are standard USEPA test species considered to be among the most sensitive species to many different types of pollutants. These test species are particularly sensitive to constituents previously identified as contributing to toxicity in water and/or sediment. *C. dubia* is a water flea known to be extremely sensitive to organophosphate pesticides and some metals and also is used as an indicator of ammonia toxicity. *H. azteca* is a sediment dwelling invertebrate that is sensitive to ammonia and organochlorine pesticides. *E. estuarius* is a burrowing amphipod that is sensitive to organochlorine and organophosphate pesticides. *A. bahia* is a shrimp known to be sensitive to organophosphate pesticides. Chronic tests will be used to assess both survival and reproductive/growth endpoints for each species. Test species may be added or removed in the future to adequately identify the presence/absence of toxicity.

Multiple dilution tests on water samples will be conducted to determine the magnitude of toxicity and subsequently the value of the toxic unit chronic (TUc). At the initiation of monitoring the following five dilutions will be used: 100%, 50%, 25%, 12.5%, and 6.25%. The number of dilutions and percent dilutions may be adjusted based on analytical results.

Follow-up Toxicity Testing

The results of toxicity testing will be used to trigger further investigations to determine the cause of observed laboratory toxicity. If testing indicates the presence of significant toxicity in the sample, TIE procedures may be initiated to investigate the cause of toxicity. For the purpose of triggering TIE procedures, significant toxicity is defined as at least 50% mortality. The 50% mortality threshold is consistent with the approach recommended in guidance published by USEPA for conducting TIEs (USEPA, 1996), which recommends a minimum threshold of 50% mortality because the probability of completing a successful TIE decreases rapidly for samples with less than this level of toxicity. A Phase 1 TIE will be conducted to determine the general class of constituent (*i.e.*, metal, non-polar organics) causing toxicity. Phase 2 TIEs may also be utilized to identify specific constituents causing toxicity if warranted. TIE methods will generally adhere to USEPA procedures documented in conducting TIEs (USEPA, 1991, 1992, 1993a-b). For samples exhibiting toxic effects consistent with carbofuran, diazinon, or chlorpyrifos, TIE procedures will follow those documented in Bailey *et al.* (1996).

At present, TIEs can not be conducted on bulk sediments; however, TIEs can be conducted on sediment porewater. To address toxicity of unknown causes in sediment, sediment porewater will be extracted and tested for toxicity when significant toxicity, defined as at least 50% mortality, is observed in the bulk sediment sample. If the sediment porewater toxicity testing results in greater than 50% mortality, a Phase 1 TIE may be initiated on the porewater.

TIEs may be conducted on samples collected at sites where non-lethal chronic toxicity is consistently observed. The decision to initiate TIE procedures on any sample, including samples exceeding the mortality threshold, will be made after consultation between the monitoring manager and the project manager for the laboratory responsible for performing toxicity testing and TIEs. When deciding whether to initiate TIE procedures for a specific site and sample event, a number of different factors will be considered including the history of toxicity at the site, the level of toxicity, and the species and endpoints exhibiting toxic effects. The rationale for initiating TIE procedures for a specific sample will be clearly documented in subsequent data reports.

Planned Use of Data

Data generated through the CCWTMP shall be used to further characterize water and sediment quality in the watershed focusing on water and sediment toxicity as well as levels of chlorpyrifos, diazinon, and OCs. Flow and chemical data collected during the study, in conjunction with other available data, may be analyzed to determine the following, as the data allow:

- Frequency of exceedance of in-stream numeric targets;
- Constituents contributing to toxicity of unknown causes in water and sediment;
- Whether a relationship can be established between reported use of chlorpyrifos and diazinon and resulting water quality;
- The particle size association of targeted organic constituents;
- Effectiveness of WLAs and LAs at meeting in-stream numeric targets; and,
- Changes in in-stream fish tissue, water, and sediment quality.

Reporting and Modification of CCWTMP

A Monitoring Report will be prepared annually within three months after the completion of the final event of the sampling year. The report will include the following components:

1. Title page;
2. Table of contents;
3. Monitoring objectives;
4. Sampling site descriptions;
5. Location map of sampling sites including GIS coordinates of sampling sites and land use;
6. Tabulated summary results of analyses;
7. Sampling and analytical methods used;
8. Summary of precision and accuracy;
9. Data interpretation including assessment of data quality objectives;
10. Conclusions and recommendations; and,
11. Chemistry results in an electronic database (does not include toxicity).

An adaptive management approach to the CCWTMP will be adopted as it may be necessary to modify aspects of the CCWTMP. Results of sampling carried out through the CCWTMP and other programs within the CCW may be used to modify this plan, as appropriate. These modifications will be summarized in the annual report. Possible modifications could include, but are not limited to the, following:

- The inclusion of additional land use stations to accurately characterize loadings;
- The removal of land use stations if it is determined they are duplicative (*i.e.*, a land use site in one subwatershed accurately characterize the land use in other subwatersheds);
- The inclusion of additional in-stream sampling stations;
- Discontinuation of analysis of sediment fractions;
- The addition of analysis for constituents identified as contributing to toxicity; and,
- The elimination of analysis for constituents no longer identified in land use and/or in-stream samples.

If a coordinated and comprehensive monitoring plan is developed and meets the goals of this monitoring plan that plan should be considered as a replacement for the CCWTMP.

Sampling Event Preparation

Sample event preparation includes preparation of field equipment, placing bottle orders, and contacting the necessary personnel regarding site access and schedule. The following steps shall be completed two weeks prior to each sampling event:

1. Contact laboratories to order bottles and to coordinate sample transportation details;
2. Confirm scheduled sampling date with field crew, and set-up sampling day itinerary including sample drop-off;
3. Prepare equipment (see Table 7);
4. Prepare sample labels and apply to bottles;
5. Prepare the sampling event summary and field log sheet to indicate the type of field measurements, field observations and samples to be taken at each of the stations; and,
6. Calibrate field measurement equipment.

Table 7 provides a checklist of field equipment to prepare prior to each sampling event.

Table 7. Field Equipment Checklist

All Events				Water Specific	
X	Monitoring Plan	X	Tape Measure	X	Peristaltic Pump
X	Sample Bottles and Jars w/ Pre-Printed and Extra Labels	X	Paper Towels or Rags in a Box	X	Extra Pump Batteries
X	Event Summary Sheets	X	Safety Equipment	X	1 length of Clean Tubing per Site
X	Field Log Forms	X	First Aid Kit		
X	Chain of Custody Forms	X	Cellular Telephone		**Sediment Specific**
X	Bubble Wrap	X	Gate Keys	X	4-mil Poly Bags
X	Coolers w/ Ice	X	Hip Waders	X	Sampling and Mixing Spoons
X	New Powder-Free Nitrile Gloves	X	Plastic Trash Bags		
X	Pens	X	Distilled/DI Wash Bottles		
X	Watch	X	Blank Water		
X	Field Measurement Equipment	X	Sealable Plastic Bags		
X	Camera	X	Grab Pole		

Sampling Event Summary and Post Event Summary

A sampling event summary sheet shall be produced for the sampling crew prior to each sampling event. Appendix II presents an example of a sampling event summary sheet. The event summary sheet shall outline sampling requirements at each sampling station, including a list of samples to be collected and QA/QC requirements. This summary will act as a guide to help field crews prepare for and track sample collection during each event. Additionally, the sheet shall show bottle and processing and storage requirements.

A post sampling event summary will be produced by the sampling crew subsequent to each sampling event. This summary will act as a guide for quality assurance personnel to qualify data. The post event summary will contain: chain-of-custody (COC) forms submitted with samples, field log sheets, and a post event summary sheet. The post event summary sheet will follow the same outline as the event summary sheet. In addition, the following information will be included: the sample collection date, name of lab(s) used, when the data were made available by the lab and the format in which they were made available (hard copy or electronic). Appendix III presents an example of a post sampling event summary sheet.

Bottle Order/Preparation

Sample bottle orders will be placed with the appropriate analytical laboratory at least two weeks prior to each sampling event. Bottles and jars will be ordered for all water and sediment samples, including quality control samples as well as extra bottles in case of a need for intermediate containers or replacement. The bottles must be the proper size and material, and contain preservatives as appropriate for the specified laboratory analytical methods. Table 8 presents the proper bottle and jar material and volume, sample type, and immediate processing and storage needs. The field crew must inventory sample bottles upon receipt from the laboratory to assure that adequate bottles have been provided to meet analytical requirements for each sampling event. After each sampling event, any bottles and tubing used to collect water samples and the equipment used for collecting sediment samples shall be cleaned by the laboratory and either picked up by or shipped to the sampling crew.

Sample Bottle Labeling

All samples will be pre-labeled before each sampling event to the extent practicable. Pre-labeling sample bottles and jars simplifies field activities; leaving only sample collection time and date, and the names of sampling personnel to be filled out in the field. Custom labels will be produced using blank water-proof labels. This approach will allow the stations and analytical constituent information to be entered into the computer program in advance, and printed as needed prior to each sampling event.

Labels shall be applied to the appropriate bottles and jars in a dry environment; attempting to apply labels to sample bottles after filling may cause problems, as labels usually do not adhere to wet bottles. The labels shall be applied to the bottles and jars rather than to the caps. Field labels shall contain the following information:

- Program Name
- Station ID
- Sample ID
- Date
- Time
- Sampling Personnel
- Analytical Requirements
- Preservation Requirements
- Laboratory Conducting Analysis

Sample Collection

Table 8 lists specific constituents for which samples will be analyzed, sample volume required, and immediate processing and storage requirements.

Table 8. Sample Container, Preservation, and Storage Requirements

Parameter	Sample Container	Sample Volume	Immediate Processing and Storage
Aquatic Toxicity			
Initial Screening	FLPE-Lined Jerrican	40 L	Store at 4^0C
Follow-up Testing			
Phase I TIE			
Sediment Toxicity			
Initial Screening	4–Mil Poly Bag	3 L	Store at 4^0C
Follow-up Testing		10 L[1]	Store at 4^0C
Phase I TIE		45 L[1]	Store at 4^0C
Fish Tissue			
Organics and Percent Lipids	Teflon sheet	200g	Store on dry ice immediately
General Water Quality Constituents (GWQC)			
Total Ammonia	Polyethylene	250 mL	H_2SO_4 and Store at 4^0C
Hardness	Polyethylene	250 mL	Store at 4^0C
Total Suspended Solids	Polyethylene	1 L	Store at 4^0C
Flow, pH, Temperature, Dissolved Oxygen, Conductivity, Salinity	Field Meter	N/A	N/A
Organic Constituents in Water			
Organics – Dry Weather	Amber Glass	4 x 1L	Store at 4^0C
Organics – Wet Weather	Glass	4 x 0.5 gallon	Store at 4^0C
Constituents in Sediment			
Total Ammonia	Glass	3 x 8 oz jar	Store at 4^0C
Percent Moisture			
Grain Size Analysis			
Total Organic Carbon			
Organics			
Acid Volatile Sulfides			
Simultaneously Extractable Metals (SEM)			

[1] Sample volumes for follow-up testing and Phase I TIEs for sediments may change based on percent solids in previous samples. In addition, collection of sediment for Follow-up Testing and Phase I TIEs may change based on observations of toxicity in previous sampling events.

All water samples will be grab samples

All sediment samples will be composite samples

N/A = Not Applicable

Sampling Technique

Samples will be collected in a manner that minimizes the possibility of sample contamination. These sampling techniques are summarized below:

- Samples are collected only into rigorously pre-cleaned sample bottles.
- At least two persons, wearing clean powder-free nitrile gloves at all times, are required on a sampling crew.

- Clean, powder-free nitrile gloves are changed whenever something not known to be clean has been touched.
- To reduce the potential for contamination, sample collection personnel must adhere to the following rules while collecting samples:
    1. No smoking.
    2. Never sample near a vehicle, running or otherwise.
    3. During wet weather events avoid allowing rain water to drip from rain gear or any other surface into sample bottles.
    4. Do not eat or drink during sample collection.
    5. Do not breathe, sneeze or cough in the direction of an open sample bottle.

Water Sample Collection

The primary objectives of water sample collection are to identify the presence/absence of chronic and/or acute toxicity as well as to determine compliance with WLAs and LAs. Toxicity samples collected in the CCW have displayed degrading toxicity. The toxic signal is lost during TIE procedures, making the results inconclusive. Collection of sample over an extended time period could lead to increased decay of constituents of interest which could affect the toxicity of the sample and the ability to determine the cause of observed toxicity. In addition, the logistics (from a cost and time perspective) of collecting composite samples for the foreseeable future seems excessive given the lack of clear benefits for collecting toxicity samples in such a manner. Due to the aforementioned concerns, all water samples will be collected as grab samples. At most stations, grab samples will be collected at approximately mid-stream, mid-depth at the location of greatest flow (where feasible) by direct submersion of the sample bottle. This is the preferred method for grab sample collection; however, due to sampling station configurations and safety concerns, direct filling of sample bottles may not always be feasible. Sampling station configuration will dictate grab sample collection technique. Grab samples will be collected directly into the appropriate bottles (containing the required preservatives as outlined in Table 8).

The grab sample techniques that may be employed are described below.

Direct Submersion: Hand Technique

Where practical, all grab samples will be collected by direct submersion at mid-stream, mid-depth using the following procedures.

1. Wear clean powder-free nitrile gloves when handling bottles and lids. Change gloves if soiled or if the potential for cross-contamination occurs from handling sampling materials or samples;
2. Use pre-labeled sample containers as described in the Sample Bottle Labeling section;
3. Remove lid, submerge bottle to mid-stream/mid-depth, let bottle fill, and replace lid;
4. Place sample on ice;
5. Collect remaining samples including quality control samples, if needed, using the same protocols described above; and,
6. Fill out COC form, note sample collection on field form, and deliver to appropriate lab.

Intermediate Container Technique

Samples for which the introduction of a secondary container is acceptable, and which will be colleted from an open channel, may be collected with the use of a specially cleaned intermediate container following the steps listed below. A secondary container could include a bottle of similar composition to the sample bottle or a pre-cleaned pitcher of the same material as the sample bottle.

1. Wear clean powder-free nitrile gloves when handling bottles and lids. Change gloves if soiled or if the potential for cross-contamination occurs from handling sampling materials or samples;
2. Use pre-labeled sample containers as described in the Sample Bottle Labeling section;
3. Submerge intermediate container to mid-stream/mid-depth, let container fill, and pour off into individual sample bottles;
4. Place sample on ice;
5. Collect remaining samples including quality control samples, if needed, using the same protocols described above; and,
6. Fill out COC form, note sample collection on field form, and deliver to appropriate lab.

Pumping

Samples for which the use of a peristaltic pump is acceptable and/or necessary because of sampling station configuration, and which will be collected from an open channel, may be collected with the use of a peristaltic pump and specially cleaned tubing following the steps listed below. Pumping may not be used to collect samples analyzed for ammonia.

1. Wear clean powder-free nitrile gloves when handling bottles, lids, and pump tubing. Change gloves if soiled or if the potential for cross-contamination occurs from handling sampling materials or samples;
2. Use pre-labeled sample containers as described in the Sample Bottle Labeling section;
3. Insert pre-cleaned tubing into the pump using "clean sampling techniques". New clean tubing must be used at each sample location for which the pump is used;
4. Place one end of the tubing below the surface of the water. To the extent possible, avoid placing the tubing near the bottom of the channel so that settled solids are not pumped into the sample container.
5. Hold the other end of the tubing over the opening of the sample container. Be careful not to touch the tubing to the sample container.
6. Pump the necessary sample volume into the sample container;
7. Place sample on ice;
8. Collect remaining samples including quality control samples, if needed, using the same protocols described above; and,
9. Fill out COC form, note sample collection on field form, and deliver to appropriate lab.

Sediment Sample Collection

Collection of in-stream sediment samples for chemical analysis and toxicity testing shall be conducted according to methods developed by the USGS and outlined in *Guidelines for Collecting* *and Processing Samples of Stream Bed Sediment for Analysis of Trace Elements and Organic Contaminants for the National Water Quality Assessment Program* (1994). Sediment sampling stations will encompass a section of the reach approximately 100 meters in length upstream from water-column sampling stations. However, this definition may vary based on conditions at each sampling station. Sediment sampling stations should contain 5 to 10 wadeable depositional zones. Depositional zones are defined as locations in streams where the energy regime is low and fine-grained particles accumulate in the stream bed. Depositional zones include areas on the inside bend of a stream or areas downstream from obstacles such as boulders, islands, sand bars, or simply shallow waters near the shore.

The purpose of selecting numerous wadeable depositional zones is to collect a representative sample of each reach. Each depositional zone identified at a sampling station shall be subsampled several times and composited in the field for chemical analysis, or at the lab for toxicity analysis. The number of subsamples collected at each depositional zone shall be based on the size of the zone. If all of the depositional zones within a reasonable distance of the water sampling station have dried, samples should be collected from a partially wetted zone. Wetted zones include areas near the active stream channel.

Sediment samples will be collected using pre-cleaned stainless steel trowels from the top two to three centimeters (cm) of sediment. In areas where water is too deep such that no wadeable zones exist (such as Mugu Lagoon), an Ekman dredge or similar device should be used. Collection of sediments in the top two to three cm is a common approach to conducting sediment sampling to conduct sediment toxicity testing. This approach was used in sediment toxicity studies conducted by the Southern California Coastal Water Research Project (SCCWRP) Bight Program and the State Water Resources Control Board Bay Protection and Toxic Cleanup Program (BPTCP), which led to the sediment toxicity listing in the lagoon.

A model developed to simulate hydrodynamics and sediment transport in Mugu Lagoon estimated sedimentation deposition rates which varied across the lagoon from 0.3 to 6 cm per year (RMA, 2003). Collection of sediment samples in the top two to three cm would exceed annual deposition rates within portions of the lagoon resulting in the characterization of current and historic deposits. The time period represented in samples would vary from site to site based on deposition rates. In addition, pollutants identified as causing toxicity may be related to historic deposits. Although identifying the presence and cause of toxicity, even if related to historic deposits, provides information on current conditions in the lagoon. Additionally, trends in sediment concentrations should be observable if sampling methodology and sampling stations remain relatively consistent.

All sediment samples to be analyzed for organic constituents shall be collected as composite samples as described below. Sediment samples analyzed for toxicity will be composited at the toxicity laboratory. Composite samples shall be collected directly into a clean polyethylene bag, mixed, and then placed into the appropriate jars as outlined in Table 8. Sediment sampling techniques that may be employed are described below.

Sediment Sample Collection for Chemical Analysis

1. Wear clean powder-free nitrile gloves when handling bottles and lids. Change gloves if soiled or if the potential for cross-contamination occurs from handling sampling materials or samples;
2. Use pre-labeled sample containers as described in the Sample Bottle Labeling section;
3. Approach first depositional zone from downstream, care should be taken to minimize the disturbance of sediments;
4. Collect a sample of the top layer (3 cm) of sediment carefully with stainless steel trowel. Avoid loosing the fines when lifting the sample;
5. Place sample into a clean polyethylene bag;
6. Repeat collection in the deposition zone 5 times, if feasible;
7. Move to the next depositional zone and repeat collection;
8. Upon gathering sediment at each depositional zone in the reach, mix the composite sample in the polyethylene bag and fill sample containers used for chemical analysis;
9. Place sample on ice; and,
10. Fill out COC form, note sample collection on field form, and deliver to appropriate lab;

Sediment Sample Collection for Toxicity Analysis

1. Wear clean powder-free nitrile gloves when handling bottles and lids. Change gloves if soiled or if the potential for cross-contamination occurs from handling sampling materials or samples;
2. Use pre-labeled sample containers as described in the Sample Bottle Labeling Section;
3. Approach first depositional zone from downstream, care should be taken to minimize the disturbance of sediments;
4. Collect a sample of the top layer (3 cm) of sediment carefully with stainless steel trowel. Avoid loosing the fines when lifting the sample;
5. Place sample into a clean polyethylene bag,
6. Collect sample for chemical analysis, as described immediately above;
7. Move to the next depositional zone and repeat collection;
8. Repeat collection with sample spoon in each of the deposition zones until a total volume of 60 L of sample has been collected;
9. Place sample on ice; and,
10. Fill out COC form, note sample collection on field form, and deliver to appropriate lab;

Fish Tissue Sample Collection

Fish species collected in the past in the CCW include goldfish, fathead minnow, black and brown bullhead, arroyo chub, mosquito fish, and green sunfish. According to USEPA guidance (2000), the target fish species for sample collection should be the largest individual fish captured from both 1) the highest trophic level sampled (e.g., predatory species) and 2) a bottom feeder. The USEPA guidance document lists bass, crappie, walleye, yellow perch, common carp, suckers, catfish, and trout among its recommended target species for inland fresh waters. Other species not listed above may be collected if they are species known to be consumed by people in the CCW, within the size range typically kept for consumption, and are predatory or bottom-feeding species.

Total length (longest length from tip of tail fin to tip of nose/mouth) and fork length should be measured and recorded in the field. Scale samples should be collected for aging purposes.

For Mugu Lagoon, the Navy has recommend the collection of spotted sand bass (predatory) and diamond turbot (benthic-feeding) (personal communication, Ruane). The diamond turbot was suggested as it is the resident benthic-feeding flatfish in southern California estuarine bays; other benthic feeding flatfishes and croakers are not likely to be resident in Mugu Lagoon. For collection considerations the spotted sand bass can be taken by hook and line whereas the diamond turbot may be caught by seine such as a beach seine.

Sampling Protocols

Either the California Department of Fish and Game (CDFG) or a local environmental consulting firm with knowledge of resident species will be contracted to perform sample collection.

Tissue monitoring will involve the field-collection of fish and the obtaining and storing of fish tissue samples to be analyzed for trace levels of target organics, using protocols detailed in CDFG's (2000) standard operating procedures for fish tissue sample collection and preparation. These protocols are summarized below.

Collection of fish for analysis of trace levels of pesticides and PCBs in tissue may be accomplished by a variety of methods, including hook and line, seines, gill nets, and electroshocking. The preferred species to be collected will be species of the highest trophic level at a given location. Efforts will be made to collect fish of a variety of sizes for each species collected, but all within the typical size range selected by anglers. Efforts also will be made to collect and freeze more samples than the target number to be initially analyzed, thereby providing opportunity to conduct subsequent rounds of tissue analyses, if appropriate.

Individual fish will be wrapped in trace metal- and organic-free Teflon™ sheets and frozen for transportation to the laboratory. The tissue samples are prepared in the laboratory using non-contaminating techniques in a clean room environment. For larger species and individual fish, tissue samples for analysis will consist of a 200-g skin-on fillet sample excised from individual fish (except for catfish and other scaleless species, which are usually prepared as skin-off fillets) (USEPA, 2000). If multiple fish are required to achieve a 200-g sample, smaller, equal-sized skin-on tissue samples from similar size individuals may be combined for a composite sample of 200 g. However, the preferred method is to collect an adequate size sample from individual fish. Collection, handling and storage of tissue samples will be performed in a manner to assure the collection of representative, uncontaminated tissue chemistry samples. Briefly, the key aspects of quality control associated with fish tissue sample collection are as follows:

- Field personnel must be trained in the proper use of sample collection gear and will be able to distinguish acceptable versus unacceptable samples in accordance with pre-established criteria.

- Field personnel must be thoroughly trained to recognize and avoid potential sources of sample contamination (e.g., engine exhaust, winch wires, deck surfaces, ice used for cooling).
- Samplers and utensils that come in direct contact with the sample will be made of non-contaminating materials (e.g., glass, high-quality stainless steel and/or Teflon™) and will be thoroughly cleaned between sampling stations.
- Sample containers will be pre-cleaned and of the recommended type.

In general, sampling protocols are consistent with national guidance developed by USEPA (2000). The minimum number of fish tissue samples to be initially analyzed for each sampling site is three, but five samples is recommended. These samples may be from the same or different fish species. For any single composite sample of smaller fish, the total length of the smallest fish should be no less than 75% of the total length of the largest fish. If, after expending a reasonable amount of effort, the field crew is unable to catch the required number of fish of an appropriate size at a location, CDFG staff or the sampling contractor will contact the sampling plan manager of the CCWTMP to discuss whether sampling should continue at that location.

Field Measurements and Observations

Field measurements (listed in Table 8) will be collected and observations made at each sampling station (water and sediment) after a sample is collected. Field measurements will include flow, pH, temperature, dissolved oxygen, salinity, and conductivity. Temperature, pH, dissolved oxygen, salinity, and conductivity measurements will be collected at approximately mid-stream, mid-depth at the location of greatest flow (if feasible). Field probes shall be lowered to mid-depth and readings recorded on the field log for that station. Field measurements for sediment samples shall be collected from within one meter of the sediment. All field measurement results and comments on field observations will be recorded in a field log similar to the one presented in Appendix IV.

Flow measurements will be collected using a velocity meter or estimated at each sampling station after a sample is collected. When a velocity meter is unavailable or flow is not sufficiently deep to use a velocity meter, depth, width, and velocity will be estimated to provide an estimate of flow. Depth will be estimated by using the average of several depth measurements taken along the channel. Width will be measured by extending a tape measure from one side of the bank to the other. Velocity will be estimated by measuring the time it takes a floating object (*e.g.,* stick, orange) to travel a known distance.

If at any time the collection of field measurements by wading appears unsafe, do not attempt to collect mid-stream, mid-depth measurements. Rather, collect field measurements from a stable, unobstructed area at the reach's edge or use an expandable pole and intermediate container to obtain a sample for field measurements.

In addition to field measurements, observations shall be made at each sampling station. Observations will include color, odor, floating materials as well as observations of contact and non-contact recreation. All comments on field observations will be recorded in a field log similar to the one presented in Appendix IV.

Chain-of-Custody

Chain-of-custody (COC) forms shall be filled out for all field samples submitted to each laboratory. Sample data, sample location, sample collection crew names, and analyses requested shall be noted on each COC form. See Appendix V for an example of a blank COC form.

Transport to Lab

Samples shall be stored in coolers with ice and bubble wrap and delivered to the appropriate laboratory (Table 9). Samples will be analyzed according to the methods listed in Table 6. In addition, Table 6 provides reporting limits and holding times.

Table 9. Analytical Laboratories

Lab	Analysis	Shipping Method	Address
To be determined	Water and sediment toxicity, TIEs	Overnight delivery	To be determined
To be determined	GWQC and Organics in water and sediment	Same day or overnight delivery	To be determined

Field Protocols

Field crews (2 persons per crew, minimum) will only be mobilized for sampling when weather conditions and flow conditions are considered to be safe. For safety reasons, sampling will occur only during daylight hours, when possible. Sampling events should proceed in the following manner:

1. Before leaving the sampling crew base of operations, confirm number and type of sample bottles as well as the complete equipment list.
2. Proceed to the first sampling station.
3. Fill-out the general information on the field log sheet.
4. Collect the samples indicated on the event summary sheet in the manner described in this study plan. Collect additional volume and blank samples for field-initiated QA/QC samples, if necessary. Place bottles and/or jars in the coolers, carefully pack and ice samples. Double check against the log sheet that all appropriate bottles were filled.
5. Collect field measurements and observations, and record on the field log sheet.
6. Repeat the procedures in steps 3, 4, and 5 for each of the remaining sampling stations.
7. Complete the chain of custody forms using the field notes.
8. After sample collection is completed, deliver and/or ship samples to appropriate laboratory listed in Table 9 on the same day as sample collection.

Quality Assurance/Quality Control

Water and sediment chemistry quality control samples shall be collected according to the schedule shown in Table 10 and Table 11. Specific collection methods for each type of quality control sample type are described below.

Field Blank

Field blanks shall be collected for the stations and events specified in Table 10. Field blanks will be collected for water samples analyzed for organic constituents. The field crew will use blank water provided by the laboratory to generate field blanks by pouring blank water directly into the sample bottles. Field blanks shall be submitted "blind" to the laboratory as Station 20. If detected values are reported for field blanks, the frequency of collection outlined in Table 10 will be increased.

Equipment Blank

Equipment blanks shall be collected once for sediment samples and once for water samples if a pump is used. Equipment blanks will be collected for organic constituents. The field crew will use blank water provided by the laboratory to generate equipment blanks. For water sampling equipment, blank water will be collected from the laboratory water provided using each of the water sampling techniques employed. For sediment sampling equipment, blank water will be poured over pre-cleaned sampling device (trowel or dredge) into a clean polyethylene bag and then poured into sample containers. Equipment blanks should be submitted "blind" to the laboratory as Station 21.

Matrix Spike/Matrix Spike Duplicate

Matrix spike and matrix spike duplicate (MS/MSD) analyses shall be requested on samples specified in Table 10. MS/MSD analyses shall be requested for water and sediment samples analyzed for organic constituents and ammonia. No special sampling considerations are required. However, double or triple the normal sample volume may be necessary for each set of water samples (check with analytical laboratory).

Field Duplicates

Field duplicates shall be collected for the stations and events specified in Table 10 and Table 11. Field duplicate water and sediment samples shall be collected and analyzed for organics and GWQC. Field duplicates for water samples shall be collected concurrently with or immediately following the collection of normal samples. In cases where multiple bottles are used for a single analysis, field duplicates and normal sample containers shall be filled in an alternating sequence (*i.e.*, sample-duplicate- sample -duplicate). Field duplicates for sediment samples shall be produced with the same composite sample as the original sample. Field duplicates shall be submitted "blind" to the laboratory as Station 22.

Laboratory Duplicates

Laboratory duplicate analyses shall be requested for all constituents for the stations and events specified in Table 10 and Table 11. No special sampling considerations are required. However, double sample volume may need to be collected, per laboratory requirements, for each analysis.

Quality Control Sample Collection Schedule

Table 10 presents the quality assurance/quality control (QA/QC) sample collection schedule for both the compliance monitoring and toxicity investigation sampling. It is intended to provide general guidance on the timing of QA/QC sample collection. However, due to the nature of environmental sampling it may not be possible to collect all QA/QC samples as outlined in this schedule. As such, this schedule is flexible and may be modified to meet in-field conditions and sampling schedule requirements. Changes to this schedule should be recorded on the event summary, field log, and post event summary.

Table 10. Quality Control Sample Collection Schedule for Water Samples

Subwatershed	Station ID	Water Event Number[1]							
		1	2	3	4	5	6	7	8
Mugu Lagoon	01_11_BR	FB, MS, FD							
Revolon Slough	04_WOOD		FB, MS, FD						
Calleguas Creek	03_CAMAR			FB, MS, FD					
Las Posas	06_SOMIS				FB, MS, FD				
Arroyo Simi	07_HITCH					FB, MS, FD			
Conejo Creek	9B_ADOLF						FB, MS, FD		
	10_GATE							FB, MS, FD	
	13_BELT								FB, MS, FD

1 After eight events the cycle of quality control sample collection is repeated.
FB = Field Blank: water quality field blanks analyzed for pesticides/PCBs. If a site requires sample collection using a peristaltic pump, a pumped sample field blank will be collected in addition to the grab sample field blank.
FD = Field Duplicate, LD = Lab Duplicate: water duplicate samples analyzed for GWQC/pesticides/PCBs.
MS = Matrix Spike/Matrix Spike Duplicate: water quality MS/MSD samples analyzed for ammonia/pesticides/PCBs.

Table 11. Quality Control Sample Collection Schedule for Sediment Samples

Subwatershed	Station ID	Sediment Event Number[1]							
		1	2	3	4	5	6	7	8
Mugu Lagoon	Multiple[2]	FD, EB							
Calleguas Creek	02_PCH		LD						
	03_CAMAR			FD					
	9A_HOWAR				LD				
Revolon Slough	04_WOOD					FD			
Conejo	9B_ADOLF						LD		
Las Posas	06_SOMIS							FD	
Arroyo Simi	07_HITCH								LD

EB = Equipment Blank: sediment quality equipment blanks analyzed for pesticides/PCBs.
FD = Field Duplicate, LD = Lab Duplicate: sediment duplicate samples analyzed for GSQC/pesticides/PCBs.
1 After eight events the cycle of quality control sample collection is repeated.
2 Sediment QA/QC samples will be collected at one of the Mugu Lagoon sampling locations for each event where a quality control sample is required in Mugu Lagoon.

Table 12. Quality Control Sample Collection Schedule for Fish Tissue Samples

Subwatershed	Station ID	Fish Tissue Event Number[1]					
		1	2	3	4	5	6
Mugu Lagoon	TBD[2]	FD, EB					
Calleguas Creek	02_PCH		LD				
Revolon Slough	04_WOOD			FD			
Conejo	9B_ADOLF				LD		
Las Posas	06_SOMIS					FD	
Arroyo Simi	07_HITCH						LD

EB = Equipment Blank: fish tissue quality equipment blanks analyzed for pesticides/PCBs.
FD = Field Duplicate; LD = Lab Duplicate: fish tissue duplicate samples analyzed % lipids/pesticides/PCBs.
TBD Fish tissue sampling locations in Mugu will be determined in conjunction with biologists prior to sample collection.
1 After six events the cycle of quality control sample collection is repeated.
2 Fish Tissue QA/QC samples will be collected at one of the Mugu Lagoon sampling locations for each event where a quality control sample is required in Mugu Lagoon.

References

SM 2450 D. APHA, AWWA, and WEF. 1998. Standard Methods for the examination of water and wastewater, 20th Edition.

American Society for Testing and Materials (ASTM). 2002. Standard test methods for determining sediment concentration in water samples: D 3977-97 (2002), vol. 11.02.

Anderson, T. D. and Lydy, M. J. 2002. Increased toxicity to invertebrates associated with a mixture of atrazine and organophosphate insecticides. Environ. Tox. and Chem. V21, No. 7, 1507–1514.

Bailey, H.C., DiGiorgio, C., Kroll, K., Miller, J.L., Hinton, D.E., Starrett, G. 1996. Development of Procedures for Identifying Pesticide Toxicity in Ambient Waters: Carbofuran, Diazinon, Chlorpyrifos. Environ. Tox. and Chem. V15, No. 6, 837–845.

California Department of Fish and Game (CDFG). 2000. Standard Operating Procedures for Fish Tissue Sample Collection and Preparation: Sampling and Processing Trace Metal and Synthetic Organic Samples of Marine and Freshwater Fish. Method 102. CDFG Marine Pollution Studies Laboratory. July 2000.

Gray, J. R, Glysson, G. D., Turcios, L. M., and Schwarz, G. E.. 2000. Comparability of Suspended-Sediment Concentration and Total Suspended Solids Data. US Geological Survey Water-Resources Investigations Report 00-4191.

Larry Walker Associates, Inc (LWA). 2003. Quality Assurance Project Plan for Calleguas Creek Watershed Salts, Metals, Toxicity, Historic Pesticides/PCBs, and Bacteria TMDL Sampling and Analysis Plans.

Resource Management Associates, Inc. (RMA). 2003. FINAL REPORT Mugu Lagoon Numerical Model Development. Prepared for: U.S. Army Corps of Engineers Los Angeles District under subcontract to Coastal Frontiers Corporation. May 2003.

Ruane, Martin. 2005. Ecologist, Naval Base Ventura County. Martin.ruane@navy.mil. Personal communicaton with S. Granade, March 30, 2005.

United States Environmental Protection Agency (USEPA). 1991. Methods for Aquatic Toxicity Identification Evaluations: Phase 1 Toxicity Characterization Procedures (Second Edition). EPA-600/6-91/003. USEPA, Environmental Research Laboratory, Duluth, MN.

United States Environmental Protection Agency (USEPA). 1992. Toxicity Identification Evaluation: Characterization of Chronically Toxic Effluents Phase I. EPA-600/6-91/005. USEPA, Office of Research and Development, Washington, D.C.

United States Environmental Protection Agency (USEPA). 1993a. Methods for Measuring the Acute Toxicity of Effluents and Receiving Waters to Freshwater and Marine Organisms, Fourth Edition. EPA/600/4-90/027F. USEPA, Office of Research and Development, Washington, D.C.

United States Environmental Protection Agency (USEPA). 1993b. Methods for Aquatic Toxicity Identification Evaluations: Phase II Toxicity Identification Procedures for Samples Exhibiting Acute and Chronic Toxicity. EPA/600/R- 92/080. USEPA, Office of Research and Development, Washington, D.C.

United States Environmental Protection Agency (USEPA). 1996. Marine Toxicity Identification Evaluation. Phase I Guidance Document EPA/600/R-96/054. USEPA, Office of Research and Development, Washington, D.C.

USEPA. 2000. Guidance for Assessing Chemical Contamination Data for Use in Fish Advisories, Volume 1, Fish Sampling and Analysis, Third Edition. EPA 823-B-00-007. USEPA Office of Water, Washington, D.C. November.

Weston, D.P., You, J.C., Lydy, M.J.. Distribution and Toxicity of Sediment-Associated Pesticides in Agriculture-Dominated Water Bodies of California's Central Valley. accepted for publication in Environ. Sci. & Technology.

Appendix I. Sampling Stations

Mugu Lagoon Subwatershed
Reach 1: Mugu Lagoon – 11th Street Bridge
Station ID: 01_11_BR
Directions: From the southern end of Camarillo, heading north on Hwy 101 exit Las Posas. Turn left onto Las Posas and follow until Naval Base Ventura County. Upon entering the base through the furthest gate south; turn left at 11th Street. Access lagoon from bridge. Thomas Guide 2004 p. 583-H4.

For remaining stations in Mugu Lagoon (01_BPT_1, 01_BPT_3, 01_BPT_6, 01_BPT_9, 01_BPT_1, and 01_SG_74) use Figure 4 to determine approximate location for sample collection. Record GPS coordinates during first event and attempt to collect at the same location during future events.

Revolon Subwatershed
Reach 4: Revolon Slough - East Side of Wood Road
Station ID: 04_WOOD
Directions: From the southern end of Camarillo, heading north on Hwy 101 exit Las Posas. Turn left onto Las Posas; turn right onto Pleasant Valley Road; turn left onto Wood Road and continue until Wood Road crosses Revolon Slough. Access slough on east side of Wood Rd through a locked VCWPD gate. Thomas Guide 2004 p. 553-H3.

Calleguas Subwatershed
Reach 2: Calleguas Creek Lower Main Stem - Northeastern side of Highway 1
Station ID: 02_PCH
Directions: From Oxnard, heading south on Hwy 1, turn left, across northbound Hwy 1 traffic, just south of Las Posas Rd intersection, onto Deer Path. Make way north to Calleguas Creek. Thomas Guide 2004 p. 583-J4.

Reach 3: Calleguas Creek Upper Main Stem - Below Camrosa Wastewater Reclamation Facility
Station ID: 03_CAMAR
Directions: From Lewis Rd take University Dr. (previously Camarillo Dr.) southeast to Calleguas Creek. Sample just upstream of bridge. Thomas Guide p. 554-E1.

Reach 9A: Conejo Creek - Below Camarillo Wastewater Treatment Plant
Station ID: 9A_HOWAR
Directions: From US 101 in Camarillo exit Pleasant Valley Rd, and head south to Pancho Rd. Turn left (south) on Pancho Rd. Turn left (east) on Howard Rd. Sample upstream of Howard Road Bridge. Thomas Guide 2004 p. 524-J7.

Las Posas Subwatershed
Reach 6: Arroyo Las Posas - Off of Somis Road
Station ID: 06_SOMIS
Directions: From Somis Rd turn east onto road at Hagel Tree Farm, between Ag Rx and Paty's Farm stand. Cross railroad tracks and follow road until you reach Arroyo Las Posas. Sample upstream of bridge. Thomas Guide 2004 p. 495-A5.

Arroyo Simi Subwatershed
Reach 7: Arroyo Simi - North of Hitch Boulevard
Station ID: 07_HITCH
Directions: Follow Hitch Blvd south from Highway 118 to intersection of Arroyo Simi. Pass through a locked VCWPD gate. Sample upstream of bridge. Thomas Guide 2004 p. 495-J3.

Conejo Creek Subwatershed
Reach 9B: Conejo Creek Main Stem - At the end of Adolfo Road
Station ID: 9B_ADOLF
Directions: From US 101 in Camarillo head north on Santa Rosa Rd. Turn right (east) on Adolfo Rd and continue to the end. Pass through a locked VCWPD gate. Thomas Guide 2004 p. 525-B4.

Reach 10: Conejo Creek Hill Canyon - Below North Fork of Conejo Creek
Station ID: 10_GATE
Directions: From Santa Rosa Rd head south on Hill Canyon Rd. Access creek through gate which is located before the last bend in the road before reaching Hill Canyon Wastewater Treatment Facility. Contact facility staff for access though gate. Thomas Guide 2004 p. 525-J3.

Reach 13: Conejo Creek South Fork - South of Confluence with Conejo Creek North Fork
Station ID: 13_BELT
Directions: From Santa Rosa Rd head south on Hill Canyon Rd. Access creek behind belt press building at Hill Canyon Wastewater Treatment Facility. Contact facility staff for access. Thomas Guide 2004 p. 526-A4.

Appendix II. Example Event Summary Sheet

Calleguas Creek Watershed TMDL Sampling Program Event Summary

Receiving Water Sites

Sampling Event # – x Month y Date, 200z

Station	Requirements	Bottles	Lab
01_11_BR + Water QA/QC – FIELD BLANK (ORGANICS ONLY)			
Water	OC & OP Pest./PCBs and Triazines	2 x 1L Amber glass	xy Labs
	Total Suspended Solids	1 L HDPE	xy Labs
	Total Ammonia	250 mL polyethylene	xy Labs
	Hardness	250 mL polyethylene	xy Labs
	Toxicity	2 x 5 Gallons FLPE-Lined Jerricans	xz Labs
	QA/QC - Field Blank - Label as Station 20 *Collect field blank with lab water before collecting any other samples at this site*		
	OC & OP Pest./PCBs and Triazines	2 x 1 L Amber	xy Labs
	Total Suspended Solids	1 L HDPE	xy Labs
	Total Ammonia	250 mL polyethylene	xy Labs
	Hardness	250 mL polyethylene	xy Labs
Sediment	**Whole Sample**	3 X 8 oz glass	xy Labs
	Total Ammonia		
	Percent Moisture		
	Grain Size Analysis		
	Total Organic Carbon		
	OC & OP Pest./PCBs, Triazines and Pyrethroids		
	Acid Volatile Sulfides		
	Simultaneously Extractable Metals (SEM)		
	2.0 mm to > 0.63 mm and < 0.63 mm fractions		
	OC & OP Pest./PCBs, Triazines and Pyrethroids		
	Acid Volatile Sulfides		
	Simultaneously Extractable Metals (SEM)		
	Sediment Toxicity	15 gallons in polyethylene bags	xz Labs
02_PCH + Sediment QA/QC - LAB DUP (ALL CONSTITUENTS) - Request Lab Dups on COC			
Sediment	**Whole Sample**	6 X 8 oz glass	xy Labs
	Total Ammonia		
	Percent Moisture		
	Grain Size Analysis		
	Total Organic Carbon		
	OC & OP Pest./PCBs, Triazines and Pyrethroids		
	2.0 mm to > 0.63 mm and < 0.63 mm fractions		
	OC & OP Pest./PCBs, Triazines and Pyrethroids		
	Sediment Toxicity	15 gallons in polyethylene bags	xz Labs

Appendix III. Example Post-Event Summary Sheet

Calleguas Creek Watershed Toxicity TMDL Sampling Program Post Event Summary
Receiving Water Sites
Sampling Event # – x Month y Date, 200z

Station	Requirements	Date Submitted to Lab	Date Returned from Lab	Format of Data	Lab
01_11_BR + Water QA/QC - FIELD BLANK (ORGANICS ONLY)					
Water	OC & OP Pest./PCBs and Triazines				xy Labs
	Total Suspended Solids				xy Labs
	Total Ammonia				xy Labs
	Hardness				xy Labs
	Toxicity				xz Labs
	QA/QC - Field Blank - Label as Station 20 **Collect field blank with lab water before collecting any other samples at this site***				
	OC & OP Pest./PCBs and Triazines				xy Labs
	Total Suspended Solids				xy Labs
	Total Ammonia				xy Labs
	Hardness				xy Labs
Sediment	**Whole Sample**				xy Labs
	Total Ammonia				
	Percent Moisture				
	Grain Size Analysis				
	Total Organic Carbon				
	OC & OP Pest./PCBs, Triazines and Pyrethroids				
	Acid Volatile Sulfides				
	Simultaneously Extractable Metals (SEM)				
	2.0 mm to > 0.63 mm and < 0.63 mm fractions				
	OC & OP Pest./PCBs, Triazines and Pyrethroids				
	Acid Volatile Sulfides				
	Simultaneously Extractable Metals (SEM)				
	Sediment Toxicity				xz Labs
02_PCH + Sediment QA/QC - LAB DUP (ALL CONSTITUENTS)					
Sediment	**Whole Sample**				xy Labs
	Total Ammonia				
	Percent Moisture				
	Grain Size Analysis				

	Total Organic Carbon				
	OC & OP Pest./PCBs, Triazines and Pyrethroids				
	2.0 mm to > 0.63 mm and < 0.63 mm fractions				
	OC & OP Pest./PCBs, Triazines and Pyrethroids				
	Sediment Toxicity				xz Labs
	Sediment Toxicity				xz Labs

Appendix IV. Blank Field Log

Calleguas Creek Watershed TMDL Monitoring Program
Field Log

GENERAL INFORMATION

Station ID: __________ Date: __________ Time: Arrival ______
Departure ______

Sampler's Name(s): __________

OBSERVATIONS

Weather: __________

Floating material or debris: __________

Oil (extent): __________ Water color or odor: __________

Photograph No. (if taken): __________

Recreation uses observed: __________

Other Notes (presence of algae, wildlife observations, etc.):

FLOW MEASUREMENTS / ESTIMATES

Measured Flow: __________

Estimated Flow:

Mid-stream depth __________ Width of flow __________ Velocity __________

SAMPLE COLLECTION – Water

Water Toxicity ID: __________ Time: ______ Volume: __________

Circle those that apply: TSS Total Ammonia Hardness Pesticides

ID: __________ Time: ______ Volume: __________

QA/QC: ______ ID: __________ Time: ______ Volume: __________

SAMPLE COLLECTION – Sediment

Sediment Toxicity ID: __________ Time: ______ Volume: __________

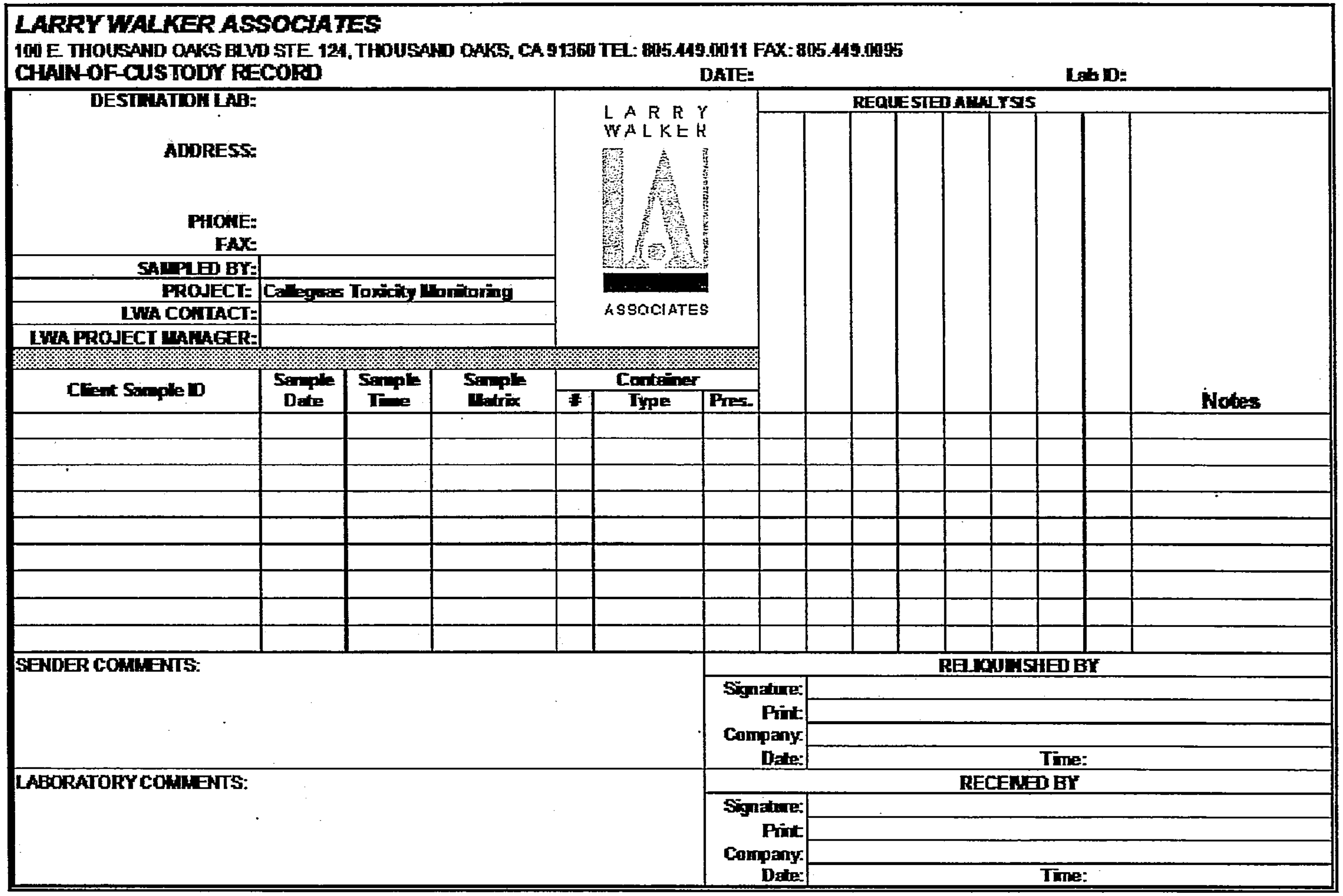
Circle those that apply: Total Ammonia Percent Moisture Grain Size Analysis

Total Organic Carbon Pesticides Acid Volatile Sulfides Simultaneously Extractable Metals

ID: __________ Time: ______ Volume: __________

QA/QC: ______ ID: __________ Time: ______ Volume: __________

Appendix V. Blank Chain of Custody Form



LARRY WALKER ASSOCIATES
100 E. THOUSAND OAKS BLVD STE. 124, THOUSAND OAKS, CA 91360 TEL: 805.449.0011 FAX: 805.449.0095
CHAIN-OF-CUSTODY RECORD DATE: Lab ID:

DESTINATION LAB:
ADDRESS:
PHONE:
FAX:
SAMPLED BY:
PROJECT: Calleguas Toxicity Monitoring
LWA CONTACT:
LWA PROJECT MANAGER:

LARRY WALKER ASSOCIATES

				Container			REQUESTED ANALYSIS								
Client Sample ID	Sample Date	Sample Time	Sample Matrix	#	Type	Pres.									Notes

SENDER COMMENTS:

RELINQUISHED BY
Signature:
Print:
Company:
Date: Time:

LABORATORY COMMENTS:

RECEIVED BY
Signature:
Print:
Company:
Date: Time:

CALIFORNIA DEPARTMENT OF FISH AND GAME

CERTIFICATE OF FEE EXEMPTION

De Minimus Impact Finding

Project Title:	Amendment to the Water Quality Control Plan for the Los Angeles Region to Incorporate a Total Maximum Daily Load (TMDL) for Toxicity, Chlorpyrifos, and Diazinon in the Calleguas Creek, its Tributaries, and Mugu Lagoon.
Project Location:	Calleguas Creek Watershed
Project Proponent:	California Regional Water Quality Control Board, Los Angeles Region 340 W. 4th Street, Los Angeles, California 90013.

Project Description:

California Regional Water Quality Control Board (Regional Board) Resolution No. R4-2005-009, adopted on July 7, 2005 by the Regional Board, modified the regulatory provisions of the Water Quality Control Plan for the Los Angeles Region (Basin Plan) by: (1) revising the Table of Contents, (2) adding introductory text for Chapter 7 (Total Maximum Daily Loads), and (3) establishing a Total Maximum Daily Load (TMDL) for Toxicity, Chlorpyrifos, and Diazinon for Calleguas Creek, Its Tributaries, and Mugu Lagoon. The TMDL addresses impairment to water quality due to elevated levels of chlorpyrifos, diazinon, other pesticides and/or other toxicants in water, sediment, and/or fish tissue. Chlorpyrifos and diazinon are organophosphate pesticides used in both agricultural and urban settings. Excessive chlorpyrifos and diazinon can cause aquatic life toxicity in inland surface and estuarine waters such as Calleguas Creek and Mugu Lagoon. The California 2002 303(d) list of impaired waterbodies includes listings for "water column toxicity," "sediment toxicity," "chlorpyrifos in fish tissue," and "organophosphate pesticides in water" for various reaches of Calleguas Creek, its tributaries and Mugu Lagoon. This TMDL establishes a numeric toxicity target of 1.0 toxicity unit – chronic (1.0 TUc) to address toxicity in reaches where the toxicant has not been identified through a Toxicity Identification Evaluation (TIE) (unknown toxicity). Numeric targets addressing ammonia toxicity in water are presented in the TMDL for Nitrogen Compounds and Related Effects in Calleguas Creek, Its Tributaries, and Mugu Lagoon. Numeric targets presented in the Total Maximum Daily Load (TMDL) for Organochlorine (OC) Pesticides, Polychlorinated biphenyls (PCBs), and Siltation in Calleguas Creek, Its Tributaries, and Mugu Lagoon will be used to address the potential contribution of toxicity attribute to 303(d) listed OC pesticides and PCBs. CDFG (2000) developed chlorpyrifos criteria and USEPA (2000a) developed diazinon criteria were selected as concentration-based numeric targets for chlorpyrifos and diazinon.

WLAs established for the major points sources, including POTWs in the Calleguas Creek Watershed (CCW) will be implemented through NPDES permit effluent limits. The final WLAs will be included in NPDES permits in accordance with the compliance schedules provided. Stormwater WLAs will be incorporated into the NPDES permit as receiving water limits measured in-stream at the base of each subwatershed and will be achieved through the implementation of BMPs as outlined below. Evaluation of progress of the TMDL will be determined through the measurement of in-stream water quality and sediment at the base of each of the CCW subwatersheds. LAs for chlorpyrifos and diazinon will be implemented through the State's Nonpoint Source Pollution Control Program (NPSPCP), nonpoint source pollution (i.e. Load Allocations). The Regional Board recently adopted a Conditional Waiver for Irrigated Lands. This Conditional Waiver Program will implement allocations and attain numeric targets of this TMDL. Compliance with LAs will be measured at the monitoring sites approved by the Executive Officer of the Regional Board through the monitoring program developed as part of the Conditional Waiver, or through a monitoring program that is required by this TMDL. The Regional Board may revise this TMDL based on additional information as described in the Special Studies and Monitoring Section of the Technical Report.

This TMDL includes implicit margin of safety to account for uncertainty concerning the relationships between WLAs and water quality. The implicit margin of safety is largely based on conservative assumptions and by using a concentration based TMDL. In addition to the implicit margin of safety, an explicit margin of safety of 5% has been added to the targets for chlorpyrifos in the Calleguas and Revolon subwatersheds to address uncertainty in the linkages between the water column criteria and fish tissue and sediment concentrations.

The implementation plan allows for separate implementation schedules for different sources. Interim chlorpyrifos and diazinon wasteload allocations apply to NPDES permittees and agricultural dischargers as the TMDL is in effect. The Implementation Plan includes final achievement of WLAs and LAs within 10 years after the effective date of the amendment.

Findings of Exemption: (See attached CEQA Checklist).

The proposed amendment could have a significant adverse effect on the environment. However, there are feasible alternatives, feasible mitigation measures, or both that would substantially lessen any significant adverse impact. The public agencies responsible for those parts of the project can and should incorporate such alternatives and mitigation into any subsequent projects or project approvals.

Certification;

I hereby certify that the California Regional Water Quality Control Board, Los Angeles Region, has made the above findings of fact and that based upon the Environmental Checklist and written report and hearing record, the project will not individually or cumulatively have an adverse effect on wildlife resources as detailed in Section 711.2 of the Fish and Game Code.

Jonathan S. Bishop
Executive Officer
California Regional Water Quality Control Board
Los Angeles Region

3/24/06
Date

LARRY WALKER ASSOCIATES

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Technical Memorandum

DATE: March 1, 2006
TO: file
CC:
SUBJECT: Calibration Results of the CCWM for Metals and Selenium

FINAL

INTRODUCTION

A Hydrologic Simulation Program – FORTRAN (HSPF) model for hydrology and water quality is being used as decision support for the development of a TMDL for metals and selenium in the Calleguas Creek watershed (CCW) located primarily in Ventura County, CA. The hydrology component of the HSPF model, described in Aqua Terra (2005), has been extended to perform the water quality simulations for the TMDL. Preliminary modifications (LWA 2005a), model run extension (LWA 2006), and the linkage analysis (LWA 2005c) describe the development and model extensions made to the HSPF model for the metals and selenium TMDL. The complete model simulates water flow and storage, temperature, sediment, chloride, hardness, copper, nickel, mercury, and selenium. Furthermore, the metals and selenium are modeled considering the dissolved, suspended particulate, and benthic particulate phases. The complete model is dubbed the Calleguas Creek Watershed Model (CCWM) and is described at length in LWA (2005c). The following is an evaluation of the CCWM.

Brief Review of CCWM

The stakeholders selected HSPF as the modeling environment based on the fact that the model has been maintained, refined, and used for TMDL development for nearly 30 years (LWA, 2005d), and a HSPF hydrologic model of the CCW has become available (Aqua Terra, 2005) to modify for water quality simulations. The subwatersheds, model reaches, and flow gages comprising the CCWM are shown in Figure 1. While the model generates flow and water quality information for each reach, only a handful of locations correspond to regular sampling locations. Of the sample sites, only three locations have data representing a range of wet and dry conditions, and these three sites serve as the calibration sites. Two sites are on Calleguas Creek at Potrero Road and Pacific Coast Highway (PCH), and one site is on Revolon Slough at Wood Road. The calibration sites are called out on Figure 1. Revolon Slough at Wood and Calleguas Creek at Potrero represent the lowest non-tidally influenced reaches in their respective subwatersheds. Calleguas Creek at PCH represents the water quality entering Mugu Lagoon from a large portion of the entire watershed. Robust data sets are not available for Revolon Slough at PCH and the agricultural drain which comprise the remaining inflows to the lagoon, precluding detailed model comparisons.

Calibration of the CCWM to represent water quality constituents is an iterative trial and error process. The process began with temperature and sediment. Calibration used available data up through December 2002, except metals and selenium where only data from January 1995 to December 2002 were used for calibration. Metals and selenium data prior to 1995 typically used detection limits an order of magnitude greater than expected concentrations, and are therefore not reliable. The calibration generally follows the methodology outlined in Donigian (2002). Sediment calibration followed recommendations of Donigian and Love (2003). For a model like HSPF, the calibration process results in an overall balance of multiple parameters, and in general is not the adjustment of one specific variable.

The expected level of agreement between measured data and model results depends on factors including: data quality, data quantity, purpose of the project, available resources, and available alternative assessments that could meet the project needs (Donigian, 2002). The weight of evidence approach to model evaluation advocated in Donigian, 2002 embodies the following ideas: models are approximations of real processes and can not precisely represent natural systems, no single statistic or test can be used to evaluate the performance of a model, both graphical and statistical tests are required for model evaluation, and models cannot be more accurate than the input and observed data.

Because the first several years of simulation are required for model "spin-up" only data from October 1, 1993 to December 31, 2004 are used in model evaluation or TMDL work.

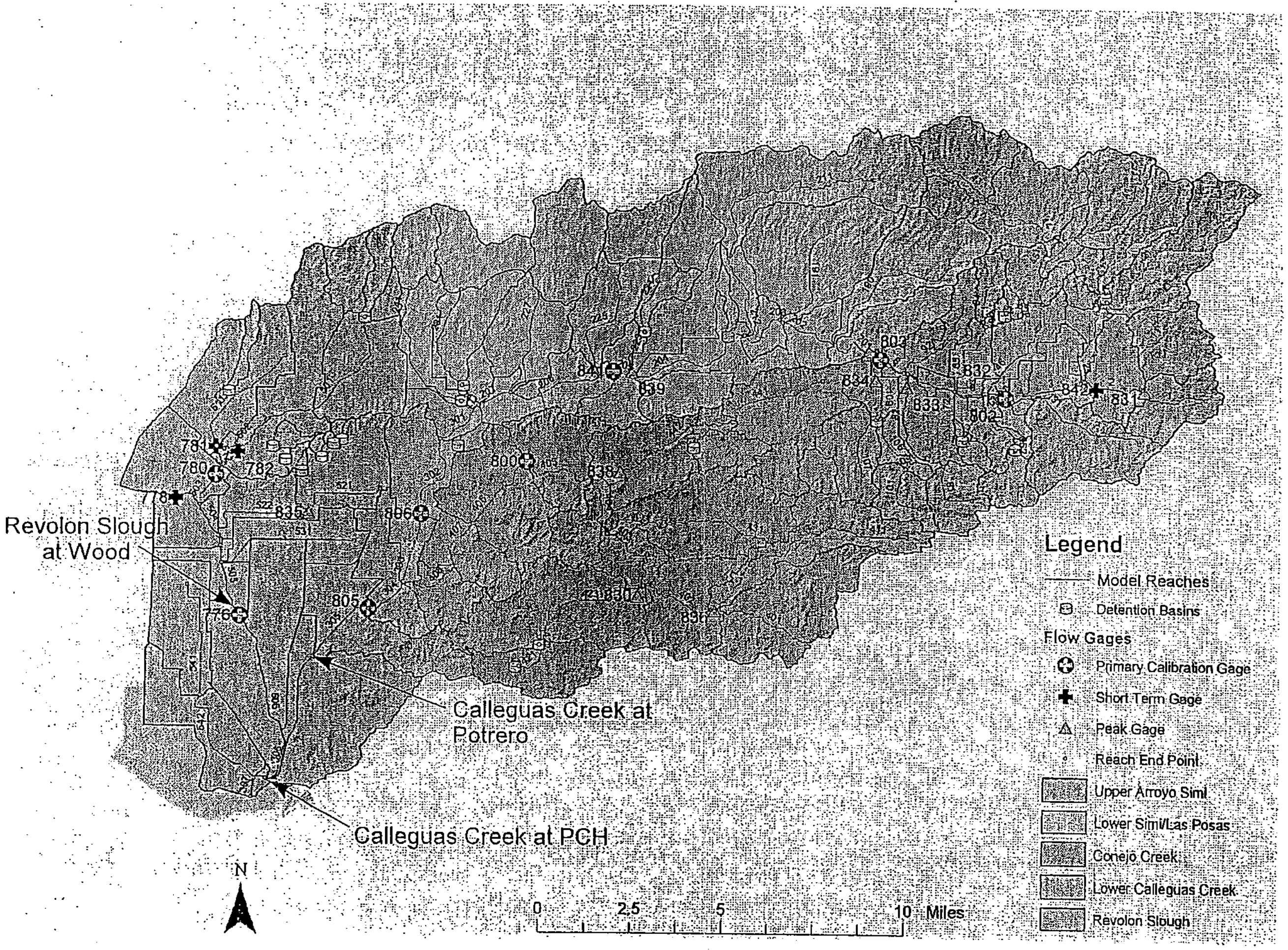

Figure 1: Calibration Sample Locations in the Lower Calleguas Creek Watershed (adapted from Aqua Terra 2005).

DATA SETS

Of the available data, only data considered to be of high quality are used to calibrate the CCWM. For the sole purpose of defining a dataset to use in evaluating the model, only data collected post January 1, 1995 with detection levels less than 0.5 µg/L (0.5 ng/L for mercury) are considered. Historically, programs performing monitoring in the watershed have found the data associated with analysis performed with detection levels greater than 0.5 µg/L (0.5 ng/L for mercury) are problematic. While it is difficult to pinpoint whether it is the clean technique sampling required for low detection levels or the laboratory procedures required for low detection levels or a combination of both that generally yield high quality data, monitoring programs in the watershed have moved to low detection level methods.

In defining a data set of concurrent total and dissolved metals and selenium for use in determining partitioning coefficients and model comparisons of dissolved fraction to total constituent, the records corresponding to a dissolved measurement greater than the total measurement by relative percent difference (RPD) greater than 30% were removed from consideration and the model evaluation work.

Grab and composite measurements are both included in the database. Composite samples in the database are assigned the date when sample collection ended, which generally corresponds to the day following the storm. Without date adjustment, the storm water quality measurement would be compared to post storm model results. To actually be able to compare the value of the composite sample to the CCWM output, the sample date has to be adjusted when the compositing period is longer than 24 hours.

ATMOSPHERIC DEPOSITION

Estimates of both wet and dry deposition of copper, nickel, mercury, and selenium are calculated with available information for the Calleguas Creek Watershed. It should be noted that dry deposition of mercury in the gaseous phase typically represents a significant source of the metal to surfaces (Laurier *et al.* 2003), and an estimate of this source is included in this assessment as well.

Estimates of dry deposition of copper, nickel, mercury, and selenium to the Calleguas Creek watershed are calculated given atmospheric concentration data taken from the California Air Resources Board (CARB), utilizing typical values for deposition velocities taken from the literature based upon particle size. Estimates of wet deposition of copper, nickel, mercury, and selenium to the Calleguas Creek watershed are calculated using typical concentrations in precipitation obtained from the literature and measurements of rainfall to the watershed area for the years from 1903 through 2004. The results from the atmospheric deposition analysis (LWA 2005e) are listed in Table 1. In the CCWM, the data in Table 1 are applied uniformly over the watershed.

Table 1: Estimated Atmospheric Deposition Rates to the CCW.

	Dry Deposition Flux	Mass Dry Deposited to Watershed	Wet Deposition Flux	Mass Wet Deposited to Watershed	Total Deposition Flux	Mass Deposited to Watershed
Contaminant	µg/m² yr	Kg/yr	µg/m² yr	Kg/yr	µg/m² yr	Kg/yr
Copper	990	881	403	359	1,393	1,240
Nickel	558	497	155	138	713	635
Mercury	646	575	19	17	665	592
Selenium	20	18	320	285	340	303

PARTITIONING MODEL

Because the model is used to calculate the particle associated and dissolved fractions of metals and selenium, the linear partitioning coefficient (K_D) must be supplied as input. Equation 1 is the linear partitioning model for equilibrium conditions (USEPA, 1993) allowing dissolved constituent concentrations to be converted to estimated total concentrations.

$$\left(1+\frac{K_D}{10^6}\cdot TSS\right)\cdot C_D=C_T \qquad (1)$$

Where: C_D = Dissolved fraction concentration of the constituent
C_T = Total concentration of the constituent
TSS = Total suspended solids concentrations
K_D = partition coefficient

To determine the value of the partitioning coefficient, K_D, equation 1 can be rearranged into the form of a line with the y-intercept equal to zero. The rearranged equation is presented as equation 2. Available data where total suspended solids, and total and dissolved constituent concentration are concurrently measured can be used the linear regression (equation 2) to determine the best estimate of K_D.

$$\left(\frac{C_T}{C_D}-1\right)=\frac{K_D}{10^6}\cdot TSS \qquad (2)$$

For use in the CCWM, the data are regressed to determine a starting value of K_D for each constituent of interest. As K_D for each constituent is a primary calibration variable of the model, the values used in the CCWM vary from the value determined through the regression. The representation of the partitioning is much more detailed in the HSPF model in that the transfer between the dissolved phase and each of suspended sand, suspended silt, suspended clay, benthic sand, benthic silt, and benthic clay particle size fractions are calculated at each time step in the non-equilibrium form if the partitioning equation (Bicknell, *et al.*, 2001). However, the simplified results presented below serve to give feel how the values used in the model compare to data.

Copper

All available high quality data where TSS, and total and dissolved copper are concurrently measured are plotted in the form of equation 2 on Figure 2. Data from different reaches are represented by different symbols. Data from the different reaches are regressed separately and the regression line, resulting equation, and correlation coefficient are plotted on the Figure. Note that the slope of the line corresponds to $K_D/10^6$. To present the data in a more intuitive form, Figure 3 is a presentation of the dissolved to total copper ratio calculated from the data as a function of the measured TSS. By rearranging equation 2 for the dissolved to total ratio, yielding equation 3, the calibrated partition coefficients for copper used in the CCWM are plotted in Figure 3 as lines. Only the maximum (8,400 L/kg) and minimum (6,000 L/kg) K_D used in the CCWM are plotted as the other values will simply plot between the two lines.

$$\frac{C_D}{C_T}=\frac{1}{\left(1+\frac{K_D}{10^6}\cdot TSS\right)} \qquad (3)$$

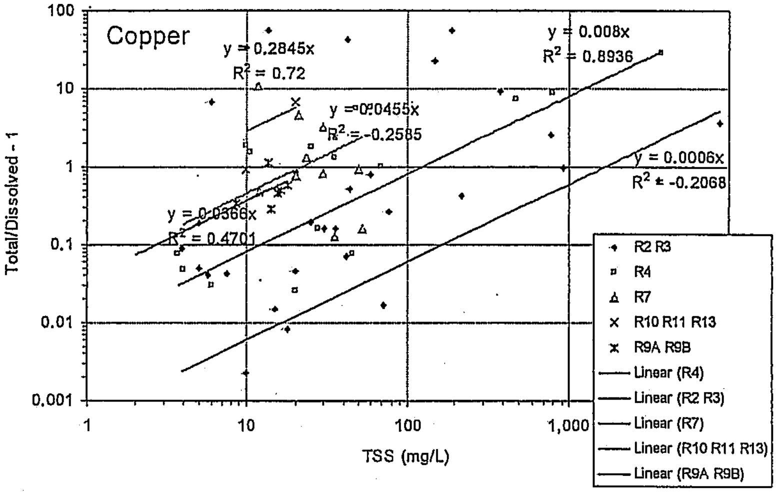

Figure 2: Regression Analysis for Copper KD in CCW.

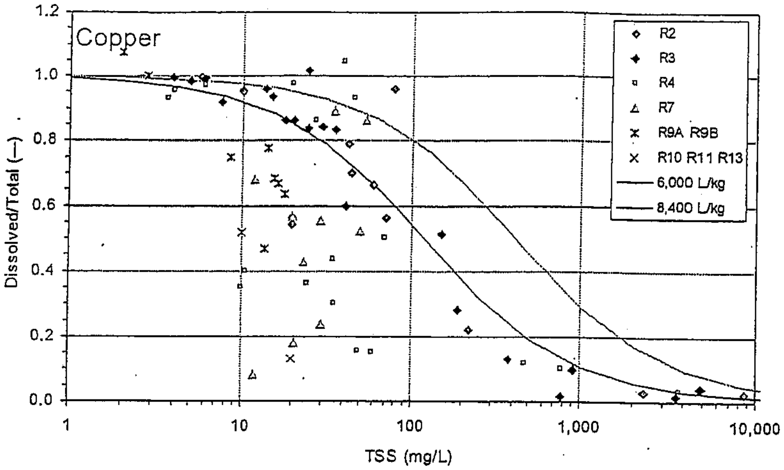

Figure 3: Measured and Theoretical (Equation 3) Dissolved to Total Copper Ratios for CCW.

Nickel

All available high quality data where TSS, and total and dissolved nickel are concurrently measured are plotted in the form of equation 2 on Figure 4. Data from different reaches are represented by different symbols. Data from the different reaches are regressed separately and the regression line, resulting equation, and correlation coefficient are plotted on the Figure. Note that the slope of the line corresponds to $K_D/10^6$. To present the data in a more intuitive form, Figure 5 is a presentation of the dissolved to total nickel ratio calculated from the data as a function of the measured TSS. By utilizing equation 3, the calibrated partition coefficients for nickel used in the CCWM are plotted in Figure 5 as lines. Only the maximum (6,200 L/kg) and minimum (2,200 L/kg) K_D used in the CCWM are plotted as the other values will simply plot between the two lines.

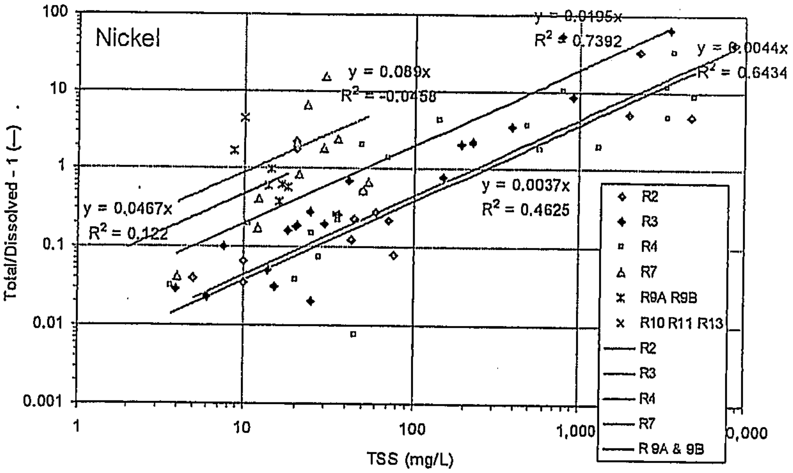

Figure 4: Regression Analysis for Nickel KD Values in CCW.

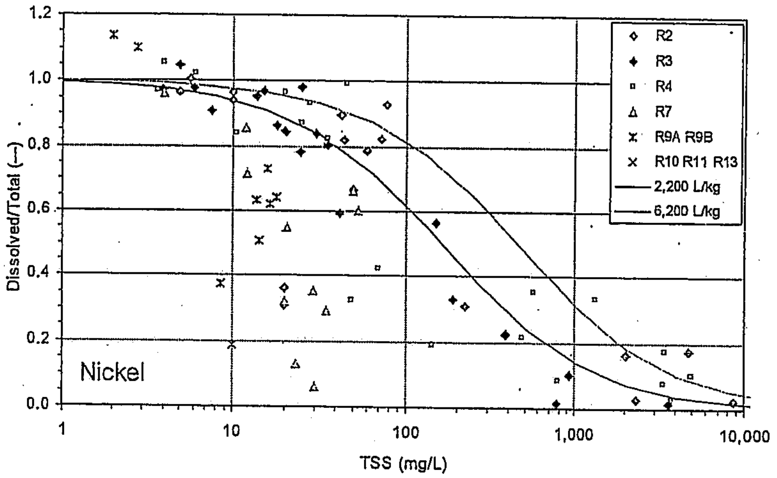

Figure 5: Measured and Theoretical (Equation 3) Dissolved to Total Nickel Ratios.

Mercury

All available high quality data where TSS, and total and dissolved mercury are concurrently measured are plotted in the form of equation 2 on Figure 6. Data from different reaches are represented by different symbols. Data from the different reaches are regressed separately and the regression line, resulting equation, and correlation coefficient are plotted on the Figure. Note that the slope of the line corresponds to $K_D/10^6$. To present the data in a more intuitive form, Figure 7 is a presentation of the dissolved to total mercury ratio calculated from the data as a function of the measured TSS. By utilizing equation 3, the calibrated partition coefficients for mercury used in the CCWM are plotted in Figure 7 as lines. Only the maximum (53,600 L/kg) and minimum (20,600 L/kg) K_D used in the CCWM are plotted as the other values will simply plot between the two lines.

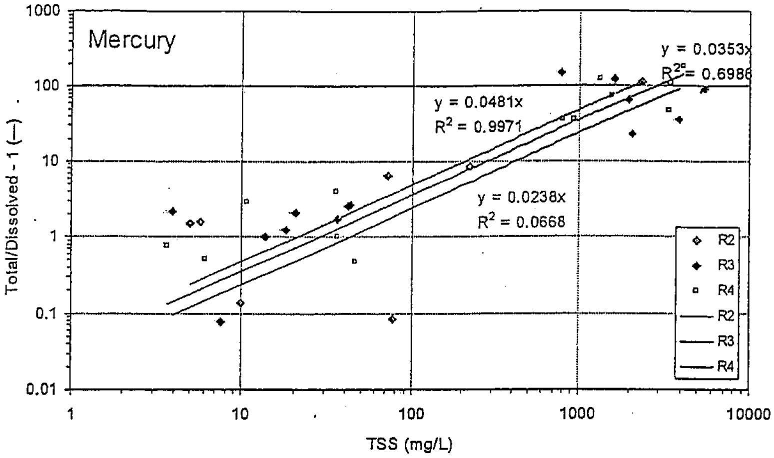

Figure 6: Regression Analysis for Mercury KD in the CCW.

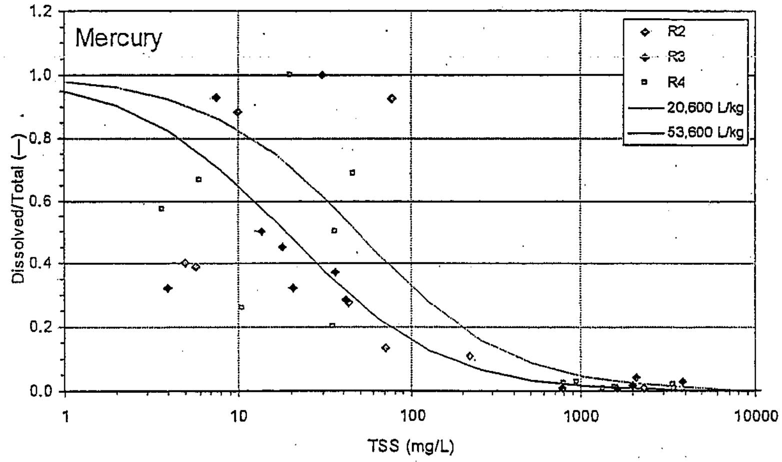

Figure 7: Measured and Theoretical (Equation 3) Dissolved to Total Mercury Ratios for CCW.

Selenium

All available high quality data where TSS, and total and dissolved selenium are concurrently measured are plotted in the form of equation 2 on Figure 8. Data from different reaches are represented by different symbols. Data from the different reaches are regressed separately and the regression line, resulting equation, and correlation coefficient are plotted on the Figure. Note that the slope of the line corresponds to $K_D/10^6$. To present the data in a more intuitive form, Figure 9 is a presentation of the dissolved to total selenium ratio calculated from the data as a function of the measured TSS. By utilizing equation 3, the calibrated partition coefficients for selenium used in the CCWM are plotted in Figure 9 as lines. Only the maximum (1,600 L/kg) and minimum (800 L/kg) K_Ds used in the CCWM are plotted as the other values will simply plot between the two lines.

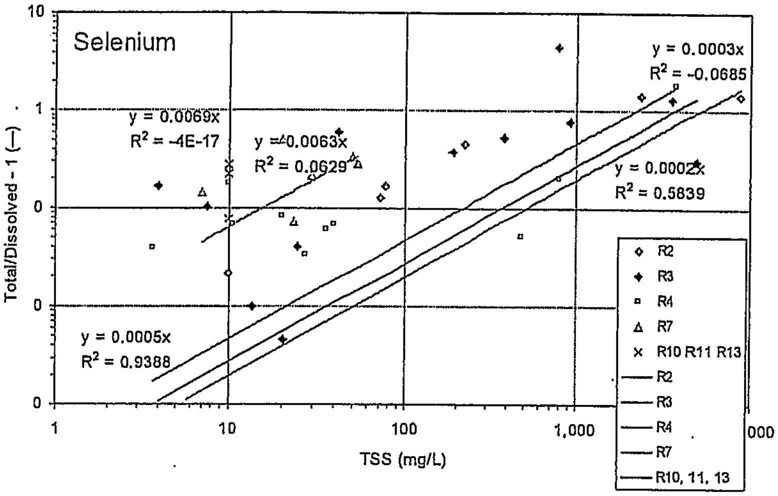

Figure 8: Regression Analysis for Selenium KD in the CCW.

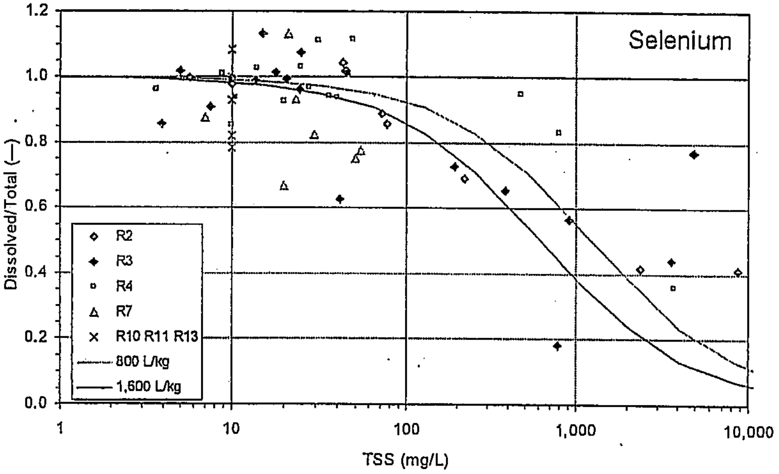

Figure 9: Measured and Theoretical (Equation 3) Dissolved to Total Selenium Ratios for the CCWM.

POTENCY FACTORS FOR METALS AND SELENIUM

The following is derived from the description in the HSPF user's manual (Bicknell, *et al.*, 2001). For particle associated constituents, HSPF is built on the assumption that the constituents are removed from the land surface in proportion to the sediment removal. Potency factors are the input variables that control the strength of the constituent relative to the sediment removed from the surface. For each constituent, separate potency factors are specified for association with washed off and scoured sediment. Typically, the washed off potency is greater then the scoured potency due to washed off sediments reflect a finer particle size fraction with a greater adsorption capacity.

Note that in addition to the sediment associated load there are contributions to the dissolved fraction to washoff via a general buildup factor and atmospheric deposition; interstitial flow; and groundwater exfiltration.

Copper

Open Space

All available copper potency data from open space are provided by the VCWPD characterization site in Ventura County but outside the CCW. CCWM open space copper washoff potency factors ranged from 0.1035 to 0.17 pounds copper per ton of sediment and scour potency factors ranged from 0.019 to 0.22 pounds copper per ton of sediment. Because of limited data, the values were determined largely through the calibration process.

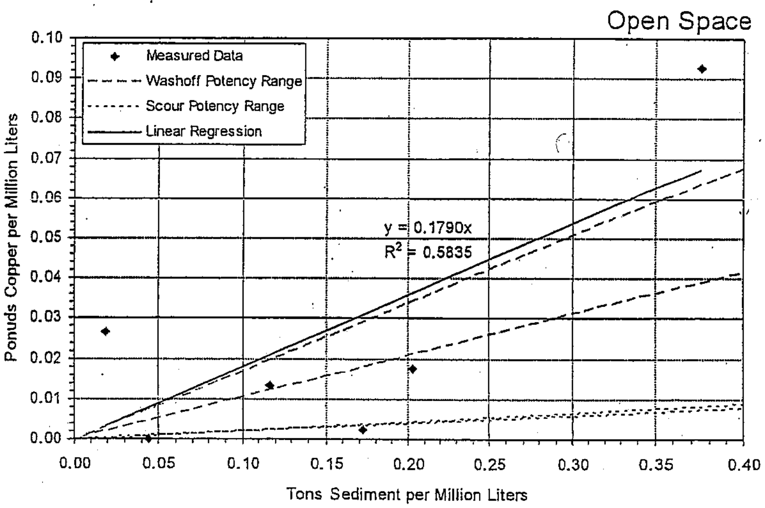

Figure 10: Copper Potency Data for Open Space Land Use With Ranges of Washoff and Scour Copper Potency used in the CCWM.

Agricultural

All but three copper potency data from agriculture are from Beardsley Wash and Revolon Slough. CCWM agricultural copper washoff potency factors ranged from 0.0872 to 0.2420 pounds copper per ton of sediment and scour potency factors ranged from 0.0372 to 0.0872 pounds copper per ton of sediment.

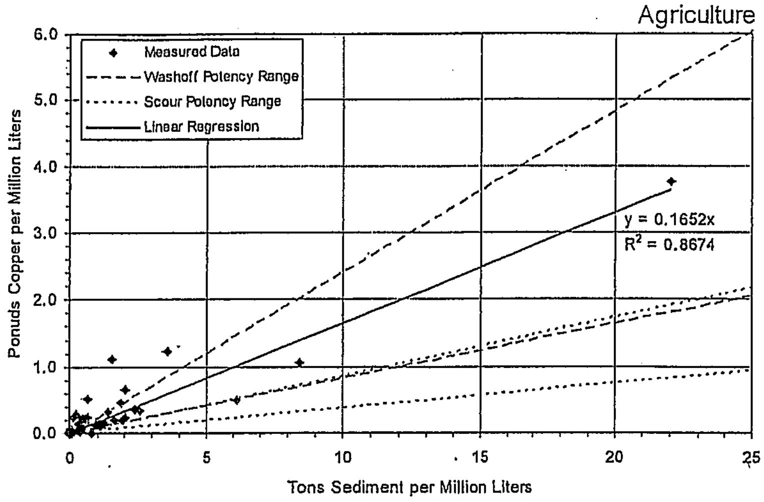

Figure 11: Copper Potency Data for Agricultural Land Use With Ranges of Washoff and Scour Copper Potency used in the CCWM.

Urban

Urban characterization sites are located both in CCW and outside the watershed in Ventura County. CCWM urban copper washoff potency factors ranged from 0.0603 to 0.2465 pounds copper per ton of sediment and scour potency factors ranged from 0.0272 to 0.0972 pounds copper per ton of sediment.

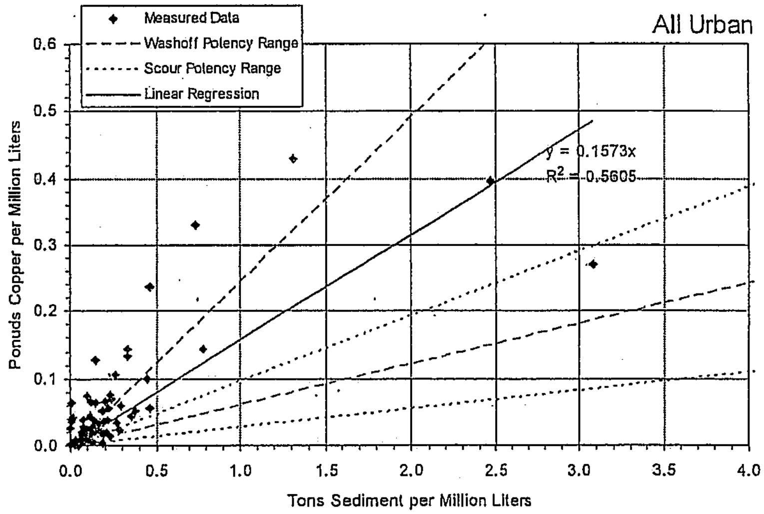

Figure 12: Copper Potency Data for All Urban Land Uses With Ranges of Washoff and Scour Copper Potency used in the CCWM .

Residential

Residential land use is a component of the total urban results presented above. Residential land use is a component of the total urban results presented above. The residential characterization sites are located outside the CCW in Ventura County. CCWM residential copper washoff potency factors ranged from 0.0603 to 0.242 pounds copper per ton of sediment and scour potency factors ranged from 0.0272 to 0.0972 pounds copper per ton of sediment.

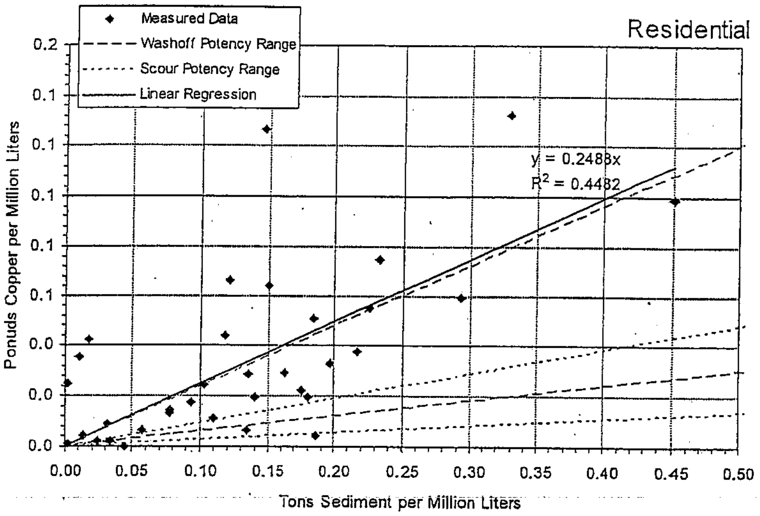

Figure 13: Copper Potency Data for Residential Land Use With Ranges of Washoff and Scour Copper Potency used in the CCWM.

Commercial and Industrial

Commercial and industrial land use is a component of the total urban results presented above. Commercial and industrial characterization sites are located both in CCW and outside the watershed in Ventura County. CCWM urban copper washoff potency factors ranged from 0.0820 to 0.2465 pounds copper per ton of sediment and scour potency factors ranged from 0.0272 to 0.0929 pounds copper per ton of sediment.

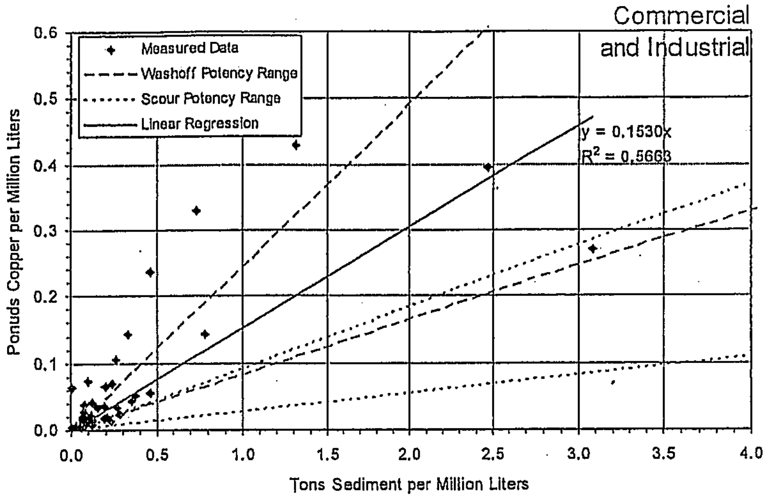

Figure 14: Copper Potency Data for Commercial and Industrial Land Use With Ranges of Washoff and Scour Copper Potency used in the CCWM.

Nickel

Open Space

All available nickel potency data from open space are provided by the VCWPD characterization site in Ventura County but outside the CCW. CCWM open space nickel washoff potency factors ranged from 0.012 to 0.12 pounds nickel per ton of sediment and scour potency factors ranged from 0.008 to 0.059 pounds nickel per ton of sediment. Because of limited data, the values were determined largely through the calibration process.

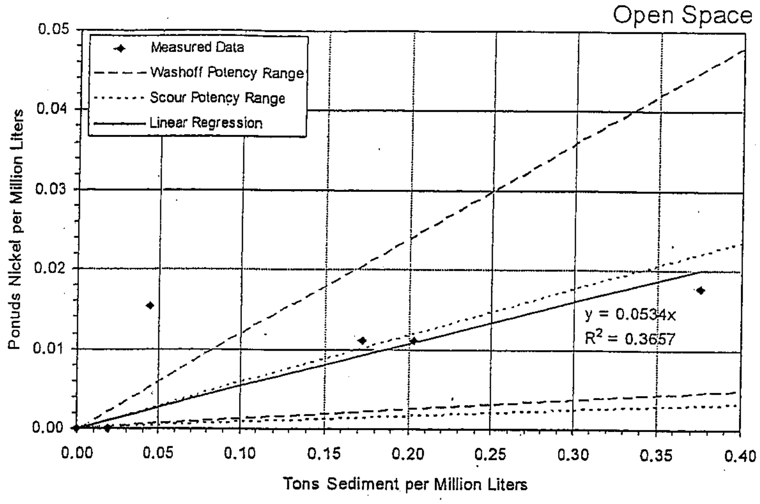

Figure 15: Nickel Potency Data for Open Space Land Use With Ranges of Washoff and Scour Potency used in the CCWM.

Agricultural

All but three nickel potency data from agriculture are from Beardsley Wash and Revolon Slough. CCWM agricultural nickel washoff potency factors ranged from 0.062 to 0.120 pounds nickel per ton of sediment and scour potency factors ranged from 0.029 to 0.059 pounds nickel per ton of sediment.

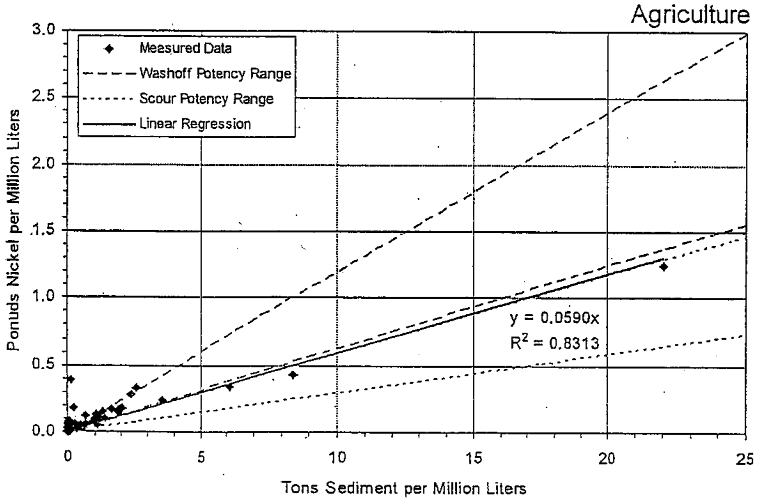

Figure 16: Copper Potency Data for Agricultural Land Use With Ranges of Washoff and Scour Copper Potency used in the CCWM.

Urban

Urban characterization sites are located both in CCW and outside the watershed in Ventura County. CCWM urban nickel washoff potency factors ranged from 0.012 to 0.120 pounds nickel per ton of sediment and scour potency factors ranged from 0.008 to 0.059 pounds nickel per ton of sediment.

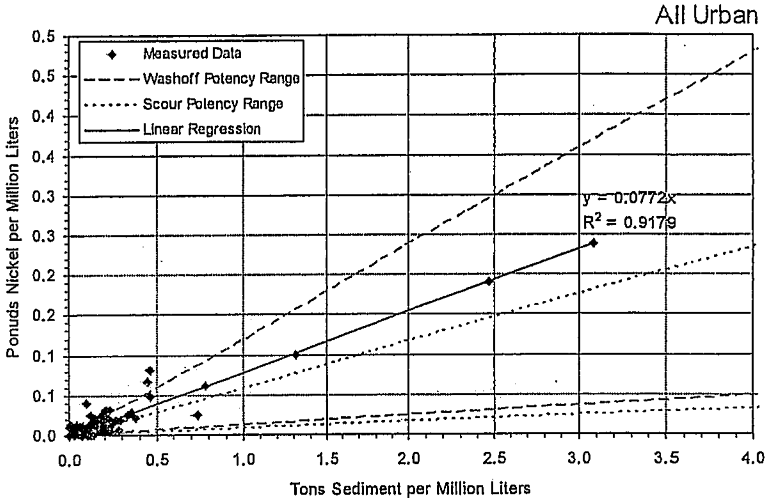

Figure 17: Nickel Potency Data for All Urban Land Uses With Ranges of Washoff and Scour Nickel Potency used in the CCWM.

Residential

Residential land use is a component of the total urban results presented above. The residential characterization sites are located outside the CCW in Ventura County. CCWM residential nickel washoff potency factors ranged from 0.012 to 0.120 pounds nickel per ton of sediment and scour potency factors ranged from 0.008 to 0.059 pounds nickel per ton of sediment.

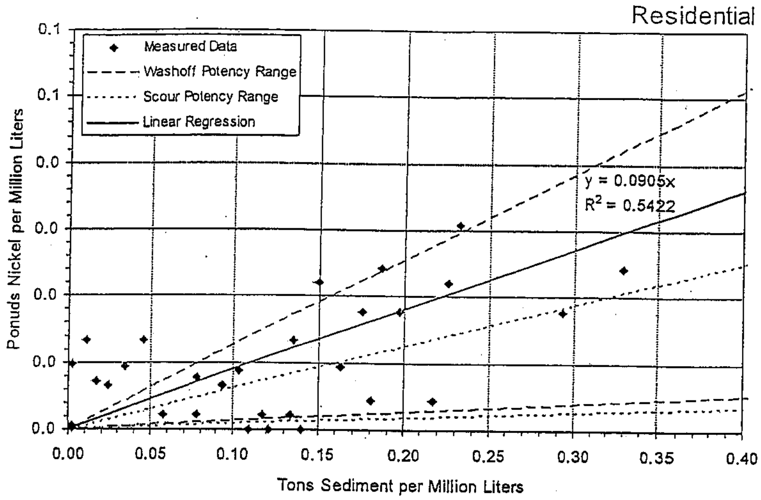

Figure 18: Nickel Potency Data for Residential Land Use With Ranges of Washoff and Scour Nickel Potency used in the CCWM.

Commercial and Industrial

Commercial and industrial land use is a component of the total urban results presented above. Commercial and industrial characterization sites are located both in CCW and outside the watershed in Ventura County. CCWM urban nickel washoff potency factors ranged from 0.012 to 0.120 pounds nickel per ton of sediment and scour potency factors ranged from 0.008 to 0.059 pounds nickel per ton of sediment.

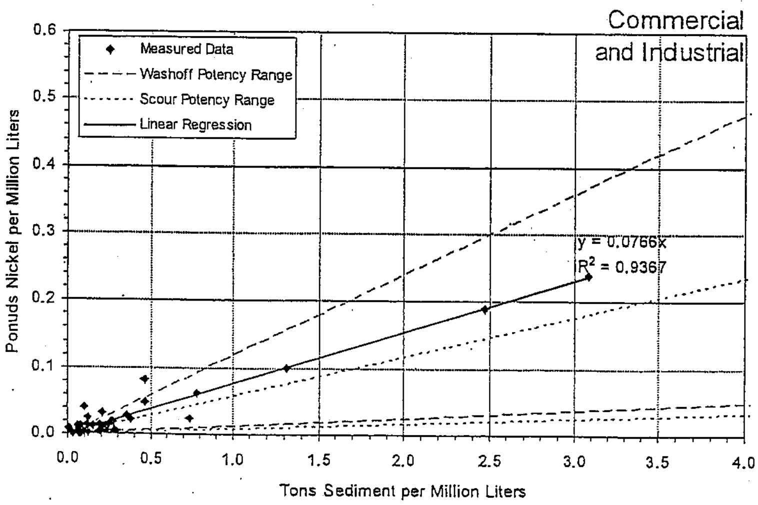

Figure 19: Nickel Potency Data for Commercial and Industrial Land Use With Ranges of Washoff and Scour Nickel Potency used in the CCWM.

Mercury

Open Space

All available mercury potency data from open space are provided by the VCWPD characterization site in Ventura County but outside the CCW. CCWM open space mercury washoff potency factors ranged from 0.000032 to 0.00022 pounds mercury per ton of sediment and scour potency factors ranged from 0.000001 to 0.000006 pounds mercury per ton of sediment. Because of limited data, the values were determined largely through the calibration process.

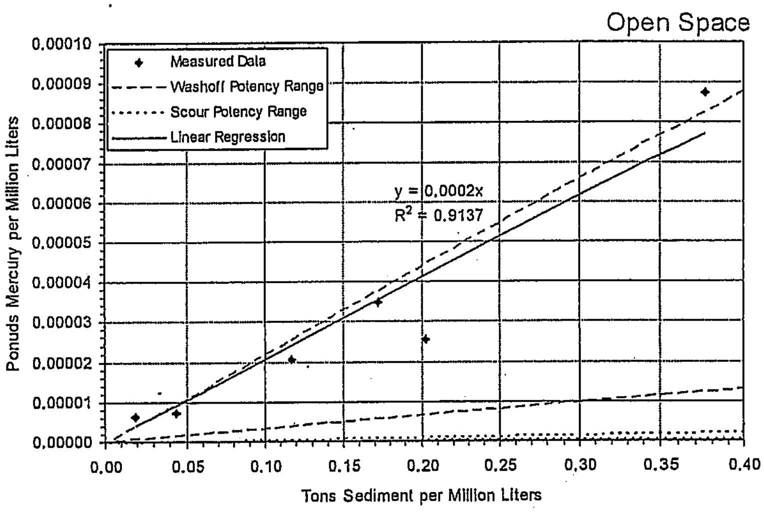

Figure 20: Mercury Potency Data for Open Space Land Use With Ranges of Washoff and Scour Potency used in the CCWM.

Agricultural

All data for agriculture mercury potency are from Beardsley Wash and Revolon Slough. CCWM agricultural mercury washoff potency factors ranged from 0.00001 to 0.000038 pounds mercury per ton of sediment and scour potency factors ranged from 0.000001 to 0.000005 pounds mercury per ton of sediment.

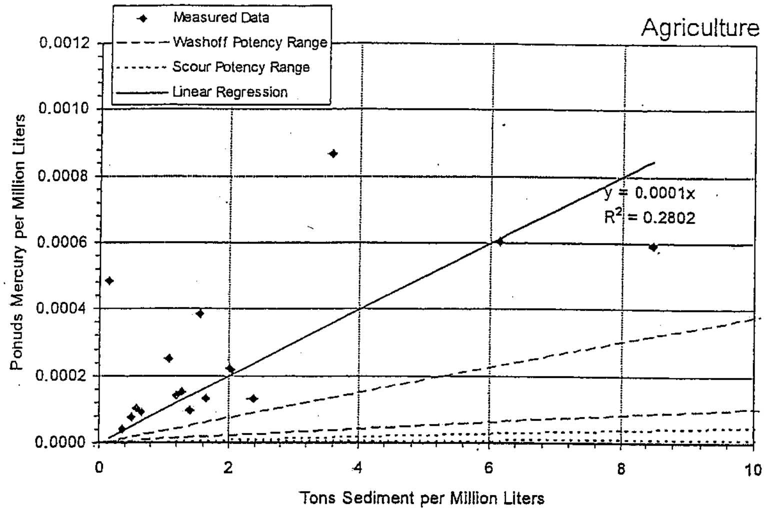

Figure 21: Mercury Potency Data for Agricultural Land Use With Ranges of Washoff and Scour Copper Potency used in the CCWM.

Urban

Urban characterization sites are located outside the watershed in Ventura County. CCWM urban mercury washoff potency factors ranged from 0.00001 to 0.000026 pounds mercury per ton of sediment and scour potency factors ranged from 0.000001 to 0.000006 pounds mercury per ton of sediment.

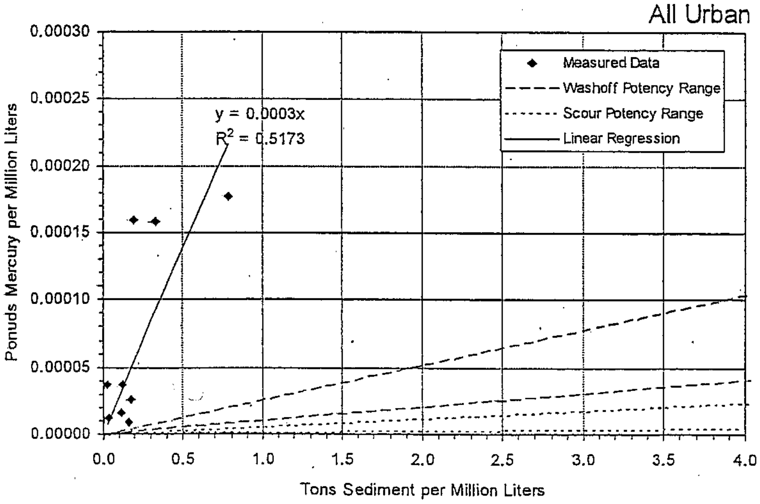

Figure 22: Mercury Potency Data for All Urban Land Uses With Ranges of Washoff and Scour Copper Potency used in the CCWM .

Residential

Residential land use is a component of the total urban results presented above. The residential characterization sites are located outside the CCW in Ventura County. CCWM residential mercury washoff potency factors ranged from 0.00001 to 0.000026 pounds mercury per ton of sediment and scour potency factors ranged from 0.000001 to 0.000006 pounds mercury per ton of sediment.

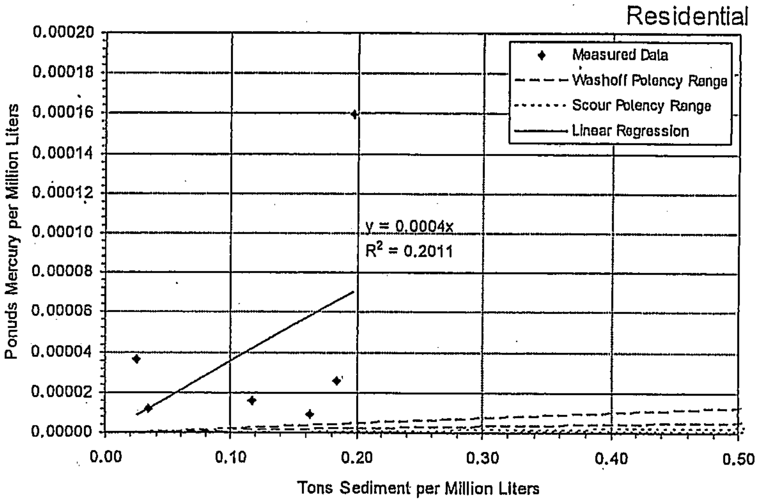

Figure 23: Mercury Potency Data for Residential Land Use With Ranges of Washoff and Scour Copper Potency used in the CCWM.

Commercial and Industrial

Commercial and industrial land use is a component of the total urban results presented above. Commercial and industrial characterization sites are located outside the watershed in Ventura County. CCWM urban mercury washoff potency factors ranged from 0.00001 to 0.000026 pounds mercury per ton of sediment and scour potency factors ranged from 0.000001 to 0.000006 pounds mercury per ton of sediment.

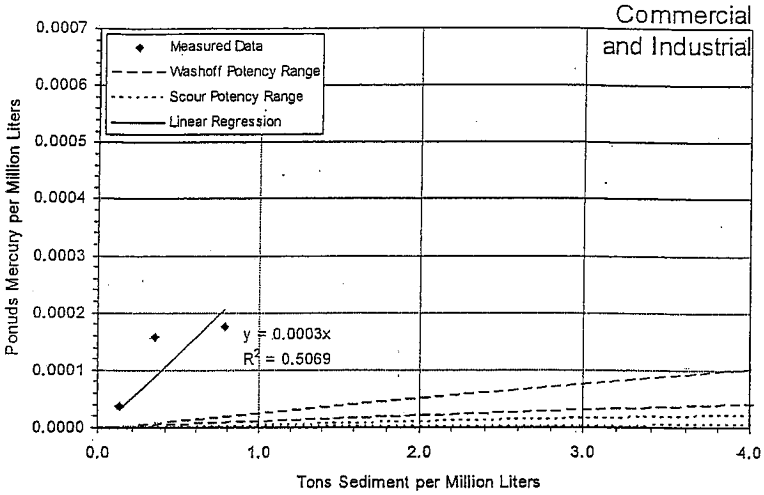

Figure 24: Mercury Potency Data for Commercial and Industrial Land Use With Ranges of Washoff and Scour Copper Potency used in the CCWM.

Selenium

Open Space

All available selenium potency data from open space are provided by the VCWPD characterization site in Ventura County but outside the CCW. CCWM open space selenium washoff potency factors ranged from 0.0045 to 0.0065 pounds selenium per ton of sediment and scour potency factors ranged from 0.00005 to 0.0008 pounds selenium per ton of sediment. Because of limited data, the values were determined largely through the calibration process.

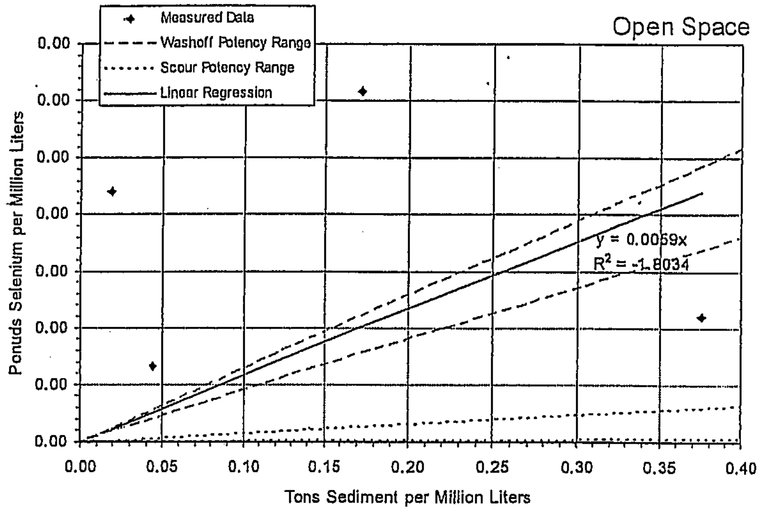

Figure 25: Selenium Potency Data for Open Space Land Use With Ranges of Washoff and Scour Potency used in the CCWM..

Agricultural

Selenium potency data from agriculture are from Beardsley Wash and Revolon Slough. CCWM agricultural selenium washoff potency factors ranged from 0.00075 to 0.0045 pounds selenium per ton of sediment and scour potency factors ranged from 0.000005 to 0.00008 pounds selenium per ton of sediment.

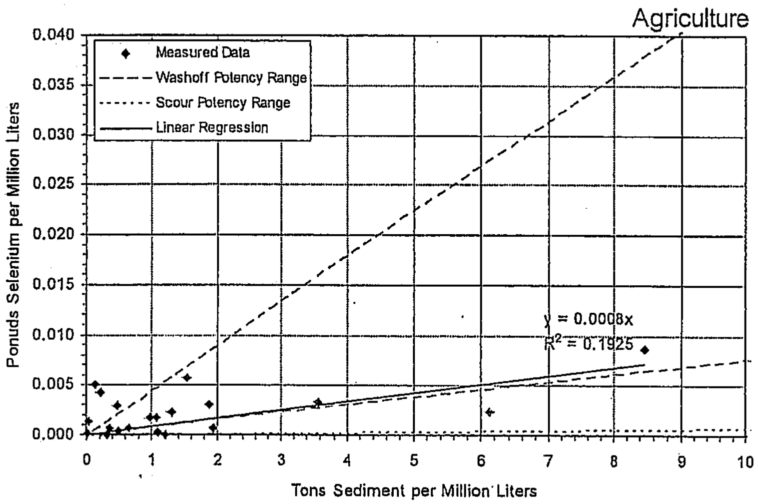

Figure 26: Selenium Potency Data for Agricultural Land Use With Ranges of Washoff and Scour Copper Potency used in the CCWM.

Urban

Urban characterization sites are located both in CCW and outside the watershed in Ventura County. CCWM urban selenium washoff potency factors ranged from 0.00015 to 0.0045 pounds selenium per ton of sediment and scour potency factors ranged from 0.00005 to 0.0008 pounds selenium per ton of sediment.

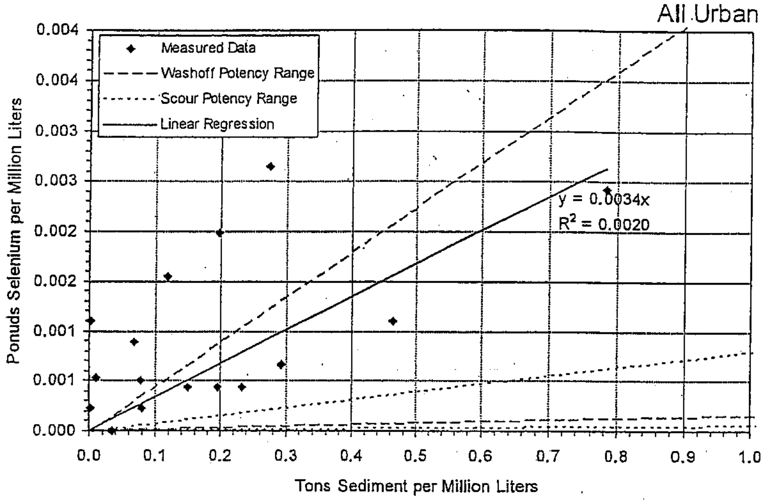

Figure 27: Selenium Potency Data for All Urban Land Uses With Ranges of Washoff and Scour Copper Potency used in the CCWM .

Residential

Residential land use is a component of the total urban results presented above. The residential characterization sites are located outside the CCW in Ventura County. CCWM residential selenium washoff potency factors ranged from 0.00015 to 0.0045 pounds selenium per ton of sediment and scour potency factors ranged from 0.00005 to 0.0008 pounds selenium per ton of sediment.

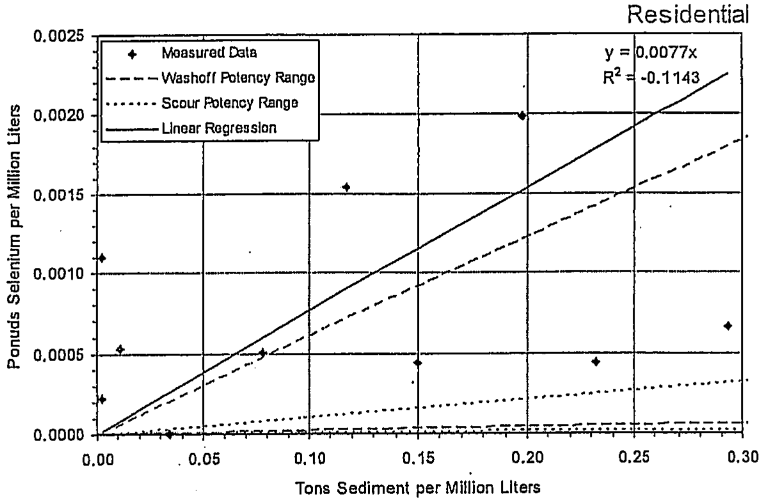

Figure 28: Selenium Potency Data for Residential Land Use With Ranges of Washoff and Scour Copper Potency used in the CCWM.

Commercial and Industrial

Commercial and industrial land use is a component of the total urban results presented above. Commercial and industrial characterization sites are located both in CCW and outside the watershed in Ventura County. CCWM urban selenium washoff potency factors ranged from 0.0015 to 0.0045 pounds selenium per ton of sediment and scour potency factors ranged from 0.00005 to 0.0008 pounds selenium per ton of sediment.

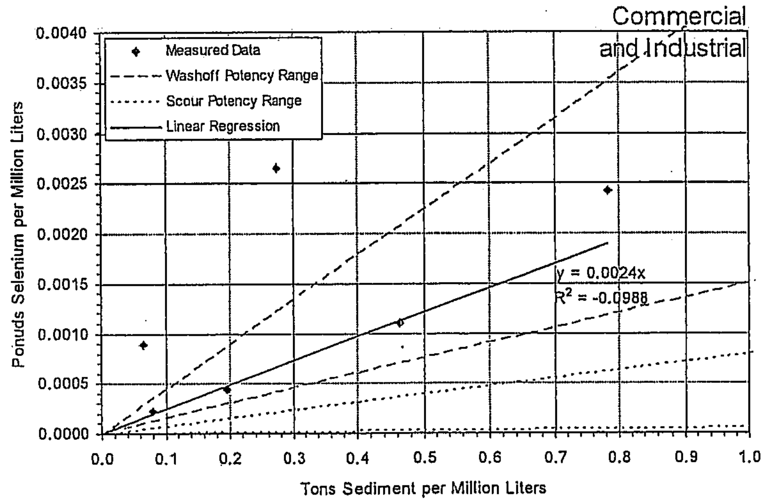

Figure 29: Selenium Potency Data for Commercial and Industrial Land Use With Ranges of Washoff and Scour Copper Potency used in the CCWM.

MODEL RESULTS

Because many of the monitoring locations in the watershed have limited detected data or have data corresponding limit range of environmental conditions, only three sites are discussed in detail below. Time series plots of model output compared to available monitoring data are presented for all applicable sites in the model linkage analysis report (LWA, 2005c).

As per the weight of evidence evaluation of the CCWM, model output is compared to measured data in various formats for each of the constituents simulated for development of the TMDL. For each of the constituents, graphical evaluations are preformed by time series plots and statistical evaluation is performed via linear regression of paired simulated and measured values. Additional graphical tests for copper and nickel are provided by plotting measured and modeled dissolved fraction vs measured and modeled total. Additional graphical tests for mercury and selenium are provided by plotting the measured and modeled total constituent vs the modeled flowrate. In these additional tests, the modeled results are blue open diamonds and the measured values are pink rectangles. Note that in most cases the model tends to match the pattern of measured data well but in general overestimates (i.e. provides a conservative estimate) the concentrations.

In addition to the graphical and statistical tests presented below, a component of the weight of evidence evaluation is a comparison the relative percent differences between paired measured and modeled values. According to Donigian (2002), the standard tolerances of toxics for HSPF applications are < 20% indicate very good fit, 20 – 30% indicate a good fit, and 30 – 40 % indicate a fair fit. The tolerances are the same for sediment with the exception of the 30 – 45 % indicate a fair fit. The ranges presented are the mean differences and individual observations may have larger differences. Adjustment to the ranges may be made on the consideration of quality and quantity of data, purpose of modeling, availability of alternate model, and resources availability (time, money, and personnel). The average of calculated tolerances for the calibration sites are presented in Table 2. Note that the percentages presented in Table 2 are not absolute value and are calculated so that positive numbers correspond to the CCWM estimating larger concentrations than measured. Calculated ranges of the relative percent differences (RPDs) are listed in Table 2. The overall percentage is the average of all paired data from the three sites. In general the CCWM over estimates each of the constituents except nickel. Because the mercury concentrations are consistently overestimated the overall assessment is deemed poor. The remaining constituents range from fair to very good. Note that with the exception of nickel, the overall assessment for each constituent is that the CCWM over predicts receiving water concentrations reflecting the conservative modeling approach and implicit margin of safety.

Table 2: Relative Percent Differences Between Measured and Modeled Values for the Calibration Sites.

Constituent	RPD (%) [1] CCPCH	 CCPot	 RSWood	 Overall	Overall Assessment
Total Suspended Solids	(-199,194) -2	(-198,199) 3	(-199,199) 51	(-199,199) 12	Fair
Total Copper	(-44,160) 34	(-110,181) 23	(-74,182) 43	(-110,182) 31	Fair - Good
Dissolved Copper	(-75,75) 16	(-48,50) 21	(-67,113) 17	(-75,113) 18	Fair - Good
Total Nickel	(-72,196) 17	(-80,169) 15	(-149,190) 47	(-149,196) 23	Very Good
Dissolved Nickel	(-81,80) -2	(-73,67) 10	(-66,148) 41	(-81,148) 15	Good
Total Mercury	(-28,199) 107	(-164,196) 74	(-146,211) 40	(-164,211) 70	Poor
Total Selenium	(-72,146) 32	(-83,152) 52	(-94,190) 68	(--94,190) 55	Fair

[1] Values in parentheses Indicate the range of RPD and the average is listed next to the range.

Total Suspended Solids

Time series of measured and modeled total suspended solids (TSS) are presented in Figures 30, 32, and 34 for the three calibration stations. Comparisons plots of the modeled vs. measured concentrations of TSS are presented in Figures 31, 33, and 35. In general the pattern of the time series data are matched by the CCWM, but the concentrations of TSS are over-predicted.

In Chang (2004), data is presented indicating that the wash load (finer sediment) is slightly greater than bed load (coarser sediment) for the CCW. Estimates of total wash and bed load for the entire watershed calculated by the NRCS in conjunction with the SCS are 220,074 ton/yr and 192.031 ton/yr, respectively. The CCWM are consistent with the estimates presented in Chang (2004). There is significant variation of sediment yield between years because storm events are responsible for the majority of sediment transport, and the rainfall amount and intensity is variable between years. Sediment yields calculated in Chang (2004) are compared to CCWM calculations for the whole Calleguas Creek and Revolon Slough subwatersheds in Figures 36 and 37, respectively. The horizontal line is the NRC/SCS estimate of sediment yield and the symbols correspond to the CCWM annual sediment yield. Inspection of the figures reveals that the CCWM calculations are consistent with the NRC/SCS estimates.

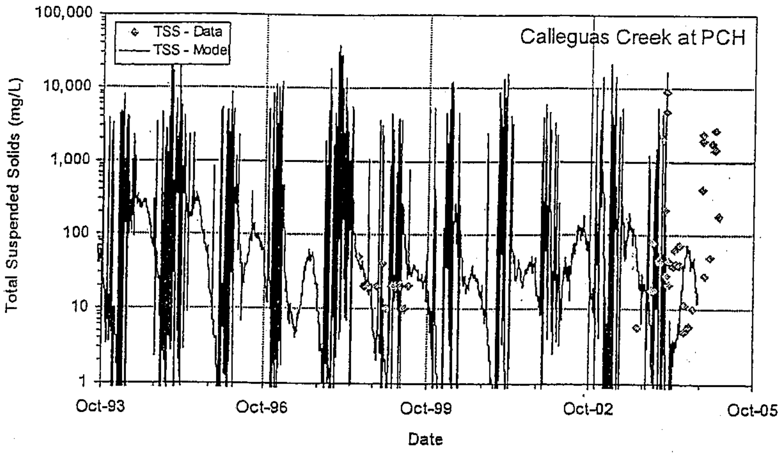

Figure 30: Time Series of Measured and Modeled Total Suspended Solids for Calleguas Creek at PCH.

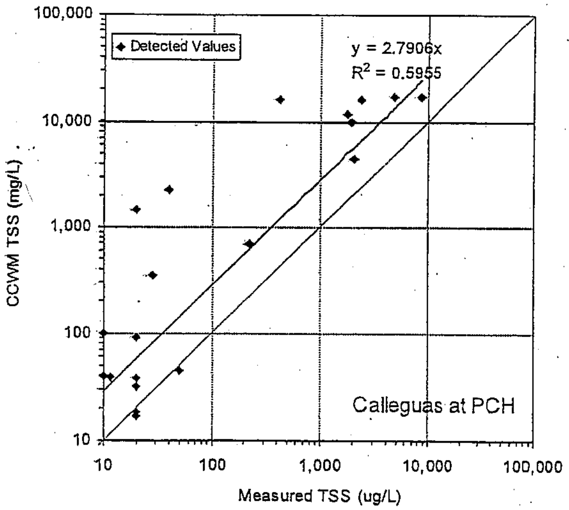

Figure 31: Measured vs. Modeled Total Suspended Solids Concentrations for Calleguas Creek at PCH.

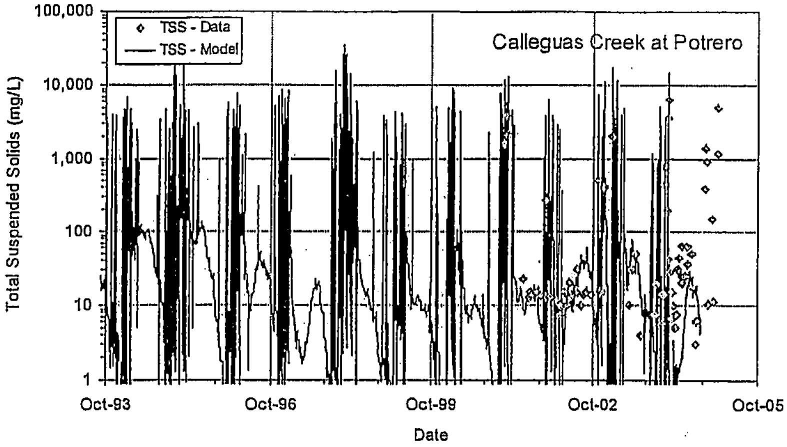

Figure 32: Time Series of Measured and Modeled Total Suspended Solids for Calleguas Creek at Potrero.

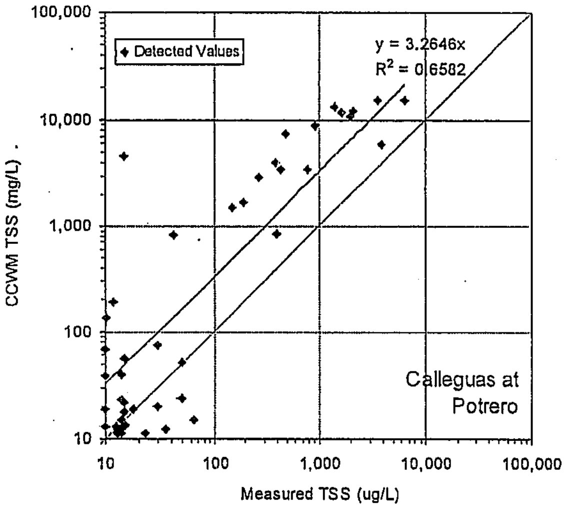

Figure 33: Measured vs. Modeled Total Suspended Solids for Calleguas at Potrero.

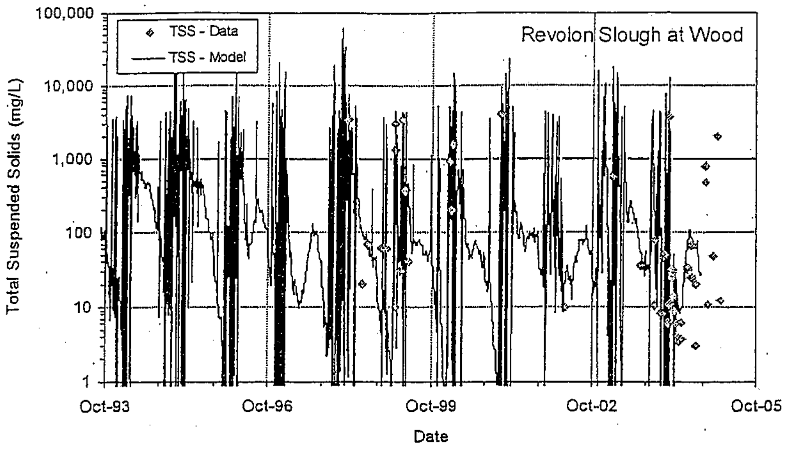

Figure 34: Time Series of Total Suspended Solids for Revolon Slough at Wood.

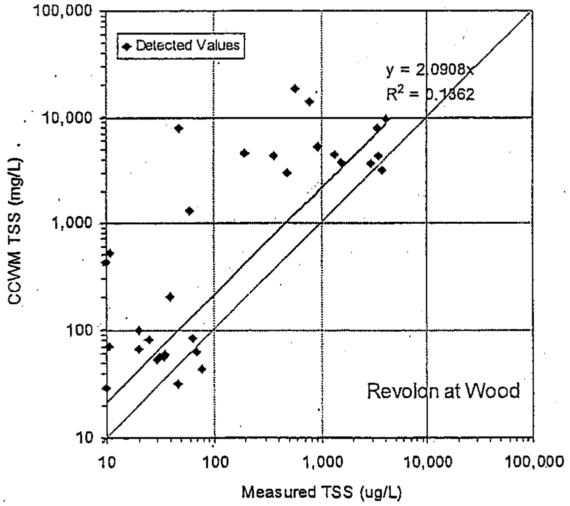

Figure 35: Measured vs. Modeled Total Suspended Solids Concentrations for Revolon at Wood.

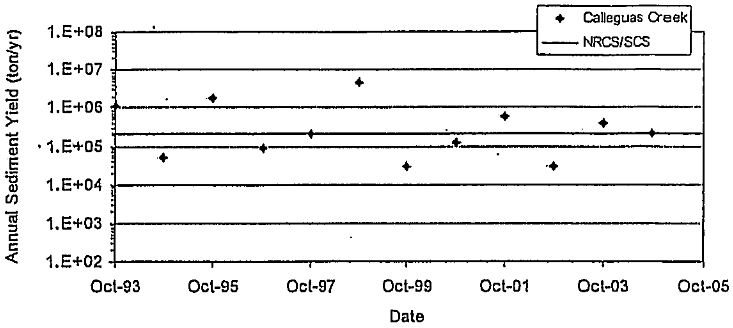

Figure 36: Estimated and Modeled Annual Sediment Yield for Calleguas Creek Subwatershed.

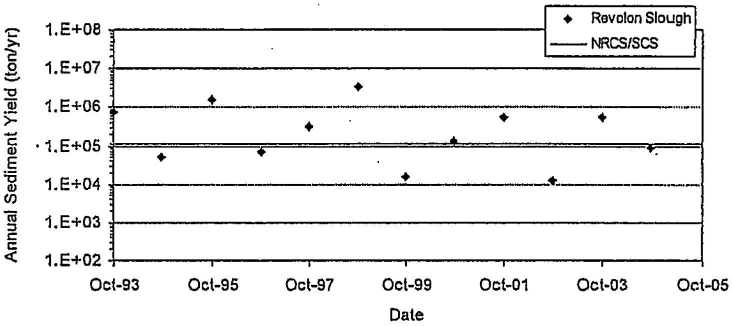

Figure 37: Estimated and Modeled Annual Sediment Yield for Revolon Slough Subwatershed.

Copper

Four plots are presented at each of the sites considered to display the CCWM output in comparison to the measured data. Time series plots of total and dissolved copper display the CCWM output and measured data in an overall context where the patterns in the data should be evaluated. Following the time series plots are plots comparing the modeled total copper to the measured total copper, and the modeled dissolved copper to the measured dissolved copper. The measured and modeled dissolved fraction to total concentration (translator) are both plotted against the TSS concentration as a check on the partitioning. Regression lines are provided on these two plots as a guide to how well the discrete calculations match the observations. For regression lines with slopes greater than 1.0 the model, in the overall sum of squares sense, over predicts concentrations. As they are regression lines, these measures are heavily influenced by the high values. In the case of dissolved measurements, because the range in concentrations is small in comparison other parameters in the model, the results are more cluster-like than line-like and the regression coefficients are negative indicating the average is a better estimator of the measured to modeled results than a line. As the slopes on the dissolved plots approach 1.0, the average of the model results approaches the average of the observed data indicating better performance by the model.

Results for Calleguas Creek at PCH are presented in Figures 38 to 42. Results for Calleguas

Creek at Potrero are presented in Figures 43 to 47. Results for Revolon Slough at Wood are presented in Figures 48 to 52.

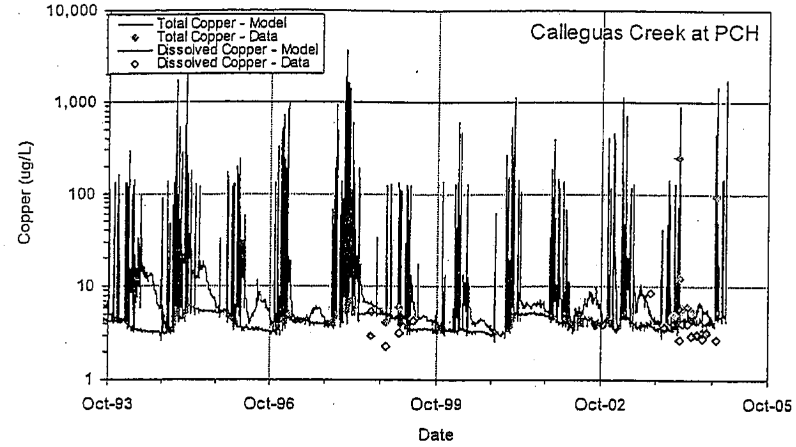

Figure 38: Time Series of Total and Dissolved CCWM output and Available Monitoring Data for Calleguas Creek at PCH.

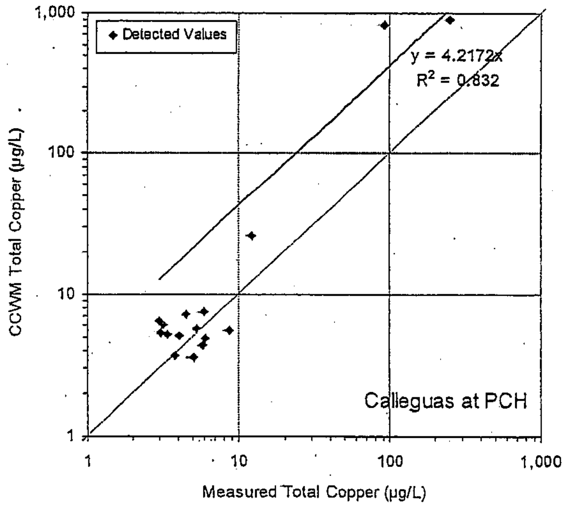

Figure 39: Modeled vs Measured Total Copper in Calleguas Creek at PCH.

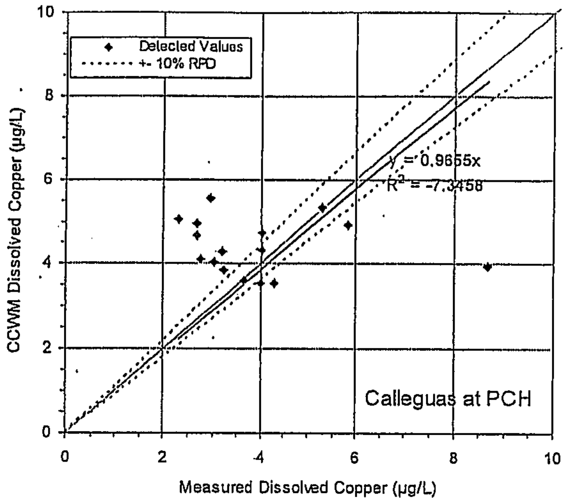

Figure 40: Modeled vs Measured Dissolved Copper in Calleguas Creek at PCH.

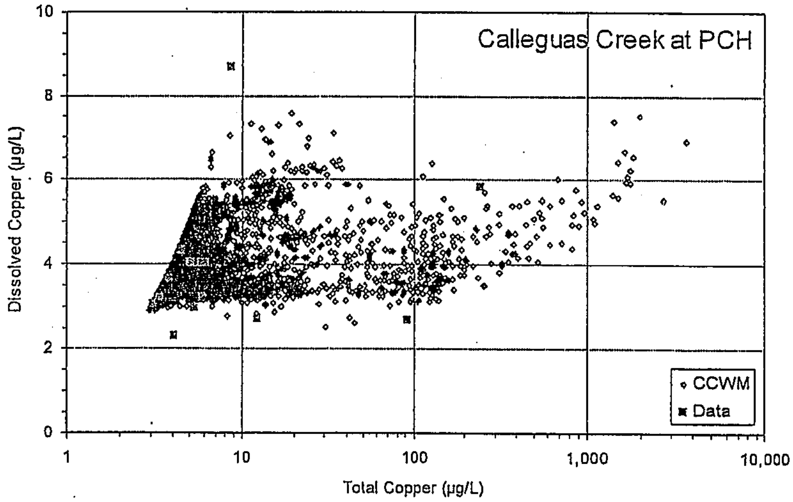

Figure 41: Measured and Modeled Dissolved vs. Total Copper Concentrations for Calleguas Creek at PCH.

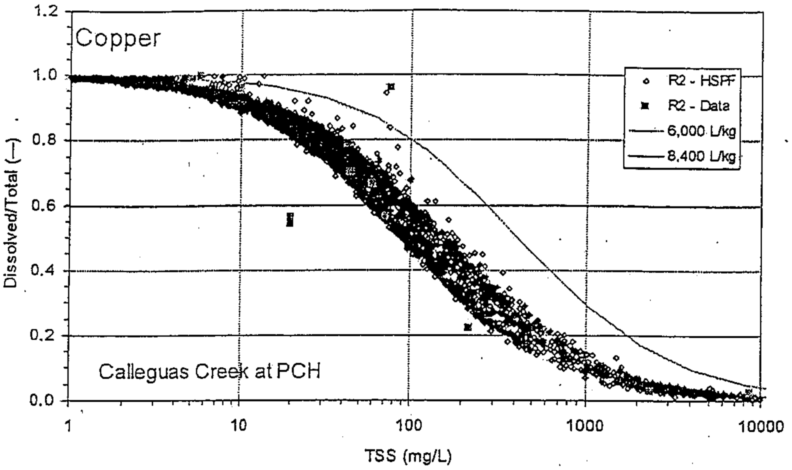

Figure 42: Measured and Modeled Dissolved Fraction to Total Copper Ratio for Calleguas Creek at PCH.

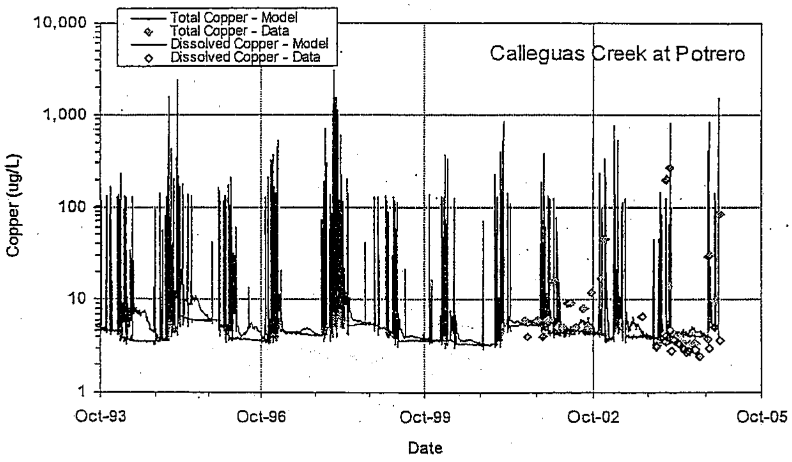

Figure 43: Time Series of Total and Dissolved CCWM output and Available Monitoring Data for Calleguas Creek at Potrero.

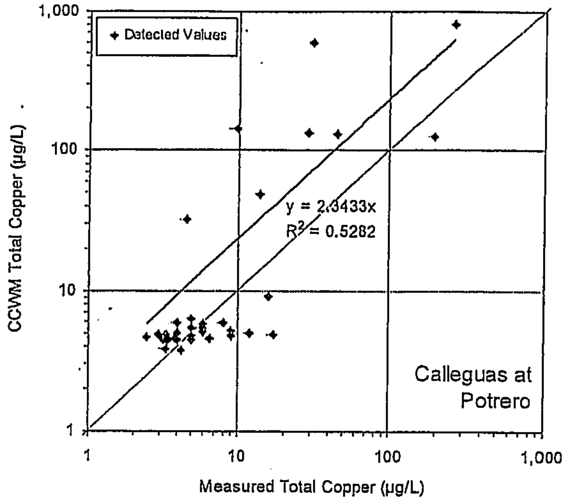

Figure 44: Modeled vs Measured Total Copper in Calleguas Creek at Potrero.

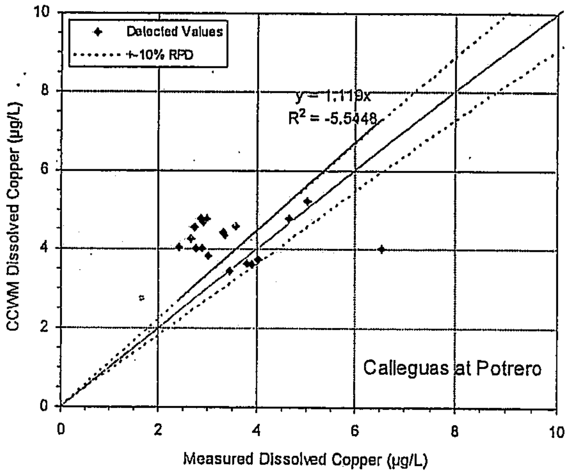

Figure 45: Modeled vs Measured Dissolved Copper in Calleguas Creek at Potrero.

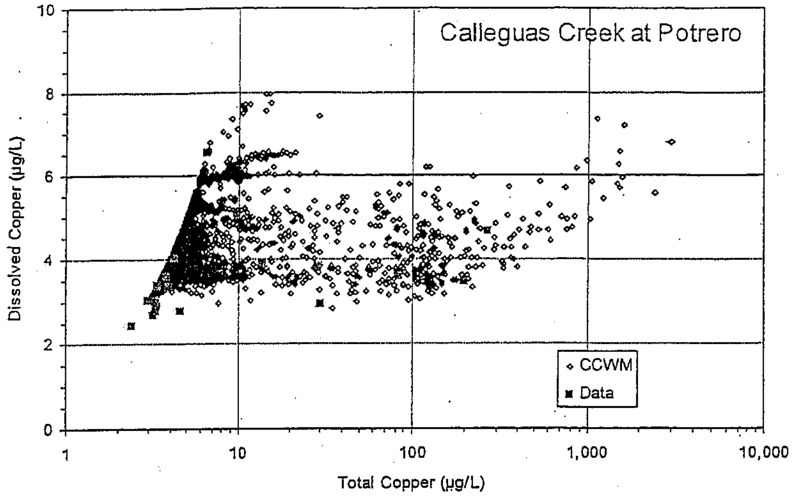

Figure 46: Modeled and Measured Dissolved vs Total Copper for Calleguas Creek at Potrero.

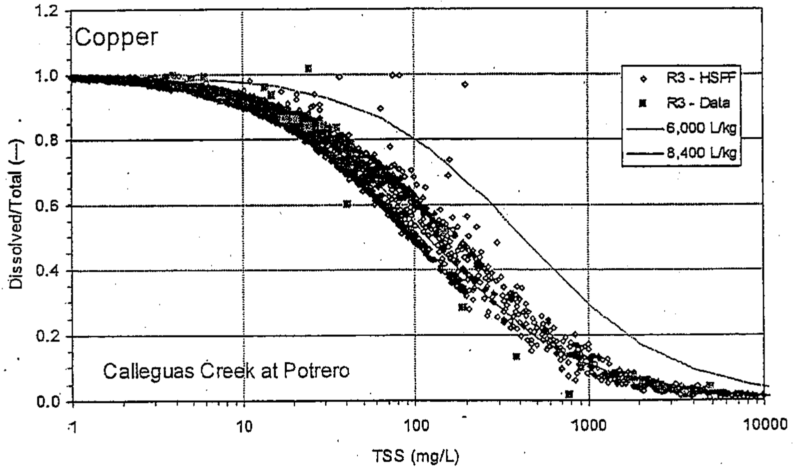

Figure 47: Measured and Modeled Dissolved Fraction to Total Copper Ratio for Calleguas Creek at Potrero.

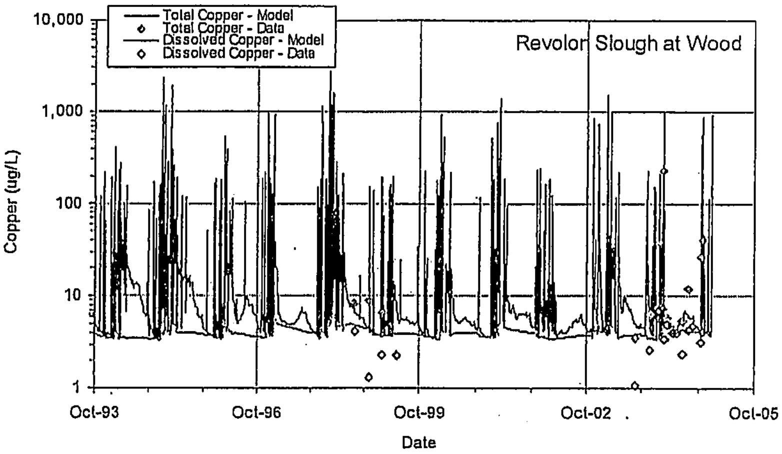

Figure 48: Time Series of Total and Dissolved CCWM output and Available Monitoring Data for Revolon Slough at Wood.

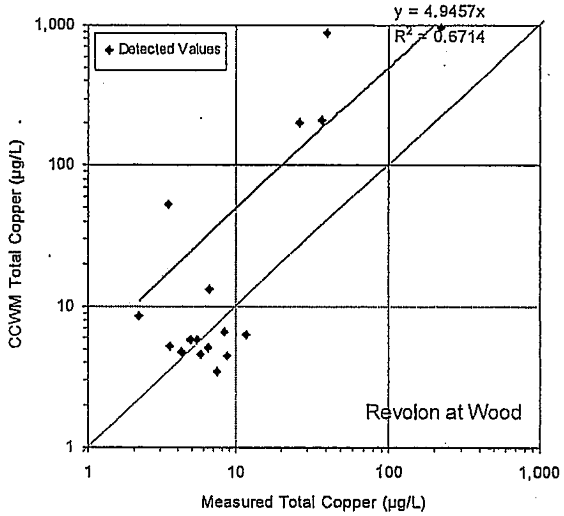

Figure 49: Modeled vs Measured Total Copper in Revolon at Wood

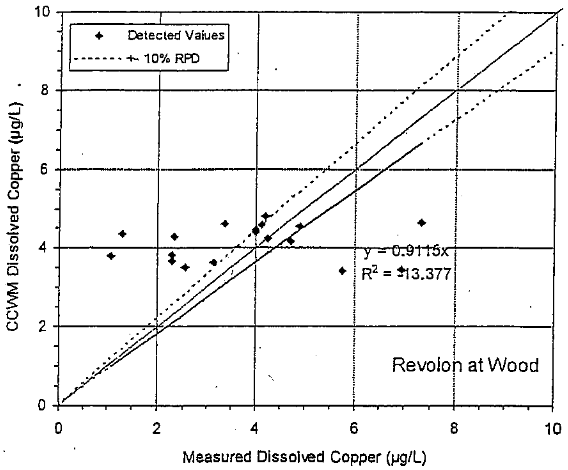

Figure 50: Modeled vs Measured Dissolved Copper in Revolon Slough at Wood

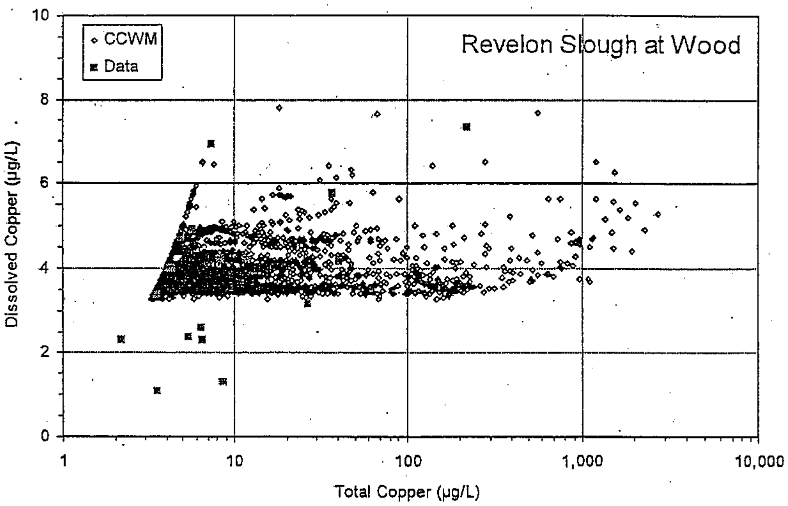

Figure 51: Measured and Modeled Dissolved Copper for Corresponding Total Copper in Revolon Slough at Wood.

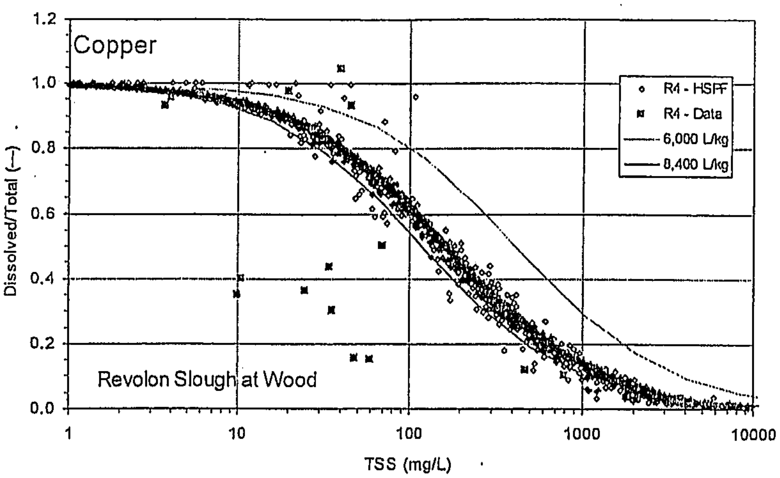

Figure 52: Measured and Modeled Dissolved Fraction to Total Copper Ratios for Revolon Slough at Wood.

Nickel

Four plots are presented at each of the sites considered to display the CCWM output for nickel in comparison to the measured data. Time series plots of total and dissolved nickel display the CCWM output and measured data in an overall context where the patterns in the data should be evaluated. Following the time series plots are plots comparing the modeled total nickel to the measured total nickel, and the modeled dissolved nickel to the measured dissolved nickel. The measured and modeled dissolved fraction to total concentration (translator) are both plotted against the TSS concentration as a check on the partitioning. Regression lines are provided on these two plots as a guide to how well the discrete calculations match the observations. For regression lines with slopes greater than 1.0 the model, in the overall sum of squares sense, over predicts concentrations. As they are regression lines, these measures are heavily influenced by the high values. In the case of dissolved measurements, because the range in concentrations is small in comparison other parameters in the model, the results are more cluster-like than line-like and the regression coefficients are negative indicating the average is a better estimator of the measured to modeled results than a line. As the slopes on the dissolved plots approach 1.0, the average of the model results approaches the average of the observed data indicating better performance by the model. However, the dissolved regression results are influenced by a limited data, and high values in Calleguas Creek. For Calleguas Creek at Potrero, there are several total nickel data but no corresponding dissolved data for dates earlier than October 2002. From inspection of the plots, the model calculation of total nickel for pre-October 2002 match the data better than more recent dates, and presumably, dissolved would match better as well because the dissolved concentration has to be less than the total. If the high points are removed from the dissolved nickel Calleguas sites the regression slopes change to 0.99 and 1.12 for PCH, and Potrero, respectively.

Results for Calleguas Creek at PCH are presented in Figures 53 to 57. Results for Calleguas Creek at Potrero are presented in Figures 58 to 62. Results for Revolon Slough at Wood are presented in Figures 63 to 67.

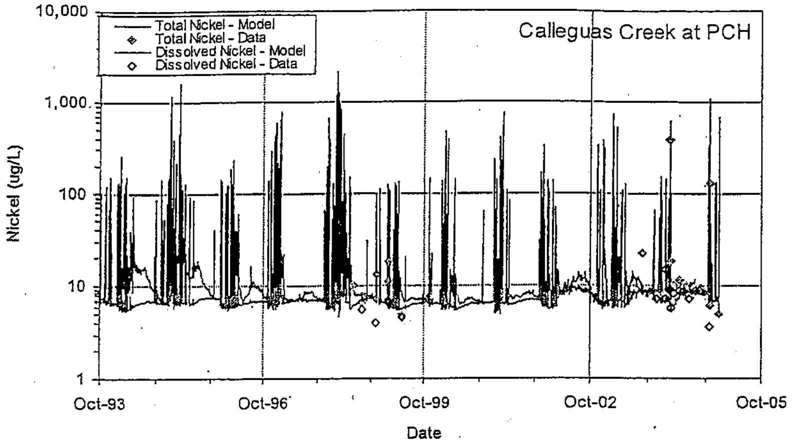

Figure 53: Time Series of Modeled and Monitored Total and Dissolved Nickel for Callegas Creek at PCH.

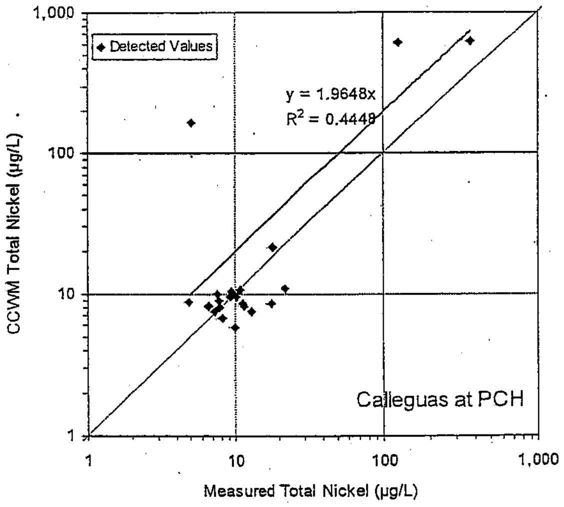

Figure 54: Modeled vs Measured Total Nickel in Calleguas Creek at PCH.

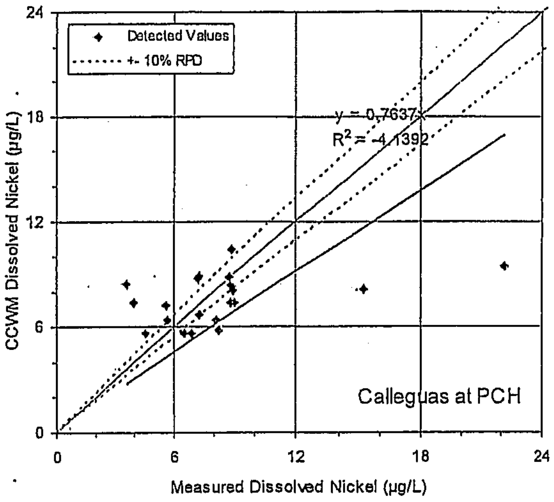

Figure 55: Modeled vs Measured Dissolved Nickel in Calleguas Creek at PCH.

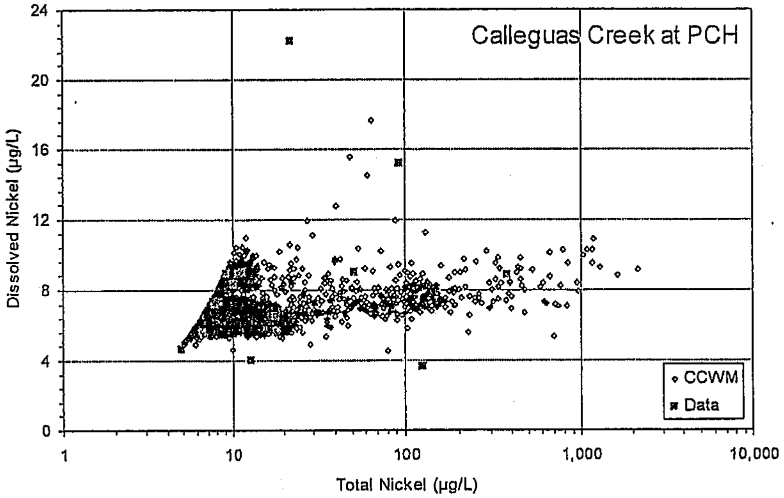

Figure 56: Measured and Modeled Dissolved vs. Total Nickel for Calleguas Creek at PCH.

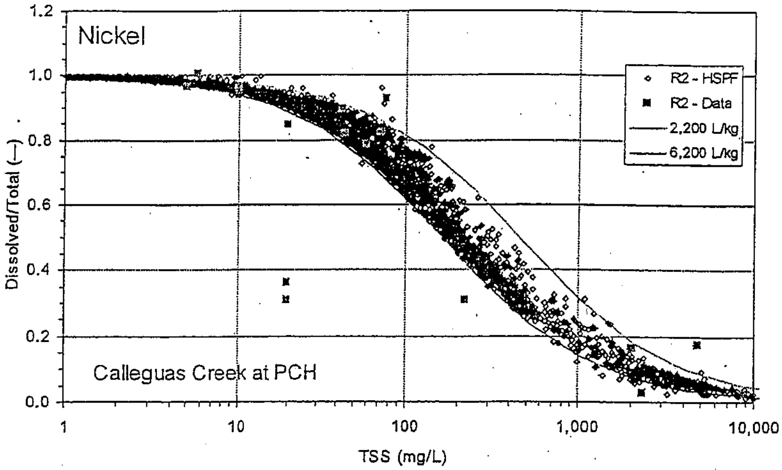

Figure 57: Measured and Modeled Dissolved Fraction to Total Nickel Ratios as a Function of TSS for Calleguas Creek at PCH.

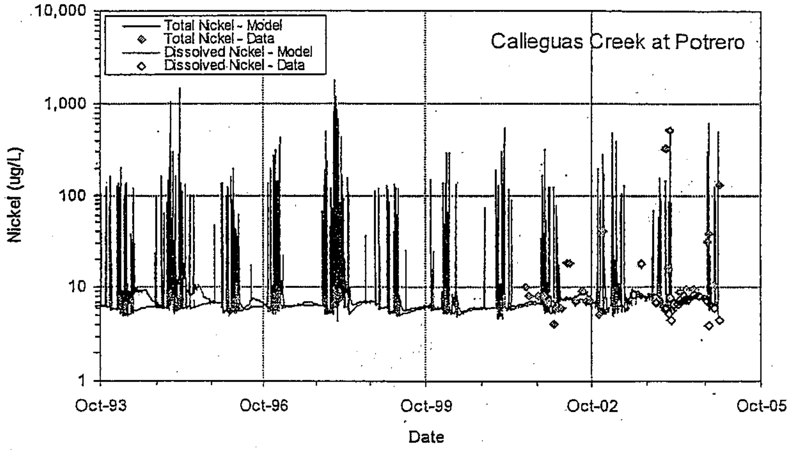

Figure 58: Time Series of Modeled and Monitored Total and Dissolved Nickel for Calleguas Creek at Potrero.

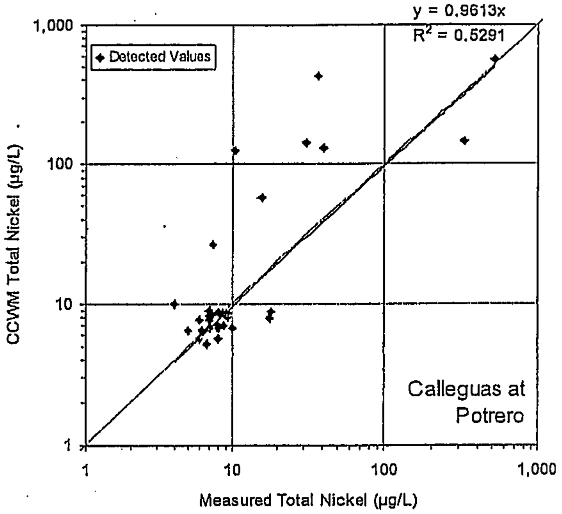

Figure 59: Modeled vs Measured Total Nickel in Calleguas Creek at Potrero.

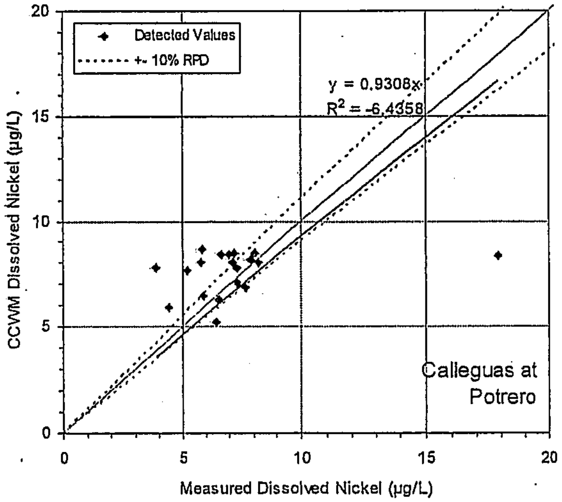

Figure 60: Modeled vs Measured Dissolved Nickel in Calleguas Creek at Potrero.

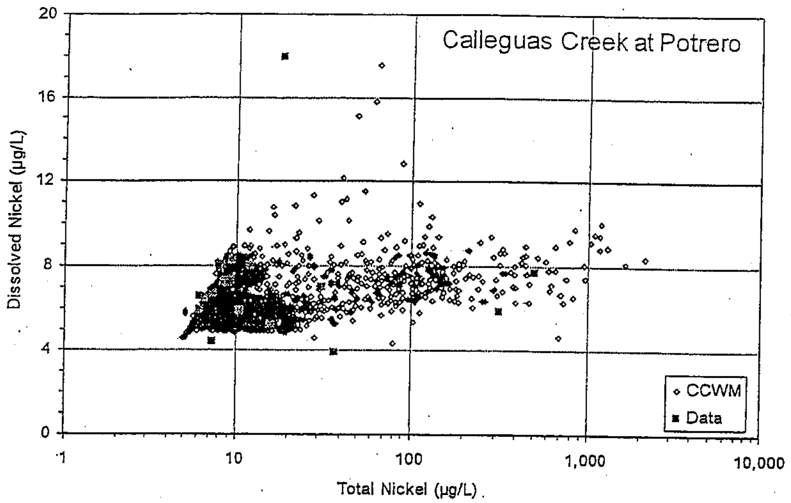

Figure 61: Measured and Modeled Dissolved vs. Total Nickel Concentrations for Calleguas at Potrero.

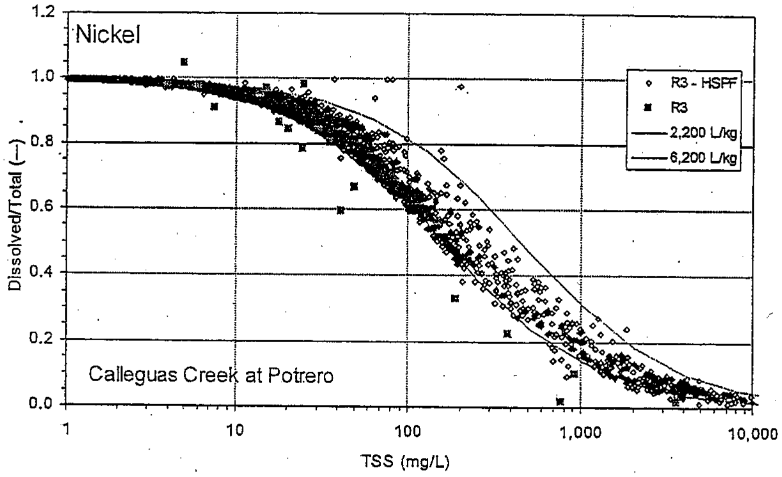

Figure 62: Measured and Modeled Dissolved Fraction to Total Nickel Ratio as a Function of TSS for Calleguas Creek at Potrero.

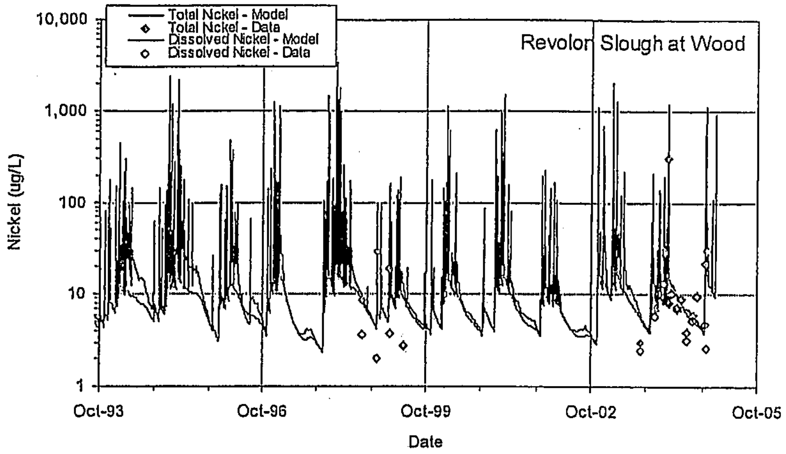

Figure 63: Time Series of Modeled and Monitored Total and Dissolved Nickel for Revolon Slough at Wood.

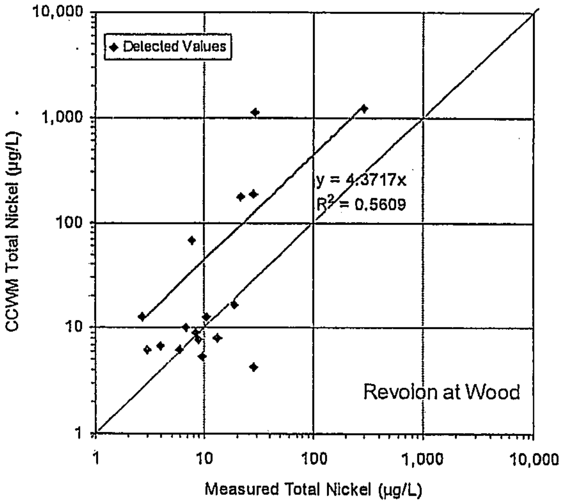

Figure 64: Modeled vs Measured Total Nickel in Revolon at Wood.

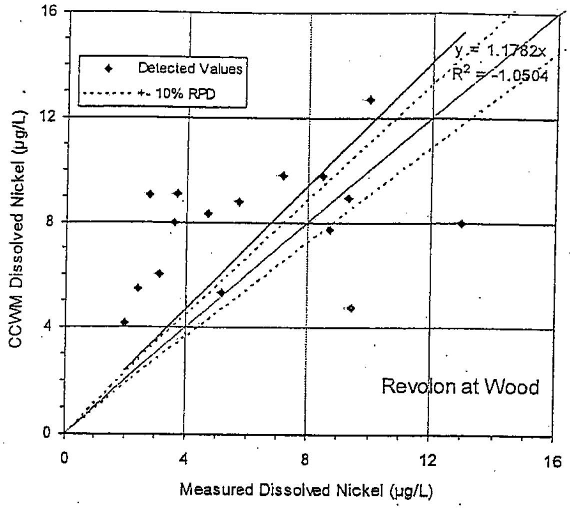

Figure 65: Modeled vs Measured Dissolved Nickel in Revolon Slough at Wood.

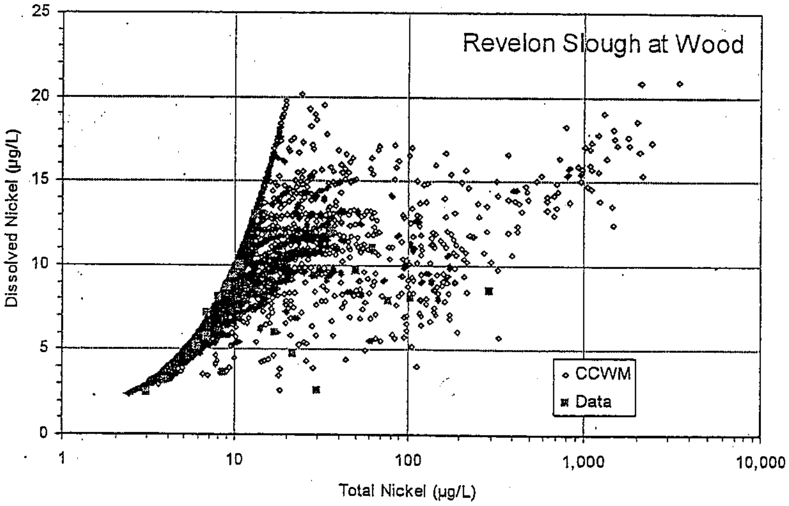

Figure 66: Measured and Modeled Dissolved vs. Total Nickel Concentrations for Revolon Slough at Wood.

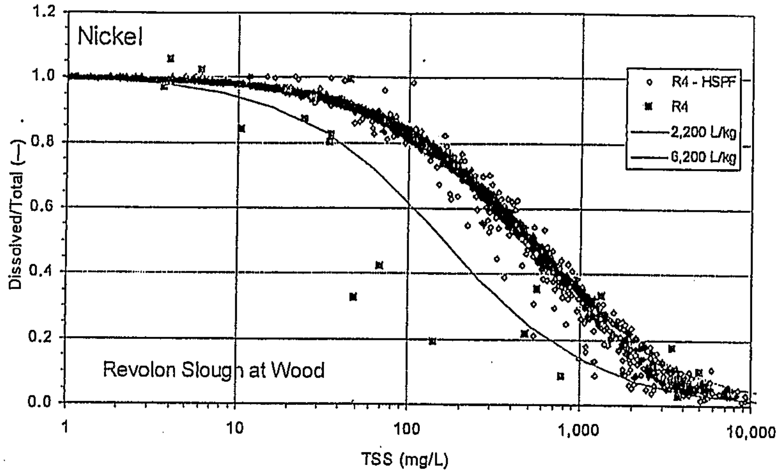

Figure 67: Measured and Modeled Dissolved Fraction to Total Nickel Ratios as a Function of TSS for Revolon Slough at Wood.

Mercury

Three types of plots are presented for each calibration site; the time series of measured and modeled total mercury, modeled vs measured total mercury with regression, and measured and modeled total nickel as a function of modeled receiving water flowrate. Time series plots of total mercury display the CCWM output and measured data in an overall context where the patterns in the data should be evaluated. Regression lines are provided on the modeled vs. measured plots as a guide to how well the discrete calculations match the observations. For regression lines with slopes greater than 1.0 the model, in the overall sum of squares sense, over predicts concentrations. As they are regression lines, these measures are heavily influenced by the high values. The measured and modeled total mercury plotted against receiving water flowrate allow comparison to how well the model will calculate loads of mercury. In general the model will overpredict total mercury concentrations, however the patterns of model output match patterns of field measurements.

Because of the multiplying effect of conservative modeling for all constituents, the CCWM calculates mercury concentrations considerably greater than observed.

Results for Calleguas Creek at PCH are presented in Figures 68 to 70. Results for Calleguas Creek at Potrero are presented in Figures 71 to 73. Results for Revolon Slough at Wood are presented in Figures 74 to 76.

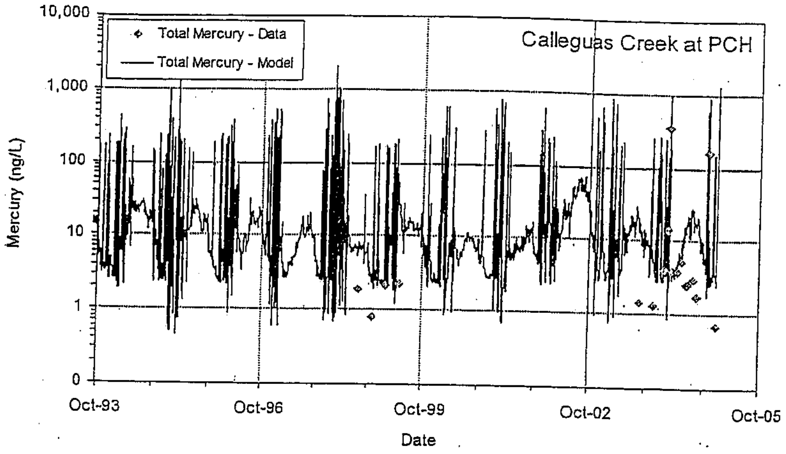

Figure 68: Time Series of CCWM Output and Measured Total Mercury for Calleguas Creek at PCH.

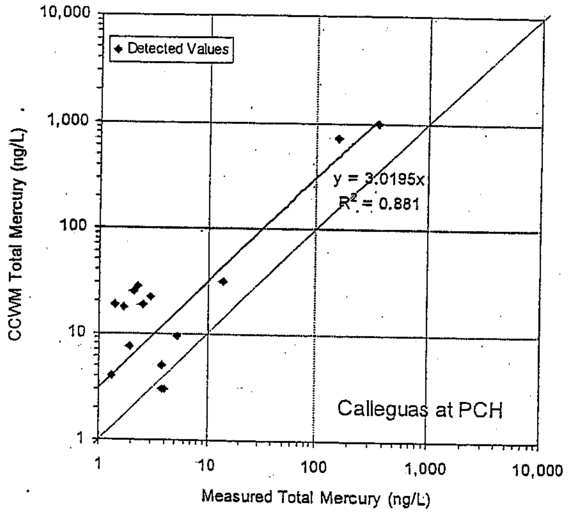

Figure 69: Modeled vs Measured Total Mercury in Calleguas Creek at PCH.

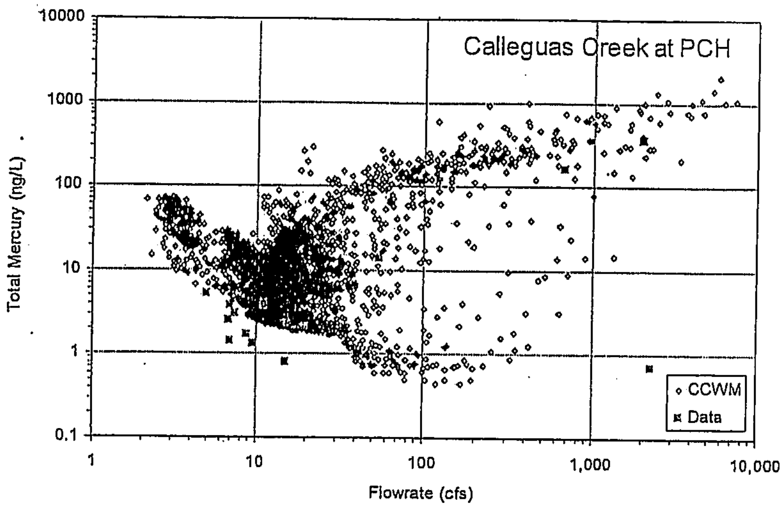

Figure 70: Measured and Modeled Total Mercury for Modeled Flowrates at Calleguas Creek at PCH.

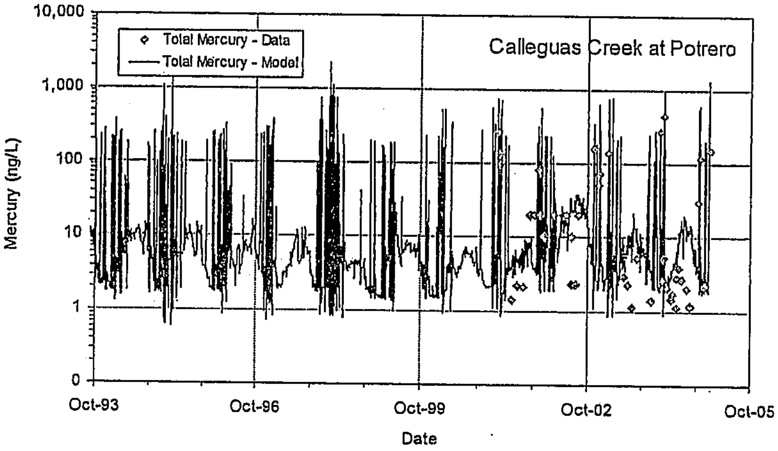

Figure 71: Time Series of CCWM Output and Measured Total Mercury for Calleguas Creek at Potrero.

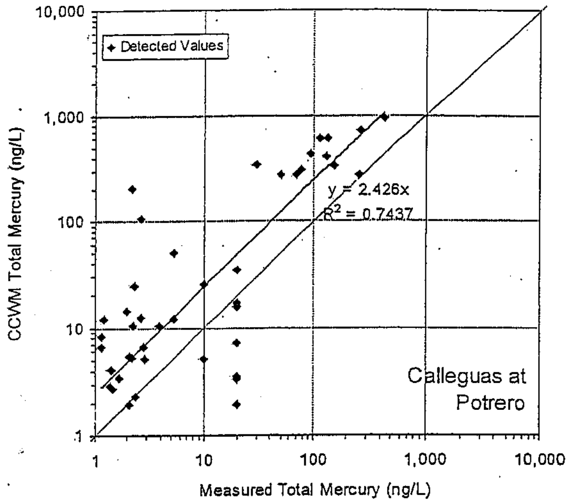

Figure 72: Modeled vs Measured Total Mercury in Calleguas Creek at Potrero.

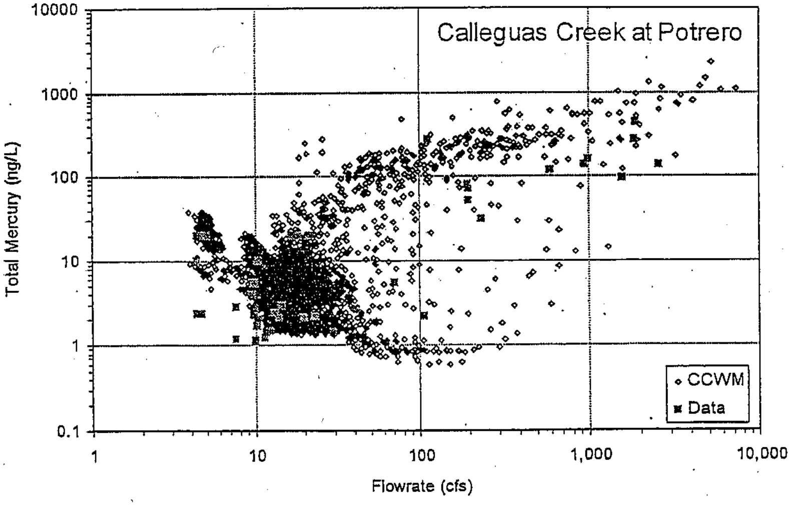

Figure 73: Measure and Modeled Total Mercury for Modeled Flowrate at Calleguas at Potrero.

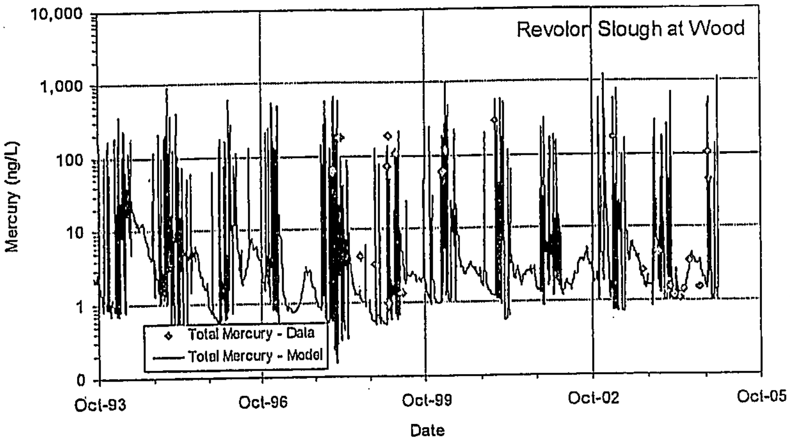

Figure 74: Time Series of CCWM Output and Measured Total Mercury for Revolon Slough at Wood.

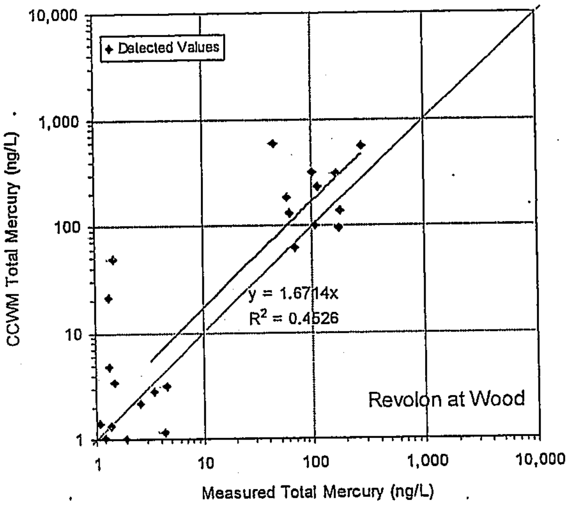

Figure 75: Modeled vs Measured Total Mercury in Revolon Slough at Wood.

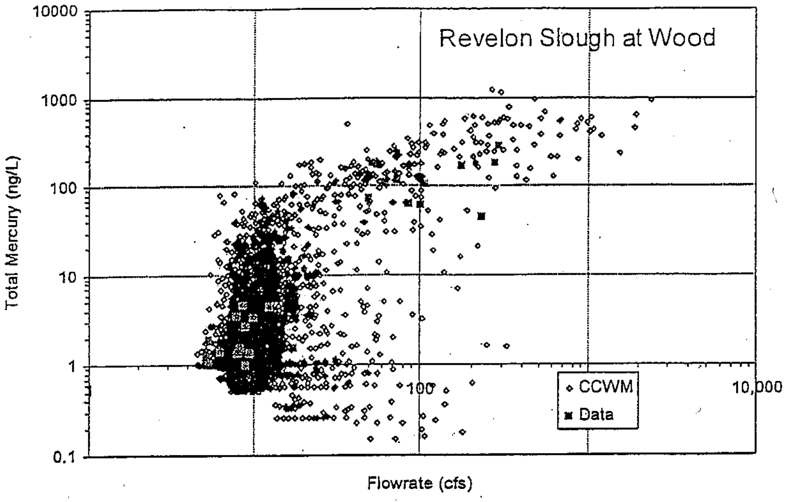

Figure 76: Measured and Modeled Total Mercury for Modeled Flowrates at Revolon Slough at Wood.

Selenium

Three types of plots are presented for each calibration site; the time series of measured and modeled total selenium, modeled vs measured total selenium with regression, and measured and modeled total selenium as a function of modeled receiving water flowrate. Time series plots of total selenium display the CCWM output and measured data in an overall context where the patterns in the data should be evaluated. Regression lines are provided on the modeled vs. measured plots as a guide to how well the discrete calculations match the observations. For regression lines with slopes greater than 1.0 the model, in the overall sum of squares sense, over predicts concentrations. As they are regression lines, these measures are heavily influenced by the high values. The measured and modeled total selenium plotted against receiving water flowrate allow comparison to how well the model will calculate loads of selenium. In general the model will represent total selenium concentrations well and the patterns of model output match patterns of field measurements.

Results for Calleguas Creek at PCH are presented in Figures 77 to 79. Results for Calleguas Creek at Potrero are presented in Figures 80 to 82. Results for Revolon Slough at Wood are presented in Figures 83 to 85.

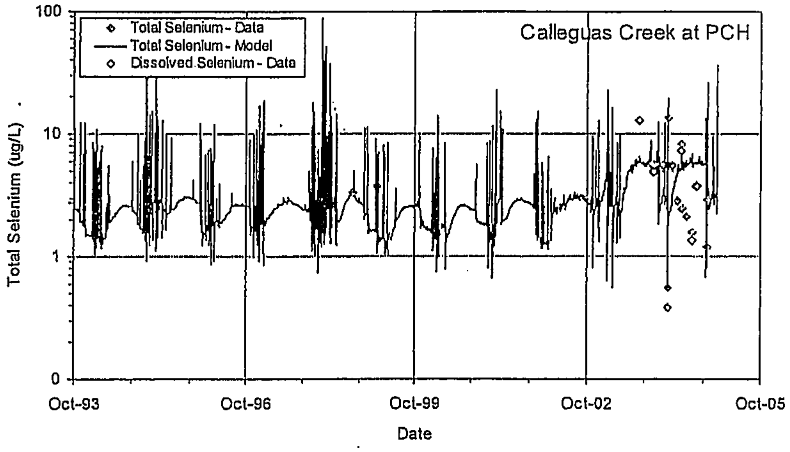

Figure 77: Time Series of CCWM Output and Measured Total Selenium for Calleguas Creek at PCH.

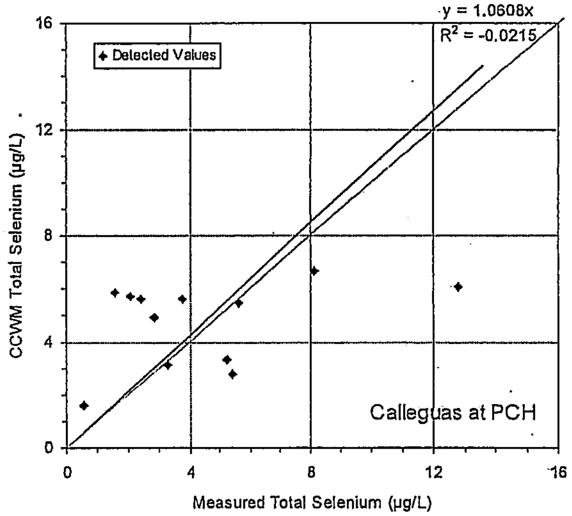

Figure 78: Modeled vs Measured Total Selenium in Calleguas Creek at PCH.

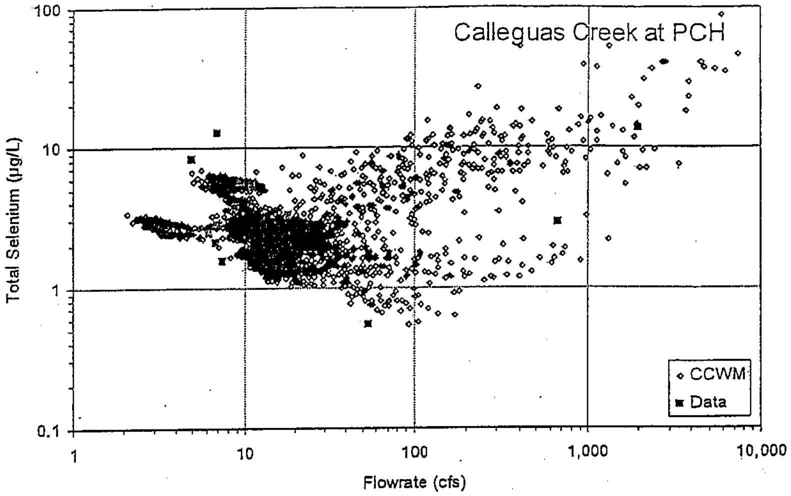

Figure 79: Measured and Modeled Total Selenium for Modeled Flowrate at Calleguas Creek at PCH.

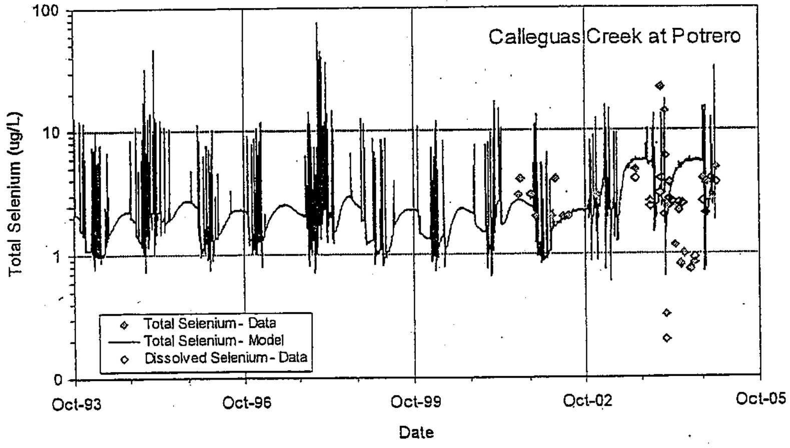

Figure 80: Time Series of CCWM Output and Measured Total Selenium for Calleguas Creek at Potrero.

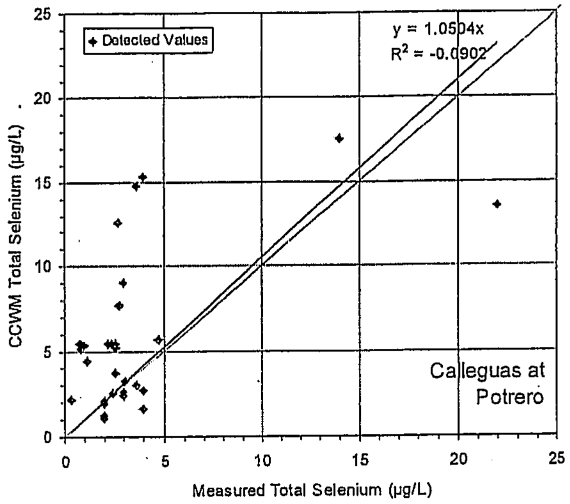

Figure 81: Modeled vs Measured Total Selenium in Calleguas Creek at Potrero.

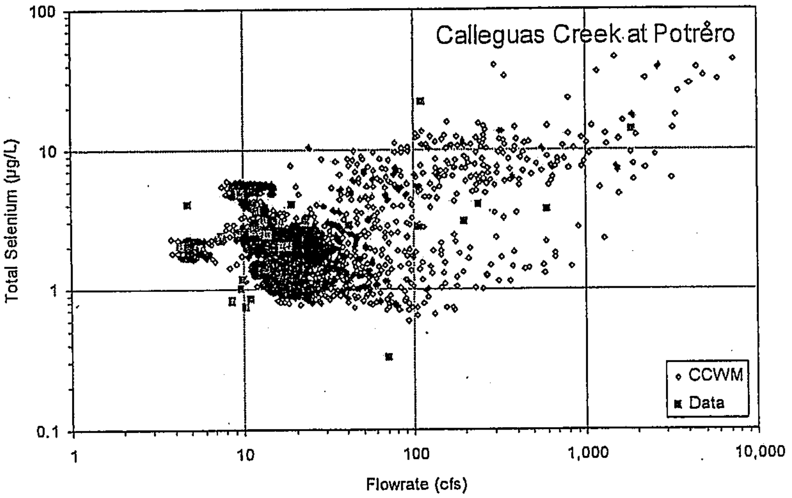

Figure 82: Measured and Modeled Total Selenium for Modeled Flowrate at Calleguas Creek at Potrero.

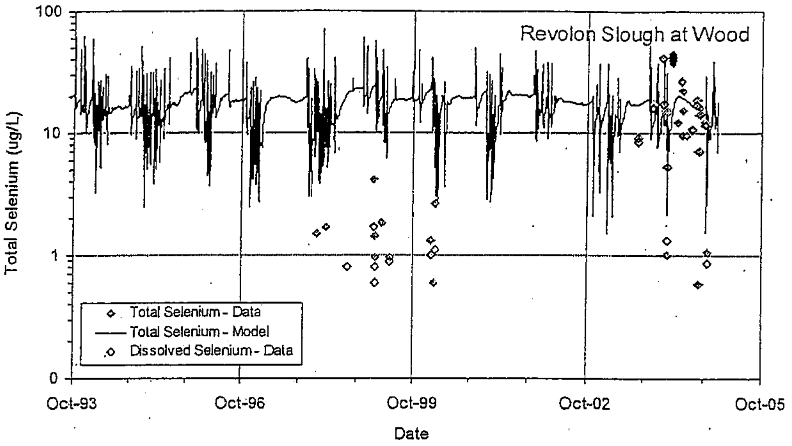

Figure 83: Time Series of CCWM Output and Measured Total Selenium for Revolon Slough at Wood.

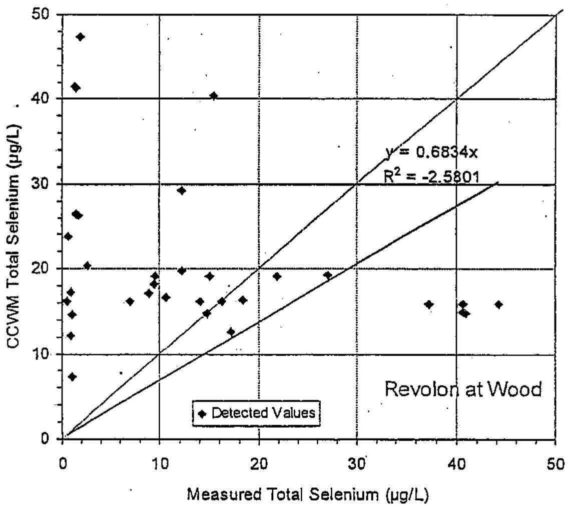

Figure 84: Modeled vs Measured Total Selenium in Revolon Slough at Wood.

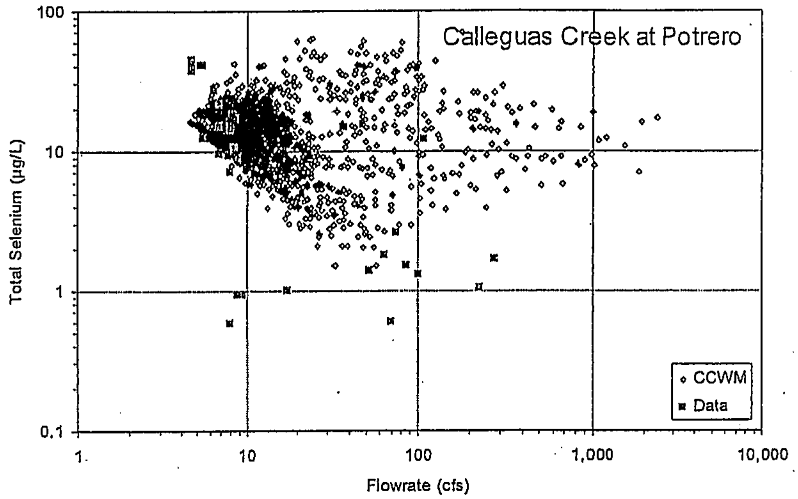

Figure 85: Measured and Modeled Total Selenium for Modeled Flowrate at Revolon Slough at Wood.

CONCLUSIONS

Review and consideration of the above analysis leads to the following conclusions.

1. The linear partitioning (constant K_D) is the only partitioning model available in HSPF, and provides the best overall fit to watershed data. Linear partitioning is used in the CCWM to calculate the transfer of metals and selenium between dissolved, suspended particulate, and benthic particulate phases.
2. The linear partitioning model works well to characterize the dissolved to total ratios for the metals and selenium considered in the TMDL. The partition coefficients selected for the CCWM result in conservative estimates of the ratio, in general calculating greater than observed dissolved concentrations.
3. Potency factors used in the CCWM match the measured values for the land uses considered in the model for copper, nickel, and selenium. Mercury potency is an order of magnitude lower than observed values reflecting the influence of atmospheric deposition as a significant source of for each of the considered land uses.
4. Time series of modeled metals and selenium match the character of the observed data well. In general the total fractions are over predicted reflecting the conservative modeling. Dissolved fractions are well represented for copper. Dissolved nickel simulation comparisons are affected by single high measured values. In both cases, the dissolved fraction vs. total concentration are well represented by the model.
5. Comparisons of corresponding dissolved and total fraction measured values to modeled values illustrate how well the CCWM covers the conditions of the watershed. Because the model covers the conditions observed in the watershed, the CCWM will serve TMDL development well if the over-prediction of total fraction is properly considered.
6. Based on the complete analysis and the entire weight of evidence, the CCWM is the

appropriate tool to use as decision support for the CCW Metals and Selenium TMDL. Users of the model must take into consideration that the output is in general a conservative estimate of the receiving water concentrations. The model should be periodically compared to new monitoring data, updating the model and reevaluating required load reductions as appropriate as part of an adaptive implementation process (NRC, 2001).

REFERENCES

Aqua Terra (2005), *Hydrologic Modeling of the Calleguas Creek Watershed with the U.S.EPA Hydrologic Simulation Program – FORTRAN (HSPF), Final Report*, March 10, 2005.

Bicknell, B.R., J.C. Imhoff, J.L. Kittle, Jr, T.H. Jobes, and A.S. Donigian, Jr. (2001), Hydrologic Simulation Program – FORTRAN, HSPF version 12, User's Manual, USEPA March 2001.

Donigian, A.S., J.T. Love. (2003). Sediment Calibration Procedures and Guidelines for Watershed Modeling. WEF TMDL 2003, November 16-19, 2003. Chicago, Illinois. WEF Specialty Conference Proceedings on CD-ROM.

Donigian, A.S. Jr. (2002). Watershed Model Calibration and Validation: The HSPF Experience. WEF National TMDL Science and Policy 2002, November 13-16, 2002. Phoenix, AZ. WEF Specialty Conference Proceedings on CD-ROM.

Larry Walker Associates (LWA 2006), *Extending the Simulation Time of the HSPF Hydrologic Model of the CCW*, Technical Memorandum to Mark Bandurraga and Sergio Vargas (VCWPD), and Henry Graumlich (Camrosa WD), February 28, 2006.

Larry Walker Associates (LWA 2005a), *CCW Metals and Selenium TMDL Preliminary Modifications to HSPF CCWM*, Technical Memorandum to File, July 7, 2005.

Larry Walker Associates (LWA 2005c), "Metals and Selenium Linkage Analysis for the Calleguas Creek Watershed", Interim Draft Report to the Calleguas Creek Watershed Management Plan, September 2005.

Larry Walker Associates (LWA 2005d), *CCW Metals and Selenium TMDL Modeling Approach*, Calleguas Creek Watershed Management Plan, June 13, 2005.

Larry Walker Associates (LWA 2005e), "Atmospheric Deposition for the Calleguas Creek Watershed", Technical Memorandum, July 2005.

Laurier, F. J. G., R. P. Mason, L. Whalin and S. Kato (2003). "Reactive gaseous mercury formation in the North Pacific Ocean's marine boundary layer: A potential role of halogen chemistry." Journal of Geophysical Research **108**(D17): 4529-4540.

National Research Council (NRC, 2001). *Assessing the TMDL Approach to Water Quality Management*. Committee to Assess the Scientific Basis of the Total Maximum Daily Load Approach to Water Pollution Reduction. Water Science and Technology Board, Division on Earth and Life Studies. National Academy Press, Washington, DC.

U.S. Environmental Protection Agency (USEPA 1993), *Guidance Document on Dynamic Modeling and Translators*, August 1993, Attachment # 3 to "Office of Water Policy and Technical Guidance on Interpretation and Implementation of Aquatic Life Metals Criteria", Memorandum from Martha G. Prothro to Water Management Division Directors Environmental Services Division Directors Regions I-X, October 1993.

CALIFORNIA DEPARTMENT OF FISH AND GAME

CERTIFICATE OF FEE EXEMPTION

De Minimus Impact Finding

Project Title: Amendment to the Water Quality Control Plan for the Los Angeles Region to Incorporate a Total Maximum Daily Load (TMDL) for Metals and Selenium in Calleguas Creek, Its Tributaries, and Mugu Lagoon.

Project Location: Calleguas Creek Watershed

Project Proponent: California Regional Water Quality Control Board, Los Angeles Region
340 W. 4th Street, Los Angeles, California 90013.

Project Description:

California Regional Water Quality Control Board Los Angeles Region (Regional Board) Resolution No. R4-2006-012, adopted on June 8, 2006 by the Regional Board, modified the regulatory provisions of the Water Quality Control Plan for the Los Angeles Region (Basin Plan) by: (1) revising the Table of Contents, (2) adding introductory text for Chapter 7 (Total Maximum Daily Loads), and (3) establishing a Total Maximum Daily Load (TMDL) for Metals and Selenium for Calleguas Creek, Its Tributaries, and Mugu Lagoon. The TMDL addresses impairment to water quality due to elevated levels of metal and selenium in water. Technical studies indicate Mugu Lagoon is a sink for metals, which endanger aquatic organisms and impair the existing habitat. Aquatic organisms also accumulate metals which cause human health concerns. The beneficial uses most affected by metals and selenium loadings into Calleguas Creek, its tributaries, and Mugu Lagoon include habitats which support wildlife (WILD) and rare, threatened or endangered species (RARE), as well as habitats which support estuarine (EST) and wetland (WET) ecosystems.

The amendment establishes four types of numeric targets with which load allocations and waste load allocations were calculated. The types of numeric targets are water quality targets for copper, nickel, zinc, mercury and selenium; fish tissue targets for mercury; bird egg targets for mercury and selenium; and sediment quality guidelines for copper, nickel and zinc for 303(d) listed reaches. In addition, the Basin Plan amendment specifies final wasteload allocations (WLAs) for point source discharges and load allocations (LAs) for nonpoint source discharges of metals and selenium. The proposed TMDL establishes a 10-year implementation schedule for POTWs and other NPDES permittees, and a 15-year implementation schedule for agricultural and permitted storm-water dischargers to reduce the loading of metals and selenium to Calleguas Creek. The TMDL also authorizes the use of BMPs, to the extent authorized by law, for various dischargers including agricultural and storm water dischargers. The implementation plan includes a combination of water quality monitoring, hot-spot waste removal, waste collection and sediment control. The proposed TMDL also consists of a monitoring program to assess compliance with waste load allocations. The monitoring program also stipulates the collection of additional data to evaluate the uncertainties and assumptions made in development of the TMDL, and to consider potential management scenarios.

The Basin Plan amendment includes a brief description of the Calleguas Creek Watershed and the existing conditions contributing to water quality problems. Calleguas Creek Watershed Metals and Selenium TMDL numeric targets, source analysis, linkage analysis, WLAs, LAs, margin of safety, future growth, critical conditions, implementation plan, and compliance schedule are also discussed in the Basin Plan amendment.

Findings of Exemption: (See attached CEQA Checklist).

This project will improve water quality in Calleguas Creek Watershed. Implementation of the TMDL could have a significant adverse effect on the environment; however, there are feasible alternatives and/or feasible mitigation measures that could be implemented by responsible jurisdictions which would substantially lessen any significant adverse impact. Responsible jurisdictions can and should incorporate such alternatives and mitigation into any subsequent projects or project approvals.

Certification:

I hereby certify that the California Regional Water Quality Control Board, Los Angeles Region, has made the above findings of fact and that based upon the Environmental Checklist and written report and hearing record, the project will not individually or cumulatively have an adverse effect on wildlife resources as detailed in Section 711.2 of the Fish and Game Code.

Chief Deputy E.O.
for

Jonathan S. Bishop
Executive Officer
California Regional Water Quality Control Board
Los Angeles Region

3-28-07
Date

ADMINISTRATIVE RECORD INDEX

LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD

RESOLUTION R4-2005-010

AMENDMENTS TO THE WATER QUALITY CONTROL PLAN FOR THE LOS ANGELES REGION TO INCORPORATE A TOTAL MAXIMUM DAILY LOAD FOR ORGANOCHLORINE PESTICIDES, POLYCHLORINATED BIPHENYLS, AND SILTATION IN CALLEGUAS CREEK, ITS TRIBUTARIES, AND MUGU LAGOON

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RESOLUTION R4-2005-010
AMENDMENTS TO THE WATER QUALITY CONTROL PLAN FOR THE LOS ANGELES REGION TO INCORPORATE A TOTAL MAXIMUM DAILY LOAD FOR ORGANOCHLORINE PESTICIDES, POLYCHLORINATED BIPHENYLS, AND SILTATION IN CALLEGUAS CREEK, ITS TRIBUTARIES, AND MUGU LAGOON

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		➢ 40 Code of Federal Regulations (40 CFR) Part 130 (TMDL Rule). 2000. United States Environmental Protection Agency (USEPA).	13-1 to 13-10
		➢ Abrol, S., Augustenborg, C., Madden, C., Suffet, M. 2003. Development of a TMDL for Organochlorine Pesticides for the Calleguas Creek Watershed. Prepared for the Los Angeles Regional Water Quality Control Board. Contract No. 01-172-140-0. September 2003.	13-11 to 13-65
		➢ Agency for Toxic Substances and Disease Registry (ATSDR). 1994. Toxicological Profile for Chlordane, U.S. Department of Health and Human Services. May 1994	13-66 to 13-320
		➢ Agency for Toxic Substances and Disease Registry (ATSDR). 1996. Toxicological Profile for Toxaphene. U.S. Department of Health and Human Services. August 1996.	13-321 to 13-569
		➢ Agency for Toxic Substances and Disease Registry (ATSDR). 2000. Toxicological Profile for Polychlorinated Biphenyls (PCBs). U.S. Department of Health and Human Services. November 2000.	13-570 to 13-1506
		➢ Agency for Toxic Substances and Disease Registry (ATSDR). 2002a. Toxicological Profile for DDT. U.S.	13-1507 to 13-1995

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		Department of Health and Human Services. September 2002	
		➢ Agency for Toxic Substances and Disease Registry (ATSDR). 2002b. Toxicological Profile for Aldrin/Dieldrin. U.S. Department of Health and Human Services. September 2002	13-119 to 13-2348
		➢ Anderson, B.S. et al. 2002. Causes of Ambient Toxicity in the Calleguas Creek Watershed of Southern California, Environmental Monitoring and Assessment, 78: 131-151-2002.	13-2349 to 13-2383
		➢ Aislabie, J.M., Richards, N.K., Boul, H.L. 1997. Microbial Degradation of DDT and its Residues – a Review. New Zealand Journal of Agricultural Research 40: 269 – 282.	13-2370 to 13-2383
		➢ Barron, M.G.; Heintz, R.; and Krahn, M.M. 2003. Contaminant Exposure and Effects in Pinnipeds: Implications for Steller Sea Lion Declines in Alaska. Science of the Total Environment, 311(1-3): 111-133.	13-2384 to 13-240
		➢ Braune, B. et al., 1999. Spatial and Temporal Trends of Contaminants in Canadian Arctic Freshwater and Terrestrial Ecosystems: a Review. Science of the Total Environment, 230(1-3): 145-207.	13-2407 to 13-2469
		➢ Buchman. 1999. NOAA Screening Quick Reference Table, NOAA HAZMAT Report 99-1, Seattle, WA, Coastal Protection and Restoration Division, National Oceanic and Atmospheric Administration, 12 pages.	13-2470 to 13-2481
		➢ Burkhard, Lawrence; Armstrong, David; and Andren, Anders. 1985. Henry's Law Constants for the Polychlorinated Biphenyls. Environmental Science & Technology 19 (7): 590-596 1985.	13-2482 to 13-2488
		➢ California Resources Agency. 1997. CWIS Mugu Lagoon. California Environmental Resources Evaluation System (CERES). Website: http://ceres.ca.gov/wetlands/geo_info/so_cal/mugu_lagoon.html.	13-2489 to 13-2501
		➢ Chan, C.H.; Bruce, G.; and Harrison, B. 1994. Wet Deposition of Organochlorine Pesticides and Polychlorinated Biphenyls to the Great Lakes. Journal of	13-2502

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		Great Lakes Research, 20 (3): 546-560.	
		➢ California Department of Pesticide Regulation (DPR). 2000. DPR Pesticide Use Reporting; An Overview of California's Unique Full Reporting System. Published May 2000. Dowloaded from DPR website, March 2004.	13-2503 to 13-2529
		➢ California Department of Pesticide Regulation (DPR). 2004. Pesticide Use Report Data for 1991-2003. Data acquired from Linda Lichtenberger, March 2004, llichtenberger@cdpr.ca.gov. (CD 1 & 2)	13-2530 to 13-2531
		➢ California Department of Water Resources (DWR). 2000. Land use survey GIS data. Website visited April 2004: http://www.landwateruse.water.ca.gov/basicdata/landuse/landusesurvey.cfm	13-2532 to 13-2532A
		➢ Cox, Caroline. 1991. Pesticides and Birds: From DDT to Today's Poisons. Journal Of Pesticide Reform / Winter, 1991 / VOL. 11, NO. 4.	13-2533 to 13-2537
		➢ EIP Associates. 1997. Organochlorine Pesticides Source Identification. Prepared for Palo Alto Regional Water Queality Control Plant by EIP Associates. October 28, 1997.	13-2538 to 13-2578
		➢ Franz, T.P.; S.J. Eisenreich; and T.M. Holsen. 1998. Dry deposition of particulate PCBs and PAHs to Lake Michigan. Environmental Science and Technology. 1998, 32: 3681-3688. Cited in ATSDR 2000. Toxicological Profile for Polychlorinated Biphenyls (PCBs). US Department of Health and Human Services Public Health Service Agency for Toxic Substances and Disease Registry. November 2000.	13-2579
		➢ Granade, Steve. 2003. Environmental Engineer, Naval Base Ventura County, steve.granade@navy.mil. Personal communication with C. Minton, August 4, 2003.	13-2580 to 13-2581
		➢ Grigorian, Grigor. 2001. Personal Communication with Ashli Cooper. January 18, 2001.	13-2582 to 13-2583
		➢ Heberer, T, and Dunnbier, U. 1999. DDT Metabolite Bis(Chlorophenyl)acetic acid: the Neglected Environmental Contaminant. Environmental Science and Technology 33: 2346-2351.	13-2584 to 13-2586
		➢ Helsel D.R. and R.M. Hirsch. 1992. Statistical Methods in	

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		➢ Helsel, D.R. and T.A. Cohn. 1988. Estimation of Descriptive Statistics for Multiply Censored Water Quality Data, Water Resour. Res. Vol. 24, No. 12, pp. 1997-2004.	13-2592 to 13-2601
		➢ Helsel, Dennis. 1990. Less than Obvious, Statistical Treatment of Data Below the Detection Limit. Environmental Science and Technology, Vol 24, No 12.	13-2602 to 13-2618
		➢ Hothem, R.L. and Powell, A.N. 2000. Contaminants in Eggs of Western Snowy Plovers and California Least Terns: Is There a Link to Population Decline? Bulletin of Environmental Contamination and Toxicology, Volume 65, Pages: 42 – 50.	13-2619 to 13-2627
		➢ Jorgenson, J. Lisa. 2001. Aldrin and Dieldrin: A Review of Research on Their Production, Environmental Deposition and Fate, Bioaccumulation, Toxicology, and Epidemiology in the United States, Environmental Health Perspectives Supplements, Volume 109, Number S1. March 2001.	13-2628 to 13-2661
		➢ Kulovaara, M., Backlund, P. and Corin, N. 1995. Light-induced degradation of DDT in humic water. Science of the Total Environment, 170(3): 185-191.	13-2662
		➢ Landis, John D. PhD. 1998. Development and Pilot Application of the California Urban and Biodiversity Analysis Model. Forthcoming in Computers, Environment, and Urban Systems, ➢ http://gis.esri.com/library/userconf/proc98/PROCEED/TO600/PAP571/P571.htm.	13-2663 to 13-2673
		➢ Larry Walker Associates (LWA). 1999. Calleguas Creek Characterization Study, Surface Water Element, 1998-1999.	13-2674 to 13-2716
		➢ Larry Walker Associates (LWA). 2004a. Calleguas Creek Watershed Database. Accessed December 2004.	13-2717
		➢ Larry Walker Associates (LWA). 2004b. Progress Report on Efforts to Address Salts on the Calleguas Creek Watershed. Submitted to Calleguas Creek Watershed Management Plan, pp. 105, June 30, 2004.	13-2718 to 13-3155
		➢ Lichtenberger, Linda. 2004. California Dept of Pesticide	

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		Regulation (DPR), llichtenberger@cdpr.ca.gov. Personal communication to Michael Casterline, April 2004.	13-3156 to 13-3157
		➢ Los Angeles Regional Water Quality Control Board (LARWQCB). 2002. Draft Staff Report – 2002 Update: Clean Water Act Section 305(b) Report and Section 303(d) List of Impaired Waters – LA Region. January 29, 2002.	13-3158 to 13-3235
		➢ Los Angeles Regional Water Quality Control Board (LARWQCB). 2003. 2002 Clean Water Act Section 303(d) List of Water Quality Limited Segments; Calleguas Creek Listings.	13-3236
		➢ Long ER, Field LJ, MacDonald DD. 1998. Predicting toxicity in marine sediments with numerical sediment quality guidelines. Environ Toxicol Chem 17: 714-727.	13-3237 to 13-3250
		➢ MacDonald, DD. 1994. Approach to the Assessment of Sediment Quality in Florida Coastal Waters. Volume 1 – Development and Evaluation of Sediment Quality Assessment Guidelines.	13-3251 to 13-3390
		➢ Mackay, D., W. Shiu, and K. Ma. 1997. Illustrated Handbook of Physical-chemical Properties and Environmental Fate for Organic Chemicals. Volume V: Pesticide chemicals. Lewis Publishers, Boca Raton, FL.	13-3391 to 13-3417
		➢ McIntyre, Sam. 2004. Pesticide Advisor, Somis Ag Management Inc. sompacag@aol.com . Personal communication to Michael Casterline, May 2004	13-3418
		➢ Minjares, Javier. 2004. Southern California Association of Governments, Population Growth by City for SCAG Region for 2000-2030 (pre-website release of population projections), minjares@scag.ca.gov.	13-3419
		➢ Mischke, Tom; Brunetti, K; Acosta, V; Weaver, D; Brown, Mary. 1985. Agricultural Sources of DDT Residues in California's Environment. California Department of Food and Agriculture (Environmental Hazards Assessment Program). http://www.cdpr.ca.gov/docs/ipminov/ddt/ddt.htm. September 1985	13-3420 to 13-3448
		➢ Muir, D. et al. 1999. Spatial and Temporal Trends and Effects of Contaminants in the Canadian Arctic Marine	13-1449 to 13-3510

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		➢ National Oceanic and Atmospheric Administration (NOAA). 1999. Sediment Quality Guidelines Developed for the National Status and Trends Program. Office of Response and Restoration, National Ocean Service. Updated 6/28/99.	13-3511 to 13-3522
		➢ Park, J.S.; Wade, T.L. 2001. Atmospheric Deposition of Organochlorine Contaminants to Galveston Bay, Texas. Atmospheric Environment, 35: 3315-3324.	13-3523 to 13-3532
		➢ San Francisco Bay Regional Water Quality Control Board (SFBRWQCB). January 2004. PCBs in San Francisco Bay, Total Maximum Daily Load Report.	13-3533 to 13-3605
		➢ San Francisco Bay Regional Water Quality Control Board (SFBRWQCB). 2004. Mercury in San Francisco Bay Total Maximum Daily Load (TMDL) Proposed Basin Plan Amendment and Staff Report. September 2, 2004.	13-3606 to 13-3621
		➢ Smith, Randy. 2004. Ventura County Mosquito Abatement and Vector Control, randy.smith@mail.co.ventura.ca.us. Personal communication to Michael Casterline, March 2004.	13-3622
		➢ Southern California Association of Governments (SCAG). 2004. Urban land use GIS data. Website visited June 2004: http://rtmisweb.scag.ca.gov/data_gis/.	13-3623
		➢ Shumway,Robert; Azari, Rahman; Kayhanian, Masoud. 2002. Statistical Approaches to Estimating Mean Water Quality Concentrations with Detection Limits. Environmental Science and Technology, Vol 36.	13-3624 to 13-3632
		➢ Snedeker, Suzanne M. March 2001. Pesticides and Breast Cancer Risk: A Review of DDT, DDE, and Dieldrin. Environmental Health Perspectives, Volume 109, Suplement 1.	13-3633 to 13-3645
		➢ Spencer W.F., Singh G., Taylor C.D., LeMert R.A., Cliath M.M., and Farmer W.J. July-August 1996. DDT Persistence and Volatility as Affected by Management Practices after 23 Years. Journal of Environmental Quality, Volume. 25.	13-3646 to 13-3652
		➢ State Water Resources Control Board (SWRCB). 1997.	13-3653 to 13-3715

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		➢ State Water Resources Control Board (SWRCB). 2004a. State Mussel Watch Program (SMWP) website visited August 2004: http://www.swrcb.ca.gov/programs/smw/index.html.	13-3716
		➢ State Water Resources Control Board (SWRCB). 2004b. Toxic Substances Monitoring Program (TSMP) website visited August 2004: http://www.swrcb.ca.gov/programs/smw/index.html.	13-3717
		➢ State Water Resources Control Board (SWRCB). 2004c. Water Quality Control Policy For Developing California's Clean Water Act Section 303(D) List. September 30th, 2004	13-3718 to 13-3754
		➢ Tegtmeier, Erin M. and Duffy, Michael D. 2004. International Journal of Agricultural Sustainability, Vol. 2, No. 1.	13-3755 to 13-3774
		➢ United States Census Bureau (USCB). Website visited May 2004:http://www.census.gov/population/projections/state/stpjpop.txt .	13-3775 to 13-3776
		➢ United States Navy. 2000. Unpublished data from Steve Granade, Environmental Engineer, Naval Base Ventura County, steve.granade@navy.mil .	13-3777
		➢ United States Department of Agriculture, Natural Resources Conservation Service (USDA, NRCS). 1995. Calleguas Creek Watershed Erosion and Sediment Control Plan for Mugu Lagoon. USDA Report prepared by Water Resources Planning Staff.	13-3778 to 13-3938
		➢ United States Environmental Protection Agency (US EPA). 1980. Ambient Water Quality Criteria for Aldrin/Dieldrin. Office of Water Regulations and Standards Criteria and Standards Division. (other criteria	13-3939 to 13-4091

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		documents available at USEPA website: http://www.epa.gov/waterscience/pc/ambient2.html).	
		➢ United States Environmental Protection Agency (US EPA). 1980. Ambient Water Quality Criteria for Chlordane. Office of Water Regulations and Standards Criteria and Standards Division. (other criteria documents available at USEPA website: http://www.epa.gov/waterscience/pc/ambient2.html).	13-4092 to 13-4159
		➢ United States Environmental Protection Agency (US EPA). 1980. Ambient Water Quality Criteria for DDT. Office of Water Regulations and Standards Criteria and Standards Division. (other criteria documents available at USEPA website: http://www.epa.gov/waterscience/pc/ambient2.html).	13-4160 to 13-4334
		➢ United States Environmental Protection Agency (US EPA). 1998. Reregistration Eligibility Decision: Dicofol. EPA 738-R-98-018. November 1998. R.E.D. Facts: Dicofol. November 1998	13-4335 to 13-436
		➢ United State Environmental Protection Agency (USEPA). 1999. The Road to Zero? U.S. Federal and State Regulatory Support for the Great Lakes Binational Toxics Strategy, Report to the U.S. Environmental Protection Agency.	13-4361 to 13-4364
		➢ United States Environmental Protection Agency (US EPA). 1991. Guidance for Water Quality-based Decisions: the TMDL Process. Office of Water. Washington, D.C. EPA 440/4-91-001. April, 1991. http://www.epa.gov/OWOW/tmdl/decisions/	13-4365 to 13-4426
		➢ United States Environmental Protection Agency (US EPA). 2002. Total Maximum Daily Loads for Toxic Pollutants – San Diego Creek and Newport Bay, California. US Environmental Protection Agency, Region 9. Established June 14, 2002.	13-4427 to 13-4515
		➢ United States Geological Survey (USGS). 2004. Website visited May 2004: http://ca.water.usgs.gov/archive/reports/ofr96_629/geog.html#1.5 .	13-4516 to 13-4539
		➢ Ventura County (website), May 2004,	

RESOLUTION R4-2005-010

AMENDMENTS TO THE WATER QUALITY CONTROL PLAN FOR THE LOS ANGELES REGION TO INCORPORATE A TOTAL MAXIMUM DAILY LOAD FOR ORGANOCHLORINE PESTICIDES, POLYCHLORINATED BIPHENYLS, AND SILTATION IN CALLEGUAS CREEK, ITS TRIBUTARIES, AND MUGU LAGOON

Date	**Section**	**Item**	**Page**
		http://www.countyofventura.org/visitor/visitor.asp.	13-4540 to 13-4543
		➢ Wandji, Serge-Alain, Ph.D.; Gandhi, Renu, Ph.D.; Snedeker, Suzanne, Ph.D. October 1998. Critical Evaluation of Chlordane's Breast Cancer Risk. Cornell University, Sprecher Institute for Comparative Cancer Research, Program on Breast Cancer and Environmental Risk Factors. http://envirocancer.cornell.edu/ .	13-4544 to 13-4574
		➢ Wania and Mackay *in litt* 1996. Cited in ATSDR 2000. Toxic-ological Profile for Polychlorinated Biphenyls (PCBs). US Department of Health and Human Services Public Health Service Agency for Toxic Substances and Disease Registry. November 2000	13-4575
		➢ Zepp, R.G., and D.M. Cline. 1977. Rates of direct photolysis in aquatic environment. Environmental Science and Technology, 11(4): 359-366.	13-4576

State of California
California Regional Water Quality Control Board, Los Angeles Region

RESOLUTION NO. R4-2005-010
July 7, 2005

Amendment to the *Water Quality Control Plan for the Los Angeles Region* to Incorporate a Total Maximum Daily Load for Organochlorine Pesticides, Polychorinated Biphenyls, and Siltation in Calleguas Creek, its Tributaries, and Mugu Lagoon

WHEREAS, the California Regional Water Quality Control Board, Los Angeles Region, finds that:

1. The Federal Clean Water Act (CWA) requires the California Regional Water Quality Control Board, Los Angles Region (Regional Board) to develop water quality objectives, which are sufficient to protect beneficial uses for each water body found within its region.

2. A consent decree between the U.S. Environmental Protection Agency (USEPA), Heal the Bay, Inc. and BayKeeper, Inc. was approved on March 22, 1999. This court order directs the USEPA to complete Total Maximum Daily Loads (TMDLs) for all impaired waters within 13 years. A schedule was established in the consent decree for the completion of the first 29 TMDLs within 7 years, including completion of a TMDL to reduce Organochlorine (OC) pesticides and Polychlorinated Biphenyls (PCBs) at Calleguas Creek Watershed by March 22, 2006. The remaining TMDLs will be scheduled by Regional Board staff within the 13-year period.

3. The elements of a TMDL are described in 40 CFR 130.2 and 130.7 and section 303(d) of the CWA, as well as in USEPA guidance documents (Report No. EPA/440/4-91/001). A TMDL is defined as the sum of the individual waste load allocations for point sources, load allocations for nonpoint sources and natural background (40 CFR 130.2). Regulations further stipulate that TMDLs must be set at levels necessary to attain and maintain the applicable narrative and numeric water quality standards with seasonal variations and a margin of safety that takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality (40 CFR 130.7(c)(1)). The regulations in 40 CFR 130.7 also state that TMDLs shall take into account critical conditions for stream flow, loading and water quality parameters.

4. The numeric targets in this TMDL are not water quality objectives and do not create new bases for enforcement against dischargers apart from the water quality objectives they translate. The targets merely establish the bases through which load allocations (LAs) and waste load allocations (WLAs) are calculated. WLAs are only enforced for a discharger's own discharges, and then only in the context of its National Pollutant Discharge Elimination System (NPDES) permit, which must be consistent with the assumptions and requirements of the WLA. The Regional Board will develop permit requirements through a subsequent permit action that will allow all interested persons, including but not limited to municipal storm water dischargers, to provide comments on how the WLA will be translated into permit requirements.

5. Upon establishment of TMDLs by the State or USEPA, the State is required to incorporate the TMDLs along with appropriate implementation measures into the State Water Quality Management Plan (40 CFR 130.6(c)(1), 130.7). This Water Quality Control Plan for the Los Angeles Region (Basin Plan), and applicable statewide plans, serves as the State Water Quality Management Plans governing the watersheds under the jurisdiction of the Regional Board.

6. The SWRCB adopted Policy for Implementation of Toxics Standards for Inland Surface Waters, Enclosed Bays, and Estuaries of California (also known as the State Implementation Plan or SIP) on March 2, 2000. The SIP was amended by Resolution No. 2000-30, on April 26, 2000, and the Office of Administrative Law approved the SIP on April 28, 2000. The SIP applies to discharges of toxic pollutants in the inland surface waters, enclosed bays and estuaries of California which are subject to regulation under the State's Porter-Cologne Water Quality Control Act (Division 7 of the Water Code) and the Federal Clean Water Act. This policy also establishes the following: implementation provisions for priority pollutant criteria promulgated by USEPA through the CTR and for priority pollutant objectives established by Regional Water Quality Control Boards in their water quality control plans (Basin Plans) and chronic toxicity control provisions.

7. On May 18, 2000, the U.S. EPA promulgated the numeric criteria for priority pollutants for the State of California, known as the California Toxics Rule (CTR) and as codified as 40 CFR section 131.38.

8. The Calleguas Creek Watershed is located in southeast Ventura County, California, and in a small portion of western Los Angeles County, and drains an area of approximately 343 square miles from the Santa Susana Pass in the east, to Mugu Lagoon in the southwest. Current land use is approximately 26 percent agriculture, 24 percent urban, and 50 percent open space. The tributaries and the streams of the Calleguas Creek Watershed are divided into fourteen segments, or reaches. The 2002 Clean Water Act 303(d) list identified eleven reaches out of thirteen reaches of the Calleguas Creek watershed as impaired for OC pesticides and PCBs. These listings were approved by the State Water Resources Control Board on February 4, 2003.

9. The Regional Board's goal in establishing the Calleguas Creek OC Pesticides, PCBs and Siltation TMDL is to determine and set forth measures needed to prevent impairment of water quality due to OC pesticides and PCBs in Calleguas Creek.

10. Calleguas Creek stakeholders have been actively engaged with US EPA and the Regional Board on a variety of watershed planning initiatives in the Calleguas Creek Watershed. Key stakeholders have formed the Calleguas Creek Watershed Management Plan (CCWMP), an established, stakeholder-led watershed management group that has been continually operating since 1996. The Calleguas Creek Watershed Management Plan has broad participation from Federal, State and County agencies, municipalities, POTWs, water purveyors, groundwater management agencies, and agricultural and environmental groups. As part of its mission to address issues of long-range comprehensive water resources; land use; economic development; open space preservation, enhancement and management, the CCWMP proposed to US EPA and Regional Board to take the lead on development of the TMDLs.

11. Regional Board staff have worked with the CCWMP and US EPA in the development of a detailed technical document that analyzes and describes the specific necessity and rationale for the development of this TMDL. The technical document entitled "Calleguas Creek

Watershed OC Pesticides and PCBs TMDL" prepared by Larry Walker Associates is an integral part of this Regional Board action and was reviewed, and accepted by the Regional Board as a supporting technical analysis before acting. Regional Board staff led the development of the TMDL analysis for siltation with participation from CCWMP and Stakeholders. The technical document provides the detailed factual basis and analysis supporting the problem statement, numeric targets (interpretation of the narrative and numeric water quality objectives, used to calculate the pollutant allocations), source analysis, linkage analysis, waste load allocations (for point sources), load allocation (for nonpoint sources), margin of safety, and seasonal variations and critical conditions of this TMDL.

12. Regional Board staff used all available information in its analysis of the siltation listing for Mugu Lagoon. Based on available information, Regional Board staff find that excessive siltation into estuaries can impair aquatic life habitat through excess deposition. Furthermore, historic pesticides and PCBs adhere to sediment particles and are transported with sediment to Calleguas Creek and Mugu Lagoon. Staff find sufficient existing data to establish the annual excess sediment and silt loading to Mugu Lagoon, but insufficient existing data to establish the annual loading of sediment and silt to Mugu Lagoon under the highly variable meteorological and hydrological conditions within the Calleguas Creek watershed. Consequently, this TMDL establishes interim wasteload and interim load allocations as a sediment mass reduction, and provides for special studies to develop a refined TMDL as discussed below in order to protect aquatic life and wetland habitat beneficial uses. The interim wasteload and load reductions represent staff's best professional judgement of the sediment mass reductions needed to achieve compliance with the TMDL targets based on achieving the regional narrative water quality objectives for wetlands hydrology and habitat, and solid, suspended, or settleable materials that can cause siltation that degrades aquatic life habitat.

13. During the implementation period, stakeholders will conduct a special study to assess the amount of sediment, silt and pollutants that are conveyed to and deposited within the Mugu Lagoon over time. After the special study has been completed and reviewed by a Science Advisory Panel in accordance with the TMDL Implementation Plan, the Regional Board will re-consider the TMDL and the final wasteload and load allocations. The revised final TMDL and allocations may be expressed in terms of total mass loading of sediment, silt and/or pollutants to Mugu Lagoon.

14. On May 5, 2005, prior to the Board's action on this resolution, public hearings were conducted on the Calleguas Creek Watershed OC Pesticides, PCBs and Siltation TMDL. Notice of the hearing for the Calleguas Creek Watershed OC Pesticides and PCBs TMDL was published in accordance with the requirements of Water Code Section 13244. This notice was published in the Ventura County Star on April 26, the Daily News Los Angeles on April 26, and the Signal Newspaper on April 27, 2005.

15. The public has had reasonable opportunity to participate in the review of the amendment to the Basin Plan. A draft of the Calleguas Creek Watershed OC Pesticides and PCBs TMDL was released for public comment on April 26, 2005; a Notice of Hearing and Notice of Filing were published and circulated 45 days preceding Board action; Regional Board staff responded to oral and written comments received from the public; and the Regional Board held a public hearing on July 7, 2005 to consider adoption of the TMDL.

16. In amending the Basin Plan, the Regional Board considered the factors set forth in Sections 13240 and 13242 of the California Water Code.

17. The amendment is consistent with the State Antidegradation Policy (State Board Resolution No. 68-16), in that it does not authorize any lowering of water quality and is designed to implement existing water quality objectives. Likewise, the amendment is consistent with the federal Antidegradation Policy (40 CFR 131.12).

18. The basin planning process has been certified as functionally equivalent to the California Environmental Quality Act requirements for preparing environmental documents (Public Resources Code, Section 21000 et seq.) and as such, the required environmental documentation and CEQA environmental checklist have been prepared. A CEQA Scoping hearing was conducted on May 31, 2005 in the City of Thousand Oaks, 2100 E. Thousand Oaks Blvd., Thousand Oaks, California. A notice of the CEQA Scoping hearing was sent to interested parties including cities and/or counties with jurisdiction in or bordering the Calleguas Creek watershed.

19. The proposed amendment could have a significant adverse effect on the environment. However, there are feasible alternatives and/or feasible mitigation measures that would substantially lessen any significant adverse impact.

20. The regulatory action meets the "Necessity" standard of the Administrative Procedures Act, Government Code, Section 11353, Subdivision (b).

21. The Basin Plan amendment incorporating a TMDL for OC Pesticides and PCBs in Calleguas Creek watershed must be submitted for review and approval by the State Water Resources Control Board (State Board), the State Office of Administrative Law (OAL), and the USEPA. The Basin Plan amendment will become effective upon approval by USEPA. A Notice of Decision will be filed with the State of California Secretary of Resources.

THEREFORE, be it resolved that pursuant to sections 13240 and 13242 of the Water Code, the Regional Board hereby amends the Basin Plan as follows:

1. Pursuant to Sections 13240 and 13242 of the California Water Code, the Regional Board, after considering the entire record, including oral testimony at the hearing, hereby adopts the amendments to Chapter 7 of the Water Quality Control Plan for the Los Angeles Region, as set forth in Attachment A hereto, to incorporate the elements of the Calleguas Creek Watershed OC Pesticides and PCBs TMDL.

2. The Executive Officer is directed to forward copies of the Basin Plan amendment to the State Board in accordance with the requirements of section 13245 of the California Water Code.

3. The Regional Board requests that the State Board approve the Basin Plan amendment in accordance with the requirements of sections 13245 and 13246 of the California Water Code and forward it to OAL and the USEPA.

4. If during its approval process Regional Board staff, the State Board or OAL determines that minor, non-substantive corrections to the language of the amendment are needed for clarity or consistency, the Executive Officer may make such changes, and shall inform the Board of any such changes.

5. The Executive Officer is authorized to sign a Certificate of Fee Exemption.

I, Jonathan S. Bishop, Executive Officer, do hereby certify that the foregoing is a full, true, and correct copy of a resolution adopted by the California Regional Water Quality Control Board, Los Angeles Region, on July 7,2005.

Jonathan S. Bishop
Executive Officer

7/15/05
Date

Attachment A to Resolution No. R4-2005-010

Amendment to the Water Quality Control Plan – Los Angeles Region

to Incorporate a
Total Maximum Daily Loads (TMDLs) for Organochlorine (OC) Pesticides, Polychlorinated Biphenyls (PCBs) and Siltation in Calleguas Creek, Its Tributaries, and Mugu Lagoon

Adopted by the California Regional Water Quality Control Board, Los Angeles Region on July 7, 2005.

Amendments

Table of Contents

Add:

Chapter 7. Total Maximum Daily Loads (TMDLs)

7- 17 Calleguas Creek Organochlorine Pesticides, Polychlorinated Biphenyls, and Siltation TMDL

List of Figures, Tables, and Inserts

Add:

Chapter 7. Total Maximum Daily Loads (TMDLs)

Tables

7-17 Calleguas Creek Organochlorine Pesticides, Polychlorinated Biphenyls, and Siltation TMDL

7-17.1 Calleguas Creek Organochlorine Pesticides, Polychlorinated Biphenyls, and Siltation TMDL: Elements

7-17.2 Calleguas Creek Organochlorine Pesticides, Polychlorinated Biphenyls, and Siltation TMDL: Implementation Schedule

Chapter 7. Total Maximum Daily Loads (TMDLs)
Calleguas Creek Organochlorine Pesticides, Polychlorinated Biphenyls, and Siltation TMDL

Add:

This TMDL was adopted by the Regional Water Quality Control Board on July 7, 2005.

This TMDL was approved by:

The State Water Resources Control Board on September 22, 2005.
The Office of Administrative Law on January 20, 2006.
The U.S. Environmental Protection Agency on March 14, 2006.

The following table includes the elements of the TMDL:

Table 7-17.1. Calleguas Creek Watershed OC Pesticides, PCBs, and Siltation TMDL: Elements

<table>
<tr><th>TMDL Element</th><th>Calleguas Creek Watershed OC Pesticide, PCBs, and Siltation TMDL</th></tr>
<tr><td>Problem Statement</td><td>Eleven of fourteen reaches in the Calleguas Creek Watershed (CCW) were identified on the 2002 303(d) list of water-quality limited segments as impaired due to elevated levels of organochlorine (OC) pesticides and/or polychlorinated biphenyls (PCBs) in water, sediment, and/or fish tissue. Additionally, Mugu Lagoon was listed as impaired for sedimentation/siltation. OC pesticides and PCBs can bioaccumulate in fish tissue and cause toxicity to aquatic life in estuarine and inland waters. Siltation may transport OC Pesticides and PCBs to surface waters and impair aquatic life and wildlife habitats.</td></tr>
<tr><td>Numeric Targets</td><td>The following tables provide the targets for water, fish tissue, and sediment for this TMDL. Water column targets were derived from the California Toxic Rule (CTR) water quality criteria for protection of aquatic life. Chronic criteria (Criteria Continuous Concentration, or CCC) were applied unless otherwise noted in the table below:
<table>
<tr><th></th><th colspan="2">Water Quality Targets (ng/L)[1]</th></tr>
<tr><th>Constituent</th><th>Freshwater</th><th>Marine[2]</th></tr>
<tr><td>Aldrin</td><td>300.0</td><td>130.0</td></tr>
<tr><td>Chlordane</td><td>4.3</td><td>4.0</td></tr>
<tr><td>Dacthal</td><td>3,500,000.0</td><td>(a)[3]</td></tr>
<tr><td>4,4'-DDD[4]</td><td>(a)[3]</td><td>(a)[3]</td></tr>
<tr><td>4,4'-DDE[5]</td><td>(a)[3]</td><td>(a)[3]</td></tr>
<tr><td>4,4'-DDT[6]</td><td>1.0</td><td>1.0</td></tr>
<tr><td>Dieldrin</td><td>56.0</td><td>1.9</td></tr>
<tr><td>Endosulfan I</td><td>56.0</td><td>8.7</td></tr>
<tr><td>Endosulfan II</td><td>56.0</td><td>8.7</td></tr>
<tr><td>Endrin</td><td>36.0</td><td>2.3</td></tr>
<tr><td>HCH (alpha-BHC[7])</td><td>(a)[3]</td><td>(a)[3]</td></tr>
<tr><td>HCH (beta-BHC)</td><td>(a)[3]</td><td>(a)[3]</td></tr>
<tr><td>HCH (delta-BHC)</td><td>(a)[3]</td><td>(a)[3]</td></tr>
</table>
</td></tr>
</table>

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[1] ng/L: nanogram per litter

[2] Marine numeric targets applied to Mugu Lagoon

[3] Numeric targets have not been established for these constituents

[4] DDD: Dichlorodiphenyldichloroethane

[5] DDE: Dichlorodiphenyldichloroethylene

[6] DDT: Dichlorodiphenyltrichloroethane

[7] BHC: Hexachlorocyclohexane

TMDL Element	Calleguas Creek Watershed OC Pesticide, PCBs, and Siltation TMDL

HCH (gamma BHC)	950.0	160.0
Heptachlor	3.8	3.6
Heptachlor Epoxide	3.8	3.6
PCBs	140.0[1]	30.0[7]
Toxaphene	0.2	0.2

Fish tissue targets are derived from CTR human health criteria for consumption of organisms.

Fish Tissue Targets (ng/Kg)

Constituent	
Aldrin	50.0
Chlordane	830.0
Dacthal	(a)[2]
4,4'-DDD	45,000.0
4,4'-DDE	32,000.0
4,4'-DDT	32,000.0
Dieldrin	650.0
Endosulfan I	65,000,000.0
Endosulfan II	65,000,000.0
Endrin	3,200,000.0
HCH (alpha-BHC)	1,700.00
HCH (beta-BHC)	6,000.0
HCH (delta-BHC)	(a)[1]
HCH (gamma BHC)	8,200.
Heptachlor	2,400.0
Heptachlor Epoxide	1,200.0
PCBs	5,300.0[3]
Toxaphene	9,800.0

Sediment targets were derived from sediment quality guidelines contained in National Oceanographic and Atmospheric Administration (NOAA) Screening Quick Reference Tables (SQuiRT, Buchman, 1999).

Sediment Quality Targets (ng/dry Kg)

Constituent	Freshwater, TEL[4]	Marine[5], ERL[6]
Aldrin	(a)[1]	(a)[1]
Chlordane	4,500.0	500.0
Dacthal	(a)[1]	(a)[1]
4,4'-DDD	3,500.0	2,000.0

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[1] Applies to sum of all congener or isomer or homolog or Aroclor analyses

[2] Numeric targets have not been established for these constituents

[3] Applies to sum of all congener or isomer or homolog or Aroclor analyses

[4] TEL = Threshold Effects Level

[5] Marine numeric targets applied to Mugu Lagoon

[6] ERL = Effects Range-Low.

<table>
<tr><th>TMDL Element</th><th>Calleguas Creek Watershed OC Pesticide, PCBs, and Siltation TMDL</th></tr>
<tr><td></td><td>
<table>
<tr><td>4,4'-DDE</td><td>1,400.0</td><td>2,200.0</td></tr>
<tr><td>4,4'-DDT</td><td>(a)[1]</td><td>1,000.0</td></tr>
<tr><td>Dieldrin</td><td>2,900.0</td><td>20.0</td></tr>
<tr><td>Endosulfan I</td><td>(a)[1]</td><td>(a)[1]</td></tr>
<tr><td>Endosulfan II</td><td>(a)[1]</td><td>(a)[1]</td></tr>
<tr><td>Endrin</td><td>2,700.0</td><td>(a)[1]</td></tr>
<tr><td>HCH (alpha-BHC)</td><td>(a)[1]</td><td>(a)[1]</td></tr>
<tr><td>HCH (beta-BHC)</td><td>(a)[1]</td><td>(a)[1]</td></tr>
<tr><td>HCH (delta-BHC)</td><td>(a)[1]</td><td>(a)[1]</td></tr>
<tr><td>HCH (gamma BHC)</td><td>940.0</td><td>(a)[1]</td></tr>
<tr><td>Heptachlor</td><td>(a)[1]</td><td>(a)[1]</td></tr>
<tr><td>Heptachlor Epoxide</td><td>600.0</td><td>(a)[1]</td></tr>
<tr><td>PCBs</td><td>34,000.0[2]</td><td>23,000.0</td></tr>
<tr><td>Toxaphene</td><td>(a)[1]</td><td>(a)[1]</td></tr>
</table>
<p>Siltation Targets</p>
<p>This TMDL includes two numeric targets for siltation reduction and maintenance of existing habitat in Mugu Lagoon which are listed below:</p>

Siltation reduction
Annual average reduction in the import of silt of 5,200 tons/year, which will be measured at the US Naval Base total suspended sediment gauge at the entrance to Mugu Lagoon.
Maintenance of existing habitat in Mugu Lagoon
Preservation of the existing 1400 acres of aquatic habitat in Mugu Lagoon.

</td></tr>
<tr><td>Source Analysis</td><td>Monitoring data from major NPDES discharges and land use runoff were analyzed to estimate the magnitude of OC pesticides and PCBs loads to Calleguas Creek, its tributaries and Mugu Lagoon. The largest source of OC pesticides in the listed waters is agricultural runoff. Most PCB residues are due to past use of PCBs as coolants and lubricants in transformers, capacitors, and other electrical equipment. Atmospheric deposition is also a potential source of PCBs. Urban runoff and POTWs are minor sources of OC pesticides and PCBs. Data analysis suggests that groundwater, atmospheric deposition, and imported water are not significant sources of OC pesticides, PCBs, or sediment. Further evaluation of these sources is set forth in the Implementation Plan.</td></tr>
<tr><td>Linkage Analysis</td><td>The linkage analysis is based on a conceptual model for the fate, transformation, and uptake of OC pesticides and PCBs and a mass-balance model that connects the sources of OC pesticides and PCBs to their fate and transport in Calleguas Creek, its tributaries, and Mugu Lagoon. The linkage analysis indicates: 1) OC pesticides</td></tr>
</table>

TMDL Element	Calleguas Creek Watershed OC Pesticide, PCBs, and Siltation TMDL
	and PCBs concentrations in tissue are proportional to OC pesticides and PCBs concentrations in sediments; 2) OC pesticides and PCBs concentrations in water are a function of OC pesticides and PCBs concentrations in sediment; and 3) OC pesticides and PCBs concentrations in sediment are a function of OC pesticides and PCBs loading and sediment transport. Because sediments store, convey and serve as a source of OC pesticides and PCBs, a reduction of OC pesticides and PCBs concentrations in sediment will result in a reduction of OC pesticides and PCBs concentration in the water column and fish tissue. In this linkage analysis, DDE is used as a representative constituent, because DDE is consistently detected in monitoring and exceeds numeric targets in water, sediment, and tissue samples. Also, other OC Pesticides and PCBs possess similar physical and chemical properties to DDE.

Wasteload Allocations

1. **Interim and Final WLAs* for Pollutants in Effluent for POTWs.**

   The interim wasteload allocations for POTWs will be reconsidered by the Regional Board on a 5-year basis. This reconsideration will be based on sufficient data to calculate Interim Wasteload Allocations in accordance with SIP procedures.

a) Interim WLAs (ng/L)

Constituent	POTW Hill Canyon Daily	Simi Valley Daily	Moorpark Daily	Camarillo Daily	Camrosa Daily
Chlordane	1.2	100.0	100.0	100.0	100.0
4,4-DDD	20.0	50.0	50.0	6.0	50.0
4,4- DDE	260.0	1.2	1.2	188.0	50.0
4,4-DDT	10.0	10.0	10.0	10.0	10.0
Dieldrin	10.0	10.0	10.0	10.0	10.0
PCBs	500.0	500.0	500.0	31.0	500.0
Toxaphene	500.0	500.0	500.0	500.0	500.0

* WLAs shall be applied to POTWs'effluent

b) Final WLAs (ng/L)

Constituent	POTW Hill Canyon		Simi Valley		Moorpark		Camarillo		Camrosa	
	Daily	Monthly	Daily	Monthly	Daily	Monthly	Daily	Monthly	Daily	Monthly
Chlordane	1.2	0.59	1.2	0.59	1.2	0.59	1.2	0.59	1.2	0.59
4,4-DDD	1.7	0.84	1.7	0.84	1.7	0.84	1.7	0.84	1.7	0.84
4,4- DDE	1.2	0.59	1.2	0.59	1.2	0.59	1.2	0.59	1.2	0.59
4,4-DDT	1.2	0.59	1.2	0.59	1.2	0.59	1.2	0.59	1.2	0.59
Dieldrin	0.28	0.14	0.28	0.14	0.28	0.14	0.28	0.14	0.28	0.14

TMDL Element	Calleguas Creek Watershed OC Pesticide, PCBs, and Siltation TMDL

PCBs	0.34	0.17	0.34	0.17	0.34	0.17	0.34	0.17	0.34	0.17
Toxaphene	0.33	0.16	0.33	0.16	0.33	0.16	0.33	0.16	0.33	0.16

The final WLAs will be included in NPDES permits in accordance with schedule in the implementation plan. The Regional Board may revise final WLAs prior to the dates they are placed into permits and/or prior to the dates of final WLA achievement based on special studies and monitoring of this TMDL.

2. Interim and Final WLAs for Pollutants in Sediment for Stormwater Permittees

a) Interim WLAs (ng/g)

Constituent	Subwatershed					
	Mugu Lagoon[1]	Calleguas Creek	Revolon Slough	Arroyo Las Posas	Arroyo Simi	Conejo Creek
Chlordane	25.0	17.0	48.0	3.3	3.3	3.4
4,4-DDD	69.0	66.0	400.0	290.0	14.0	5.3
4,4- DDE	300.0	470.0	1,600.0	950.0	170.0	20.0
4,4-DDT	39.0	110.0	690.0	670.0	25.0	2.0
Dieldrin	19.0	3.0	5.7	1.1	1.1	3.0
PCBs	180.0	3,800.0	7,600.0	25,700.0	25,700.0	3,800.0
Toxaphene	22,900.0	260.0	790.0	230.0	230.0	260.0

Compliance with sediment based WLAs is measured as an in-stream annual average at the base of each subwatershed where the discharges are located.

b) Final WLAs (ng/g)

Constituent	Subwatershed					
	Mugu Lagoon[1]	Calleguas Creek	Revolon Slough	Arroyo Las Posas	Arroyo Simi	Conejo Creek
Chlordane	3.3	3.3	0.9	3.3	3.3	3.3
4,4-DDD	2.0	2.0	2.0	2.0	2.0	2.0
4,4- DDE	2.2	1.4	1.4	1.4	1.4	1.4
4,4-DDT	0.3	0.3	0.3	0.3	0.3	0.3
Dieldrin	4.3	0.2	0.1	0.2	0.2	0.2
PCBs	180.0	120.0	130.0	120.0	120.0	120.0
Toxaphene	360.0	0.6	1.0	0.6	0.6	0.6

[1] The Mugu Lagoon subwatershed includes Duck Pond/Agricultural Drain/Mugu/Oxnard Drain #2.

Compliance with sediment based WLAs is measured as an in-stream annual average at the base of each subwatershed where the discharges are located.

3. Final WLAs for Pollutants in Water Column for Minor Point Sources

WLAs for pollutants in water column are allocated below to

TMDL Element	Calleguas Creek Watershed OC Pesticide, PCBs, and Siltation TMDL

minor point sources enrolled under NPDES permits or WDRs, which discharge to Calleguas Creek.

Constituent	Daily Maximum (ng/L)	Monthly Average (ng/L)
Chlordane	1.2	0.59
4,4-DDD	1.7	0.84
4,4- DDE	1.2	0.59
4,4-DDT	1.2	0.59
Dieldrin	0.28	0.14
PCBs	0.34	0.17
Toxaphene	0.33	0.16

4. Siltation WLA for MS4

MS4 dischargers will receive an allocation of 2,496-tons/yr. reduction in sediment yield to Mugu Lagoon. The baseline from which the load reduction will be evaluated will be determined by a special study of this TMDL. The load allocation will apply after the baseline is established, as described in the Implementation Plan.

Load Allocations

Compliance with sediment based LAs listed below is measured as an in-stream annual average at the base of each subwatershed.

1. Interim and Final Load Allocations

a) Interim Sediment LAs (ng/g)

Constituent	Subwatershed					
	Mugu Lagoon[1]	Calleguas Creek	Revolon Slough	Arroyo Las Posas	Arroyo Simi	Conejo Creek
Chlordane	25.0	17.0	48.0	3.3	3.3	3.4
4,4-DDD	69.0	66.0	400.0	290.0	14.0	5.3
4,4- DDE	300.0	470.0	1,600.0	950.0	170.0	20.0
4,4-DDT	39.0	110.0	690.0	670.0	25.0	2.0
Dieldrin	19.0	3.0	5.7	1.1	1.1	3.0
PCBs	180.0	3,800.0	7,600.0	25,700.0	25,700.0	3,800.0
Toxaphene	22900.0	260.0	790.0	230.0	230.0	260.0

[1] The Mugu Lagoon subwatershed includes Duck Pond/Agricultural Drain/Mugu/Oxnard Drain #2.

b) Final Sediment LAs (ng/g)

Constituent	Subwatershed					
	Mugu Lagoon[1]	Calleguas Creek	Revolon Slough	Arroyo Las Posas	Arroyo Simi	Conejo Creek

<table>
<tr><th>TMDL Element</th><th>Calleguas Creek Watershed OC Pesticide, PCBs, and Siltation TMDL</th></tr>
<tr><td></td><td>
<table>
<tr><td>Chlordane</td><td>3.3</td><td>3.3</td><td>0.9</td><td>3.3</td><td>3.3</td><td>3.3</td></tr>
<tr><td>4,4-DDD</td><td>2.0</td><td>2.0</td><td>2.0</td><td>2.0</td><td>2.0</td><td>2.0</td></tr>
<tr><td>4,4- DDE</td><td>2.2</td><td>1.4</td><td>1.4</td><td>1.4</td><td>1.4</td><td>1.4</td></tr>
<tr><td>4,4-DDT</td><td>0.3</td><td>0.3</td><td>0.3</td><td>0.3</td><td>0.3</td><td>0.3</td></tr>
<tr><td>Dieldrin</td><td>4.3</td><td>0.2</td><td>0.1</td><td>0.2</td><td>0.2</td><td>0.2</td></tr>
<tr><td>PCBs</td><td>180.0</td><td>120.0</td><td>130.0</td><td>120.0</td><td>120.0</td><td>120.0</td></tr>
<tr><td>Toxaphene</td><td>360.0</td><td>0.6</td><td>1.0</td><td>0.6</td><td>0.6</td><td>0.6</td></tr>
</table>
[1] The Mugu Lagoon subwatershed includes Duck Pond/Agricultural Drain/Mugu/Oxnard Drain #2.

2. Siltation LAs

Agricultural dischargers will receive an allocation of 2,704 tons/yr. Reduction in sediment yield to Mugu Lagoon. The baseline from which the load reduction will be evaluated will be determined by a special study of this TMDL. The load allocation will apply after the baseline is established, as described in the Implementation Plan.
</td></tr>
<tr><td>**Margin of Safety**</td><td>This TMDL relies on an implicit margin of safety, by incorporating conservative assumptions throughout its development, including:
♣ Basing percent reductions on the historical data set of water and fish tissue concentrations, which does not reflect the effects of attenuation the over the past ten years.
♣ Determining the percent reduction in sediment, by basing it on the greater percent reduction of either water or fish tissue concentrations based on available data.
♣ Reducing the allowable concentration for upstream subwatersheds, to ensure protection of those subwatersheds downstream from upstream inputs.
♣ Choosing Threshold Effects Levels (TELs) and Effects Range Lows (ERLs) as numeric targets for sediment, which are the most protective applicable sediment guidelines.
♣ Selecting the more stringent of the allowable concentration (as calculated by percent reduction methodology) or the numeric target for sediment (TEL or ERL), when available, as the WLA and LA for all reaches with 303(d) listings for sediment.</td></tr>
<tr><td>**Future Growth**</td><td>Ventura County accounts for slightly more than 2% of the state's residents with a population of 753,197 (US Census Bureau, 2000). GIS analysis of the 2000 census data yields a population estimate of 334,000 for the CCW, which equals about 44% of the county population. According to the Southern California Association of Governments (SCAG), growth in Ventura County averaged about 51% per decade from 1900-2000; with growth exceeding 70% in the 1920s, 1950s, and 1960s. Significant population growth is expected to occur within and near present city limits until at least</td></tr>
</table>

TMDL Element	Calleguas Creek Watershed OC Pesticide, PCBs, and Siltation TMDL
	2020. Since most of the listed OCs and PCBs in the CCW are banned, this growth is not expected to increase current loads. Urban application of those OC pesticides which are still legal (dacthal and endosulfan) may increase, but overall use may decrease because urban expansion tends to reduce total acreage of agricultural land. Population growth may result in greater OC loading to POTW influent from washing food products containing OC residues. This loading may be proportional to the increase in population, if per capita domestic water use and pesticide load per household remain constant. Increased flow from POTWs should not result in impairment of the CCW as long as effluent concentration standards are met for each POTW. As urban development occurs, construction activities may have a range of effects on OC loading to the CCW. Exposure of previously vegetated or deeply buried soil might lead to increased rates of transportation and volatilization. Conversely, urbanization of open space and/or agriculture areas may cover OC pesticides bound to sediments. Future growth in the CCW may result in increased groundwater concentrations of currently used OC pesticides. This is a potential concern for dacthal, which is still used and has been found in groundwater (although current levels of dacthal are significantly lower than all available targets). The effects of future growth upon PCB loads are unknown, but not likely to prove significant, since atmospheric deposition and accidental spills are the primary loading pathways. Any increase in OCs due to population growth may be offset by decreased inputs from banned OCs, as their presence attenuates due to fate and transport processes.
Critical Conditions	The linkage analysis found correlation between concentrations of OC pesticides and PCBs in water and total suspended solids (TSS), and a potential correlation between OC pesticides and PCBs concentrations in water and seasonality (wet vs. dry season). A similar correlation between sediment loading and wet weather is also noted. OC pesticides and PCB pollutants are of potential concern in the Calleguas Creek Watershed due to possible long-term loading and food chain bioaccumulation effects. There is no evidence of short-term effects. However, pollutant loads and transport within the

TMDL Element	Calleguas Creek Watershed OC Pesticide, PCBs, and Siltation TMDL
	watershed may vary under different flow and runoff conditions. Therefore the TMDLs consider seasonal variations in loads and flows but are established in a manner which accounts for the longer time horizon in which ecological effects may occur. Wet weather events, which may occur at any time of the year, produce extensive sediment redistribution and transport downstream. This would be considered the critical condition for loading. However, the effects of organochlorine compounds are manifested over long time periods in response to bioaccumulation in the food chain. Therefore, short-term loading variations (within the time scale of wet and dry seasons each year) are not likely to cause significant variations in beneficial use effects. Therefore, although seasonal variations in loads and flows were considered, the TMDL was established in a manner which accounts for the longer time horizon in which ecological effects may occur
Implementation Plan	The final WLAs will be included in NPDES permits in accordance with the compliance schedules provided in Table 7-17.2. The Regional Board may revise these WLAs based on additional information developed through Special Studies and/or Monitoring of this TMDL. WLAs established for the five major POTWs in this TMDL will be implemented through NPDES permit limits. The proposed permit limits will be applied as end-of-pipe concentration-based effluent limits for POTWs. Compliance will be determined through monitoring of final effluent discharge as defined in the NPDES permit. The implementation plan for POTWs focuses on implementation of source control activities. Consideration of annual averaging of compliance data will be evaluated at the time of permit renewal based on available information, Regional Board policies, and US EPA approval. In accordance with current practice, a group concentration-based WLA has been developed for MS4s, including the Caltrans MS4. The grouped allocation will apply to all NPDES-regulated municipal stormwater discharges in the CCW. Other NPDES-regulated stormwater permittees will be assigned a concentration-based WLA consistent with the interim and final WLAs set forth above. Stormwater WLAs will be incorporated into the NPDES permit as receiving water limits measured at the downstream points of each subwatershed and are expected to be achieved through the implementation of BMPs as outlined in the implementation plan.

TMDL Element	Calleguas Creek Watershed OC Pesticide, PCBs, and Siltation TMDL
	The Regional Board will need to ensure that permit conditions are consistent with the assumptions of the WLAs. If BMPs are to be used, the Regional Board will need to detail its findings and conclusions supporting the use of BMPs in the NPDES permit fact sheets. Should federal, state, or regional guidance or practice for implementing WLAs into permits be revised, the Regional Board may reevaluated the TMDL to incorporate such guidance. LAs will be implemented through the State's Nonpoint Source Pollution Control Program (NPSPCP). The LARWQCB is developing a Conditional Waiver for Irrigated Lands, which includes monitoring at sites subject to approval by the Executive Officer of the Regional Board. Should adoption of the Conditional Waiver be delayed, monitoring will be required as part of this TMDL. Studies are currently being conducted to assess the effectiveness of BMPs for reduction of pollutants from agricultural operations. Results will be used to develop Agricultural Water Quality Management Plans, including the implementation of agricultural BMPs. Additionally, an agricultural education program will be developed to inform growers of the recommended BMPs and the Management Plan. As shown in Table 7-17.2, implementation actions will be taken by agricultural dischargers located in the CCW. The implementation of agricultural BMPs will be based on a comprehensive approach to address pollutant loads discharged from agricultural operations. The Regional Board may revise these LAs based on the collection of additional information developed through special studies and/or monitoring conducted as part of this TMDL. A number of provisions in this TMDL might provide information that could result in revisions to the TMDL. Additionally, the development of sediment quality criteria and other water quality criteria revisions may require the reevaluation of this TMDL. Finally, the use of OC pesticides in other countries which may be present in imported food products, compounded with the persistence of OC pesticides and PCBs in the environment, indicate that efforts to control sources and transport of OCs to receiving waters may not result in attainment of targets and allocations due to activities that are outside the control of local agencies and agriculture. For these reasons, the Implementation Plan includes this provision for reevaluating the TMDL to consider revised water

TMDL Element	Calleguas Creek Watershed OC Pesticide, PCBs, and Siltation TMDL
	quality objectives and the results of implementation studies, if appropriate. The siltation portion of the TMDL includes wasteload and load allocations set as an annual mass reduction from a baseline value of sediment and silt deposited in Mugu Lagoon. The baseline value of sediment and silt conveyed to Mugu Lagoon is to be determined by a TMDL Special Study and established by the Regional Board through an amendment to the TMDL. The Special Study is eight years in duration to ensure that the full range of current conditions that affect loading of sediment and siltation to Mugu Lagoon are considered. If appropriate, the Special Study may also result in a revision to the mass load reduction. The Special Study will be overseen by a Science Advisory Panel consisting of local, regional, and/or national experts in estuarine habitat biology, hydrology, and engineering. At the conclusion of the special study, the Regional Board will reconsider the TMDL to establish sustainable wasteload and load allocations recommended by the Special Study to support aquatic life and wetland habitat beneficial uses. In implementing this TMDL, staff recognize that dischargers may be implementing management measures and management practices to reduce sediment and Siltation loads through permit and waiver programs during the special studies. Further, since the effective date of the Consent Decree, reaches of Calleguas Creek have been listed due to sediment, and another TMDL may be initiated during the Special Study of this TMDL. Staff's intent is to coordinate the requirements of this TMDL with other programs that reduce sedimentation and siltation. The Special Study can consider sediment and silt load reductions through existing permits and the forthcoming conditional waiver for irrigated lands. Load and wasteload allocations become effective after the Regional Board actions based on the Special Study, nine years after the effective date of the TMDL.

Table 7-17.2 Implementation Schedule

Item	Implementation Action[1]	Responsible Party	Completion Date
1	Interim organochlorine pesticide and polychlorinated biphenyls wasteload allocations apply.	NPDES Permittees	Effective date of the amendment
2	Interim organochlorine pesticide and polychlorinated biphenyls load allocations apply.	Agricultural Dischargers	Effective date of the amendment
3	Finalize and submit workplan for organochlorine pesticide and polychlorinated biphenyls TMDL monitoring, or finalize and submit a workplan for an Integrated Calleguas Creek Watershed organochlorine pesticide and polychlorinated biphenyls Monitoring Program for approval by the Executive Officer. The monitoring workplan will include, but not be limited to, appropriate water, biota, and sediment loading and monitoring to verify attainment of targets and protection of beneficial uses.	POTW Permittees, MS4 Permittees, Agricultural Dischargers, US Navy	6 months after effective date of the amendment
4	Initiate Calleguas Creek Watershed organochlorine pesticide, polychlorinated biphenyls, and siltation Monitoring Program developed under the Task 3 workplan approved by the Executive Officer.	POTW Permittees, MS4 Permittees, Agricultural Dischargers, US Navy	6 months after Executive Officer approval of Monitoring Program (Task 3) workplan
5	Submit a workplan for approval by the Executive Officer to identify urban, industrial and domestic sources of organochlorine pesticides and polychlorinated biphenyls and control methods and to implement a collection and disposal program for organochlorine pesticides and polychlorinated biphenyls .	POTW Permittees, MS4 Permittees, US Navy	1 year after effective date of the amendment
6	Submit a workplan for approval by the Executive Officer to identify agricultural sources and methods to implement a collection and disposal program for organochlorine pesticides and polychlorinated biphenyls.	Agricultural Dischargers	1 year after effective date of the amendment
7	Special Study #1 – Submit a workplan and convene a Science Advisory Panel to quantify sedimentation in Mugu Lagoon and sediment transport throughout the Calleguas Creek Watershed. Evaluate management methods to control siltation and contaminated sediment transport to Calleguas Creek, identify appropriate BMPs to reduce sediment loadings, evaluate numeric targets and wasteload and load allocations for siltation/sedimentation to support habitat related beneficial uses in Mugu Lagoon, evaluate the effect of sediment on habitat preservation in Mugu Lagoon, and evaluate appropriate habitat baseline, effectiveness of sediment and siltation load allocations on a subwatershed basis, and methods to restore habitat for approval by the Executive Officer. Additionally, this special study will evaluate the concentration of organochlorine pesticides and polychlorinated biphenyls in sediments from various sources/land use types.[2]	POTW Permittees, MS4 Permittees, Agricultural Dischargers, and US Navy	1 year after effective date of the amendment
8	Special study #2 – Conduct a study to identify land areas with high organochlorine pesticide and polychlorinated biphenyls concentrations, and submit a workplan including milestones and an implementation period that is as short as possible, but not to exceed 6 years, for removal to mitigate the effects of flood control practices on organochlorine pesticides, polychlorinated biphenyls, and sediment loadings to Calleguas Creek waterbodies from any high	Agricultural Dischargers, MS4 Permittees, US Navy	1 years after effective date of the amendment

Item	Implementation Action[1]	Responsible Party	Completion Date
	concentration areas identified. Milestones shall include proposed percentages of reductions achieved by removal. Such practices include but are not limited to management of agricultural runoff, sediment reduction practices and structures, streambank stabilization, and other projects related to stormwater conveyance and flood control improvements in the Calleguas Creek watershed.[2]		
9	Develop an Agricultural Water Quality Management Plan in consideration of the forthcoming Conditional Waiver for Irrigated Lands, or, if the Conditional Waiver for Irrigated Lands is not adopted in a timely manner, develop an Agricultural Water Quality Management Plan as part of the Calleguas Creek WMP. Implement an educational program on BMPs identified in the Agricultural Water Quality Management Plan.	Agricultural Dischargers	3 years after effective date of the amendment
10	Based on results of the Task 5 workplan approved by Executive Officer, implement a collection and disposal program for organochlorine pesticides and polychlorinated biphenyls.	POTW Permittees, MS4 Permittees, US Navy	5 years after effective of the amendment
11	Based on results of the Task 6 workplan approved by Executive Officer implement a collection and disposal program for organochlorine pesticides and polychlorinated biphenyls.	Agricultural Dischargers	5 years after effective of the amendment
12	Re-evaluation of POTW Interim wasteload allocations for organochlorine pesticides and polychlorinated biphenyls based on State Implementation Plan procedures.	Regional Board	5 years, 10 years and 15 years after the effective date of the amendment
13	Special Study #1 – Submit results of Special Study #1, including recommendations for refining the siltation load and wasteload allocations.	POTW Permittees, MS4 Permittees, Agricultural Dischargers, and US Navy	8 years after effective date of the amendment
14	Re-evaluation of siltation and sediment load and wasteload allocations based on Special Study #1.	Regional Board	9 years after effective date of the amendment
15	Effective date of siltation load allocation and wasteload allocation.	Agricultural dischargers, US Navy, MS4 permittees	9 years after effective date of the amendment
16	Special Study #3 – Evaluate natural attenuation rates and evaluate methods to accelerate organochlorine pesticide and polychlorinated biphenyl attenuation and examine the attainability of wasteload and load allocations in the Calleguas Creek Watershed.[2,3]	POTW Permittees, Agricultural Dischargers, MS4 Permittees, and US Navy	10 years after effective date of the amendment
17	Special Study #4 (optional) – Examine of the food web and bioconcentration relationships throughout the watershed to evaluate assumptions contained in the Linkage Analysis and ensure that protection of beneficial uses is achieved.[2]	Interested Parties	12 years after effective date of the amendment
18	Based on the results of Implementation Items 1-17, if sediment guidelines are promulgated or water quality criteria are revised, and/or if fish tissue and water column targets are achieved without attainment of WLAs or LAs, the Regional Board will consider revisions to the TMDL targets, allocations, and schedule for expiration of Interim Wasteload and Interim Load Allocations.[3]	Regional Board	10 years after effective date of the amendment
19	Achieve Final WLAs and LAs	Agricultural Dischargers, POTW Permittees, and MS4 Permittees	20 years after effective date of the amendment

[1] The Regional Board regulatory programs addressing all discharges in effect at the time an implementation task is due may contain requirements substantially similar to the requirements of an implementation task. If such a requirement is in place in another regulatory program including other TMDLs, the Executive Officer may determine that such other requirements satisfy the requirements of an implementation task of this TMDL and thereby coordinate this TMDL implementation plan with other regulatory programs.

[2] Special studies included in the Implementation Plan are based on the TMDL Technical Documents.

[3] After completion of this special study, the TMDL will be reopened in order to enable the Regional Board to evaluate whether a shorter time period is appropriate for the achievement of the final WLAs and LAs.

STATE WATER BOARD
RESOLUTION NO. 2005-0068

APPROVING AN AMENDMENT TO THE WATER QUALITY CONTROL PLAN FOR THE LOS ANGELES REGION TO INCORPORATE A TOTAL MAXIMUM DAILY LOAD FOR ORGANOCHLORINE PESTICIDES, POLYCHLORINATED BIPHENYLS, AND SILTATION IN THE CALLEGUAS CREEK WATERSHED AND MUGU LAGOON

WHEREAS:

1. The Los Angeles Regional Water Quality Control Board (Los Angeles Water Board) adopted the revised Water Quality Control Plan for the Los Angeles Region (Basin Plan) under Resolution No. 94-07 on June 13, 1994. The State Water Resources Control Board (State Water Board) approved the revised Basin Plan on November 17, 1994 and by the Office of Administrative Law (OAL) on February 23, 1995.

2. A consent decree between the U.S. Environmental Protection Agency (USEPA), Heal the Bay, Incorporated and Baykeeper, Incorporated was approved on March 22, 1999. This court order establishes a requirement to establish a TMDL to reduce organochlorine (OC) pesticides and polychlorinated biphenyls (PCBs) in the Calleguas Creek watershed by March 22, 2006.

3. On July 7, 2005, the Los Angeles Water Board adopted Resolution No. R4-2005-010 (Attachment) to incorporate a Total Maximum Daily Load TMDL) for organochlorine pesticides, polychlorinated biphenyls, and siltation in Calleguas Creek, its tributaries, and Mugu Lagoon.

4. Los Angeles Water Board Resolution No. R4-2005-010 delegated to its Executive Officer authority to make minor, non-substantive corrections to the adopted amendment if needed for clarity or consistency. The State Water Board staff finds that provisions of the amendment, as adopted, warranted minor, non-substantive clarification of the language of various provisions. The Los Angeles Water Board Executive Officer has made the necessary corrections to the amendment.

5. The State Water Board finds that the amendment is in conformance with the requirements for TMDL development specified in section 303(d) of the federal Clean Water Act and the State Water Board Resolution No. 68-16 and is an appropriate program of implementation pursuant to Water Code section 13242.

6. The State Water Board finds that the Basin Plan amendment is in conformance with the requirements of Water Code section 13240, which specifies that Regional Water Quality Control Boards shall periodically review and may revise Basin Plans.

7. Basin Plan amendments do not become effective until approved by the State Water Board and until the regulatory provisions are approved by OAL. In addition, TMDLs must be approved by the USEPA.

THEREFORE BE IT RESOLVED THAT:

The State Water Board:

1. Approves the amendment to the Basin Plan as adopted under the Los Angeles Water Board Resolution No. R4-2005-010 as corrected by the Regional Water Board Executive Officer.
2. Authorizes the Executive Director to submit the amendment adopted under Los Angeles Water Board Resolution R4-2005-010, as approved, and the administrative record for this action to OAL and the TMDL to USEPA for approval.

CERTIFICATION

The undersigned, Clerk to the Board, does hereby certify that the foregoing is a full, true, and correct copy of a resolution duly and regularly adopted at a meeting of the State Water Resources Control Board held on September 22, 2005.

Debbie Irvin
Clerk to the Board

RECEIVED
JAN 24 2006
SWRCB
EXECUTIVE OFFICE

TRH/DWQ - James Maughn
cy: OCC

STATE OF CALIFORNIA
OFFICE OF ADMINISTRATIVE LAW

In re:

STATE WATER RESOURCES CONTROL BOARD

REGULATORY ACTION:

Title 23, California Code of Regulations

Adopt sections 3939.17

NOTICE OF APPROVAL OF REGULATORY ACTION

Government Code Section 11353

OAL File No. **05-1206-03 S**

This amendment to the Water Quality Control Plan for the Los Angeles Region (Basin Plan) establishes a Total Maximum Daily Load (TMDL) for organochlorine (OC) pesticides, polychlorinated biphenyls (PCBs), and siltation in Calleguas Creek, its tributaries, and Mugu Lagoon. The TMDL sets numeric concentration-based targets for OC pesticides and PCBs in water, sediment, and/or fish tissue to ensure protection of designated beneficial uses. The specific pollutants addressed are aldrin, chlordane, dacthal, dichlorodiphenyldichloroethane (DDD), dichlorodiphenyldichloroethelyene (DDE), dichlorodiphenyltrichloroethane (DDT), dieldrin, endosulfan I, endosulfan II, endrin, hexachlorocyclohexane (alpha, beta, delta, and gamma BHC), heptachlor, heptachlor epoxide, PCBs, and toxaphene.

OAL approves this regulatory action pursuant to section 11353 of the Government Code.

DATE: 01/20/06

Debra M Cornez
DEBRA M. CORNEZ
Assistant Chief Counsel

for: WILLIAM L. GAUSEWITZ
Director

Original : Celeste Cantu, Executive Director
cc : Joanna Jensen

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, CA 94105-3901

2006 MAR 17 PM 1:51

MAR 14 2006

Ms. Celeste Cantú
Executive Director
State Water Resources Control Board
P.O. Box 100
Sacramento, CA 95812-0100

Dear Ms. Cantú:

Thank you for submitting the Basin Plan amendments containing total maximum daily loads (TMDLs) for Calleguas Creek watershed. The organophosphate pesticides and toxicity TMDL submittal was dated January 12, 2006 and the organochlorine pesticides and siltation TMDL submittal was dated February 6, 2006. The State adopted TMDLs to address the following water body-pollutant combinations on California's 2002 Clean Water Act Section 303(d) list:

- Calleguas Creek Reach 1 [Mugu Lagoon] for sediment toxicity, chlordane, DDT, dieldrin, PCBs, toxaphene, sedimentation/siltation
- Duck Pond drain/Mugu Drain/Oxnard Drain #2 for ambient and sediment toxicity, chlordane, DDT, dieldrin, PCBs, toxaphene
- Calleguas Ck. R2 [estuary] for sediment toxicity, chlordane, DDT, dieldrin, PCBs, toxaphene
- Calleguas Ck. R4 [Revolon Slough] for ambient toxicity, chlorpyrifos, chlordane, DDT, dieldrin, PCBs, toxaphene
- Calleguas Ck. R5 [Beardsley Channel] for ambient toxicity, chlorpyrifos, chlordane, DDT, dieldrin, PCBs, toxaphene
- Calleguas Ck. R6 [Arroyo Las Posas] for chlordane, DDT, dieldrin, PCBs, toxaphene
- Calleguas Ck. R7 [Arroyo Simi] for chlorpyrifos, diazinon
- Calleguas Ck. R9A [Conejo Ck.] for chlordane, DDT, dieldrin, PCBs, toxaphene
- Calleguas Ck. R9B [Conejo Ck. mainstem] for ambient toxicity, chlordane, DDT, dieldrin, PCBs, toxaphene
- Calleguas Ck. R10 [Conejo Ck., Hill Canyon] for ambient toxicity, chlordane, DDT, dieldrin, PCBs, toxaphene
- Calleguas Ck. R11 [Arroyo Santa Rosa] for ambient toxicity, chlordane, DDT, dieldrin, PCBs, toxaphene
- Calleguas Ck. R12 [Conejo Ck, north fork] for chlordane, DDT, dieldrin, PCBs, toxaphene
- Calleguas Ck. R13 [Conejo Ck., south fork] for ambient toxicity, chlordane, DDT, dieldrin, PCBs, toxaphene.

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During the TMDL development process, the State determined the following additional water body-pollutant combinations need TMDLs pursuant to the requirements of Section 303(d)(1), and adopted TMDLs to address these additional combinations:

- Calleguas Ck. R2 [estuary] for chlorpyrifos, diazinon
- Calleguas Ck. R3 [Potrero Rd., upstream] for ambient toxicity, chlorpyrifos, diazinon, chlordane, DDT, dieldrin, PCBs, toxaphene
- Calleguas Ck. R4 [Revolon Slough] for diazinon
- Calleguas Ck. R5 [Beardsley Channel] for diazinon
- Calleguas Ck. R6 [Arroyo Las Posas] for ambient toxicity, chlorpyrifos, diazinon
- Calleguas Ck. R7 [Arroyo Simi R1 & R2] for ambient toxicity, chlordane, DDT, dieldrin, PCBs, toxaphene
- Calleguas Ck. R8 [Tapo Cyn. R1 & R2] for chlorpyrifos, diazinon, chlordane, DDT, dieldrin, PCBs, toxaphene
- Calleguas Ck. R9A [Conejo Ck.] for ambient toxicity, chlorpyrifos, diazinon
- Calleguas Ck. R9B [Conejo Ck. mainstem] for chlorpyrifos, diazinon
- Calleguas Ck. R10 [Conejo Ck., Hill Canyon] for chlorpyrifos, diazinon

During the decision-making process, the State identified these additional water body-pollutant combinations as water quality limited waters for which TMDLs are required. The State provided sufficient documentation to support its determination and provided opportunities for public review and comment on the additional water body-pollutant identifications. The State's decision to concurrently identify additional water quality limited segments and adopt TMDLs for those segments is consistent with the provisions of the Clean Water Act and federal regulations. As the State's decision to identify the additional water body-pollutant combinations is consistent with the requirements of Section 303(d) and federal regulations at 40 CFR 130.7, EPA hereby approves the identification of these additional combinations pursuant to Section 303(d)(2).

Based on EPA's review of the TMDL submittals under Clean Water Act Section 303(d)(2), I have concluded the TMDLs adequately address the pollutants of concern and, upon implementation, will result in attainment of the applicable water quality standards. These TMDLs include waste load and load allocations as needed, take into consideration seasonal variations and critical conditions, and provide an adequate margin of safety.

The State provided sufficient opportunities for public review and comment on the TMDLs and demonstrated how public comments were considered in the final TMDLs. All required elements are adequately addressed; therefore, the TMDLs are hereby approved pursuant to Clean Water Act Section 303(d)(2).

The State submittals also contain detailed plans for implementing these TMDLs. Current federal regulations do not define TMDLs as containing implementation plans; therefore, EPA is not taking action on the implementation plans provided with the TMDLs. However, EPA generally concurs with the State's proposed implementation approaches.

The enclosed review discusses the basis for these decisions in greater detail. I appreciate the State and Regional Boards' work to adopt these TMDLs and look forward to our continuing partnership in TMDL development. If you have questions concerning this action, please call me at (415) 972-3572 or David Smith at (415) 972-3416.

Sincerely yours,

Alexis Strauss 14 March 2006
Alexis Strauss, Director
Water Division

enclosures

cc: Jonathan Bishop, LARWQCB

Enclosure: Staff Analysis of TMDL Submittals
Calleguas Creek Pesticides, PCBs, Toxicity and Siltation
March 2006

Introduction

The State of California adopted TMDLs to address water body impairments in Calleguas Creek, its tributaries and Mugu Lagoon. The TMDLs are contained in two Basin Plan Amendments submitted by the State. One amendment includes the toxicity and organophosphate pesticides TMDLs; a second amendment includes TMDLs for organochlorine pesticides and PCBs in several segments and a siltation TMDL for Mugu Lagoon.

EPA reviewed the submittals to ensure that all TMDL elements required by Clean Water Act Section 303(d) and associated federal regulations at 40 CFR 130.2 and 130.7 were adequately addressed. EPA Region 9 reviews of State TMDL submittals are organized in checklist form. This document includes separate checklists for the two Basin Plan Amendments that briefly discuss the State's approaches to meeting TMDL requirements. EPA has determined that the TMDLs meet all federal approval requirements.

By approving these TMDL submittals, EPA is in compliance with the TMDL completion requirements for these waters and pollutants established in a 1999 federal consent decree pursuant to the *Heal the Bay v. Browner* litigation. This consent decree requires completion of TMDLs for many watersheds in the Los Angeles region in accordance with a specific time schedule. The consent decree schedule requires completion of required pesticide, PCB, and toxicity TMDLs for Calleguas Creek watershed and a siltation TMDL for Mugu Lagoon by March 22, 2006.

As described below, the State of California determined that some waters identified in the consent decree do not require TMDL development because available data and information indicate that these waters are not water quality limited pursuant to Section 303(d) and do not require TMDL development. Pursuant to the provisions of paragraph 8 of the consent decree, TMDLs are not required to be completed for water body-pollutant combinations identified in the consent decree if the State or EPA determine, consistent with the requirements of Section 303(d), that the water body-pollutant combinations are not water quality limited. The State of California has determined that several water body-pollutant combinations in the Calleguas Creek watershed do not require TMDL development. Several of these combinations were removed from the Section 303(d) list during the 2002 revisions to California's Section 303(d) list and are not addressed in these TMDL submittals as EPA previously approved these delisting decisions.

During development of the, the State determined that several additional water-pollutant combinations included on California's 2002 Section 303(d) list are not impaired and do not require TMDL development. Consistent with the provisions of consent decree paragraph 8, the State's documentation prepared to support these TMDL submittals clearly describes the basis for the State's conclusion that TMDLs are not needed for these combinations. The public had several opportunities to review and comment on these determinations. EPA concurs in these determinations that TMDLs are not required for these additional combinations. EPA expects these combinations will be removed from the Section 303(d) list during the ongoing revisions to California's Section 303(d) list, scheduled for completion in 2006.

Some listed segments in these watersheds covered in the consent decree were listed on the Section 303(d) list due to ambient water or sediment toxicity. The State developed TMDLs for all pollutants found at levels associated with toxicity to aquatic organisms. The State also developed separate toxicity TMDLs to address unidentified toxic agents of ambient or sediment toxicity. EPA concurs with this approach to addressing the toxicity listings in these waters.

In addition to addressing the water body-pollutant combinations included in the consent decree, the State determined through its analysis that water quality standards were being violated in several additional segments in the subject watershed. The State identified these additional water body-pollutant combinations in the Technical Reports supporting the Basin Plan Amendments as waters and pollutants requiring TMDLs pursuant to Section 303(d)(1). The State also described the analytical basis for its determinations concerning these additional segments and pollutants and provided ample opportunities for public review of these additional identifications. The State concurrently developed TMDLs for these additional water body-pollutant combinations that are included with the Basin Plan Amendment submittals. The State's approach of concurrently identifying waters and pollutants needing TMDLs and adopting the required TMDLs is consistent with the provisions of the Clean Water Act and associated federal regulations. This approach is also efficient as it comprehensively addresses water quality problem associated with pesticides, PCBs, and toxicity in these waters.

The technical analyses for most of these TMDLs were developed by a third party, Larry Walker Associates, under contract with the Calleguas Creek Watershed Management Steering Committee. One technical report describes the toxicity and organophosphate pesticide TMDLs (June 21, 2005). Another technical report (June 20, 2005) describes the organochlorine pesticide and PCBs TMDLs. Both technical reports were developed with input and guidance from the Los Angeles Regional Water Quality Control Board and EPA. The Los Angeles Regional Board staff prepared a separate technical memo (Staff Memo, April 25, 2005) for the siltation TMDL, which was included in the Basin Plan Amendment for the organochlorine pesticide and PCBs TMDLs.

TMDL Checklist

State:	California
Waterbodies:	Calleguas Creek, tributaries and Mugu Lagoon
Pollutant(s):	Toxicity and Organophosphate pesticides (chlorpyrifos and diazinon)
Date of State Submission:	January 12, 2006
Date Received By EPA:	January 26, 2006
EPA Reviewer:	Cindy Lin

Review Criteria	Comments
1. Submittal Letter: State submittal letter indicates final TMDL(s) for specific water(s)/pollutant(s) were adopted by state and submitted to EPA for approval under 303(d).	Letter dated January 12, 2006. The Los Angeles Regional Water Quality Control Board (Regional Board) adopted the TMDLs on July 7, 2005 through Resolution No. R4-2005-009. The State Water Resources Control Board (State Board) approved the basin plan amendment through Resolution No. 2005-0067 on September 22, 2005. The State Office of Administrative Law approved the TMDLs on December 27, 2005 as file No. 05-1110-02 S. These TMDLs address water body-pollutant combinations identified in Analytical Units # 2 and 5 of the *Heal the Bay* consent decree. TMDLs were adopted for following segments and impairments as identified on the state's 2002 303d list: (June 21, 2005 Technical Report (Technical Report), p. 23) - Calleguas Ck Reach 1 = Mugu Lagoon (sediment toxicity) - Duck Pond drain/Mugu drain/ Oxnard drain #2 (ambient and sediment toxicity) - Calleguas Creek R2 = estuary (sediment toxicity) - Calleguas Ck R4 = Revolon Slough (ambient toxicity, chlorpyrifos) - Calleguas Ck R5 = Beardsley Channel (ambient toxicity, chlorpyrifos) - Calleguas Ck R7 = Arroyo Simi (organophosphate pesticides; i.e., chlorpyrifos and diazinon) - Calleguas Ck R9B = Conejo Ck mainstem (ambient toxicity) - Calleguas Ck R10 = Conejo Ck, Hill Canyon (ambient toxicity) - Calleguas Ck R11 = Arroyo Santa Rosa (ambient toxicity) - Calleguas Ck R13 = Conejo Ck, south fork (ambient toxicity) As discussed above, the State identified several additional segments in the Calleguas Creek watershed for which organophosphate pesticides and toxicity TMDLs were also adopted (Technical Report, pp. 45-46): - Calleguas Creek R2 = estuary (chlorpyrifos, diazinon) - Calleguas Ck R3 = Potrero Rd. (ambient toxicity, chlorpyrifos, diazinon) - Calleguas Ck R4 = Revolon Slough (diazinon) - Calleguas Ck R5 = Beardsley Channel (diazinon) - Calleguas Ck R6 = Arroyo Las Posas (ambient toxicity, chlorpyrifos, diazinon) - Calleguas Ck R7 = Arroyo Simi (ambient toxicity) - Calleguas Ck R8 = Tapo Cyn R1 & R2 (chlorpryifos, diazinon) - Calleguas Ck R9A = Conejo Ck (ambient toxicity, chlorpryifos, diazinon) - Calleguas Ck R9B = Conejo Ck mainstem (chlorpryifos, diazinon) - Calleguas Ck R10 = Conejo Ck, Hill Canyon (chlorpyrifos, diazinon) - Calleguas Ck R11 = Arroyo Santa Rosa (chlorpryifos, diazinon) EPA finds the State's analysis concerning water body impairment associated with toxicity, chlorpyrifos and diazinon organophosphate compounds in the Calleguas Creek watershed and Mugu Lagoon is reasonable and consistent with the requirements of Section 303(d).

2. Water Quality Standards Attainment: TMDL and associated allocations are set at levels adequate to result in attainment of applicable water quality standards.	The June 21, 2005 Technical Report, pp. 13-15. The TMDL is designed to implement the existing narrative objectives for toxicity and toxic pollutant that apply in Calleguas Creek, its tributaries and Mugu Lagoon. The Regional Board Basin Plan specifies narrative water quality objectives stating that toxic substances shall not be present at levels that will bioaccumulate in aquatic organisms to levels that are harmful to aquatic life or human health. Although there are no Basin Plan Objectives specific to sediment toxicity, the narrative ambient water toxicity objectives may be used to address sediment toxicity for the purposes of identifying targets for sediment toxicity. In addition, the Basin Plan specifies that no individual pesticide or combination of pesticides shall be present in concentrations that adversely affect beneficial uses. The Basin Plan also prohibits increases pesticide concentrations found in bottom sediments or aquatic life. (Technical Report Section 2.2.2) Currently, there are no adopted numeric water, sediment, or fish tissue objectives in the Basin Plan or California Toxics Rule for any organophosphate pesticides (i.e., chlorpyrifos and diazinon). The State reasonably concluded that implementation of the TMDLs, load allocations, and waste load allocations will result in elimination of the adverse effects associated with high toxicity and organophosphate pesticide loads and bring about attainment of the applicable standards for these toxicant compounds in water and sediments.
3. Numeric Target(s): Submission describes applicable water quality standards, including beneficial uses, applicable numeric and/or narrative criteria. Numeric water quality target(s) for TMDL identified, and adequate basis for target(s) as interpretation of water quality standards is provided.	Basin Plan Amendment Resolution, pp. 2-3. The TMDL report identifies numeric targets for chlorpyrifos, diazinon and water and sediment toxicity. The TMDL establishes a numeric toxicity target of 1.0 toxicity unit-chronic (1.0 TUc) to address toxicity in reaches where the toxicant has not been identified through a Toxicity Identification Evaluation (TIE) (unknown toxicity). A sediment toxicity target was defined for reaches for which TIEs did not identify the causes of sediment toxicity. (Technical Report, pp. 53-56) The TMDL establishes numeric targets for chlorpyrifos and diazinon based on USEPA's 1985 Guidelines for Deriving Numeric National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses. (Technical Report, pp. 50-52) Chlorpyrifos Numeric Targets (ug/L) — Chronic — Acute Freshwater — 0.014 — 0.025 Saltwater (Mugu Lagoon) — 0.009 — 0.02 Diazinon Numeric Targets (ug/L) — Chronic — Acute Freshwater — 0.10 — 0.10 Saltwater (Mugu Lagoon) — 0.40 — 0.82 The State's approach is a reasonable and environmentally protective approach for applying applicable numeric criteria to derive numeric targets.
4. Source Analysis: Point, non-point, and background sources of pollutants of concern are described, including the magnitude and location of sources. Submittal demonstrates all significant	Basin Plan Amendment Resolution, p. 3. The TMDL analysis evaluates all available data and information concerning the sources of toxicity and organophosphate pesticides into Calleguas Creek, its tributaries and Mugu Lagoon. The TMDL focuses on the potential sources of chlorpyrifos and diazinon as these two organophosphate pesticides have been identified as principal causes of water and/or sediment toxicity in the watershed.

sources have been considered.	The Calleguas Creek Watershed Nutrients TMDL (approved in 2003) addresses potential contributions to toxicity from ammonia. As the causes of toxicity in some listed reaches have not been fully identified, monitoring will continue to investigate toxicity of unknown causes (as stipulated in the Implementation Plan). Toxicity investigations to date suggest the unknown toxicity is associated with organic toxicants and, in particular, organophosphate pesticides. (Technical Report, p. 57) The largest source of chlorpyrifos and diazinon pesticides is agricultural runoff and urban runoff within the watershed. During dry weather, publicly owned treatment works (POTWs) contribute a significant load of diazinon to the water bodies. However, urban use of chlorpyrifos and diazinon are unlikely to be a long-term source to the watershed as both pesticides have been banned for most non-agricultural uses starting December 31, 2005. (Technical Report, pp. 58-85) The TMDL report adequately considered all significant sources of organophosphate compounds to Calleguas Creek watershed and other potential causes of observed toxicity.
5. Allocations: Submittal identifies appropriate waste load allocations for point sources and load allocations for non-point sources. If no point sources are present, waste load allocations are zero. If no non-point sources are present, load allocations are zero.	Basin Plan Amendment Resolution, pp. 4-6. The TMDLs include both wasteload allocations for point sources and load allocations for non point sources. A wasteload allocation of 1.0 TUc is allocated to point sources (POTWs, urban stormwater co-permittees (MS4), and minor NPDES-regulated sources). In addition, the major and minor point sources receive wasteload allocations set equal to the established numeric targets for chlorpyrifos (equal to the 4-day chronic numeric target) and diazinon (equal to the 1 hour acute target). All nonpoint sources received a load allocation of 1.0 TUc. Load allocations of chlorpyrifos and diazinon are set equal to the numeric targets for each subwatershed. (Technical Report, pp. 109-115) Since chlorpyrifos and diazinon are not naturally occurring, the background load allocation is set equal to zero. (Technical Report, pp. 118) Based on the information in the Technical Report and the Basin Plan Attachment to Resolution, EPA concludes that the TMDLs include as appropriate wasteload and load allocations that are consistent with the Clean Water Act and federal regulations.
6. Link Between Numeric Target(s) and Pollutant(s) of Concern: Submittal describes relationship between numeric target(s) and identified pollutant sources. For each pollutant, describes analytical basis for conclusion that sum of waste load allocations, load allocations, and margin of safety does not exceed the loading capacity of the receiving water(s).	Basin Plan Amendment Resolution, p. 3-4. The State used water quality modeling to establish the linkage between sources of chlorpyrifos and diazinon in the watershed to observed water quality data. A mass balance water quality model used existing data to determine loads and partitioning between dissolved and adsorbed fractions. The TMDL report presented a conceptual model describing the relationship between water column concentrations and fish tissue and sediment concentrations. The model incorporated the specific characteristics of chlorpyrifos (preferentially binds to sediment) and diazinon (preferentially partition to water phase) and reasonably calculated conservative loads and loading capacities. (Technical Report, pp. 86-108) The State's analysis sufficiently describes the link between numeric targets and the pollutant sources in Calleguas Creek watershed.

7. Margin of Safety: Submission describes explicit and/or implicit margin of safety for each pollutant.	Basin Plan Amendment Resolution, p. 7. The TMDL includes both an implicit and explicit margin of safety. The primary implicit margin of safety is provided through the adoption of concentration based TMDLs and allocations that are sensitive to temporal and spatial variability of pollutant loads, and through the adoption of toxicity based TMDLs to address unexplained toxicity causes. The TMDL also includes an explicit margin of safety of 5%. This 5% explicit margin of safety is added to the targets for chlorpyrifos in the Calleguas and Revolon subwatersheds to address the uncertainty in the linkages between water column criteria and fish tissue and sediment concentrations. (Technical Report, pp. 118) EPA considers this a permissible and appropriate way of dealing with uncertainty concerning the relationships between allocations and water quality.

8. Seasonal Variations and Critical Conditions: Submission describes method for accounting for seasonal variations and critical conditions in the TMDL(s)	Basin Plan Amendment Resolution, p. 7. The critical condition in this TMDL is defined as the flowrate at which the model calculated the greatest in-stream diazinon or chlorpyrifos concentration in comparison to the appropriate criterion. The critical condition for chlorpyrifos was in dry weather based on a chronic numeric target. For diazinon, wet weather (based on acute numeric target) is defined as the critical period, except in Mugu Lagoon where critical condition is in dry weather based on the chronic numeric target. (Technical Report, pp. 110 and 119) The State's approach adequately accounts for critical conditions by defining crucial hydrological periods in which ecological effects may occur.
9. Public Participation: Submission documents provision of public notice and public comment opportunity; and explains how public comments were considered in the final TMDL(s).	The Regional and State Boards provided public notice and opportunities for public comment to comment on the TMDLs through mailings, by holding numerous public meetings, and by receiving public comments at these meetings. Public comments were received in writing and in oral testimony. The State demonstrated how it considered these comments in its final decision by providing reasonably detailed responsiveness summaries, which include responses to each comment. The Regional Board held public meetings to discuss the Calleguas Creek Toxicity and Chlorpyrifos and Diazinon TMDLs on May 5, May 31 and July 7, 2005. (See summary of responses to public comments by Regional Board, July 2005.) The State Board also received public comment on the TMDLs on September 22, 2005.
10. Technical Analysis: Submission provides appropriate level of technical analysis supporting TMDL elements.	The TMDL analysis provides a thorough review and summary of available information concerning toxicity, chlorpyrifos and diazinon organophosphate pesticides impairing Calleguas Creek, its tributaries and Mugu Lagoon. EPA concludes the State was reasonably diligent in its technical analysis of toxicity, chlorpyrifos and diazinon in Calleguas Creek and its watershed.

TMDL Checklist

State:	California
Waterbodies:	Calleguas Creek, tributaries and Mugu Lagoon
Pollutant(s):	Organochlorine pesticides (DDT, dieldrin, chlordane, toxaphene), PCBs and siltation
Date of State Submission:	February 6, 2006
Date Received By EPA:	February 8, 2006
EPA Reviewer:	Peter Kozelka

Review Criteria	Comments
1. Submittal Letter: State submittal letter indicates final TMDL(s) for specific water(s)/pollutant(s) were adopted by state and submitted to EPA for approval under 303(d).	Letter dated February 6, 2006. The Los Angeles Regional Water Quality Control Board (Regional Board) adopted the TMDLs on July 7, 2005 through Resolution No. R4-2005-010. The State Water Resources Control Board (State Board) approved the basin plan amendment through Resolution No. 2005-0068 on September 22, 2005. The State Office of Administrative Law approved the TMDLs on January 20, 2006 as file No. 05-1026-03 S. These TMDLs address water body-pollutant combinations identified in Analytical Units # 5 and 7 of the *Heal the Bay* consent decree. TMDLs were adopted for following segments identified on the state's 2002 303d list: - Calleguas Ck Reach 1 = Mugu Lagoon (chlordane, DDT, dieldrin, PCBs toxaphene) - Duck Pond drain/Mugu drain/ Oxnard drain #2 (chlordane, DDT, dieldrin, PCBs toxaphene) - Calleguas Creek R2 = estuary (chlordane, DDT, dieldrin, PCBs toxaphene) - Calleguas Ck R4 = Revolon Slough (chlordane, DDT, dieldrin, PCBs toxaphene) - Calleguas Ck R5 = Beardsley Channel (chlordane, DDT, dieldrin, PCBs toxaphene) - Calleguas Ck R6 = Arroyo Las Posas (chlordane, DDT, dieldrin, PCBs toxaphene) - Calleguas Ck R9A= Conejo Ck (chlordane, DDT, dieldrin, PCBs toxaphene) - Calleguas Ck R9B = Conejo Ck mainstem (chlordane, DDT, dieldrin, PCBs toxaphene) - Calleguas Ck R10 = Conejo Ck, Hill Canyon (chlordane, DDT, dieldrin, PCBs toxaphene) - Calleguas Ck R11 = Arroyo Santa Rosa (chlordane, DDT, dieldrin, PCBs toxaphene) - Calleguas Ck R12 = Conejo Ck, north fork (chlordane, DDT, dieldrin, PCBs toxaphene) - Calleguas Ck R13 = Conejo Ck, south fork (chlordane, DDT, dieldrin, PCBs toxaphene) As discussed above, the State identified several additional segments in the Calleguas Creek watershed for which organochlorine pesticides and PCBs TMDLs were also adopted (Technical Report, pp. 23): - Calleguas Ck R3 = Potrero Rd., upstream (chlordane, DDT, dieldrin, PCBs toxaphene) - Calleguas Ck R7 = Arroyo Simi R1 & R2 (chlordane, DDT, dieldrin, PCBs toxaphene) - Calleguas Ck R8 = Tapo Cyn R1 & R2 (chlordane, DDT, dieldrin, PCBs toxaphene) As discussed above, the State concluded that several water body-pollutant combinations in the watershed that were covered by the consent decree are not water quality limited pursuant to the Clean Water Act and that TMDLs are not required. The State found the following water body segments, as identified on the 2002 303(d) list, were not impaired due to the corresponding pollutants: - Calleguas Ck Reach 1 = Mugu Lagoon (endosulfan) - Duck Pond drain/Mugu drain/ Oxnard drain #2 (Chem A group) - Calleguas Creek R2 = estuary (Chem A, endosulfan) - Calleguas Ck R4 = Revolon Slough (Chem A, endosulfan) - Calleguas Ck R5 = Beardsley Channel (Chem A, endosulfan, dacthal) - Calleguas Ck R9A= Conejo Ck (Chem A, endosulfan, hexachlorocyclohexane)

	- Calleguas Ck R9B = Conejo Ck mainstem (Chem A, endosulfan) - Calleguas Ck R10 = Conejo Ck, Hill Canyon (Chem A, endosulfan) - Calleguas Ck R11 = Arroyo Santa Rosa (Chem A, endosulfan) - Calleguas Ck R13 = Conejo Ck, south fork (Chem A, endosulfan) (TMDL report pp. 19-24 and pp. 32-33) EPA finds the State's analysis concerning water body impairment associated with organochlorine compounds in Calleguas Creek watershed and siltation in Mugu Lagoon is reasonable and consistent with the requirements of Section 303(d).
2. Water Quality Standards Attainment: TMDL and associated allocations are set at levels adequate to result in attainment of applicable water quality standards.	The June 20, 2005 Technical TMDL Report (Technical Report), pp. 14-16. The TMDL is designed to implement the existing numeric and narrative objectives for organochlorine compounds apply in Calleguas Creek, its tributaries and Mugu Lagoon. The federal California Toxics Rule (CTR) specifies numeric water quality criteria for organochlorine pesticides and PCBs that apply in these waters. The Regional Board's Basin Plan specifies narrative water quality objectives stating that toxic substances shall not be present at levels that will bioaccumulate in aquatic organisms to levels which are harmful to aquatic life or human health. (Technical Report, pp. 14-16) The TMDL also addresses narrative objectives regarding wetlands, which emphasize that existing habitat for flora and fauna shall be maintained. This objective is relevant to the protection of Mugu Lagoon. (Technical Report, p. 16) The State reasonably concluded that implementation of the TMDLs, load allocations, and waste load allocations will result in elimination of the adverse effects associated with high organochlorine pesticide, PCBs and siltation loads and bring about attainment of the applicable standards for these toxicant compounds and silt/sediment.
3. Numeric Target(s): Submission describes applicable water quality standards, including beneficial uses, applicable numeric and/or narrative criteria. Numeric water quality target(s) for TMDL identified, and adequate basis for target(s) as interpretation of water quality standards is provided.	Basin Plan Amendment Resolution, pp. 2-4. The TMDL report identifies numeric targets for several media (e.g., water, sediment, fish tissue, wildlife tissue). The TMDLs are designed to implement the numeric water quality criteria in the CTR as well as related fish tissue targets based on translation of the CTR human health criteria. Organochlorine pesticide and PCB targets in sediment are identified for freshwater and saltwater values based on sediment quality guidelines. Targets for bird eggs and seal blubber are included. (Technical Report, pp. 52-57) Two siltation targets are identified in the TMDL for silt reduction and maintenance of existing habitat. (Staff technical memo, dated April 25, 2005, p. 5) The State's approach is a reasonable and environmentally protective approach for applying applicable numeric criteria to derive numeric targets.
4. Source Analysis: Point, non-point, and background sources of pollutants of concern are described, including the magnitude and location of sources. Submittal demonstrates all	Basin Plan Amendment Resolution, p. 4. The TMDL analysis evaluates all available data and information concerning the sources of organochlorine pesticides and PCBs into Calleguas Creek, its tributaries and Mugu Lagoon. The largest source of organochlorine pesticides is agricultural runoff (regulated via waste discharge requirements) with minor inputs from urban runoff and wastewater treatment plants (regulated via NPDES permits) within the watershed. Atmospheric deposition is identified as a potential source of PCBs but not the other compounds. Groundwater and imported water are not significant sources of organochlorine pesticides, PCBs and sediment. (Technical Report, pp. 58-83)

significant sources have been considered.	The siltation TMDL also identified five sources as contributors of sediment to the lagoon basin. (Staff Memo, p. 5) The TMDL report adequately considered all significant sources of organochlorine compounds to Calleguas Creek watershed. It also adequately considered sources of sediments (silt) to Mugu Lagoon. The TMDL sufficiently described all sources of impairments.
5. Allocations: . Submittal identifies appropriate waste load allocations for point sources and load allocations for non-point sources. If no point sources are present, waste load allocations are zero. If no non-point sources are present, load allocations are zero.	Basin Plan Amendment Resolution, pp. 5-8. The TMDLs include both waste load allocations for point sources and load allocations for non point sources. Allocations are categorized by sources and expressed in terms of allowable concentrations of organochlorine pesticides and PCBs. POTWs and minor point sources received daily and monthly wasteload allocations. Stormwater permittees (point source) and agricultural (non-point) sources received annual average wasteload allocations for toxicants in sediments. (Technical Report, pp. 102-105) For the separate siltation TMDL, stormwater permittees and agricultural sources each received a mass-based allocation for sediment yield to Mugu Lagoon. (Staff Memo, pp. 7-9) Based on the information in the Staff Report and the Basin Plan Attachment to Resolution, EPA concludes that the TMDLs include as appropriate wasteload and load allocations that are consistent with the Clean Water Act and federal regulations.
6. Link Between Numeric Target(s) and Pollutant(s) of Concern: Submittal describes relationship between numeric target(s) and identified pollutant sources. For each pollutant, describes analytical basis for conclusion that sum of waste load allocations, load allocations, and margin of safety does not exceed the loading capacity.	Basin Plan Amendment Resolution, pp. 4-5. The TMDL report provides a conceptual model that describes the fate, transformation and uptake of OC pesticides and PCBs and a mass balance model to connect sources of these compounds to their fate and transport in Calleguas Creek and Mugu Lagoon. Sediments serve as the primary exposure pathway and so reductions in sediment concentrations will yield in pollutant reductions in water and fish tissue. DDE is used as a surrogate indicator in the modeling analysis because it is consistently detected in water, sediment and tissue at levels above media specific numeric targets. (Technical Report, pp. 84-95) The Siltation TMDL memo cited several studies to demonstrate that increased sediment accumulation (via deposition of upstream sources) would create land elevation changes in areas that currently contain habitat and would impact estuarine marshes and tidal mudflats. (Staff Memo, pp. 5-6) The State's analysis sufficiently describes the link between numeric targets and the pollutant sources in Calleguas Creek watershed.
7. Margin of Safety: Submission describes explicit and/or implicit margin of safety for each pollutant.	Basin Plan Amendment Resolution, p. 8. The pesticides and PCBs TMDLs include an implicit margin of safety based on several conservative methods utilized during TMDL development. For example, the TMDLs are set based on the greater percent reduction required of either water or fish tissue concentrations in order to determine the percent reductions required for sediments. (Technical Report, pp. 106-107) The siltation TMDL also includes an implicit margin of safety based on conservative estimates of sediment volume reduction need to preserve and improve habitat conditions affected by silt loads. (Staff Memo, p. 7) EPA considers this a permissible and appropriate way of dealing with uncertainty concerning the relationships between allocations and water quality.

8. Seasonal Variations and Critical Conditions: Submission describes method for accounting for seasonal variations and critical conditions in the TMDL(s)	Basin Plan Amendment Resolution, p. 9-10. The TMDL report presents a direct correlation between organochlorine pollutant concentrations and suspended sediment levels, and a positive correlation between sediment loads and wet weather, to support a finding that critical conditions occur during wet weather. The report acknowledges that wet weather events may occur at any time of the year, and these events produce extensive sediment and organochlorine compound redistribution and transport downstream. For bioaccumulative pollutants such as these, which manifest effects over long time periods, the short-term load variations are not likely to create significant variations in beneficial use effects. (Technical Report, pp. 98-99) The siltation analysis recognizes that storm conditions account for the majority of sediment transport and deposition into Mugu Lagoon. However, as beneficial use effects in Mugu Lagoon are associated with the cumulative effects of sediment loads over multi-year periods, short term load variations are unlikely to cause measurable effects. (Staff Memo, pp. 6-7) The State's approach adequately accounts for critical conditions by establishing TMDLs for longer timeframes in which ecological effects may occur.
9. Public Participation: Submission documents provision of public notice and public comment opportunity; and explains how public comments were considered in the final TMDL(s).	The Regional and State Boards provided public notice and opportunities to comment on the TMDLs through mailings, by holding numerous public meetings, and by hearing public comments at these meetings. Public comments were received in writing and in oral testimony. The State demonstrated how it considered these comments in its final decision by providing reasonably detailed responsiveness summaries, which include responses to each comment. The Regional Board held public meetings to discuss the Calleguas Creek organochlorine compound and siltation TMDLs on May 5 and July 7, 2005. (See summary of responses to public comments by Regional Board, July 2005). The State Board also received public comment on the TMDLs on September 7, 2005.
10. Technical Analysis: Submission provides appropriate level of technical analysis supporting TMDL elements.	The TMDL analysis provides a thorough review and summary of available information concerning organochlorine pesticides and PCBs impairing Calleguas Creek, its tributaries and Mugu Lagoon. The analysis also provides appropriate review and summary information for siltation build up and effects in Mugu Lagoon. EPA concludes the State was reasonably diligent in its technical analysis of DDT, dieldrin, chlordane, PCBs and toxaphene in Calleguas Creek and its watershed, as well as the analysis for siltation in Mugu Lagoon.

April 25, 2005

Calleguas Creek Watershed OC Pesticides and PCBs TMDL Technical Report

Submitted to Los Angeles Regional Quality Control Board

Prepared by Larry Walker Associates
on behalf of the Calleguas Creek Watershed Management Plan

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1 INTRODUCTION

The Calleguas Creek Watershed OC Pesticides and PCBs Total Maximum Daily Load (TMDL) document presents the required elements for addressing impairments to Calleguas Creek and its tributaries caused by organochlorine pesticides and PCBs in water, sediment, and fish tissue. This report describes the analyses completed to determine causes of these impairments, the appropriate loadings for various sources, and measures to remove these impairments. Organochlorine pesticides and PCBs are referred to collectively and interchangeably in this TMDL as "OC pesticides and PCBs" or simply "OCs" (since all of these chemicals are organochlorine compounds).

Eleven of fourteen reaches in the Calleguas Creek Watershed (CCW), in southern Ventura County, are identified on the 2002 Clean Water Act Section 303(d) list of water-quality limited segments as impaired due to elevated levels of OC pesticides and PCBs (OCs) in water, sediment and/or fish tissue (Figure 1). The 303(d) listings, which were approved by the State Water Resources Control Board in February 2003, require the development of TMDLs to establish the maximum amount of pollutants a water body can receive without exceeding water quality standards. The CCW reaches identified as impaired on the 2002 303(d) list are presented below in Table 1. TMDLs for listed OCs are presented herein in one document because as a class of compounds they possess similar physical and chemical properties that influence their persistence, fate and transport in the environment.

The Clean Water Act requires TMDLs to be developed to restore impaired water bodies, and the Porter-Cologne Water Quality Act requires that an Implementation Plan be developed to achieve water quality objectives. This document fulfills these statutory requirements and serves as the basis for amending the Water Quality Control Plan for the Los Angeles Region (Basin Plan) to achieve water quality standards in Calleguas Creek for OC pesticides and PCBs in water, sediment, and fish tissue. This TMDL addresses the requirements prescribed by Section 303(d) of the Clean Water Act (40 CFR 130.2 and 130.7) and USEPA guidance (USEPA, 1991).

This TMDL is based on analysis provided by Larry Walker Associates under contract to the Calleguas Creek Watershed Management Plan Steering Committee (Steering Committee) with support from the California Regional Water Quality Control Board, Los Angeles Region (Regional Board or LARWQCB), and the United States Environmental Protection Agency, Region 9 (USEPA).

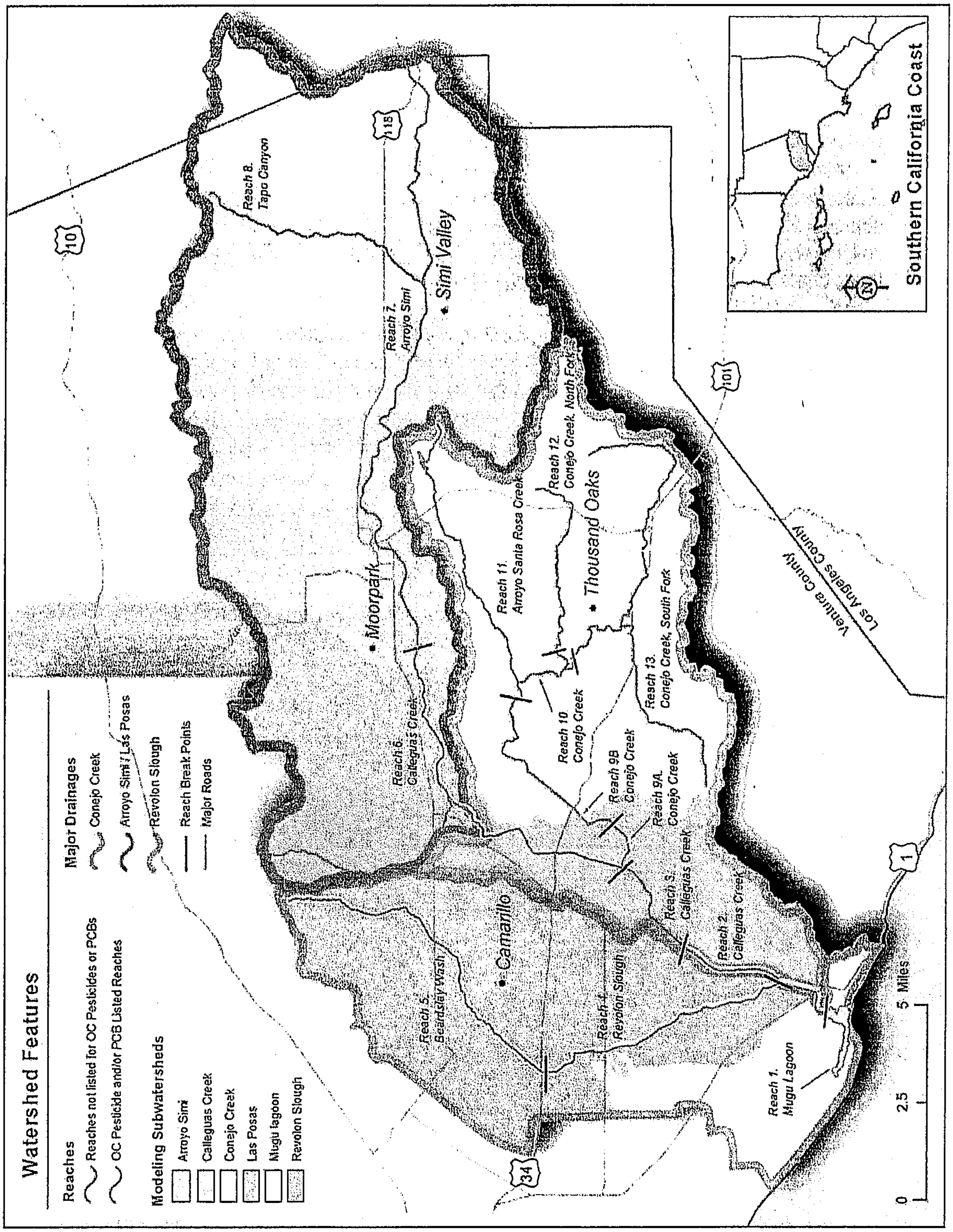


Figure 1. Map of Calleguas Creek Watershed, showing 303d listed reaches for OC pesticides and PCBs.

Table 1. 2002 303(d) Listings for OC Pesticides and PCBs in the CCW. [1]

Reach	Chem-A [2]	Chlordane	DDT	Dacthal	Dieldrin	HCH [3]	Endosulfan	PCBs	Toxaphene
1 – Mugu Lagoon		T	S,T			T		T	
2 – Calleguas Creek, Lower	T	T	S,T,W			T		T	S,T
4 – Revolon Slough	T	S,T	S,T		T	S,T		T	S,T
5 – Beardsley Channel	T	S,T	S,T	S	T	S,T		T	S,T
6 – Arroyo Las Posas			S						
9A – Conejo Creek	T	T	T		T	T	T	T	S,T
9B – Conejo Creek Mainstem	T		T			T			S,T
10 – Conejo Creek, Hill Canyon	T		T			T			S,T
11 – Arroyo Santa Rosa	T		T			T			S,T
12 – Conejo Creek, North Fork		T	T						
13 – Conejo Creek, South Fork	T		T			T			S,T

[1] S = sediment listing; T = tissue listing; W = water column listing.
[2]Chem A Pesticides: aldrin, chlordane, dieldrin, endosulfan, endrin, heptachlor, heptachlor epoxide, hexachlorocyclohexane (HCH, including lindane), and toxaphene.
[3] HCH = Hexachlorocyclohexane, including lindane.

1.1 Regulatory Background

Section 303(d) of the Clean Water Act (CWA) requires that "Each State shall identify those waters within its boundaries for which the effluent limitations are not stringent enough to implement any water quality standard applicable to such waters." The CWA also requires states to establish a priority ranking for waters on the 303(d) list of impaired waters and establish TMDLs for such waters.

The elements of a TMDL are described in 40 CFR 130.2 and 130.7 and Section 303(d) of the CWA, as well as in USEPA guidance (USEPA, 1991). A TMDL is defined as the "sum of the individual waste load allocations for point sources and load allocations for non-point sources and natural background" (40 CFR 130.2) such that the capacity of the water body to assimilate pollutant loadings (the loading capacity) is not exceeded. TMDLs are also required to account for seasonal variations, and include a margin of safety to address uncertainty in the analysis.

States must develop water quality management plans to implement the TMDL (40 CFR 130.6). The USEPA has oversight authority for the 303(d) program and is required to review and either approve or disapprove the TMDLs submitted by states. If the USEPA disapproves a TMDL submitted by a state, USEPA is required to establish a TMDL for that water body. The Regional Board identified over 700 water body-pollutant combinations in the Los Angeles Region where TMDLs are required (LARWQCB, 2003). A schedule for development of TMDLs in the Los Angeles Region was established in a consent decree (Heal the Bay Inc., et al. v. Browner C 98-4825 SBA) approved on March 22, 1999. The consent decree combined water body pollutant combinations in the Los Angeles Region into 92 TMDL analytical units. In accordance with the consent decree, this document summarizes the analyses performed and presents the TMDL for addressing analytical unit 7, which contains PCBs listings, and the organochlorine listings presented in analytical unit 5. The remaining analytical unit 5 listings for sediment toxicity are addressed through the CCW Toxicity TMDL. According to the consent decree, TMDLs addressing analytical units 2, 5, and 7 must be approved or established by USEPA by March 2006.

In addition to the federal and state regulations described above, the Regional Board enacted Resolution No. 97-10, *Support for Watershed Management in the Calleguas Creek Watershed* on April 7, 1997. Resolution 97-10 recognized watershed management as an innovative, cost-effective strategy for the protection of water quality. Resolution 97-10 also recognized that the Calleguas Creek Municipal Water District and the POTWs in the Calleguas Creek watershed had worked cooperatively with the Regional Board to develop an integrated watershed-wide monitoring program. The Calleguas Watershed Management Plan has been active since 1996 in the development of a watershed management plan for the Calleguas Creek watershed and has proactively worked with the Regional Board and the USEPA to develop TMDLs in the watershed.

1.2 Calleguas Creek TMDL Stakeholder Participation Process

The Calleguas Creek Watershed Management Plan has been active since 1996. In 2001, the group began discussions with the Regional Board and USEPA to provide assistance in the development of the TMDLs for the watershed. In December 2002, the group developed TMDL work plans for most constituents on the 2002 303(d) list. The OC Pesticides and PCBs TMDL Work Plan, developed with input from the LARWQCB and USEPA, forms the basis of all of the work conducted to develop this TMDL. USEPA Region IX approved the OC Pesticides and PCBs TMDL Work Plan in October 2003.

The purpose of the watershed group assisting with the development of the TMDLs was to incorporate local expertise and reach a broad group of stakeholders to develop implementation plans to resolve the water quality problems within the watershed. Stakeholders include representatives of cities, counties, water districts, sanitation districts, private property owners, agricultural organizations, and environmental groups with interests in the watershed.

A high level of stakeholder involvement has occurred throughout the TMDL development process. There have been no interventions from outside groups, and much of the work has been performed, or paid for, by members of local government agencies with partial USEPA grant funding.

1.3 Elements of a TMDL

The CCW OC Pesticides and PCBs TMDL contains the following elements:

- Section 2: Problem Statement – Explanation of environmental setting, beneficial uses, and the basis for listings addressed through this TMDL .
- Section 3: Current Conditions – Summarizes current conditions in water, sediment, and fish tissue.
- Section 4: Numeric Targets – Presents appropriate numeric targets that will result in the attainment of water quality objectives as well as the basis for selection of targets.
- Section 5: Source Analysis – Presents an inventory of the sources of the pollutants of concern.
- Section 6: Linkage Analysis – Analysis developed to describe the relationship between the input of the pollutants of concern and the subsequent environmental response with regard to listings.
- Section 7: TMDL and Allocations – Identifies the TMDL allocations for point sources (waste load allocations) and non-point sources (load allocations) that will result in the attainment of water quality objectives.
- Section 8: Implementation Plan – describes the strategy for implementing the TMDL and achieving water quality objectives, as well as a brief overview of the strategy for monitoring the effects of implementation actions.

2 PROBLEM STATEMENT

The Problem Statement Section provides the context and background for this TMDL. The environmental setting provides an overview of the hydrology, climate, and anthropogenic influences in the CCW. In addition, this section includes an overview of water quality standards for the watershed and reviews water, sediment, and fish tissue data used to develop the 1996, 1998, and 2002 303(d) listings.

2.1 Environmental Setting

Calleguas Creek and its tributaries are located in southeast Ventura County and a small portion of western Los Angeles County. Calleguas Creek drains an area of approximately 343 square miles from the Santa Susana Pass in the east to Mugu Lagoon in the southwest. The main surface water system drains from the mountains in the northeast part of the watershed toward the southwest where it flows through the Oxnard Plain before emptying into the Pacific Ocean through Mugu Lagoon. The watershed, which is elongated along an east-west axis, is about thirty miles long and fourteen miles wide. The Santa Susana Mountains, South Mountain, and Oak Ridge form the northern boundary of the watershed; the southern boundary is formed by the Simi Hills and Santa Monica Mountains.

Land uses in the Calleguas Creek watershed include agriculture, high and low density residential, commercial, industrial, open space, and a Naval Air Base located around Mugu Lagoon. The watershed includes the cities of Simi Valley, Moorpark, Thousand Oaks, and Camarillo. Most of the agriculture is located in the middle and lower watershed with the major urban areas (Thousand Oaks and Simi Valley) located in the upper watershed. The current land use in the watershed is approximately 26% agriculture, 24% urban, and 50% open space. Patches of high quality riparian habitat are present along the length of Calleguas Creek and its tributaries.

The watershed is generally characterized by three major subwatersheds: Revolon Slough in the west, Conejo Creek in the south, and Arroyo Simi/Las Posas in the north. Additionally, the lower watershed is also drained by several minor agricultural drains in the Oxnard plain. The following sections describe the major subwatersheds in more detail. Figure 1 depicts the CCW with reach names and designations used in this TMDL, the three major subwatersheds, and six smaller subwatersheds which are defined for analysis and modeling in this TMDL (Mugu, Revolon, Calleguas, Conejo, Arroyo Las Posas, and Arroyo Simi).

Arroyo Simi / Las Posas

The northern portion of the watershed is drained by the Arroyo Las Posas and the Arroyo Simi, which is tributary to the Arroyo Las Posas. The northern part of the watershed system originates in the Simi Valley and surrounding foothills. The surface flow comes from the headwaters of the Arroyo Simi at Santa Susanna pass (upper parts of Reach 7) and Tapo Canyon (Reach 8). Arroyo Simi and Arroyo Las Posas flow through the cities of Simi Valley and Moorpark and join with Calleguas Creek near Camarillo. Upstream of Simi Valley, the creek is unlined and passes through open space and recreational areas. Through the city of Simi Valley, the Arroyo Simi flows through concrete lined or rip-rapped channels. Between Simi Valley and Moorpark, a distance of approximately 7 miles, the creek is unlined and without rip-rap. From the edge of Moorpark to Hitch Boulevard, the creek is once again rip-rapped on the sides with a soft bottom throughout most of the channel, but in some areas, such as under bridges, the bottom is covered with concrete and rip rap. The Arroyo Simi flows into the Arroyo Las Posas at Hitch Blvd. Downstream of Hitch Boulevard, Arroyo Las Posas passes through agricultural fields and orchards in a primarily natural channel. Although the Arroyo Las Posas channel joins with Calleguas Creek near Camarillo, surface flow is typically not present in this portion of the channel due to evaporation and groundwater recharge upstream of Seminary Road.

Two POTWs discharge in this subwatershed. The Simi Valley Water Quality Control Plant (WQCP) discharges to the Arroyo Simi on the western edge of the City of Simi Valley. The Moorpark Wastewater Treatment Plant (WTP) discharges primarily to percolation ponds near the Arroyo Las Posas downstream of Hitch Boulevard. Direct discharges to the Arroyo Las Posas from the Moorpark WTP only occur during extremely wet periods.

Conejo Creek

Conejo Creek and its tributaries (Arroyo Conejo and Arroyo Santa Rosa) drain the southern portion of the watershed. Flow in the southern portion of the watershed originates in the City of Thousand Oaks and flows through the City of Camarillo before joining Calleguas Creek upstream of the California State University Channel Islands. This area supports significant residential and agricultural land uses. The following sections describe Conejo Creek and its tributaries.

Arroyo Conejo

The Arroyo Conejo runs through Thousand Oaks and has three branches, the main fork, the north fork, and the south fork. The main fork of the Arroyo Conejo runs underground for most of its length. The portions that are above ground are concrete lined until the creek enters Hill Canyon on the western side of the city and converges with the south fork. The south fork runs through the southern and western portions of Thousand Oaks. For most of its length, the south fork flows underground or through concrete lined channels. The Hill Canyon Wastewater Treatment Plant (WTP) discharges to the north fork of the Arroyo Conejo on the western edge of the City of Thousand Oaks. The north fork runs through Thousand Oaks upstream of the Hill Canyon WTP. The channel is concrete lined for the portion that runs through the city, but becomes unlined when it nears the treatment plant. The main fork and the south fork join together about a mile upstream of the treatment plant. The joined flow (usually called the south fork at this point) and the north fork converge approximately 0.4 miles downstream of the Hill Canyon WTP. The Arroyo Conejo then flows in a natural channel through a primarily open space area until it merges with the Arroyo Santa Rosa to form Conejo Creek at the base of the canyon.

Arroyo Santa Rosa

Arroyo Santa Rosa runs on the northern edge of the City of Thousand Oaks and through agricultural land in the Santa Rosa Valley. Arroyo Santa Rosa is a natural channel for most of its length with portions of riprap and concrete lining along the sides and bottom of the channel in the vicinity of homes (such as near Las Posas Road). Prior to 1999, a wastewater treatment plant (Olsen Rd.) discharged to Arroyo Santa Rosa and maintained a constant surface flow in the reach. Since 1999, the POTW has not discharged and much of the channel is dry during non-storm events.

Conejo Creek

Arroyo Conejo and Arroyo Santa Rosa converge at the base of Hill Canyon to form Conejo Creek. Conejo Creek flows downstream approximately 7.5 miles, through the City of Camarillo, to its confluence with Calleguas Creek. Just downstream of the city, the Camarillo Sanitary District Water Reclamation Plant (CSDWRP) discharges to Conejo Creek. Because the Arroyo Las Posas does not generally provide surface flow to Calleguas Creek during dry periods, Conejo Creek provides the majority of the flow in

Calleguas Creek. For most of the length of the Conejo and Calleguas Creeks, the sides of the channel are rip rapped and the bottom is unlined.

Revolon Slough

Revolon Slough drains the agricultural land in the western portion of the watershed (Oxnard Plain). The slough does not pass through any urban areas, but does receive drainage from tributaries that drain urban areas. Revolon Slough starts as Beardsley Wash in the hills north of Camarillo. The wash is a rip rapped channel for most of its length and combines with Revolon Slough at Central Avenue in Camarillo. The slough is concrete lined just upstream of Central Avenue and remains lined for approximately 4 miles to Wood Road. From there, the slough is soft bottomed with rip-rapped sides. The lower mile to mile and a half of the slough to above Las Posas Road appears to be tidally influenced by inflows from Mugu Lagoon. Revolon Slough flows into Mugu Lagoon in a channel that runs parallel to Calleguas Creek. The flows from Revolon Slough and Calleguas Creek only converge in the lagoon. In addition to Revolon Slough, a number of agricultural drains (Oxnard Drain, Mugu Drain, and Duck Pond Drain) serve as conveyances for agricultural and industrial drainage water to the Calleguas Creek estuary and Mugu Lagoon.

Mugu Lagoon

Mugu Lagoon, an estuary at the mouth of Calleguas Creek, supports a diverse wildlife population including migratory birds and endangered species. This area is affected by military land uses of the Point Mugu Naval Air Weapons Station and substantial agricultural activities in the Oxnard Plain. The lagoon consists of approximately 287 acres of open water, 128 acres of tidal flats, 40 acres of tidal creeks, 944 acres of tidal marsh and 77 acres of salt pan (California Resources Agency, 1997). It is comprised of a central basin into which flows from Revolon Slough and Calleguas Creek enter and two arms (eastern and western) that receive some drainage from agricultural and industrial drains. In addition, multiple drainage ditches drain into the lagoon. Two of these ditches, Oxnard drainage ditches 2 and 3, discharge urban and agricultural runoff originating beyond the Station's boundaries into the central and western portion of the lagoon. The remaining ditches discharge urban and industrial runoff originating on the Station.

The salinity in the lagoon is generally between 31 and 33 parts per thousand (ppt) (Granade, 2001). The central basin of the lagoon has a maximum tidal range of approximately -1.1 to 7 feet (as compared to mean sea level) with smaller ranges in the two arms. The western arm of the lagoon receives less tidal volume because of a bridge culvert that restricts the flows in that area. The velocity of water traveling through the mouth of the lagoon is approximately 5-6 knots, which is a high velocity for a lagoon (Grigorian, 2001). The mouth of the lagoon never closes, apparently as a result of a large canyon present at the mouth of Calleguas Creek. The canyon prevents ocean sand from building up to a high enough level to close the mouth and likely accounts for the high velocities in the lagoon (Grigorian, 2001).

Climate and Hydrology

The climate in the watershed is typical of the southern California coastal region. Summers are relatively warm and dry and winters are mild and wet. Eighty-five percent of the rainfall occurs between November and March with most of the precipitation occurring during just a few major storms. Annual rainfall in Ventura County averages 15 inches and varies from 13 inches on the Oxnard Plain to a maximum of 20 inches in the higher elevations (USDA, 1995). Storm events concentrated in the wet-weather months produce runoff usually ranging in duration from one-half day to several days. Discharge during runoff from storm events is commonly 10 to 100 times greater than at other times. Storm events and the resulting high stream flows are highly seasonal, grouped heavily in the months of November through February, with an occasional major storm as early as September and as late as April. Rainfall is rare in other months, and major storm flows historically have not been observed outside the wet-weather season.

Surface Waters

The main surface water system drains from the mountains toward the southwest, where it flows through the Oxnard Plain before emptying to the Pacific Ocean through Mugu Lagoon. Dry weather surface water flow in the Calleguas Creek watershed is primarily composed of groundwater, municipal wastewater, urban non-storm water discharges, and agricultural runoff. In the upper reaches of the watershed, upstream of any wastewater discharges, groundwater discharge from shallow surface aquifers provides a constant base flow. Additionally, urban non-stormwater runoff and groundwater extraction for construction dewatering or remediation of contaminated aquifers contribute to the base flow. Stream flow in the upper portion of the watershed is minimal, except during and immediately after rainfall. Flow in Calleguas Creek is described as storm peaking and is typical of smaller watersheds in coastal southern California.

In the Arroyo Simi/Las Posas Subwatershed, additional flow is contributed by groundwater pumped for dewatering and discharged under permit to the Arroyo Simi upstream of Madera Road. The Simi Valley WQCP discharges downstream of the City of Simi Valley and provides much of the flow in the Arroyo Simi during dry weather. During most of the year, at the point where the channel reaches Seminary Road, the surface water flow has been lost to groundwater percolation and evaporation. During and immediately following significant rains, surface flows in the Arroyo Las Posas discharge to Calleguas Creek. In the Conejo Creek Subwatershed, the Hill Canyon WTP provides the majority of the surface water flow. Additionally, the Camarillo WTP provides some flow in the lower portion of Conejo Creek. Revolon Slough receives all of its flow from agricultural discharges, groundwater seepage, and some urban non-stormwater flow.

Groundwater

Groundwater features of the watershed are dominated by the Fox Canyon Aquifer System, which is linked to the neighboring Santa Clara River Watershed. The Fox Canyon Aquifer System is a series of deep, confined aquifers. These aquifers today receive little or no recharge from the watershed. The water quality in these aquifers is very high. However, because there is little recharge to these aquifers they suffer from overdraft. Major groundwater basins within the watershed include the Simi Basin, East Las Posas, West Las Posas, South Las Posas, Pleasant Valley, and Arroyo Santa Rosa Basins. Significant aquifers within the watershed include the Epworth Gravels, the Fox Canyon aquifer, and the Grimes Canyon aquifer in order from shallowest to deepest. In addition, the top 350 feet of sediments within the Pleasant Valley Basin are often referred to as the "Upper Zone", and are thought by some to be equivalent to the Hueneme aquifer zone that is a more well-defined and recognized layer to the west of the Pleasant Valley Basin.

Shallower, unconfined aquifers are located in the valleys of the watershed. In the upper sub-watersheds of Simi Valley and Conejo Valley, groundwater collects in the lower areas and overflows into the down-gradient valleys. The Tierra Rejada, Santa Rosa and South Las Posas valley basins are larger than the upper valley basins and are the most significant unconfined basins on the watershed. Areas of perched and unconfined groundwater are also present along the base of the Santa Monica Mountains, and overlying areas of the southeastern Oxnard Plain in the Pleasant Valley.

Water rights have not been adjudicated in many of these basins, and groundwater production is not comprehensively controlled or maintained. However, groundwater extractions are regulated in the Oxnard

Plain, Pleasant Valley Basin and the Las Posas Basin by the Fox Canyon Groundwater Management Agency. In some basins, groundwater is being over-drafted and as a result Pleasant Valley has experienced subsidence. In other basins, such as the South Las Posas Basin, groundwater storage has increased significantly in the last several decades.

The chemical properties of groundwater may influence the fate and transport of pesticides and affect toxicity of constituents to aquatic organisms. Data for many of these parameters were analyzed in groundwater samples, and the summary statistics for the results are presented in Table 2. For Calleguas Creek groundwater, temperature and Eh (redox) data were not readily available. The groundwater of the Calleguas Creek watershed is slightly alkaline, with pH typically ranging from 7.3 to 8.0, and alkalinity from 140 to 270 mg/L. Hardness also influences solubility; the analyzed Calleguas Creek groundwater samples exhibited an average hardness of 431 mg/L as $CaCO_3$. The average bicarbonate concentration was 151 mg/L. Finally, the presence of cations, often measured as electrical conductivity, can affect the sorption characteristics of infiltrating loads. As seen in Table 2, Calleguas Creek groundwater is highly heterogeneous with respect to electrical conductivity, typically ranging from 465 to 1,521 µS/cm. Consideration of these chemical properties is important when assessing the impacts of the recharge of surface waters on groundwater supplies.

Table 2. Groundwater Chemical Characteristics.

Water Quality Parameter	n	Mean	Std. Dev	Maximum	90th Percentile	10th Percentile	Minimum
pH	372	7.6	0.3	10.1	8.0	7.3	7.0
Alkalinity (mg/L)	220	199	54	420	270	140	70
Hardness (mg/L, CaCO3)	76	431	136	700	585	235	132
Bicarbonate (mg/L)	79	151	99	449	233	8	7
Electrical Conductivity (µS/cm)	370	805	428	2,470	1,520	465	321

Anthropogenic Alterations

Historically, the Oxnard Plain served as the flood plain for Calleguas Creek. Starting in the 1850's, agriculture began to be practiced extensively in the watershed. By 1889, a straight channel from the area near the present day location of Highway 101 to the Conejo Creek confluence had been created for Calleguas Creek. In the 1920's, levees were built to channelize flow directly into Mugu Lagoon (USDA, NRCS, 1995). Increased agricultural and urban land uses in the watershed resulted in continued channelization of the creek to the current channel system. Historically, Calleguas Creek was an ephemeral creek flowing only during the wet season. The cities of Simi Valley, Moorpark, Camarillo, and Thousand Oaks experienced rapid residential and commercial development beginning in the 1960s. In the early 70's, State Water Project supplies began being delivered to the watershed. In 1957, the Camarillo Water Reclamation Plant came online, followed by the Hill Canyon WTP in Thousand Oaks in 1961. Increasing volumes of discharges from these POTWs eventually caused the Conejo/Calleguas system to become a perennial stream by 1972 (SWRCB, 1997). When the Simi Valley Water Quality Control Facility began discharging in the early 1970's, the Arroyo Simi/Arroyo Las Posas became a perennial stream that gradually flowed further downstream and currently reaches Seminary Road in Camarillo. However, surface flows from the Arroyo Simi/Arroyo Las Posas do not connect with surface flows in the Conejo Creek/Calleguas system, except during and immediately following storm events.

Sedimentation

Agricultural development and urbanization have brought about significant changes in the watershed such as increased runoff and freshwater flows, accelerated erosion and sedimentation and transport of agricultural chemicals and urban pollutants. Previous to the channelization of lower Calleguas Creek, sediment was deposited largely in a vast estuarine network that meandered across the Oxnard Plain. Numerous drop structures, channel bed stabilizers, dams, and debris basins have since been constructed to compensate for the loss of flood plain. Extensive urban development, farmland conversion, and the resulting redevelopment of orchards onto steeper slopes have changed the hydrology of the area and led to accelerated erosion rates. Accelerated erosion rates have contributed to flooding and sedimentation of the Oxnard Plain and Mugu Lagoon (USDA, NRCS, 1995).

Flow Diversion Project

The Conejo Creek Diversion project in the Calleguas Creek watershed diverts the majority of flow in Conejo Creek to agricultural uses in the Pleasant Valley area. The diversion project is located approximately 7 miles downstream from the Hill Canyon Wastewater Treatment Plant (WTP). The water rights application allows the diversion of an amount equal to Hill Canyon's effluent minus 4 cfs for in-stream uses and channel losses. An additional amount of water equal to the flow contributed by use of imported water in the region (estimated at 4 cfs) may be diverted when at least 6 cfs of water will remain in the stream downstream of the diversion point (SWRCB, 1997). Natural flows due to precipitation will not be diverted. As a result of this project, flows in the lower reach of Conejo Creek have been reduced to less than half of the previous creek flows. Projects similar to the Conejo Creek Diversion project may be developed as part of the overall Watershed Management Plan for Calleguas Creek to address water resource, water quality, or flooding/erosion concerns. As such, TMDLs must be developed in a manner that considers the impacts of changing flows in the watershed and does not result in restrictions on the necessary use of the water for other purposes.

Reach Designations

Table 3 summarizes the reach descriptions of Calleguas Creek used in this TMDL and the correlation between these reaches with the 303(d) and consent decree listed reaches. These reach designations provide greater detail than the designations in the current Basin Plan, and are developed for purposes of this TMDL. The reach revisions may provide an appropriate analytical tool for future analyses in the watershed. At this time, though, the reach revisions are not regulatory and do not alter water quality objectives for the reaches in the existing Basin Plan.

Table 3. Description of CCW Reaches Based on 2002 303(d) List..

Reach Names for OC Pesticides and PCBs TMDL	Reach Names as Listed in 303(d) List and Consent Decree	Geographic Description	Notes: Hydrology, land uses, etc.
1 Mugu Lagoon	Mugu Lagoon	Lagoon fed by Calleguas Creek	Estuarine; brackish, contiguous with Pacific Ocean
2 Calleguas Creek South	Calleguas Creek Reach 1 and Reach 2 (Estuary to Potrero Rd.)	Downstream (south) of Potrero Rd	Tidal influence; concrete lined; tile drains; Oxnard Plain
3 Calleguas Creek North	Calleguas Creek Reach 3 (Potrero to Somis Rd.)	Potrero Rd. upstream to confluence Conejo Creek	Concrete lined ; no tidal influence; Agriculture tile drains; Pleasant Valley Basin. Camrosa WRP discharges to percolation ponds.
4 Revolon Slough	Revolon Slough Main Branch	Revolon Slough from confluence with Calleguas Creek to Central Ave	Concrete lined ; tile drains; Oxnard Plain; tidal influence
5 Beardsley Channel	Beardsley Channel	Revolon Slough upstream of Central Ave.	Concrete lined ; tile drains; Oxnard Plain
6 Arroyo Las Posas	Arroyo Las Posas Reach 1 and Reach 2 (Lewis Somis Rd. to Moorpark Fwy (23))	Confluence with Calleguas Creek to Hitch Road	Ventura Co. POTW discharge at Moorpark to percolation ponds; discharges enter shallow aquifer; dry at Calleguas confluence
7 Arroyo Simi	Arroyo Simi Reach 1 and Reach 2 (Moorpark Fwy (23) to Headwaters)	End of Arroyo Las Posas (Hitch Rd) to headwaters in Simi Valley.	Simi Valley WQCP discharge; discharges from shallow aquifers; pumped GW; GW discharges from shallow aquifers.
8 Tapo Canyon	Tapo Canyon Reach 1 and Reach 2	Confluence w/ Arroyo Simi up Tapo Cyn to headwaters	Origin near gravel mine, used by nursery, ends in residences.
9A Conejo Creek	Conejo Creek Reach 1 (Confl with Calleguas Creek to Santa Rosa Rd.)	Extends from the confluence with Arroyo Santa Rosa downstream to the Camrosa Diversion	Camarillo WTP discharge; Pleasant Valley Groundwater Basin contains both confined and unconfined perched aquifers. Groundwater and surface water used for agriculture.
9B Conejo Creek	Conejo Creek Reach 1 and Reach2 (Confl with Calleguas Creek to Tho. Oaks city limit)	Extends from Camrosa Diversion to confluence with Calleguas Creek.	Pleasant Valley Groundwater Basin contains both confined and unconfined perched aquifers. Camarillo WTP discharges to percolation ponds near downstream end.
10 Hill Canyon reach of Conejo Creek	Conejo Creek Reach 2 and Reach 3 (Santa Rosa Rd. to Lynn Rd.)	Confluence w/ Arroyo Santa Rosa to confluence w/ N. Fork; and N. Fork to just above Hill Canyon WTP	Hill Canyon WTP; stream receives N. Fork Conejo Creek surface water.
11 Arroyo Santa Rosa	Arroyo Santa Rosa	Confluence w/ Conejo Creek to headwaters	Olsen Rd. WRP; dry before Calleguas Ck confluence except during storm flow.
12 North Fork Conejo Creek	Conejo Creek Reach 3 (Tho. Oaks city limit to Lynn Rd.)	Confluence w/Conejo Creek to headwaters	
13 Arroyo Conejo (S.Fork Conejo Cr)	Conejo Creek Reach 4 (Above Lynn Rd.)	Confluence w/ N. Fork to headwaters—two channels	City of Thousand Oaks; pumped/treated GW

2.2 Water Quality Standards

Federal law requires the states to adopt water quality standards, which are defined as the designated beneficial uses of a water segment and the water quality criteria necessary to support those uses (33 U.S.C. §1313). California implements the federal water quality standard requirements by providing for the reasonable protection of designated beneficial uses through the adoption of water quality objectives (CA Water Code §13241). Water quality objectives may be numeric values or narrative statements. For inland surface waters in the Los Angeles Region, beneficial uses and numeric/narrative objectives are identified in the Basin Plan and additional numeric objectives for toxic pollutants are contained in the California Toxics Rule as adopted by the U.S. EPA (40 CFR 131.38). In addition, federal regulation requires states to adopt a statewide antidegradation policy that protects high quality waters and the level of water quality necessary to maintain and protect existing uses.

2.3 Beneficial Uses

The Basin Plan identifies 21 existing, potential and intermittent beneficial uses for water bodies in the Calleguas Creek Watershed (Table 4). The federally-defined beneficial uses (and the Los Angeles Region Basin Plan equivalents) listed as impaired due to elevated levels of OC pesticides and PCBs in the CCW include: aquatic life (WARM, COLD, EST, WET, MAR, WILD, BIOL, RARE, MIGR, SPWN), fish consumption (COMM), shellfish harvesting (SHELL), and primary and secondary contact recreation (REC-1, REC-2). The designated beneficial uses identified as impaired due to elevated levels of OC pesticides and PCBs in the CCW are briefly described below.

Habitat-Related Uses (WARM, COLD, EST, WET, MAR, WILD, BIOL, RARE, MIGR, SPWN)

Several habitat-related beneficial uses are designated for the CCW. These uses include warm and cold freshwater habitats; estuarine, wetland and marine habitats; wildlife habitat; biological habitats (including Areas of Special Biological Significance); habitats that support rare, threatened, or endangered species; habitats that support migration of aquatic organisms; and habitats that support spawning, reproduction, and/or early development of fish.

Human Consumption of Aquatic Organisms (COMM; SHELL)

Uses of water for commercial or recreational collection of fish, shellfish, or other organisms including, but not limited to, uses involving organisms intended for human consumption or bait purposes.

Recreational Uses (REC-1, REC-2)

Water Contact Recreation (REC-1) and Non-Contact Water Recreation (REC-2) are defined as uses of water for recreational activities involving body contact and proximity to water. Some of these activities include swimming and fishing, and where the ingestion of water is reasonably possible.

Table 4. Beneficial Uses Associated With Impaired Reaches in the Calleguas Creek Watershed.

Water body	Reach[1]	Hydro Unit	Aquatic Life Beneficial Uses Potentially Impaired by OC Pesticides and PCBs										Other Potentially Impaired Beneficial Uses						Remaining Beneficial Uses				
			WARM	COLD	EST	WET	MAR	WILD	BIOL	RARE	MIGR	SPWN	MUN	GWR	REC1	REC2	COMM	SHELL	FRSH	NAV	IND	PROC	AGR
Mugu Lagoon	1	403.11			E	E	E	E	E	E	E	E			P	E	E	E		E			
Calleguas Crk Estuary	2	403.11			E	E		E		E	E	E			P	E	E			P			
Calleguas Creek	2, 3	403.11	E	E		E		E		E			P*	E	E	E			E				E
Revolon Slough	4	403.11	E			E		E					P*	E	E	E					P		E
Beardsley Wash	5	403.61	E					E					P*		E	E			E				
Arroyo Las Posas	6	403.12	E	P				E					P*	E	E	E					P	P	P
Arroyo Las Posas	6	403.62	E	P				E					P*	E	E	E			E		P	P	P
Conejo Creek	3, 9A	403.12	E					E					P*	E	E	E					E	E	E
Conejo Creek	9B	403.63	I					E				E	P*	I	I	I			I				
Arroyo Conejo	9A/B,10	403.64	I					E		E			P*	I	I	I			I				
Arroyo Conejo	13	403.68	I					E					P*	I	I	I			I				
Arroyo Santa Rosa	11	403.63	I					E					P*	I	I	I			I				
Arroyo Santa Rosa	11	403.65	I					E					P*	I	I	I			I				
Arroyo Conejo, N.Fork	12	403.64	E					E				E	P*	E	E	E							E

[1] Reach numerical designations based on 2002 303(d) List. P = Potential beneficial use E = Existing beneficial use I = Intermittent beneficial use

* Conditional designations that were designated under SB 88-63 and RB 89-03. Conditional designations are currently not recognized under federal law and are not water quality standards subject to enforcement at this time (see letter from Alexis Strauss [USEPA] to Celeste Cantu [State Board], dated 2/15/02.)

2.4 Water Quality Objectives

Basin Plan Objectives

The Basin Plan contains the following narrative and numeric water quality objectives applicable to the listed chlorinated compounds and their related effects:

<u>Regional Objectives for Inland Surface Waters</u>

- Bioaccumulation – Toxic pollutants shall not be present at levels that will bioaccumulate in aquatic life to levels which are harmful to aquatic life or human health.

- Pesticides: No individual pesticide or combination of pesticides shall be present in concentrations that adversely affect beneficial uses. There shall be no increase in pesticide concentrations found in bottom sediments or aquatic life.

- Polychlorinated Biphenyls (PCBs) - The purposeful discharge of PCBs to waters of the Region, or at locations where the waste can subsequently reach waters of the Region, is prohibited. Pass-through or uncontrollable discharges to waters of the Region, or at locations where the waste can subsequently reach water of the Region, are limited to 70 pg/L (30 day average) for protection of human health and 14 ng/L and 30 ng/L (daily average) to protect aquatic life in inland fresh waters and estuarine waters respectively.

- Toxicity - All waters shall be maintained free of toxic substances in concentrations that are toxic to, or that produce detrimental physiological responses in, human, plant, animal or aquatic life. Effluent limits for specific toxicants can be established by the Regional Board to control toxicity identified under Toxicity Identification Evaluations (TIEs). There are no Basin Plan Objectives specific to sediment toxicity. However, the narrative ambient water toxicity objectives may be used to address sediment toxicity for the purposes of identifying targets for sediment toxicity.

Regional Narrative Objective for Wetlands

- Habitat - Existing habitats and associated populations of wetlands fauna and flora shall be maintained by: protecting food supplies for fish and wildlife.

California Toxics Rule (CTR) Water Quality Criteria

CTR numeric criteria for priority toxic pollutants are promulgated for the protection of aquatic life and human health. The aquatic life criteria indicate one-hour average (acute) and four-day average (chronic) concentrations of these chemicals to which aquatic life can be exposed without harmful effect. The human health criteria are 30 day average concentrations for consumption of organisms and water or consumption of organisms only.

2.5 Antidegradation

The state's Antidegradation Policy is contained in State Board Resolution 68-16, Statement of Policy with Respect to Maintaining High Quality Water in California. The Antidegradation Policy maintains that water quality in surface and ground waters of the state must be maintained unless it is demonstrated that a change will be consistent with the maximum benefit of the people of the state, not unreasonably affect present and anticipated beneficial use of such water, and not result in water quality less than that prescribed in water quality plans and policies. In addition to meeting state Antidegradation Policy, any actions that may result in a reduction of water quality of a water of the United States are subject to the federal Antidegradation Policy provisions contained in 40 CFR 131.12, which allows for the reduction in water quality as long as existing beneficial uses are maintained and that the lowering of water quality is necessary to accommodate economic and social development in the area.

The proposed TMDL is consistent with state and federal antidegradation policies since it does not result in a reduction of water quality.

2.6 Basis For Listings

This section presents the basis for development of the 303(d) listings for OC pesticides and PCBs in the CCW. Regional Board staff conducted water quality assessments in 1996, 1998 and 2002, with the majority of OC pesticides & PCB listings first appearing on the 1996 303(d) list. The only water column listing, for DDT in Reach 2, was based on data from the Calleguas Creek Characterization Study (LWA, 1999). The data used for fish tissue listings included databases from three SWRCB monitoring programs: the Bay Protection Toxic Cleanup Program (BPTCP, 1994-1000), the State Mussel Watch Program (SMWP, 1977-2000), and the Toxic Substances Monitoring Program (TSMP, 1978-2000). Data used for sediment listings included the BPTCP, SMWP, and the Los Angeles Regional Board databases (1952-1998).

The majority of sediment quality data found in the RWQCB database is listed in units of µg/L and could not be directly compared with sediment quality objectives, which are in units of µg/Kg (dry weight). Sediment quality data from the RWQCB database were therefore not included in this discussion.

Beneficial uses were listed as impaired based on exceedances of the following sediment and tissue guidelines listed below in Table 5 (from Table 3-3 of the Regional Board's 2002 305(b) report). The values used by the Regional Board were presented using ug/Kg. Thus, they are presented in Table 5 as ug/Kg, even though values presented in other sections of this TMDL use ug/g (the number of significant digits was preserved whenever numeric targets were converted to ug/g in later sections of this document). A discussion of each guideline follows.

Table 5. Assessment Guidelines for Sediment Chemistry and Fish Tissue Bioaccumulation Data

Constituent	Sediment **ERM** (µg/Kg dry weight)	Sediment **PEL** (µg/Kg dry weight)	Tissue **MTRL** (Inland) (ug/Kg)	Tissue **MTRL** (bay/estuary) (ug/Kg)	**NAS** Whole Fish Guidelines (ug/Kg)
Aldrin			0.05	0.33	100 [2]
Chlordane (total)	6	4.79	8.0	8.3	100 [2]
p,p'-DDD	20	7.81	44.5	44.5	
p,p'-DDE	27	374	32.0	32.0	
p,p'-DDT	7	4.77	32.0	32.0	
DDT (total)	46.1	51.7			1000
Dieldrin	8	4.3	0.65	0.7	100 [2]
Endosulfan I			29700	64800	
Endosulfan II			29700	64800	
Endosulfan sulfate			29700	64800	
Endosulfan (total)					100 [2]
Endrin	45		3020	3020	100 [2]
Alpha-BHC (HCH)			0.5	1.7	
beta-BHC (HCH)			1.8	6.0	
gamma-BHC (HCH)		0.99	2.5	8.2	
Hexachlorocyclohexane (HCH, total)					100 [2]
Heptachlor			2.4	2.3	100 [2]
Heptachlor Epoxide			1.1	1.2	100 [2]
PCBs (total)	180	189	5.3	5.3	500
Toxaphene			9.6	9.8	100 [2]

[1] ERM = Effects Range-Median; PEL = Probable Effects Level; MTRL = Maximum Tissue Residue Level; NAS = National Academy of Sciences

[2] Individually or in combination. Chemicals in this group are referred to collectively as Chem A.

Sediment Guideline - Effects Range Median (ERM)

Sediment Effects Range-Median (ERM) values are numerical sediment quality guidelines developed by the National Oceanographic & Atmospheric Administration (NOAA) as informal (non-regulatory) guidelines to estimate the possible toxicological significance of chemical concentrations in sediments (Long et al., 1998). They were derived using a database compiled from saltwater studies. Data from each study were arranged in order of ascending concentrations. Study endpoints in which adverse effects were reported were identified. From the ascending data tables, the 50th percentile (median) of the effects database was identified for each substance. The 50th percentiles were named the "Effects Range-Median" (ERM) values, representative of concentrations above which effects frequently occur. The ERMs were not intended for use in predicting effects in wildlife or humans through bioaccumulation pathways. Because the ERM values were derived from saltwater chemistry and toxicity data, they apply to marine and estuarine waters only; they do not apply to freshwater systems. The ERMs listed in the 2002 Regional Board 305(b) report (and Table 5, above) are applicable to marine sediments.

Sediment Guideline - Probable Effects Level (PEL)

Sediment Probable Effects Levels (PELs) are marine sediment quality assessment guidelines (SQAGs) that were developed by the Florida Department of Environmental Protection for evaluating sediment quality conditions in Florida coastal systems (MacDonald, 1994). A weight of evidence approach developed by NOAA was modified and used to develop the guidelines. This approach involved the collection, evaluation and analysis of sediment chemistry and toxicity data from a wide variety of sources in North America (including data from the NOAA National Status and Trends Program database). The data were used to establish relationships between concentrations of sediment-associated contaminants and their potential for adverse biological effects. The PEL defines the lower limit of the range of contaminant concentrations that are "usually or always" associated with adverse biological effects. PELs do not consider the potential for bioaccumulation in tissues of aquatic organisms or the potential for adverse effects on human and non-human (wildlife) consumers of these aquatic organisms. The SQAGs are applicable to marine and estuarine waters only; they are not applicable to freshwater systems.

Fish Tissue Guideline - Maximum Tissue Residue Levels (MTRLs)

The California State Water Resources Control Board (SWRCB) developed Maximum Tissue Residue Levels (MTRLs) by multiplying the human health water quality criteria in the CTR (for inland MTRLs) and the California Ocean Plan (2000, for bay/estuary MTRLs) by the bioconcentration factor (BCF) for each substance. BCFs were taken from the USEPA 1980 Ambient Water Quality Criteria Documents for each substance (USEPA, 1980). According to the 1994-1995 Toxic Substances Monitoring Program Data Report (SWRCB), "The water quality criteria represent concentrations in water that protect against consumption of fish, shellfish and water (freshwater only) that contain substances at levels which could result in significant human health problems. MTRLs are used as alert levels or guidelines indicating water bodies with potential human health concerns and are an assessment tool and not compliance or enforcement criteria. MTRLs are compared only to fillet or edible tissue samples and should not be compared to whole body or liver samples."

Whole Fish Guideline - National Academy of Sciences (NAS)

National Academy of Sciences (NAS) Guidelines are recommended maximum concentrations of toxic substances in freshwater fish tissue (NAS 1973). They were established not only to protect the organisms containing the toxic compounds, but also to protect the species that consume these contaminated organisms. NAS guidelines are compared to data from whole fish samples only.

2.7 303(d) Listing Data

Summaries of the data used to develop 303(d) listings in the CCW are shown in the tables below. Table 6 contains water column data, Table 7 contains sediment data, and Table 8 through Table 10 contain fish tissue data.

Table 6. Calleguas Creek Watershed: Data Summary for Water Column Listings [1]

Reach	Constituent	Year Listed	Impaired Use Listed	n	Range	Median [2]	% Exceedances
2	4,4'-DDT	2002	Aquatic Life	4	<0.0005 – 0.0055	0.0023	50

[1] All results are listed in units of µg/L.

[2] For median values calculated as the average of a non-detected and detected result, the detection limit for the non-detected result was used in the calculation.

Table 7. Calleguas Creek Watershed: Data Summary for Sediment Listings [1]

Reach	Constituent	Year Listed	Impaired Use Listed	n	Range	Median [2]	% Exceedances
1	DDT	1996	Aquatic Life	9	30.5 - 293	187.9	89 [7]
2	DDT	1996	Aquatic Life	4	187.9 – 575.9	248.4	100 [7]
2	Toxaphene	1996	Aquatic Life	4	30.2 – 1900	157.1	N/A
4	Chlordane	1996	Aquatic Life	4	20.3 – 40.9	31.7	100
4	DDT	1996	Aquatic Life	4	525 – 1648	728.5	100 [7]
4	Endosulfan	1996	Aquatic Life	4	<5 – 32.6	9.0	N/A
4	Toxaphene	1996	Aquatic Life	4	258 - 510	365	N/A
5	Chlordane [3]	1996	Aquatic Life	0	--------	--------	--------
5	Dacthal [3]	1996	Aquatic Life	0	--------	--------	--------
5	DDT [3]	1996	Aquatic Life	0	--------	--------	--------
5	Endosulfan [3]	1996	Aquatic Life	0	--------	--------	--------
5	Toxaphene [3]	1996	Aquatic Life	0	--------	--------	--------
6	DDT [4]	1996	Aquatic Life	1	24.0	24.0	0 [7]
9A	Toxaphene [5]	1996	Aquatic Life	0	--------	--------	N/A
9B	Toxaphene [5]	1996	Aquatic Life	0	--------	--------	N/A
10	Toxaphene	1996	Aquatic Life	0	--------	--------	N/A
11	Toxaphene [6]	2002	Not Indicated	0	--------	--------	N/A
13	Toxaphene	1996	Aquatic Life	0	--------	--------	N/A

[1] All results are listed in units of µg/Kg dry weight.

[2] For median values calculated as the average of a non-detected and detected result, the detection limit for the non-detected result was used in the calculation.

[3] Although results for 4 samples collected at Central Avenue exist in the Regional Board database, units were listed as µg/L and could not be directly compared to sediment quality guidelines.

[4] The single data point cited in the 1996 305(b) report as supporting this listing was collected in 2002 Reach 2 (verified by GIS coordinates) but applied to 2002 Reach 6.

[5] There exists one toxaphene data point for both Reaches 9A and 9B in the Regional Board database, but units were listed as µg/L and could not be directly compared to sediment quality guidelines.

[6] Reach 11 (Arroyo Santa Rosa) did not appear on either the 1996 or 1998 303(d) lists. The Reach 11 toxaphene listing was added to the 2002 303(d) list without an accompanying fact sheet explaining the rationale for the listing.

N/A = No applicable sediment quality guidelines exist for this constituent.

[7] All forms of DDT (DDD, DDE, DDT, and Total DDT) were considered in determining the % exceedance values, according to appropriate targets for each form.

Table 8. Calleguas Creek Watershed: Data Summary for Tissue Listings, Reaches 1-4 [1]

Reach	Constituent	Year Listed	Impaired Use Listed [2]	n	Range	Median [3]	% Exceedances
1	Chlordane	1996	[2]	21	<5 – 40.6	3.5	43
1	DDT	1996	[2]	25	8.7 – 594	96.0	76
1	Endosulfan	1996	[2]	18	<5 – 132	18.6	17
1	PCBs	1996	[2]	25	<50 – 120	17.0	72
2	Chem A [4]	1996	[2]	0 [5]	--------	--------	--------
2	Chlordane	1996	[2]	5	23.9 – 40.6	30.7	100
2	DDT	1996	[2]	5	224 – 495	338	100
2	Endosulfan [6]	1996	[2]	5	<5 – 132	51.4	20
2	Toxaphene	1996	[2]	5	147 – 468	277.2	100
2	PCBs	1996	[2]	5	9.0 – 83.7	22.5	100
3 [7]	Chem A [4]	N/L	---	6	815 – 5541	2400	100
3 [7]	Chlordane	N/L	---	17	<5 – 117.7	33.2	53
3 [7]	DDT	N/L	---	17	208 – 4948	1500	100
3 [7]	PCBs	N/L	---	17	<50 – 346	<50	45
3 [7]	Toxaphene	N/L	---	17	<100 – 5400	640	88
4	Chem A [4]	1996	[2]	4	3389 – 12328	4265	100
4	Chlordane	1996	[2]	14	30.3 – 303.9	128.5	100
4	DDT	1996	[2]	14	107.9 – 9885	2900	100
4	Dieldrin	1996	[2]	14	4.4 – 120	18.5	79
4	Endosulfan	1996	[2]	14	<85 – 2355	127.5	33
4	Toxaphene	1996	[2]	14	<50 – 12,000	3056	93
4	PCBs	1996	[2]	14	<5 – 6100	47.2	36

[1] All results are listed in units of µg/Kg wet weight.

[2] Aquatic Life; COMM (commercial or sport fishing involving human consumption of fish); REC-1 (water contact recreation, which may involve fishing); REC-2 (non-contact recreation).

[3] For median values calculated as the average of a non-detected and detected result, the detection limit for the non-detected result was used in the calculation.

[4] TSMP combination of Chem-A pesticides, including aldrin, dieldrin, chlordane, endrin, heptachlor, heptachlor epoxide, hexachlorocyclohexane (including lindane), endosulfan, and toxaphene. The NAS guideline for Chem A is applicable to whole fish samples only.

[5] Supporting data for this listing were missing from the TSMP database. Although TSMP data were cited for this listing, there are no TSMP monitoring stations between the estuary and Potrero Road.

[6] The 1996 303(d) List Staff Report listed dry weight results (880 ppb) for this constituent. This table contains wet weight results.

[7] Although this TSMP monitoring location was originally identified to be in "Reach 1/2" in the 1996 305(b) report, the GIS coordinates place this station in 2002 Reach 3 at Lewis Road.

N/L = Not listed.

Table 9. Calleguas Creek Watershed: Data Summary for Tissue Listings, Reaches 5-10 [1]

Reach	Constituent	Year Listed	Impaired Use Listed [2]	n	Range	Median [3]	% Exceedances
5	Chem A [4]	1996	[2]	0 [5]	--------	--------	--------
5	Chlordane	1996	[2]	0 [5]	--------	--------	--------
5	DDT	1996	[2]	0 [5]	--------	--------	--------
5	Dieldrin	1996	[2]	0 [5]	--------	--------	--------
5	Endosulfan	1996	[2]	0 [5]	--------	--------	--------
5	Toxaphene	1996	[2]	0 [5]	--------	--------	--------
5	PCBs	1996	[2]	0 [5]	--------	--------	--------
9A	Chem A [4]	1996	[2]	5	883 – 2322	1800	100
9A	Chlordane [6]	2002	[2]	5	39.7 – 94.9	50.0	0
9A	DDT	1996	[2]	5	1002 – 2422	1391	100
9A	Dieldrin [6]	2002	[2]	5	16.5 – 39	20.0	0
9A	Endosulfan	1996	[2]	5	<85 – 210	<10	20
9A	Hexachlorocyclohexane [6]	2002	[2]	5	2.6 – 7.9	4.0	0
9A	Toxaphene	1996	[2]	5	819 – 2200	1700	100
9A	PCBs [6]	2002	[2]	5	20.3 – 356	51	0
9B	Chem A [4]	1996	[2]	0 [7]	--------	--------	--------
9B	DDT	1996	[2]	0 [7]	--------	--------	--------
9B	Endosulfan	1996	[2]	0 [7]	--------	--------	--------
9B	Toxaphene	1996	[2]	0 [7]	--------	--------	--------
10	Chem A [4] [8]	1996	[2]	4	3.4 – 80.5	12.8	0
10	DDT	1996	[2]	4	7.4 – 59	15.1	25
10	Endosulfan [8]	1996	[2]	3	<2 – <85	<2	0
10	Toxaphene [8]	1996	[2]	4	<20 – <100	<60	0

[1] All results are listed in units of μg/Kg wet weight.

[2] Aquatic Life; COMM (commercial or sport fishing involving human consumption of fish); REC-1 (water contact recreation, which may involve fishing); REC-2 (non-contact recreation).

[3] For median values calculated as the average of a non-detected and detected result, the detection limit for the non-detected result was used in the calculation.

[4] TSMP combination of Chem-A pesticides, including aldrin, dieldrin, chlordane, endrin, heptachlor, heptachlor epoxide, hexachlorocyclohexane (including lindane), endosulfan, and toxaphene. The NAS guideline for Chem A is applicable to whole fish samples only.

[5] No TSMP tissue samples were collected in Reach 5. When the 1996-designated Revolon Slough/Beardsley Wash reach was split into two reaches in 1998 303(d) list, Reach 4 (Revolon) listings were likely applied to Reach 5 (Beardsley).

[6] This constituent was listed by comparing data from whole fish samples to MTRLs.

[7] Data from Reach 9A (Conejo Creek at Pancho/Howard Rd) were used for this listing. There were no TSMP tissue samples collected in Reach 9B.

[8] This constituent was listed based on data collected in 1996 Conejo Reach 1 (2002 Reach 9A), which was originally applied to all 4 1996 Conejo Creek Reaches.

Table 10. Calleguas Creek Watershed: Data Summary for Tissue Listings, Reaches 11-13 [1]

Reach	Constituent	Year Listed	Impaired Use Listed [2]	n	Range	Median [3]	% Exceedances
11	Chem A [4] [5]	2002	not indicated	0	--------	--------	--------
11	Chlordane [5]	2002	not indicated	0	--------	--------	--------
11	DDT [5]	2002	not indicated	0	--------	--------	--------
11	Dieldrin [5]	2002	not indicated	0	--------	--------	--------
12	Chlordane	1996	[2]	2	<2 – 42.1	22.1	0
12	DDT	1996	[2]	2	<2 – 63.4	32.7	0
13	Chem A [6] [7]	1996	[2]	3	<18 – 18	<18	0
13	DDT [7]	1996	[2]	3	<5 – 32	9.2	0
13	Endosulfan [7]	2002	[2]	3	<85	<85	0
13	Toxaphene [7]	1996	[2]	3	<100	<100	0

[1] All results are listed in units of µg/Kg wet weight.

[2] Aquatic Life; COMM (commercial or sport fishing involving human consumption of fish); REC-1 (water contact recreation, which may involve fishing); REC-2 (non-contact recreation).

[3] For median values calculated as the average of a non-detected and detected result, the detection limit for the non-detected result was used in the calculation.

[4] TSMP combination of Chem-A pesticides, including aldrin, dieldrin, chlordane, endrin, heptachlor, heptachlor epoxide, hexachlorocyclohexane (including lindane), endosulfan, and toxaphene. The NAS guideline for Chem A is applicable to whole fish samples only.

[5] Reach 11 (Arroyo Santa Rosa) did not appear on either the 1996 or 1998 303(d) lists. The Reach 11 tissue listings were added to the 2002 303(d) list without an accompanying fact sheet explaining the rationale for the listing.

[6] All samples are fish fillets; the NAS guideline therefore does not apply.

[7] Data from Reach 9A (Conejo Creek at Pancho/Howard Rd) were likely used for this listing.

3 CURRENT CONDITIONS

This section summarizes available information and monitoring data for describing the presence of OC pesticides and PCBs in the Calleguas Creek Watershed. Several constituents included on the 2002 303(d) list for the CCW are currently exceeding target levels rarely or not at all (referred to as category-2 constituents). A detailed discussion of current conditions is presented for the remaining constituents (referred to as category-1 constituents) using recent water, sediment, and fish tissue data.

3.1 Regulatory Status

OC pesticides and PCBs are often called historic or legacy pollutants, since concentrations of these chemicals persist in the environment despite enactment of regulations to restrict and/or end their use. All but two of the OCs listed for the CCW (dacthal and endosulfan) have been banned from use and manufacture in the United States, as shown in Table 11. The unique properties that contribute to the effectiveness of these chemicals as pesticides and industrial products have also contributed to their tendency to persist in soils and sediment, concentrate in biota, and magnify in the food chain.

Table 11. Use History of OC Pesticides and PCBs in the United States (shading indicates time period of legalized use).

CONSTITUENT	1925 - 1929	1930 - 1934	1935 - 1939	1940 - 1944	1945 - 1949	1950 - 1954	1955 - 1959	1960 - 1964	1965 - 1969	1970 - 1974	1975 - 1975	1980 - 1984	1985 - 1989	1990 - 1994	1995 - 1999	2000 - 2004
Chlordane					1948	▨	▨	▨	▨	▨	▨	▨	1988			
Dacthal							1958	▨	▨	▨	▨	▨	▨	▨	▨	▨
DDT			1939	▨	▨	▨	▨	▨	▨	▨	1972					
Dieldrin/Aldrin					1948	▨	▨	▨	▨	▨	▨	▨	1987			
Endosulfan						1954	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Endrin						1951	▨	▨	▨	▨	▨	▨	▨	1991		
Heptachlor						1952	▨	▨	▨	▨	▨	▨	1988			
HCH/Lindane					1945	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	2002
PCBs	1929	▨	▨	▨	▨	▨	▨	▨	▨	▨	1979					
Toxaphene					1945	▨	▨	▨	▨	▨	▨	▨	▨	1990		
Dicofol [1]							1957	▨	▨	▨	▨	▨	▨	▨	▨	▨

[1] Dicofol is not included on the 303(d) list for the CCW, but does contain trace amounts of DDT.

3.2 Sources of Monitoring Data

Since the mid-1990's various studies have been conducted to assess water, sediment, and fish tissue quality in the CCW. Portions of the data collected through these studies were incorporated into the 1996, 1998, and 2002 LARWQCB Water Quality Assessments to identify exceedances of water quality objectives. The portion of the available data that formed the basis of the listings was presented in the Problem Statement section. This section presents additional relevant environmental monitoring data that may not have been included in the Water Quality Assessments; which includes water column, sediment, and tissue chemistry data. Sources and associated types of data used for completion of the OC Pesticides and PCBs TMDL are shown in Table 12.

TMDL Work Plan Data

Development of this TMDL included monitoring of OC pesticides and PCBs in water, sediment, and fish tissue during 2003-2004 (TMDL Work Plan monitoring). The purpose of TMDL Work Plan monitoring is to augment previously existing data for the CCW, which contained a high proportion of non-detected values and very few sampling events occurring concurrently across mediums (water, sediment, fish tissue). TMDL Work Plan data accounts 42% of all water, sediment, and tissue records in the CCW database and 52% of data collected since 1996, when the original 303(d) listings were issued. Analysis of TMDL Work Plan samples used methods with lower detection limits than much of the previously existing data and included several events with concurrent water, fish tissue, and sediment monitoring. Thus, these data significantly improve understanding of current conditions relating to OCs in the CCW and also improve the capability for data analysis and modeling.

Table 12. Summary of Data Sources Used for the OC Pesticides and PCBs TMDL.

Data Source	Begin Date	End Date	OC Pesticides	PCBs	Fish Tissue	Flow
Bay Protection Toxic Cleanup Program – BPTCP	10/92	2/97	S	S	X	
Calleguas Creek Characterization Study – CCCS (LWA, 2000)	7/98	6/99	W, S	W, S		X
Camarillo WWTP NPDES Monitoring (City of Camarillo)	9/85	12/01	W	W		X
Camrosa WWRF NPDES Monitoring	1/86	12/02	W	W		X
Hill Canyon WWTF (City of Thousand Oaks)	1/90	8/03	W	W		X
Moorpark WWTP (City of Moorpark)	2/95	12/02	W	W		X
Olsen Road WRP (City of Thousand Oaks)	1/87	8/02	W	W		X
Simi Valley WQCP	12/93	1/03	W	W		X
State Mussel Watch Program – SMWP	7/77	2/94	S	S		X
City of Thousand Oaks	5/74	8/01				X
Toxic Substance Monitoring Program – TSMP	4/85	8/00	S	S	X	
TMDL Work Plan Monitoring (LWA, 2004)	8/03	8/04	W, S	W, S	X	X
United States Navy (personal communication, S.Granade)	1/94	6/02	W,S	W,S	X	
University of California Davis Study (Anderson *et al.*, 2002)	3/95	6/99	W			
University of California Los Angeles Study (Abrol *et al.*, 2003)	1/98	12/01	W			
Ventura County Watershed Protection District, VCWPD	10/68	9/03	W	W		X

W – Water Column Data, S – Sediment Data

3.3 Summary of Monitoring Data

The data summary tables presented below consider all water, tissue, and sediment data collected from receiving waters in the CCW which are included in the CCW Database (LWA, 2004a). In one instance, water samples collected during a storm event were split and analyzed as filtrate and filtered solids. The measured values of the filtrate and filtered solids were combined as a total value before statistical analysis was conducted. This was done so the stormwater data would be comparable to the remaining data which had been analyzed as whole samples. Only sediment samples collected from the streambed surface are considered in the summary tables (in the case of multi-depth samples, lower depth values were removed to maintain consistency with the majority of sediment data). During analysis of samples from two sediment sampling events, samples were split into two grain size fractions and analyzed separately. The measured values of the two grain size fractions were combined based on the percent grain size in each fraction before statistical analysis was conducted using the data. This was done so these sediment data would be comparable to the remaining data which had been analyzed as whole samples.

A large proportion of the data used to develop the summary statistics for this TMDL are non-detected values. Using these data requires methods for dealing with the inherent uncertainty in characterizing the true range of conditions. The method used in this TMDL to consider non-detected data is typically known as regression on order statistics (ROS). ROS utilizes detected and non-detected data to estimate the distribution of actual concentrations (Helsel, 1988, 1990). The ROS method develops probability-plotting positions for each data point (censored and uncensored) based on the ordering of the data. A least-squares regression line is fitted by regressing log-transformed values to the uncensored probability plotting positions. The censored data points (non-detects) are assigned values based on their probability plotting positions and the regression line equation (Helsel, 1990 and Shumway et al, 2002). Summary statistics are then calculated based on the uncensored data points and the filled-in censored values. Criteria for sufficient data to use the ROS method are: 1) at least 20% and preferably 50% detected data and 2) at least three unique detected values. Instances of insufficient detected data are marked in the summary statistics tables. Use of the ROS method, when statistical criteria are met, more appropriately estimates actual values than the commonly employed practice of assuming one half the detection limit for non-detect values.

In order to calculate percent exceedances for the data summary tables presented in this section, data are compared with a range of criteria and guideline concentration values. Water column data are compared with CTR aquatic life criteria (lower of chronic or acute criteria used when available, human health criteria used if no chronic or acute criteria exist). Tissue concentrations for filet/muscle samples are compared with CTR-based criteria (TTRLs, described in the Numeric Targets section) and whole organism samples are compared with National Academy of Science targets. Sediment data are compared with Threshold Effects Level targets (TELs) from the NOAA Screening Quick Reference Tables (Buchman, 1999).

Numeric targets used in the 303(d) listing process (see Problem Statement section, Basis for Listings) differ from those used in this section. The targets used in this section are lower on average, in order to ensure that estimates of "percent exceedance" are conservative (i.e., any bias would suggest higher than actual percent exceedance, rather than lower). In the Numeric Targets section, the range of potential targets are narrowed down to the most appropriate for each medium and those final targets are used throughout the rest of the TMDL development process, including calculation of final allocations.

Receiving Water Data (Water, Sediment, Aquatic Biota)

Summarized in

Table 13 through Table 15 are the water column, streambed sediment, and aquatic biota data, respectively, for the entire watershed considering all years of available data. These results provide the following information.

- 4,4'-DDE, total DDT (sum of DDD, DDE, and DDT), and dacthal were the only OCs detected in greater than 20% of receiving water samples (only 4,4'-DDE exceeded criteria in greater than 10% of freshwater and marine samples).

- 4,4'-DDE, 4,4'-DDT, 4,4'-DDD, total DDT, total chlordane, dacthal, total PCBs, and toxaphene were detected in greater than 20% of freshwater or marine sediment samples.
- 4,4'-DDE, 4,4'-DDT, 4,4'-DDD, total DDT, chlordane, and toxaphene were detected in greater than 20% of aquatic biota samples; and all of these exceeded applicable criteria in greater than 20% of aquatic biota samples (dieldrin was detected and exceeded criteria in 16% of filet/muscle samples).

Based on the data presented in this section, only 4,4'-DDE (hereafter referred to simply as DDE), dacthal, and total DDT have been detected consistently enough to allow for robust statistical analysis. Among these three constituents, only DDE consistently exceeded applicable targets in water, sediment, and tissue (targets for total DDT only exist for water toxicity, and that criterion is exceeded due mainly to the presence of DDE).

Selection of DDE as a Representative Constituent

Since no other constituent is consistently detected and found to routinely exceed applicable targets, and because OCs possess many similar physical and chemical properties that influence their fate and transport in the environment (see Linkage Analysis section), DDE is chosen as a representative constituent for most of the analyses and modeling used to develop this TMDL.

Table 13. Summary statistics for OCs in all water column samples, 1986-2004.

Constituent	Freshwater				Marine			
	n	% Detect	Target (ug/L)	% Exceed	n	% Detect	Target (ug/L)	% Exceed
4,4'-DDD	435	10%	0.00084[2]	10%	138	8%	0.00084[2]	8%
4,4'-DDE	449	23%	0.00059[2]	23%	138	20%	0.00059[2]	20%
4,4'-DDT	448	12%	0.00059[2]	12%	138	7%	0.00059[2]	7%
DDT, Total (Summed DDD, DDE, DDT)	450	25%	NA		120	23%	NA	
Aldrin	432	0%	0.00014[2]	0%	20	0%	0.00014[2]	0%
BHC-alpha (HCH)	416	1%	0.013[2]	0%	19	0%	0.013[2]	0%
BHC-beta (HCH)	420	1%	0.046[2]	0%	137	1%	0.046[2]	0%
BHC-delta (HCH)	413	3%	NA		137	1%	NA	
BHC-gamma (HCH, Lindane)	422	6%	0.063[2]	0%	138	8%	0.063[2]	2%
HCH, Total (summed alpha,beta,delta,gamma)	426	9%	NA		120	11%	NA	
Chlordane	167	0%	0.00059[2]		0	--	0.00059[2]	--
Chlordane (technical)	32	0%	NA		0	--	NA	--
Chlordane,Total (summed alpha,gamma)	249	5%	0.00059[2]	5%	119	4%	0.00059[2]	4%
DCPA (Dacthal)	136	46%	3500[3]	0%	13	92%	NA	
Dieldrin	437	0%	0.00014[2]	0%	138	1%	0.00014[2]	1%
Endosulfan I	436	0%	0.056[1]	0%	138	0%	0.0087[1]	0%
Endosulfan II	424	0%	0.056[1]	0%	138	1%	0.0087[1]	0%
Endosulfan sulfate	424	3%	240	0%	138	4%	240[2]	0%
Endrin	437	0%	0.036[1]	0%	138	1%	0.0023[1]	1%
Heptachlor	434	0%	0.00021[2]	0%	138	2%	0.00021[2]	2%
Heptachlor epoxide	432	1%	0.00011[2]	1%	137	1%	0.00011[2]	1%
PCBs,Total (Summed Aroclors)	384	1%	0.00017[2]	1%	119	1%	0.00017[2]	1%
Toxaphene	418	0%	0.00075[2]	0%	20	0%	0.00075[2]	0%

[1] Lower of acute or chronic CTR criteria.
[2] CTR human health criteria.
[3] Drinking water standard of 3500 ug/L adopted by states of Florida and Arizona is the only potentially applicable target. It is used here only as a reference point, and is likely overprotective.

Table 14. Summary statistics for OCs in all sediment samples, 1989-2004.

Constituent	Freshwater[1]				Marine[2]			
	n	% Detect	Target (ug/g)	% Exceed	n	% Detect	Target (ug/g)	% Exceed
4,4'-DDD	82	33%	0.00354	26%	137	63%	0.00122	61%
4,4'-DDE	82	56%	0.00142	54%	137	86%	0.00207	83%
4,4'-DDT	82	34%	NA		137	45%	0.00119	34%
DDT, Total (Summed DDD, DDE, DDT)	82	56%	0.0069	39%	138	86%	0.0039	80%
Aldrin	80	0%	NA		15	0%	NA	
BHC-alpha (HCH)	80	0%	NA		22	5%	NA	
BHC-beta (HCH)	62	0%	NA		122	2%	NA	
BHC-delta (HCH)	82	2%	NA		130	0%	NA	
BHC-gamma (HCH, Lindane)	82	6%	0.00094	4%	137	1%	0.00032	1%
HCH, Total (summed alpha,beta,delta,gamma)	82	6%	NA		137	4%	NA	
Chlordane	18	0%	0.0045	0%	0	--	0.00226	--
Chlordane (technical)	0	--	NA	--	0	--	NA	--
Chlordane,Total (summed alpha, gamma)	64	22%	0.0045	16%	137	23%	0.00226	18%
DCPA (Dacthal)	44	27%	NA		19	63%	NA	
Dieldrin	82	9%	0.00285	4%	137	12%	0.00072	10%
Endosulfan I	74	12%	NA		130	5%	NA	
Endosulfan II	74	8%	NA		137	9%	NA	
Endosulfan sulfate	54	0%	NA		121	5%	NA	
Endrin	82	1%	0.00267	0%	137	1%	NA	
Heptachlor	66	0%	NA		129	3%	NA	
Heptachlor epoxide	54	0%	0.0006	0%	120	0%	NA	
PCBs,Total (Summed Congeners)	44	11%	0.0341	11%	15	73%	0.0216	67%
Toxaphene	80	11%	NA		15	33%	NA	

[1] Freshwater sediment quality guidelines contained in NOAA Screening Quick Reference Tables (Buchman, 1999); TEL = Threshold Effects Level

[2] Marine Sediment quality guidelines contained in NOAA Screening Quick Reference Tables (Buchman, 1999); TEL = Threshold Effects Level

Table 15. Summary statistics for OCs in all aquatic biota samples, 1977-2004.

Constituent	Filet / Muscle[1]				Whole Organism[2]			
	n	% Detect	Target (ug/g,dry)	% Exceed	n	% Detect	Target (ug/g,dry)	% Exceed
4,4'-DDD	69	52%	0.045	28%	93	90%	NA	
4,4'-DDE	69	90%	0.032	65%	93	100%	NA	
4,4'-DDT	69	35%	0.032	28%	93	72%	NA	
DDT, Total (Summed DDD, DDE, DDT)	69	90%	NA		109	100%	1.0	23%
Aldrin	69	0%	0.00005	0%	49	0%	0.1	0%
BHC-alpha (HCH)	69	0%	0.002	0%	63	10%	NA	
BHC-beta (HCH)	69	0%	0.006	0%	49	0%	NA	
BHC-delta (HCH)	69	0%	NA		49	0%	NA	
BHC-gamma (HCH, Lindane)	69	12%	0.008	0%	62	31%	0.1	2%
HCH, Total (summed alpha,beta,delta,gamma)	69	12%	NA		63	35%	NA	
Chlordane	0	--	0.0083	--	0	--	NA	--
Chlordane (technical)	0	--	0.0083	--	0	--	NA	--
Chlordane,Total (summed alpha, gamma)	69	33%	0.0083	22%	67	66%	0.1	3%
DCPA (Dacthal)	69	35%	NA		65	80%	NA	
Dieldrin	69	16%	0.0007	16%	63	57%	0.1	2%
Endosulfan I	66	20%	64.8	0%	63	22%	NA	
Endosulfan II	53	4%	64.8	0%	57	21%	NA	
Endosulfan sulfate	53	6%	64.8	0%	57	26%	NA	
Endrin	69	3%	3.22	0%	63	17%	0.1	0%
Heptachlor	69	0%	0.0024	0%	63	3%	0.1	0%
Heptachlor epoxide	69	0%	0.0012	0%	63	16%	0.1	0%
PCBs,Total (Summed Congeners)	32	9%	0.0053	9%	40	53%	0.5	0%
Toxaphene	69	26%	0.0098	26%	65	57%	0.1	46%

[1] TTRLs are used (explained in the numeric targets section).
[2] National Academy of Science guidelines are used.

3.4 Definition of Category-1 and Category-2 Constituents

A total of nine constituents or combinations of constituents are included on the 2002 303(d) list for the Calleguas Creek Watershed. Available data suggest that some of these constituents are frequently exceeding criteria or guideline concentration levels, while others are exceeding infrequently or not at all. For the purposes of this TMDL, those constituents frequently exceeding are referred to as category-1 constituents, and those which rarely or never exceed are referred to as category-2. Methodology recently released by the State Water Resource Control Board for describing allowable numbers of exceedances according to sample size (SWRCB, 2004c) was used to define CCW 303(d) listed constituents as either category-1 or category-2. Data from the CCW Database for each constituent were compared against the allowed number of exceedances in the guidance tables of the SWRCB document. Constituents having more than the allowed number of exceedances in any medium (water, fish tissue, or sediment) are defined as category-1. Constituents having fewer than the allowed number of exceedances in all mediums (water, fish tissue, and sediment) are defined as category-2. Constituents in the group listing Chem-A are considered individually. Category-1 and category-2 constituents are summarized in Table 16.

Table 16. Exceedance status of 303d listed constituents in the CCW.

Constituents included on 303(d) list, 2002	Constituents evaluated during TMDL work plan monitoring	Category-1 Constituents [1]	Category-2 Constituents [1]
Chlordane	Chlordane [3]	Chlordane	--
DDT (DDE, DDD)	DDT (DDE, DDD)	DDT (DDE, DDD)	--
Dacthal	Dacthal	--	Dacthal [2]
Dieldrin	Dieldrin [3]	Dieldrin	--
HCH (incl. Lindane)	HCH (incl. Lindane) [3]	--	HCH (incl. Lindane)
Endosulfan	Endosulfan [3]	--	Endosulfan
PCBs	PCBs	PCBs	--
Toxaphene	Toxaphene [3]	Toxaphene	--
Chem-A [3]	Aldrin [3]	--	Aldrin
	Endrin [3]	--	Endrin
	Heptachlor [3]	--	Heptachlor
	Heptachlor Epoxide [3]	--	Heptachlor Epoxide

[1] Category-1 vs. Category-2 status defined according to SWRCB guidance document (SWRCB, 2004c)

[2] No approved toxicity or human health criteria exist for dacthal in water, sediment, or fish tissue. However, dacthal concentrations in the CCW are well below the drinking water standard of 3500ug/L adopted in the states of Arizona and Florida (see Numeric Targets Section)

[3] Chem-A includes the following constituents, which are considered individually: aldrin, chlordane, dieldrin, endosulfan, endrin, heptachlor, heptachlor epoxide, hexachlorocyclohexane (HCH, including lindane), and toxaphene

In-depth analysis conducted for category-1 constituents is presented in the Current Conditions, Source Analysis and Linkage Analysis sections; and final allocations are calculated according to methods described in the TMDL Allocations section. A brief summary of detections and exceedances in all years of available receiving water data for category-2 constituents is presented below, in Table 17. Since available data suggest that category-2 constituents are not causing impairment of beneficial uses, and because in-depth analysis of those constituents is not possible due to their low frequency of detection, they are generally excluded from analysis and modeling in the remainder of the TMDL. Final allocations for category-2 constituents are set equal to numeric targets for listed reaches, as explained in the TMDL Allocations section.

Table 17. Percent detected and exceedance of Category-2 constituents in water, sediment, and tissue. [1]

Constituent	Water Column				Sediment				Tissue			
	Freshwater		Marine		Freshwater		Marine		Filet/Muscle		Whole Org	
	% Det	% Exc	% Det	% Exc	% Det	% Exc	% Det	% Exc	% Det	% Exc	% Det	% Exc
Aldrin	0	0	0	0	0		0		0	0	0	0
BHC-alpha (HCH)	1	0	0	0	0		5		0	0	10	
BHC-beta (HCH)	1	0	1	0	0		2		0	0	0	
BHC-delta (HCH)	3		1		2		0		0	0	0	
BHC-gamma (HCH, Lindane)	6	0	8	2	6	4	1	1	12	0	31	2
DCPA (Dacthal)	46	0	92		27		63		35		80	
Endosulfan I	0	0	0	0	12		5		20	0	22	
Endosulfan II	0	0	1	0	8		9		4	0	21	
Endosulfan sulfate	3	0	4	0	0		5		6	0	26	
Endrin	0	0	1	1	1	0	1		3	0	17	0
Heptachlor	0	0	2	2	0		3		0	0	3	0
Heptachlor epoxide	1	1	1	1	0		0		0	0	16	0

[1] Yellow shaded cells indicate instances where no applicable criteria or guidelines exist.

3.5 Status of Category-1 Constituents

In this section, time series plots and tables of current conditions are presented for water column, sediment, and tissue data for each category-1 constituent. The time series plots aggregate data from the entire watershed, and the current conditions tables present data individually by reach. All years of available data are used for the time series plots in order to best convey long term trends, while the current conditions tables for each constituent consider only more recent data from 1996-2004. This time frame is selected for the current conditions tables because most of the 303(d) listings for the CCW are originally from the 1996 listing cycle and also because detection limits improved significantly in the years following 1996. When only these more recent years are considered, the data set contains a very low proportion of detected values. Thus, final percent reductions presented later in the TMDL and Allocations section draw upon all years of data in order to have sufficient detected data for robust statistical analysis.

As previously mentioned, use of the ROS method for developing summary statistics requires certain prerequisite data conditions (i.e., minimum number of samples and percent detected). When "na" appears in the data tables presented below, it indicates a value not calculated by the ROS method due to considerations of statistical validity. In order to prevent calculations from being biased by non-detected data with high detection limits, non-detected samples were removed when detection limits were higher than concentrations considered characteristic of the reach (based on the range of detected values, according to best professional judgment). Table 18 presents the range of detection limits that were considered uncharacteristic. Very few records were removed as a result of this procedure.

Table 18. Removal of non-detect data records with abnormally high detection limits.

Medium	Constituent	Data Removed if DL > this value	Units
Water	4,4'-DDE	10	ug/L
	4,4'-DDT	10	
Sediment	BHC-gamma	0.02	ug/g
	Dieldrin	0.33	
Tissue	None	--	--

DDT (DDE, DDD)

As stated earlier, DDE is the constituent most detected at levels exceeding criteria in all mediums and is designated as the representative constituent for much of the analysis and modeling in this TMDL. Figure 2 shows the detected values for DDE across all years of available data for water, sediment, and fish tissue. Data for DDT and DDD parallel those for DDE in water, sediment, and fish tissue; although at slightly lower concentrations on average.

During 1995-1996, DDE concentrations recorded in water samples ranged from 28-302 ug/L. This is noticeably high relative to concentrations during 1997-2004, which ranged from 0.001-0.8 ug/L (Figure 2). The elevated concentrations detected during 1995-96 are not understood, although original records were checked to confirm the anomalous data were not the result of errors in CCW database data entry. Possible explanations for these elevated data include, but are not limited to:

- illegal use of DDT during that time period;
- construction activity in 1995-1996 on land where heavy DDT use occurred previously;
- erroneous lab results or mistakes in original data entry;
- large storm events causing flux of high DDT concentration sediment from unknown source;

Of these potential explanations, illegal use of DDT or construction activity seem most plausible, since the elevated levels occurred only in a single subwatershed (Revolon Slough) and because concentrations declined suddenly after 1996. Erroneous lab results seem unlikely, since the elevated levels are found in almost a dozen separate sampling events which occurred during that time period. The possibility these data resulted from large storm events is not supported by corresponding spikes in sediment or fish tissue data.

The possibility that elevated data from 1995-1996 are representative of average concentrations during the 1980s and early 1990s was also considered. Given that pre-1995 sampling recorded no detected values of DDE, and the fact that pre-1995 detection levels were sufficiently low to record concentrations comparable to those from 1995-1996 (Figure 3); there is no evidence to support the possibility that the 1995-1996 data are representative of concentrations from earlier years.

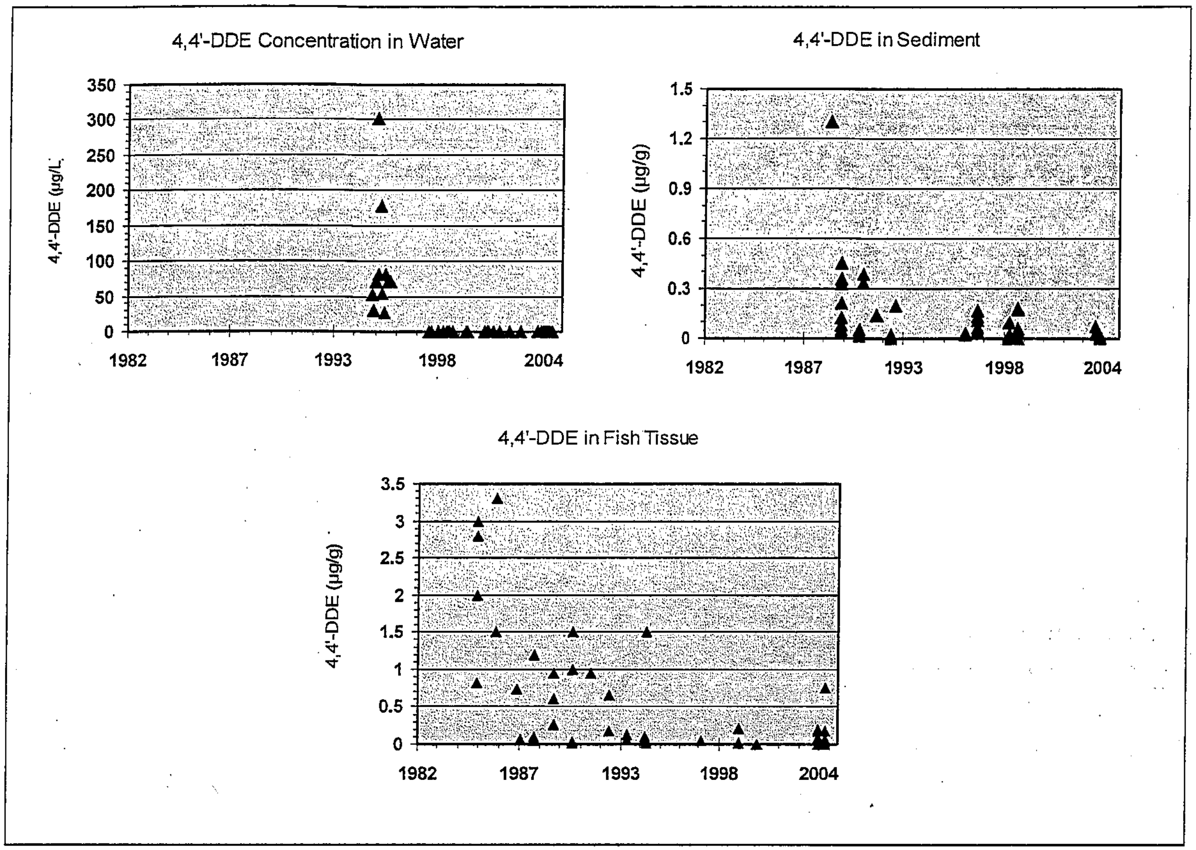


Figure 2. Detected values for DDE in water, sediment, and fish tissue samples for all years of available data. Note elevated levels of DDE in water during 1995-1996.

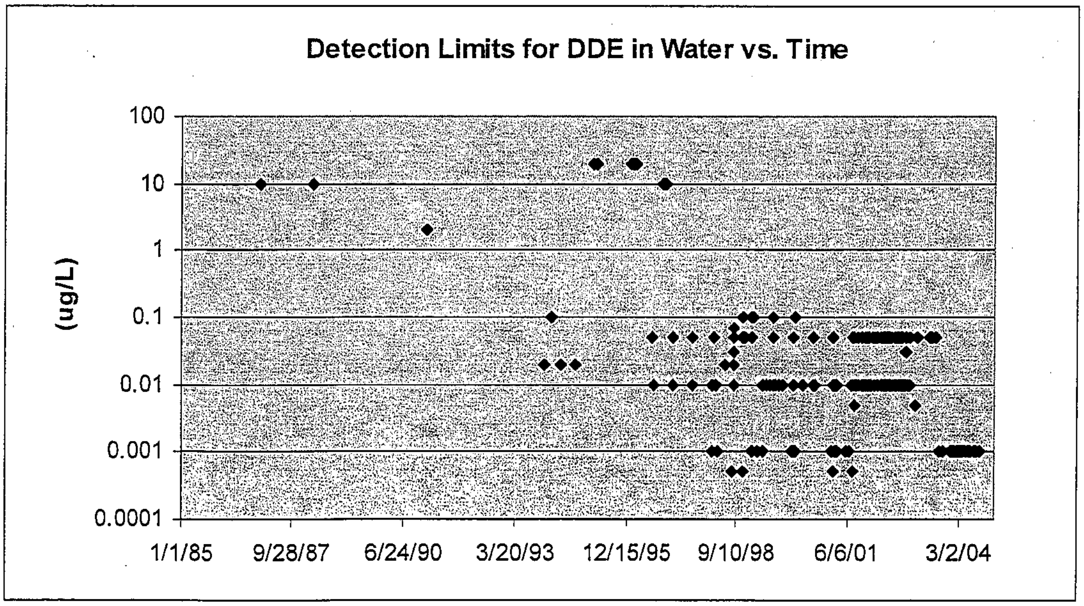


Figure 3. Detection limits reported for all DDE data in the CCW Database, plotted versus time.

The data for DDD, DDE, and DDT in water samples from 1996-2004 (Table 19) indicate the highest percent of detections in the Mugu, Revolon, and Calleguas Subwatersheds (reaches 1, 2, 3, 4, and 5). Detections in sediment samples occur throughout the watershed, but concentrations are much lower in samples from the Conejo subwatershed (reaches 9b, 10,11,12) -- as shown in Table 20. A noticeably higher percentage of exceedances is apparent in tissue samples for DDE than for DDD or DDT (Table 21, Table 22). Samples from the Conejo subwatershed (reaches 9b, 10,11,12) have very few detections or exceedances compared to samples from the rest of the watershed.

Table 19. DDD, DDE, and DDT current conditions in water by reach using data from 1996-2004.

Reach	Form	n	# Detect	# Exceed	% Detect	% Exceed	Mean ug/L	SD	Median ug/L	Max Detect ug/L
1	4,4'-DDD	64	6	6	9.4%	9.4%	na	na	na	0.030
	4,4'-DDE	64	21	21	32.8%	32.8%	0.010	0.008	0.008	0.050
	4,4'-DDT	64	7	7	10.9%	10.9%	na	na	na	0.020
2	4,4'-DDD	21	4	4	19.0%	19.0%	na	na	na	0.220
	4,4'-DDE	21	6	6	28.6%	28.6%	0.043	0.188	0.000	0.863
	4,4'-DDT	21	2	2	9.5%	9.5%	na	na	na	0.003
3	4,4'-DDD	68	5	5	7.4%	7.4%	na	na	na	0.015
	4,4'-DDE	67	21	21	31.3%	31.3%	0.019	0.055	0.005	0.430
	4,4'-DDT	68	15	15	22.1%	22.1%	0.021	0.133	0.001	1.10
4	4,4'-DDD	37	15	15	40.5%	40.5%	0.031	0.096	0.002	0.564
	4,4'-DDE	37	28	28	75.7%	75.7%	0.130	0.294	0.020	1.56
	4,4'-DDT	37	18	18	48.6%	48.6%	0.057	0.155	0.006	0.901
5	4,4'-DDD	14	6	6	42.9%	42.9%	0.016	0.048	0.001	0.183
	4,4'-DDE	14	10	10	71.4%	71.4%	0.093	0.279	0.014	1.06
	4,4'-DDT	14	3	3	21.4%	21.4%	0.043	0.151	0.000	0.567
6	4,4'-DDD	18	0	0	0.0%	0.0%	--	--	--	--
	4,4'-DDE	18	5	5	27.8%	27.8%	0.004	0.007	0.001	0.024
	4,4'-DDT	18	2	2	11.1%	11.1%	na	na	na	0.025
7	4,4'-DDD	97	2	2	2.1%	2.1%	na	na	na	0.159
	4,4'-DDE	83	7	7	8.4%	8.4%	na	na	na	0.267
	4,4'-DDT	83	2	2	2.4%	2.4%	na	na	na	0.176
8	4,4'-DDD	11	0	0	0.0%	0.0%	--	--	--	--
	4,4'-DDE	11	0	0	0.0%	0.0%	--	--	--	--
	4,4'-DDT	11	0	0	0.0%	0.0%	--	--	--	--
9A	4,4'-DDD	20	1	1	5.0%	5.0%	na	na	na	0.092
	4,4'-DDE	20	11	11	55.0%	55.0%	0.020	0.068	0.002	0.309
	4,4'-DDT	20	1	1	5.0%	5.0%	na	na	na	0.317
9B	4,4'-DDD	32	0	0	0.0%	0.0%	--	--	--	--
	4,4'-DDE	32	4	4	12.5%	12.5%	na	na	na	0.007
	4,4'-DDT	32	0	0	0.0%	0.0%	--	--	--	--
10	4,4'-DDD	42	1	1	2.4%	2.4%	na	na	na	0.002
	4,4'-DDE	41	1	1	2.4%	2.4%	na	na	na	0.070
	4,4'-DDT	42	0	0	0.0%	0.0%	--	--	--	--
11	4,4'-DDD	18	1	1	5.6%	5.6%	na	na	na	0.001
	4,4'-DDE	18	3	3	16.7%	16.7%	na	na	na	0.139
	4,4'-DDT	16	1	1	6.3%	6.3%	na	na	na	0.006
12	4,4'-DDD	32	0	0	0.0%	0.0%	--	--	--	--
	4,4'-DDE	39	1	1	2.6%	2.6%	na	na	na	0.130
	4,4'-DDT	39	1	1	2.6%	2.6%	na	na	na	0.010
13	4,4'-DDD	18	0	0	0.0%	0.0%	--	--	--	--
	4,4'-DDE	25	2	2	8.0%	8.0%	na	na	na	0.001
	4,4'-DDT	25	0	0	0.0%	0.0%	--	--	--	--

"na" indicates value not calculated by the ROS method due to considerations of statistical validity.

Table 20. DDD, DDE, and DDT current conditions in sediment by reach using data from 1996-2004. [1]

Reach	Form	n	# Detect	# Exceed	% Detect	% Exceed	Mean ug/g	SD	Median ug/g	Max Detect ug/g
1	4,4'-DDD	37	27	13	73.0%	35.1%	0.010	0.013	0.005	0.064
	4,4'-DDE	37	35	1	94.6%	2.7%	0.061	0.080	0.028	0.440
	4,4'-DDT	37	24	15	64.9%	40.5%	0.012	0.020	0.004	0.086
2	4,4'-DDD	7	2	0	28.6%	0.0%	na	na	na	0.004
	4,4'-DDE	7	6	0	85.7%	0.0%	0.017	0.022	0.006	0.062
	4,4'-DDT	7	0	[2]	0.0%	[2]	--	--	--	--
3	4,4'-DDD	6	1	0	16.7%	0.0%	na	na	na	0.004
	4,4'-DDE	6	4	2	66.7%	33.3%	0.011	0.015	0.004	0.039
	4,4'-DDT	6	1	[2]	16.7%	[2]	na	na	na	0.016
4	4,4'-DDD	7	5	2	71.4%	28.6%	0.005	0.004	0.004	0.010
	4,4'-DDE	7	6	6	85.7%	85.7%	0.054	0.064	0.029	0.184
	4,4'-DDT	7	5	[2]	71.4%	[2]	0.031	0.072	0.004	0.193
5	4,4'-DDD	3	3	1	100.0%	33.3%	0.048	0.078	0.009	0.138
	4,4'-DDE	3	3	3	100.0%	100.0%	0.190	0.243	0.083	0.467
	4,4'-DDT	3	3	[2]	100.0%	[2]	0.219	0.375	0.017	0.653
6	4,4'-DDD	6	2	0	33.3%	0.0%	na	na	na	0.005
	4,4'-DDE	6	3	2	50.0%	33.3%	0.010	0.014	0.002	0.033
	4,4'-DDT	6	2	[2]	33.3%	[2]	na	na	na	0.020
7	4,4'-DDD	9	2	2	22.2%	22.2%	na	na	na	0.015
	4,4'-DDE	9	7	4	77.8%	44.4%	0.025	0.042	0.004	0.118
	4,4'-DDT	9	2	[2]	22.2%	[2]	na	na	na	0.025
8	4,4'-DDD	3	0	0	0.0%	0.0%	--	--	--	--
	4,4'-DDE	3	0	0	0.0%	0.0%	--	--	--	--
	4,4'-DDT	3	0	[2]	0.0%	[2]	--	--	--	--
9A	4,4'-DDD	6	3	1	50.0%	16.7%	0.003	0.004	0.001	0.010
	4,4'-DDE	6	5	4	83.3%	66.7%	0.056	0.068	0.020	0.179
	4,4'-DDT	6	2	[2]	33.3%	[2]	na	na	na	0.030
9B	4,4'-DDD	3	1	0	33.3%	0.0%	na	na	na	0.005
	4,4'-DDE	3	3	1	100.0%	33.3%	0.016	0.021	0.008	0.040
	4,4'-DDT	3	1	[2]	33.3%	[2]	na	na	na	0.002
10	4,4'-DDD	6	0	0	0.0%	0.0%	--	--	--	--
	4,4'-DDE	6	3	0	50.0%	0.0%	0.001	0.001	0.001	0.004
	4,4'-DDT	6	1	[2]	16.7%	[2]	na	na	na	0.002
12	4,4'-DDD	3	0	0	0.0%	0.0%	--	--	--	--
	4,4'-DDE	3	1	0	33.3%	0.0%	na	na	na	0.130
	4,4'-DDT	3	1	[2]	33.3%	[2]	na	na	na	0.010
13	4,4'-DDD	3	0	0	0.0%	0.0%	--	--	--	--
	4,4'-DDE	3	0	0	0.0%	0.0%	--	--	--	--
	4,4'-DDT	3	0	[2]	0.0%	[2]	--	--	--	--

[1] No samples have been collected from Reach 11.

[2] No sediment guidelines exist for DDT in freshwater.

"na" indicates value not calculated by the ROS method due to considerations of statistical validity.

Table 21. DDD, DDE, and DDT current conditions in fish tissue (filet/muscle) samples by reach, 1996-2004. [1]

Reach [1]	Form	n	# Detect	# Exceed	% Detect	% Exceed	Mean ug/g	SD	Median ug/g	Max ug/g
1	4,4'-DDD	1	0	0	0.0%	0.0%	--	--	--	--
	4,4'-DDE	1	1	1	100.0%	100.0%	na	na	na	0.043
	4,4'-DDT	1	0	0	0.0%	0.0%	--	--	--	--
3	4,4'-DDD	7	6	0	85.7%	0.0%	0.009	0.006	0.008	0.019
	4,4'-DDE	7	7	7	100.0%	100.0%	0.143	0.060	0.130	0.208
	4,4'-DDT	7	2	1	28.6%	14.3%	na	na	na	0.042
4	4,4'-DDD	2	2	1	100.0%	50.0%	na	na	na	0.071
	4,4'-DDE	2	2	2	100.0%	100.0%	na	na	na	0.757
	4,4'-DDT	2	1	1	50.0%	50.0%	na	na	na	0.048
7	4,4'-DDD	2	0	0	0.0%	0.0%	--	--	--	--
	4,4'-DDE	2	2	0	100.0%	0.0%	na	na	na	0.004
	4,4'-DDT	2	0	0	0.0%	0.0%	--	--	--	--
9A	4,4'-DDD	5	4	0	80.0%	0.0%	0.006	0.005	0.004	0.015
	4,4'-DDE	5	5	5	100.0%	100.0%	0.171	0.173	0.122	0.466
	4,4'-DDT	5	2	0	40.0%	0.0%	na	na	na	0.010
9B	4,4'-DDD	5	3	0	60.0%	0.0%	0.005	0.007	0.002	0.018
	4,4'-DDE	5	5	3	100.0%	60.0%	0.074	0.067	0.056	0.189
	4,4'-DDT	5	0	0	0.0%	0.0%	--	--	--	--
10	4,4'-DDD	8	0	0	0.0%	0.0%	--	--	--	--
	4,4'-DDE	8	6	0	75.0%	0.0%	0.007	0.005	0.005	0.019
	4,4'-DDT	8	0	0	0.0%	0.0%	--	--	--	--
12	4,4'-DDD	1	0	0	0.0%	0.0%	--	--	--	--
	4,4'-DDE	1	0	0	0.0%	0.0%	--	--	--	--
	4,4'-DDT	1	0	0	0.0%	0.0%	--	--	--	--
13	4,4'-DDD	6	0	0	0.0%	0.0%	--	--	--	--
	4,4'-DDE	6	3	0	50.0%	0.0%	0.003	0.001	0.003	0.005
	4,4'-DDT	6	0	0	0.0%	0.0%	--	--	--	--

[1] No samples were collected in reaches 2, 5, 6, 8, 11.
"na" indicates value not calculated by the ROS method due to considerations of statistical validity.

Table 22. DDD, DDE, and DDT current conditions in whole aquatic organism samples by reach, 1996-2004. [1]

Reach	Form	n	# Detect	# Exceed [2]	% Detect	% Exceed [2]	Mean ug/g	SD	Median ug/g	Max Detect ug/g
1	4,4'-DDD	24	24		100.0%		0.044	0.115	0.013	0.574
	4,4'-DDE	24	24		100.0%		0.207	0.156	0.156	0.495
	4,4'-DDT	24	24		100.0%		0.005	0.004	0.003	0.012
2	4,4'-DDD	2	2		100.0%		na	na	na	0.052
	4,4'-DDE	2	2		100.0%		na	na	na	0.433
	4,4'-DDT	2	0		0.0%		--	--	--	--
3	4,4'-DDD	7	7		100.0%		0.114	0.130	0.053	0.300
	4,4'-DDE	7	7		100.0%		1.89	1.54	1.29	4.10
	4,4'-DDT	7	5		71.4%		0.042	0.038	0.027	0.100
4	4,4'-DDD	3	3		100.0%		0.205	0.212	0.145	0.450
	4,4'-DDE	3	3		100.0%		2.31	2.23	1.59	4.80
	4,4'-DDT	3	3		100.0%		0.079	0.105	0.040	0.200
5	4,4'-DDD	3	2		66.7%		na	na	na	0.016
	4,4'-DDE	3	3		100.0%		0.045	0.008	0.045	0.052
	4,4'-DDT	3	0		0.0%		--	--	--	--
6	4,4'-DDD	2	2		100.0%		na	na	na	0.019
	4,4'-DDE	2	2		100.0%		na	na	na	0.339
	4,4'-DDT	2	0		0.0%		--	--	--	--
7	4,4'-DDD	8	4		50.0%		0.004	0.005	0.002	0.012
	4,4'-DDE	8	8		100.0%		0.036	0.015	0.034	0.067
	4,4'-DDT	8	0		0.0%		--	--	--	--
9A	4,4'-DDD	2	2		100.0%		na	na	na	0.035
	4,4'-DDE	2	2		100.0%		na	na	na	0.932
	4,4'-DDT	2	2		100.0%		na	na	na	0.100
9B	4,4'-DDD	3	3		100.0%		0.018	0.005	0.017	0.023
	4,4'-DDE	3	3		100.0%		0.317	0.063	0.313	0.369
	4,4'-DDT	3	0		0.0%		--	--	--	--
12	4,4'-DDD	4	2		50.0%		na	na	na	0.018
	4,4'-DDE	4	4		100.0%		0.050	0.009	0.050	0.061
	4,4'-DDT	4	0		0.0%		--	--	--	--

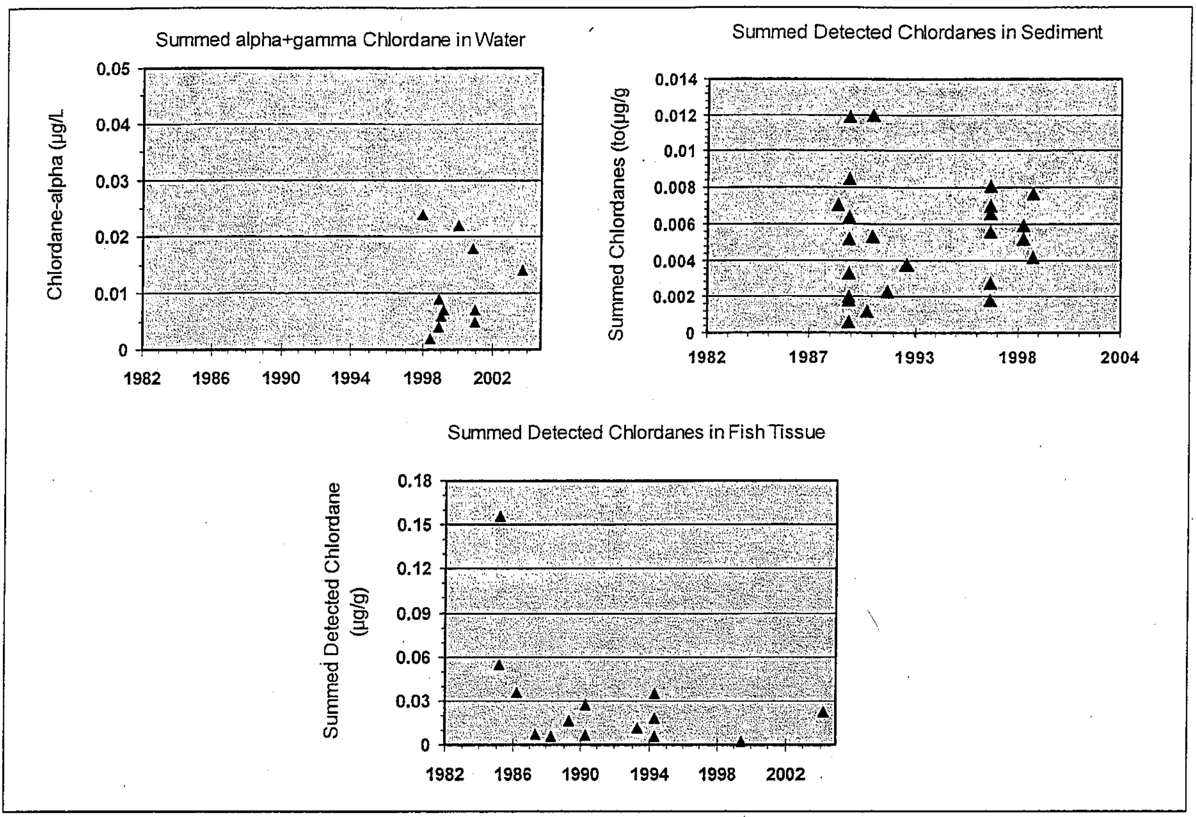
[1] No samples were collected in reaches 8, 10, 11, 13.

[2] Appropriate numeric targets do not exist (NAS are not adopted criteria, OEHHA are for frequent consumers of sport fish).

"na" indicates value not calculated by the ROS method due to considerations of statistical validity.

Chlordane

For the purpose of this TMDL, and in accordance with standard convention, chlordane is considered as the sum of alpha-chlordane and gamma-chlordane, displayed in Figure 4 below as "summed" chlordane. Like most of the organochlorine compounds, chlordane is more frequently detected in sediment and fish tissue than in water. Chlordane detections in water during the 1996-2004 time period occur in the Mugu, Revolon, Calleguas, and Simi subwatersheds -- reaches 1, 3, 4, 5, 7 (Table 23). Sixteen sediment samples from Mugu contained detectable levels of chlordane; while only four other detections occurred in the rest of the watershed. A high proportion of tissue samples during 1996-2004 recorded detections of chlordane, although the total number of samples was not large (Table 25 and Table 26).



Summed alpha+gamma Chlordane in Water

Summed Detected Chlordanes in Sediment

Summed Detected Chlordanes in Fish Tissue

Figure 4 - Detected values for Chlordane in water, sediment, and fish tissue samples for all years of available data

Table 23. Chlordane current conditions in water samples by reach, 1996-2004.

Reach	n	# Detect	# Exceed	% Detect	% Exceed	Mean ug/L	SD	Median ug/L	Max Detect ug/L
1	118	6	6	5.1%	5.1%	0.015	0.017	0.008	0.040
2	22	0	0	0.0%	0.0%	--	--	--	--
3	42	2	2	4.8%	4.8%	na	na	na	0.007
4	39	9	9	23.1%	23.1%	0.085	0.225	0.010	0.684
5	14	1	1	7.1%	7.1%	na	na	na	0.014
6	18	0	0	0.0%	0.0%	--	--	--	--
7	42	1	1	2.4%	2.4%	na	na	na	0.294
8	11	0	0	0.0%	0.0%	--	--	--	--
9A	20	0	0	0.0%	0.0%	--	--	--	--
9B	19	0	0	0.0%	0.0%	--	--	--	--
10	23	0	0	0.0%	0.0%	--	--	--	--
11	5	0	0	0.0%	0.0%	--	--	--	--
12	11	0	0	0.0%	0.0%	--	--	--	--
13	18	0	0	0.0%	0.0%	--	--	--	--

"na" indicates value not calculated by the ROS method due to considerations of statistical validity.

Table 24. Chlordane current conditions in sediment samples by reach, 1996-2004. [1]

Reach	n	# Detect	# Exceed	% Detect	% Exceed	Mean ug/g	SD	Median ug/g	Max Detect ug/g
1	43	16	2	37.2%	4.7%	0.004	0.005	0.003	0.020
2	7	0	0	0.0%	0.0%	--	--	--	--
3	6	0	0	0.0%	0.0%	--	--	--	--
4	7	2	0	28.6%	0.0%	na	na	na	0.008
5	3	0	1	0.0%	33.3%	--	--	--	--
6	6	0	0	0.0%	0.0%	--	--	--	--
7	7	0	0	0.0%	0.0%	--	--	--	--
8	3	0	0	0.0%	0.0%	--	--	--	--
9A	6	1	0	16.7%	0.0%	na	na	na	0.004
9B	3	0	0	0.0%	0.0%	--	--	--	--
10	6	1	0	16.7%	0.0%	na	na	na	0.006
12	3	0	0	0.0%	0.0%	--	--	--	--
13	3	0	0	0.0%	0.0%	--	--	--	--

[1] No samples were collected from Reach 11.
"na" indicates value not calculated by the ROS method due to considerations of statistical validity.

Table 25. Chlordane current conditions in fish tissue (filet/muscle) samples by reach, 1996-2004. [1]

Reach[1]	n	# Detect	# Exceed	% Detect	% Exceed	Mean ug/g	SD	Median ug/g	Max ug/g
1	1	0	0	0.0%	0.0%	--	--	--	--
3	7	1	0	14.3%	0.0%	na	na	na	0.002
4	2	1	1	50.0%	50.0%	na	na	na	0.022
7	2	0	0	0.0%	0.0%	--	--	--	--
9A	5	1	0	20.0%	0.0%	na	na	na	0.005
9B	5	1	0	20.0%	0.0%	na	na	na	0.001
10	8	0	0	0.0%	0.0%	--	--	--	--
12	1	0	0	0.0%	0.0%	--	--	--	--
13	6	0	0	0.0%	0.0%	--	--	--	--

[1] No samples were collected in reaches 2, 5, 6, 8, 11.
"na" indicates value not calculated by the ROS method due to considerations of statistical validity.

Table 26. Chlordane current conditions in whole aquatic organism samples by reach, 1996-2004. [1]

Reach	n	# Detect	# Exceed [2]	% Detect	% Exceed [2]	Mean ug/g	SD	Median ug/g	Max Detect ug/g
2	2	1		50.0%		na	na	na	0.009
3	7	4		57.1%		0.027	0.020	0.021	0.047
4	3	2		66.7%		na	na	na	0.092
5	3	0		0.0%		--	--	--	--
6	2	0		0.0%		--	--	--	--
7	8	1		12.5%		na	na	na	0.003
9A	2	2		100.0%		na	na	na	0.008
9B	3	1		33.3%		na	na	na	0.002
12	4	1		25.0%		na	na	na	0.010

[1] No samples were collected in reaches 1, 8, 10, 11, 13.

[2] Appropriate numeric targets do not exist (NAS are not adopted, OEHHA are for frequent consumers of sport fish).

"na" indicates value not calculated by the ROS method due to considerations of statistical validity.

Dieldrin

Dieldrin has been detected only once in water across all years of available data, yet many detections occur in both sediment and fish tissue samples (Figure 5). In recent data from 1996-2004, only one detection of dieldrin in water is present, from Mugu Lagoon. Six out of seven recent detections in sediment also occurred in samples from Mugu Lagoon (Table 28). Only two detections of dieldrin occur in recent filet/muscle tissue samples (Table 29), one each in the Calleguas and Conejo Subwatersheds. A total of eight detections occurred in whole organism samples during 1996-2004 (Table 30).

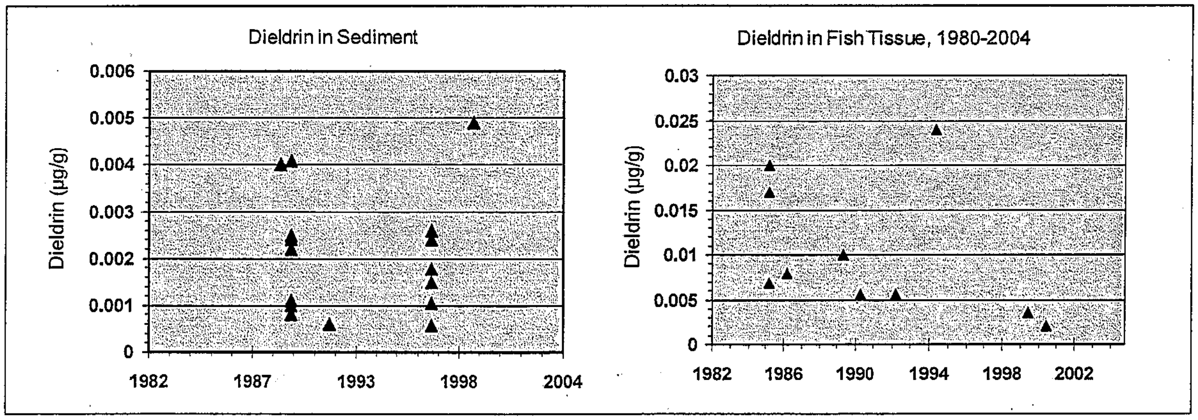


Figure 5. Detected values for Dieldrin in sediment and fish tissue samples for all years of available data. Dieldrin was not detected in any water samples.

Table 27. Dieldrin current conditions in water column by reach, 1996-2004.

Reach	n	# Detect	# Exceed	% Detect	% Exceed	Mean ug/L	SD	Median ug/L	Max Detect ug/L
1	64	1	1	1.6%	1.6%	na	na	na	0.002
2	21	0	0	0.0%	0.0%	--	--	--	--
3	68	0	0	0.0%	0.0%	--	--	--	--
4	37	0	0	0.0%	0.0%	--	--	--	--
5	14	0	0	0.0%	0.0%	--	--	--	--
6	18	0	0	0.0%	0.0%	--	--	--	--
7	97	0	0	0.0%	0.0%	--	--	--	--
8	11	0	0	0.0%	0.0%	--	--	--	--
9A	20	0	0	0.0%	0.0%	--	--	--	--
9B	32	0	0	0.0%	0.0%	--	--	--	--
10	42	0	0	0.0%	0.0%	--	--	--	--
11	18	0	0	0.0%	0.0%	--	--	--	--
12	39	0	0	0.0%	0.0%	--	--	--	--
13	24	0	0	0.0%	0.0%	--	--	--	--

"na" indicates value not calculated by the ROS method due to considerations of statistical validity.

Table 28. Dieldrin current conditions in sediment samples by reach, 1996-2004. [1]

Reach	n	# Detect	# Exceed	% Detect	% Exceed	Mean ug/g	SD	Median ug/g	Max Detect ug/g
1	37	6	0	16.2%	0.0%	na	na	na	0.003
2	7	0	0	0.0%	0.0%	--	--	--	--
3	6	0	0	0.0%	0.0%	--	--	--	--
4	7	1	0	14.3%	0.0%	na	na	na	0.005
5	3	0	0	0.0%	0.0%	--	--	--	--
6	6	0	0	0.0%	0.0%	--	--	--	--
7	9	0	0	0.0%	0.0%	--	--	--	--
8	3	0	0	0.0%	0.0%	--	--	--	--
9A	6	0	0	0.0%	0.0%	--	--	--	--
9B	3	0	0	0.0%	0.0%	--	--	--	--
10	6	0	0	0.0%	0.0%	--	--	--	--
12	3	0	0	0.0%	0.0%	--	--	--	--
13	3	0	0	0.0%	0.0%	--	--	--	--

[1] No samples have been collected from Reach 11.

"na" indicates value not calculated by the ROS method due to considerations of statistical validity.

Table 29. Dieldrin current conditions in fish tissue (filet/muscle) samples by reach, 1996-2004.

Reach[1]	n	# Detect	# Exceed	% Detect	% Exceed	Mean ug/g	SD	Median ug/g	Max ug/g
1	1	0	0	0.0%	0.0%	--	--	--	--
3	7	1	1	14.3%	14.3%	na	na	na	0.004
4	2	0	0	0.0%	0.0%	--	--	--	--
7	2	0	0	0.0%	0.0%	--	--	--	--
9A	5	0	0	0.0%	0.0%	--	--	--	--
9B	5	0	0	0.0%	0.0%	--	--	--	--
10	8	1	1	12.5%	12.5%	na	na	na	0.002
12	1	0	0	0.0%	0.0%	--	--	--	--
13	6	0	0	0.0%	0.0%	--	--	--	--

[1] No samples were collected in reaches 2, 5, 6, 8, 11.
"na" indicates value not calculated by the ROS method due to considerations of statistical validity.

Table 30. Dieldrin current conditions in whole aquatic organism samples by reach, 1996-2004. [1]

Reach	n	# Detect	# Exceed [2]	% Detect	% Exceed [2]	Mean ug/g	SD	Median ug/g	Max Detect ug/g
2	2	0		0.0%		--	--	--	--
3	7	3		42.9%		0.007	0.006	0.005	0.016
4	3	1		33.3%		na	na	na	0.063
5	3	0		0.0%		--	--	--	--
6	2	0		0.0%		--	--	--	--
7	8	1		12.5%		na	na	na	0.004
9A	2	2		100.0%		na	na	na	0.017
9B	3	0		0.0%		--	--	--	--
12	4	1		25.0%		na	na	na	0.010

[1] No samples were collected in reaches 1, 8, 10, 11, 13.
[2] Appropriate numeric targets do not exist (NAS are not adopted criteria, OEHHA are for frequent consumers of sport fish).
"na" indicates value not calculated by the ROS method due to considerations of statistical validity.

PCBs

PCBs have been detected consistently in water, sediment, and tissue samples across all years of data (Figure 6). PCB concentrations are typically quantified as either the sum of Aroclors or the sum of PCB congeners. Aroclors are various PCB mixtures identified by a four-digit numbering code in which the first two digits indicate the molecular type of the mixture and the last two digits indicate the approximate chlorine content by weight percent (ATSDR, 2000). Congeners are single, unique, specifically-defined forms of PCB which are named according to the total number of chlorine substituents and the position of each chlorine (website, www.epa.gov/toxteam/pcbid/defs.htm). Total Aroclor concentrations are used to evaluate water data and total PCB congener concentrations are used to evaluate sediment and fish data, in accordance with numeric targets for each medium. During 1996-2004, PCBs have been generally been detected in a low percentage of all samples (Table 31 - Table 34). However, 88% of 203 sediment samples from Mugu Lagoon contained detectable levels of PCBs.

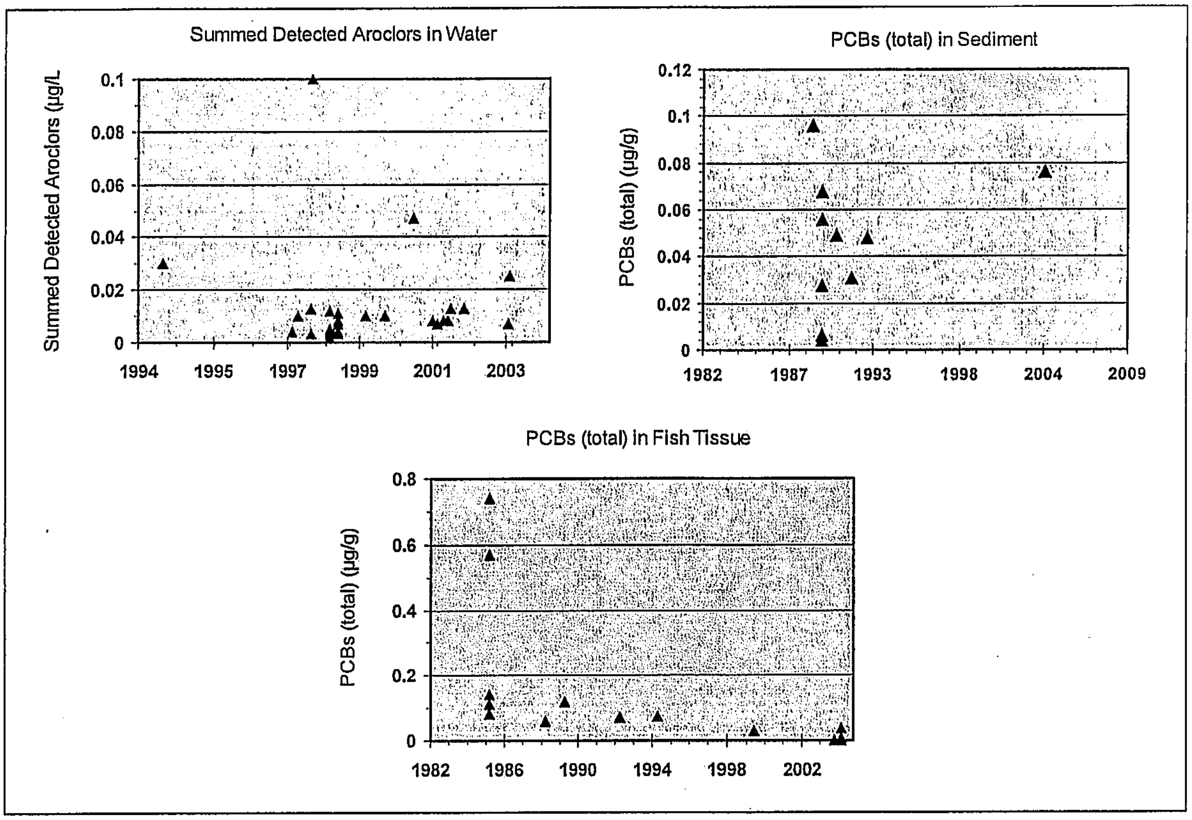


Figure 6 - Detected values for PCBs in water, sediment, and fish tissue samples for all years of available data.

Table 31. Summed detected Aroclors, current conditions in water by reach, 1996-2004.

Reach	n	# Detect	# Exceed	% Detect	% Exceed	Mean ug/L	SD	Median ug/L	Max Detect ug/L
1	287	1	1	0.3%	0.3%	na	na	na	0.064
2	27	0	0	0.0%	0.0%	--	--	--	--
3	62	0	0	0.0%	0.0%	--	--	--	--
4	41	1	1	2.4%	2.4%	na	na	na	2.980
5	13	1	1	7.7%	7.7%	na	na	na	0.036
6	41	0	0	0.0%	0.0%	--	--	--	--
7	348	1	1	0.3%	0.3%	na	na	na	1.671
8	10	0	0	0.0%	0.0%	--	--	--	--
9A	19	0	0	0.0%	0.0%	--	--	--	--
9B	31	0	0	0.0%	0.0%	--	--	--	--
10	162	1	1	0.6%	0.6%	na	na	na	0.025
11	18	0	0	0.0%	0.0%	--	--	--	--
12	30	0	0	0.0%	0.0%	--	--	--	--
13	17	0	0	0.0%	0.0%	--	--	--	--

"na" indicates value not calculated by the ROS method due to considerations of statistical validity.

Table 32. PCBs (total) current conditions in sediment samples by reach, 1996-2004. [1]

Reach	n	# Detect	# Exceed	% Detect	% Exceed	Mean ug/g	SD	Median ug/g	Max Detect ug/g
1	203	180	0	88.7%	0.0%	0.001	0.001	0.001	0.007
2	4	0	0	0.0%	0.0%	--	--	--	--
3	4	0	0	0.0%	0.0%	--	--	--	--
4	4	0	0	0.0%	0.0%	--	--	--	--
5	3	0	0	0.0%	0.0%	--	--	--	--
6	4	0	0	0.0%	0.0%	--	--	--	--
7	4	0	0	0.0%	0.0%	--	--	--	--
8	3	0	0	0.0%	0.0%	--	--	--	--
9A	4	0	0	0.0%	0.0%	--	--	--	--
9B	3	0	0	0.0%	0.0%	--	--	--	--
10	4	0	0	0.0%	0.0%	--	--	--	--
12	3	0	0	0.0%	0.0%	--	--	--	--
13	3	0	0	0.0%	0.0%	--	--	--	--

[1] No samples have been collected from Reach 11.
"na" indicates value not calculated by the ROS method due to considerations of statistical validity.

Table 33. PCBs(total) in fish tissue (filet/muscle) by reach, 1996-2004

Reach	n	# Detect	# Exceed	% Detect	% Exceed	Mean ug/g	SD	Median ug/g	Max ug/g
1	1	0	0	0.0%	0.0%	--	--	--	--
3	6	1	1	16.7%	16.7%	na	na	na	0.035
4	2	0	0	0.0%	0.0%	--	--	--	--
7	2	0	0	0.0%	0.0%	--	--	--	--
9A	5	2	2	40.0%	40.0%	na	na	na	0.023
9B	5	0	0	0.0%	0.0%	--	--	--	--
10	6	0	0	0.0%	0.0%	--	--	--	--
12	1	0	0	0.0%	0.0%	--	--	--	--
13	6	0	0	0.0%	0.0%	--	--	--	--

[1] No samples were collected in reaches 2, 5, 6, 8, 11.
"na" indicates value not calculated by the ROS method due to considerations of statistical validity.

Table 34. PCBs(total) in whole aquatic organism samples by reach, 1996-2004. [1]

Reach	n	# Detect	# Exceed[2]	% Detect	% Exceed[2]	Mean ug/g	SD	Median ug/g	Max Detect ug/g
1	1	0		0.0%		--	--	--	--
2	2	2		100.0%		na	na	na	0.047
3	4	3		75.0%		0.060	0.039	0.053	0.105
4	2	1		50.0%		na	na	na	0.019
5	3	0		0.0%		--	--	--	--
6	2	0		0.0%		--	--	--	--
7	5	0		0.0%		--	--	--	--
9A	1	0		0.0%		--	--	--	--
9B	3	0		0.0%		--	--	--	--
12	3	0		0.0%		--	--	--	--

[1] No samples were collected in reaches 8, 10, 11, 13.
[2] Appropriate numeric targets do not exist (NAS are not adopted criteria, OEHHA are for frequent consumers of sport fish).
"na" indicates value not calculated by the ROS method due to considerations of statistical validity.

Toxaphene

There have been no detections of toxaphene in any water samples collected within the CCW across all years of available data, but many detections have occurred in sediment and fish tissue samples (Figure 7). Toxaphene was not detected in any water or sediment samples during 1996-2004 (Table 35 and Table 36). Only one detection of toxaphene has occurred in recent filet/muscle tissue samples, in reach 3 (Table 37). A total of eight detections occur in recent data for whole organism tissue (Table 38), several of which are from upper reaches in the watershed.

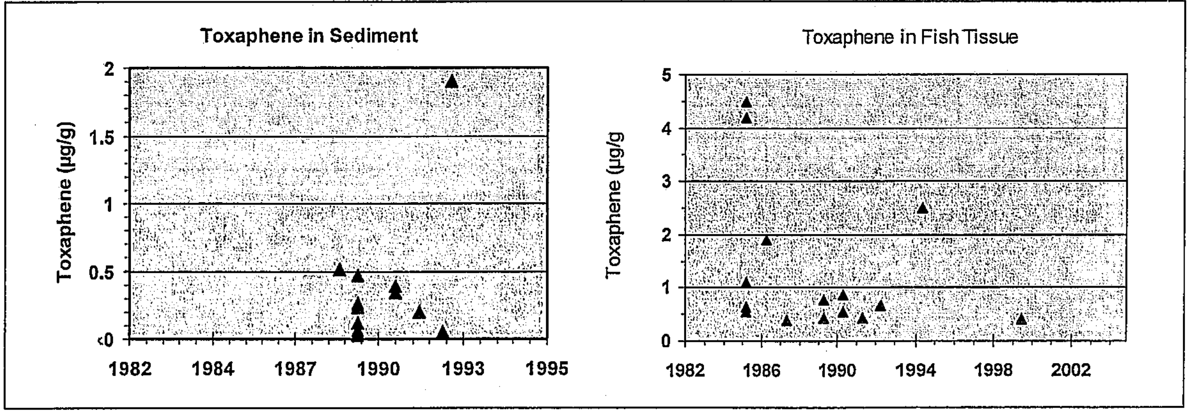


Figure 7. Detected values for Toxaphene in sediment and fish tissue samples for all years of available data. Toxaphene was not detected in any water samples.

Table 35 - Toxaphene current conditions in water column by reach, 1996-2004

Reach	n	# Detect	# Exceed	% Detect	% Exceed	Mean ug/L	SD	Median ug/L	Max Detect ug/L
1	3	0	0	0.0%	0.0%	--	--	--	--
2	16	0	0	0.0%	0.0%	--	--	--	--
3	67	0	0	0.0%	0.0%	--	--	--	--
4	33	0	0	0.0%	0.0%	--	--	--	--
5	13	0	0	0.0%	0.0%	--	--	--	--
6	13	0	0	0.0%	0.0%	--	--	--	--
7	94	0	0	0.0%	0.0%	--	--	--	--
8	11	0	0	0.0%	0.0%	--	--	--	--
9A	19	0	0	0.0%	0.0%	--	--	--	--
9B	30	0	0	0.0%	0.0%	--	--	--	--
10	41	0	0	0.0%	0.0%	--	--	--	--
11	18	0	0	0.0%	0.0%	--	--	--	--
12	39	0	0	0.0%	0.0%	--	--	--	--
13	23	0	0	0.00%	0.00%	--	--	--	--

"na" indicates value not calculated by the ROS method due to considerations of statistical validity.

Table 36. Toxaphene current conditions in sediment samples by reach, 1996-2004. [1]

Reach	n	# Detect	# Exceed [2]	% Detect	% Exceed [2]	Mean ug/g	SD	Median ug/g	Max Detect ug/g
2	6	0		0.0%		--	--	--	--
3	6	0		0.0%		--	--	--	--
4	6	0		0.0%		--	--	--	--
5	3	0		0.0%		--	--	--	--
6	6	0		0.0%		--	--	--	--
7	9	0		0.0%		--	--	--	--
8	3	0		0.0%		--	--	--	--
9A	6	0		0.0%		--	--	--	--
9B	3	0		0.0%		--	--	--	--
10	6	0		0.0%		--	--	--	--
12	3	0		0.0%		--	--	--	--
13	3	0		0.0%		--	--	--	--

[1] No samples have been collected from Reaches 1 or 11.
[2] No sediment guidelines exist for toxaphene.
"na" indicates value not calculated by the ROS method due to considerations of statistical validity.

Table 37. Toxaphene current conditions in fish tissue (filet/muscle) samples by reach, 1996-2004.

Reach[1]	n	# Detect	# Exceed	% Detect	% Exceed	Mean ug/g	SD	Median ug/g	Max ug/g
1	1	0	0	0.0%	0.0%	--	--	--	--
3	7	1	1	14.3%	14.3%	na	na	na	0.424
4	2	0	0	0.0%	0.0%	--	--	--	--
7	2	0	0	0.0%	0.0%	--	--	--	--
9A	5	0	0	0.0%	0.0%	--	--	--	--
9B	5	0	0	0.0%	0.0%	--	--	--	--
10	8	0	0	0.0%	0.0%	--	--	--	--
12	1	0	0	0.0%	0.0%	--	--	--	--
13	6	0	0	0.0%	0.0%	--	--	--	--

[1] No samples were collected in reaches 2, 5, 6, 8, 11.
"na" indicates value not calculated by the ROS method due to considerations of statistical validity.

Table 38. Toxaphene current conditions in whole aquatic organism samples by reach, 1996-2004. [1]

Reach	n	# Detect	# Exceed[2]	% Detect	% Exceed[2]	Mean ug/g	SD	Median ug/g	Max Detect ug/g
2	2	0		0.0%		--	--	--	--
3	7	3		42.9%		1.671	2.426	0.383	5.400
4	3	1		33.3%		na	na	na	12.000
5	3	0		0.0%		--	--	--	--
6	2	0		0.0%		--	--	--	--
7	8	1		12.5%		na	na	na	0.033
9A	2	2		100.0%		na	na	na	0.874
9B	3	0		0.0%		--	--	--	--
12	4	1		25.0%		na	na	na	0.027

[1] No samples were collected in reaches 1, 8, 10, 11, 13.
[2] Appropriate numeric targets do not exist (NAS are not adopted criteria, OEHHA are for frequent consumers of sport fish).
"na" indicates value not calculated by the ROS method due to considerations of statistical validity.

3.6 Conclusions

Receiving water data for water, sediment, and tissue include a large proportion of non-detected values for most of the OC pesticides and PCBs included on the 2002 303(d) list for the CCW. In general, a higher proportion of detected samples occurs in fish tissue and sediment samples than in water samples. DDE is designated as an appropriate representative constituent for data analysis and modeling throughout this TMDL, since it is the only constituent consistently detected in exceedance of targets in water, sediment, and fish tissue samples; and for additional reasons detailed in the Linkage Analysis section.

Several constituents in the watershed appear to no longer be exceeding target levels, and are referred to hereafter as "category-2 constituents". Only constituents currently exceeding targets, referred to as "category-1 constituents", are discussed in depth in the Source Analysis and Linkage Analysis Sections. However, waste load and load allocations are assigned in the TMDL and Allocations Section for all listed constituents.

A downward trend is observed over time for many category-1 constituent concentrations, which is especially apparent in fish tissue concentrations. When data from 1996-2004 are examined, even the category-1 constituents are currently being detected only rarely in many locations throughout the watershed. Since all category-1 constituents have been banned from legal use for more than ten years, such a pattern may reflect the natural attenuation of residual sources in the watershed. These degradation trends are further examined later in the Linkage Analysis Section. The highest concentrations for category-1 constituents tend to occur in the Revolon Slough, Mugu Lagoon, and Calleguas Creek Subwatersheds.

4 NUMERIC TARGETS

Numeric targets identify specific goals for the OC Pesticides and PCBs TMDL which equate to attainment of water quality standards and provide the basis for data analysis and final TMDL allocations. Multiple numeric targets are often considered when there is uncertainty that a single numeric target is sufficient to ensure protection of designated beneficial uses. The 2002 303(d) list for the Calleguas Creek Watershed contains listings for OC pesticides and PCBs (OCs) in the water column, fish tissue, and sediment. In order to address these listings, water criteria and fish tissue and sediment guidelines are selected as numeric targets (Table 39).

Inclusion of the water, fish tissue, and sediment targets mentioned above adequately protects benthic and aquatic organisms, wildlife, and human health from potentially harmful effects associated with OC pesticides and PCBs. A complete description of each set of numeric targets follows.

Table 39. Numeric targets for water, fish tissue, and sediment.

Constituent	Water Quality Targets [1] (ug/L)		Fish Tissue Targets [2] (ug/Kg)	Sediment Targets [3] (ug/dry Kg)	
	Freshwater	Marine		Freshwater, TEL	Marine, ERL
Aldrin	3.0 [4]	1.3 [4]	0.050	NA	NA
Chlordane	0.0043	0.0040	8.3	4.5	0.5
Dacthal	3500 [5]	NA [5]	NA [5]	NA	NA
DDD	NA	NA	45	3.5	2.0
DDE	NA	NA	32	1.4	2.2
DDT	0.001	0.001	32	NA	1.0
Dieldrin	0.056	0.0019	0.65	2.9	0.02
Endosulfan I	0.056	0.0087	65,000	NA	NA
Endosulfan II	0.056	0.0087	65,000	NA	NA
Endrin	0.036	0.0023	3200	2.7	NA
HCH (alpha-BHC)	NA	NA	1.7	NA	NA
HCH (beta-BHC)	NA	NA	6.0	NA	NA
HCH (delta-BHC)	NA	NA	NA	NA	NA
HCH (gamma-BHC)	0.95 [4]	0.16 [4]	8.2	0.94	NA
Heptachlor	0.0038	0.0036	2.4	NA	NA
Heptachlor Epoxide	0.0038	0.0036	1.2	0.6	NA
PCBs	0.014 [6]	0.030 [6]	5.3 [7]	34 [7]	23 [7]
Toxaphene	0.00020	0.00020	9.8	NA	NA

[1] CTR water quality criteria for protection of aquatic life. Chronic criteria (Criteria Continuous Concentration, or CCC) are applied, where they exist. In the absence of chronic standards, acute criteria (Criteria Maximum Concentration, or CMC) are applied.

[2] Threshold Tissue Residue Levels (TTRLs), derived from CTR human health criteria for consumption of organisms only.

[3] Sediment quality guidelines contained in NOAA Screening Quick Reference Tables (Buchman, 1999); TEL = Threshold Effects Level

[4] No chronic criteria exist; acute criteria are used.

[5] No chronic or acute criteria exist, drinking water standard of 3500 ug/L adopted by Florida and Arizona is applied for freshwater.

[6] PCBs in water are measured as sum of seven Aroclors.

[7] PCBs in fish tissue and sediment are measured as sum of all congeners.

"NA" indicates that no applicable target exists for the constituent.

4.1 Water Column Targets

California Toxics Rule (CTR) aquatic life criteria for water are selected as numeric targets for protection of freshwater and marine life from aquatic toxicity. Chronic criteria (Criteria Continuous Concentration, or CCC) are applied when available. In the absence of chronic criteria, acute criteria (Criteria Maximum Concentration, or CMC) are applied. When neither chronic nor acute criteria are defined by the CTR for a given constituent, no numeric target is presented (since no other appropriate water criteria exist for protection of aquatic life from toxicity). As described in 40 CFR 131, compliance with these CTR criteria is required for all CCW reaches.

Alternative Considered

CTR water quality criteria for protection of human health from consumption of contaminated fish or other aquatic organisms were considered. Generating water concentration values resulting in fish tissue levels safe for human consumption involves significant uncertainties. Because of these uncertainties and since many of the CTR human health criteria numbers are below current detection limits for OCs in water, fish tissue targets derived from the CTR human health criteria are used instead (see below).

4.2 Fish Tissue Targets

Fish tissue targets selected for this TMDL are derived from CTR human health criteria, which are adopted criteria for water designed to protect humans from consumption of contaminated fish or other aquatic organisms. The derived fish tissue targets are referred to in this document as Threshold Tissue Residue Levels (TTRLs). Use of fish tissue targets is appropriate to account for uncertainties in the relationship between pollutant loadings and beneficial use effects (EPA, Newport Bay TMDL, 2002) and most directly addresses potential human health impacts from consumption of contaminated fish or other aquatic organisms. Since the TTRL numeric targets are generally higher than current detection limits (unlike many of the water column criteria for protection of human health), compliance monitoring is feasible with current technology. Use of fish tissue targets also allows the TMDL analysis to more completely use site-specific data where limited water column data are available, consistent with the provisions of 40 CFR 130.7(c)(1)(i). Thus, use of TTRLs provides an effective method for accurately quantifying achievement of the water quality objectives/standards.

Derivation of the Threshold Tissue Residue Levels (TTRLs)

The TTRLs shown in the far right column of Table 40 are derived from CTR human health criteria for "consumption of organisms only." CTR human health criteria were developed by determining OC pesticide and PCB concentrations in edible fish tissue that would pose a health risk to humans consuming 6.5 grams per day of fish. These fish tissue concentrations were then converted to water column concentrations using a bioconcentration factor (BCF), which is the ratio of the chemical concentration in fish to the chemical concentration in water. TTRLs are calculated by eliminating the BCF from the human health criteria equation, thereby reverting back to the original fish tissue concentration upon which the CTR human health criteria are based.

Table 40. Derivation of Threshold Tissue Residue Levels (TTRLs)

Constituent	CTR Human Health Water Criteria (µg/L) [1]	BCF (L/Kg) [2]	TTRL, Edible Tissue Concentration (µg/Kg wet weight)
Aldrin [3]	0.00014	[4]	0.05
Chlordane [3]	0.00059	14100	8.3
4,4'-DDT	0.00059	53600	32
4,4'-DDE	0.00059	53600	32
4,4'-DDD	0.00084	53600	45
Dieldrin [3]	0.00014	4670	0.65
Endosulfan I [3]	240	270	65,000
Endosulfan II [3]	240	270	65,000
Endosulfan sulfate [3]	240	270	65,000
Endrin [3]	0.81	3970	3200
Heptachlor [3]	0.00021	11200	2.4
Heptachlor Epoxide [3]	0.00011	11200	1.2
alpha-BHC (HCH) [3]	0.013	130	1.7
beta-BHC (HCH [3]	0.046	130	6
gamma-BHC (HCH) [3]	0.063	130	8.2
PCBs (total)	0.00017	31200	5.3 [5]
Toxaphene [3]	0.00075	13100	9.8

[1] USEPA. 2000. Water Quality Standards; Establishment of Numeric Criteria for Priority Toxic Pollutants for the State of California; Rule. May 18, 2000. The human health criteria listed are "For the Consumption of Organisms Only".

[2] Obtained from the USEPA 1980 Ambient Water Quality Criteria Documents for each constituent.

[3] Included in the list of "Chem A" pesticides.

[4] The numeric target for aldrin was derived from a combination of aldrin and dieldrin risk factors and BCFs as recommended in "Ambient Water Quality Criteria for Aldrin/Dieldrin" (USEPA 1980, 1990).

[5] Applies to the sum of all congener or isomer or homolog or Aroclor analyses.

4.3 Sediment Targets

Sediment quality guidelines endorsed by the National Oceanic and Atmospheric Administration (NOAA) and contained in NOAAs Screening Quick Reference Tables (SQuiRTs) (Buchman, 1999) are selected as numeric targets for sediment. NOAA included the following caveat in the introductory comments to the SQuiRTs: "These tables are intended for preliminary screening purposes only; they do not represent NOAA policy and do not constitute criteria or clean-up levels. NOAA does not endorse their use for any other purposes." Multiple sediment screening values are included in the SQuiRTs "to help portray the entire spectrum of concentrations which have been associated with various probabilities of adverse biological effects." The specific numeric values selected from the SQuiRTs tables as numeric targets are the Threshold Effects Level (TEL) values for freshwater sediment and the Effects Range Low (ERL) values for marine sediment. TELs are calculated using the geometric mean of the 15th percentile concentration of the data set and the median of the no-effect data set; they represent the concentration below which adverse effects are expected to occur only rarely. ERLs are calculated as the lower 10th percentile concentration of the available sediment toxicity data which has been screened for only those samples which were identified as toxic by original investigators; they represent the value at which toxicity may begin to be observed in sensitive species. Thus, use of TELs and ERLs represents a conservative (i.e., more protective choice). Since these sediment guidelines are not adopted sediment quality criteria, they are used as numeric targets only for reaches with sediment listings (the exact methodology for use of the sediment guidelines is explained in the TMDL Allocations section).

The CCW Toxicity TMDL did not identify any OC pesticides or PCBs as causing toxicity in water or sediment. Any unidentified toxicity which may result from OCs is addressed in this TMDL by selection of numeric targets which are protective of toxicity in water and sediment.

4.4 Protection of Wildlife Habitat and Endangered Species

While most of the original basis for listing of OCs was for protection of human health (i.e., tissue listings), this TMDL must also protect the beneficial uses of wildlife habitat (WILD) and preservation of rare and endangered species (RARE) to be federally approvable. The working assumption is that numeric targets, load and waste load allocations, and the resulting implementation actions that are derived to protect human health are also protective of wildlife. As a backstop, it is also appropriate to define additional numeric targets specific to species of concern, where sufficient risk assessment information is available.

Table 41 Summarizes common names, scientific names, diet, effects of concern, and proposed targets for Federally Endangered Species that live in the CCW in and around Mugu Lagoon (see Appendix I for more complete list of CCW species). In general, for avian species, the most appropriate indicator is the concentration of organochlorines in eggs, because the effect of concern is impairment of reproductive success. For harbor seals, the effect of concern is suppression of the immune system, and the appropriate indicator is the OC concentration of blubber.

A literature review was conducted to gather no-effect levels and critical levels for OC contaminants in wildlife. The available data support definition of targets that are no-effect levels for DDE and total PCBs in bird eggs, and PCBs and DDT in harbor seal blubber. Critical levels have been established for Dieldrin in bird eggs and Toxaphene in bird tissue. It is important to note that these critical levels correspond to known effect levels. Numeric targets would necessarily be lower than the critical levels.

Other species, such as raccoons, coyote, weasels, and raptors, that forage in the Calleguas Creek watershed should also be protected by attainment of human health targets; since aquatic organisms represent only a portion of their diet. If more protective targets are established for these organisms through consultation with wildlife resource agencies, those targets will be established in the TMDL through the reevaluation process.

The linkage from risk assessment targets to OC concentrations in food items, sediments and water is not well understood in this watershed. Reducing OC loads to attain human health based targets will result in progress toward attainment of wildlife targets. In the implementation phase of the TMDL, additional wildlife targets will be defined and established through reevaluation if needed as risk assessment information becomes available.

Table 41. Proposed targets for protection of Federally listed wildlife species.

Federally Endangered Species					
Common Name	California Brown pelican	western snowy plover	California least tern	Light-footed clapper rail	harbor seals
Scientific name	*Pelecanus occidentalis*	*Charadrius alexandrinus nivosus*	*Sterna antillarum browni*	*Rallus longirostris levipes*	*Phoca vitulina*
Diet	Piscivore	Insectivore	Piscivore	Benthic omnivore	Piscivore
Effect of concern	Reproductive Impairment				Immune system impairment
p,p'-DDE target	1 µg/g in eggs [1]				
DDT (total) Target					0.3 µg/g or mg/kg lipid (blubber) [2]
Dieldrin target	< 1 µg/g in eggs [3]				
PCBs (total) target	0.5 µg/g in eggs [4]				5 mg/kg lipid (blubber) [2]
Toxaphene target	< 40 µg/g in bird tissue [3]				

[1] Hothem and Powell (2000); no-effect level for DDE in Forster's Tern eggs from Texas.

[2] Barron et al (20003); no-effect level for total DDTs in harbor seals from Germany, Denmark, and the United Kingdom.

[3] From Braune et al (1999); critical levels in peregrine falcon eggs and critical levels in bird tissue.

[4] Muir et al (1999); no-effect level for deformities for total PCBs in White Leghorn Chicken eggs.

Water quality criteria designed to protect wildlife from adverse impacts resulting from consumption of food and/or water from the Great Lakes ecosystem are shown in Table 42 for DDT and PCBs (criteria are not defined for any other OCs). These criteria take into consideration the reproductive success and survival of a species. Relevant CTR aquatic life criteria are also shown in Table 42 for comparison. Since CTR criteria are lower than the Great Lakes wildlife criteria, numeric targets selected for this TMDL should protect wildlife. Monitoring, special studies, and adaptive management described in the Implementation Plan will further assure necessary protections for wildlife. Data of DDE concentrations in Least Tern and Clapper Rail chicks and eggs from the Point Mugu Naval Base which are included in Appendix II may prove useful for future efforts to gauge effectiveness of wildlife protection.

Table 42. Comparison of Tier I Great Lakes Wildlife Criteria and CTR Aquatic Life Criteria.

Constituent	Great Lakes Wildlife Criteria		CTR Aquatic Life Criteria (ug/L)	
	(mg/L)	(ug/L)	Freshwater	Marine
DDT & Metabolites	0.000011	0.011	NA	NA
DDD	NA	NA	NA	NA
DDE	NA	NA	NA	NA
DDT	NA	NA	0.001	0.001
PCBs (total)	0.000074	0.074	0.014	0.03

4.5 Alternatives Considered

Whole organism tissue targets were considered, but filet/muscle tissue targets are selected since no appropriate standards exist for whole organism concentrations (NAS standards are not adopted criteria, OEHHA targets are for frequent consumers of sport fish) and because filet/muscle tissue targets are most relevant for protection of human health from consumption.

The State Water Resources Control Board is currently developing sediment quality guidelines, which will be incorporated into the CCW OCs TMDL, if appropriate.

5 SOURCE ANALYSIS

Initial steps in the development of a TMDL include assessing sources and then linking the loads from those sources to concentrations in environmental compartments. A generalized conceptual model of the linkage between sources, pathways, and reservoirs of OC pesticides and PCBs is presented in Figure 8. Most sources to surface waters in the CCW are related to historical uses of OCs. Agricultural runoff is likely responsible for the majority of OC pesticides introduced into the watershed over time. Past use of PCBs as coolants and lubricants in transformers, capacitors, and other electrical equipment is suspected as the primary source of PCB residues. Available evidence suggests that POTWs, groundwater, atmospheric deposition, and imported water are not responsible for major contributions to current loading of OCs in the watershed. This section focuses on the category-1 constituents defined in the Current Conditions section.

As mentioned previously, DDE is chosen as a representative constituent for analyses used to develop this TMDL. This is appropriate since DDE is the only constituent to consistently exceed applicable targets in water, sediment, and tissue samples (see Current Conditions); and also because OC Pesticides and PCBs possess similar physical and chemical properties that influence their fate and transport in the environment (see Linkage Analysis).

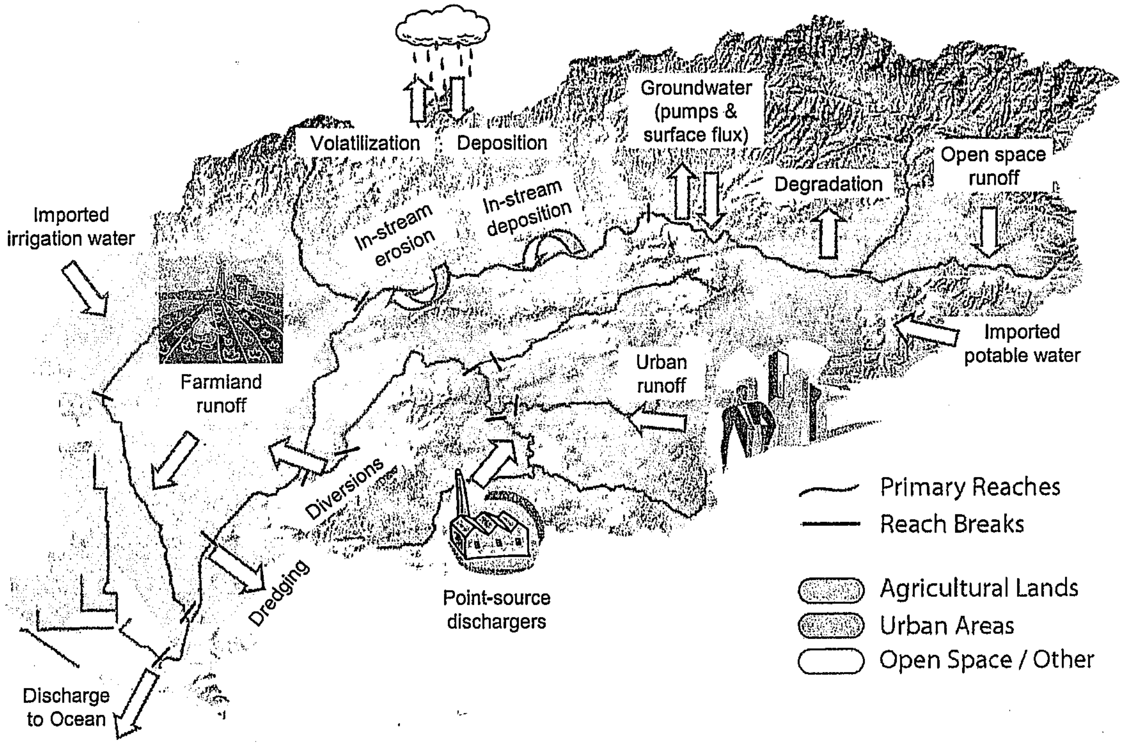


Figure 8. Generalized conceptual model of sources and pathways of OCs in the Calleguas Creek Watershed.

5.1 Data Resources and Analysis

Land-Use Runoff and Discharge Data

Runoff data characterized by land use (land-use runoff data) and data from point source discharges (discharge data) are available from several sources, shown in Table 43. This information is used to gain understanding about the relative contributions of OCs from agricultural, urban, groundwater discharge, and POTW sources. Debris basins, atmospheric deposition, and imported water are discussed separately since land-use runoff data cannot directly address those two issues.

Table 43. Summary of Land-Use Runoff and Discharge Data Sources

Data Source	Begin Date	End Date	Urban Land Use Sites	Agricultural Land Use Sites	Groundwater Discharge	POTW
205(j) Non Point Source Study	11/98	5/99	X	X		
Ventura County WPD	2/92	2/04	X	X		
Calleguas Creek Characterization Study(LWA, 1999)	8/98	5/99	X	X	X	X
Camrosa WRF	12/95	12/02				X
Camarillo WRP	8/98	12/01				X
Hill Canyon WWTP	2/94	11/02				X
Moorpark WWTP	9/97	2/02				X
Olsen Road WRP	8/93	5/99				X
Simi Valley WQCP	12/93	10/02				X
TMDL Work Plan Monitoring (LWA, 2004a)	8/03	8/04	X			

All available land-use runoff and discharge data for the major point and non-point source categories are summarized in Table 44, which includes: agricultural runoff, urban runoff (commercial/industrial and residential), runoff from native land (undeveloped open space), pumped groundwater, and POTW effluent. Every OC summarized was detected most often in agricultural runoff.

Pumped groundwater discharged from the Simi Valley dewatering wells was sampled on four occasions, of which one sample contained detectable concentrations of DDE, lindane, and PCBs. A NPDES permit allows the discharge of pumped groundwater from these dewatering wells to the storm drain system, for the purpose of lowering the local water table. Since these four samples may not accurately represent groundwater discharges from the Simi Valley dewatering wells, a special study is included in the Implementation Plan to determine potential contributions from these groundwater discharges. Note that these groundwater discharges are unlike natural exfiltration, and are not likely representative of any exfiltration which may occur in other parts of the watershed.

Runoff from native land has not been monitored explicitly; however, one monitoring site drains a lightly developed portion of Tapo Canyon considered representative of native land. Samples from this site have been analyzed for concentrations of OCs on five occasions, all of which were non-detected. Thus, there is no indication that native land in the watershed is a contributing source of OCs to water bodies.

Table 44. Summary of land-use runoff and discharge data indicating the percentages of samples that were measured at concentrations exceeding the analytical detection limits for each constituent.

Constituent	n Total	n Det.	Agricultural Runoff (% detect)	Urban Runoff [1] (% detect)	Native Land [2] (% detect)	Effluent Discharge (% detect)	Pumped Groundwater (% detect)
4,4'-DDD	299	83	71	4	0	4	0
4,4'-DDE	299	108	82	16	0	7	25 [4]
4,4'-DDT	298	89	81	3	0	0	0
Aldrin	300	31	29	0	0	0	0
Chlordane, Summed Detected [3]	148	55	55	0	0	4	0
Dacthal	6	0	0	NA	NA	NA	NA
Dieldrin	301	20	19	0	0	0	0
Endosulfan I	287	41	38	0	NA	0	0
Endosulfan II	287	53	50	0	NA	0	0
Endosulfan sulfate	299	60	46	0	0	11	0
Endrin	299	30	27	0	0	1	0
HCH (BHC-alpha)	302	28	26	0	0	0	0
HCH (BHC-beta)	302	53	49	0	0	1	0
HCH (BHC-delta)	299	37	35	0	0	0	0
HCH (BHC-gamma, Lindane)	301	68	44	4	0	17	25 [4]
Heptachlor	301	21	20	0	0	0	0
Heptachlor epoxide	299	38	36	0	0	0	0
PCBs, Summed Detected Aroclors	227	3	3	0	0	1	25 [4]
Toxaphene	230	0	0	0	0	0	0

[1] Represented by industrial, residential, and commercial runoff sites.

[2] Represented by Site 8.

[3] Measured as summed detections of alpha-chlordane + gamma-chlordane.

[4] 25% = one detection out of four samples taken from pumped groundwater discharged by the Simi Valley dewatering wells.

N/A = constituent has not been analyzed in samples from this source

Debris Basin Samples

In February of 2004, sediment collected from seven debris basins within the CCW was analyzed for OC pesticides and PCBs (Table 45). Sediments were sieved into <63um and 63um – 2mm fractions. Five of the seven sampled debris basin sediments contained detectable DDT's, three contained detectable levels of chlordane, and one contained detectable PCB's. Dieldrin, lindane, and toxaphene were not detected in any samples. None of the category-2 constituents were detected in any samples. The 11D_DB3-05 debris basin had the greatest number of detections and highest concentrations and was also the only debris basin in which flow was present. All the other basins were dry, with very coarse sediments.

Table 45. Concentration of OCs Detected in Sediment Collected from Debris Basins on February 21st, 2004 (ng/dry g).

Sample Site [1] [2]	Numeric Target	5D_DB3-13	5D_DB3-13	6D_DB3-15	6D_DB3-15	7D_DB3-09	7D_DB3-09	11D_DB3-05	11D_DB3-05
Fraction		63µm-2mm	<63µm	63µm-2mm	<63µm	63µm-2mm	<63µm	63µm-2mm	<63µm
4,4'-DDD	3.54	2.3	1.3	1.2	ND	ND	ND	**10.5**	2.7
4,4'-DDE	1.42	16.8	11.7	10	4.2	1.7	1.3	**37.9**	5.1
4,4'-DDT	NA	6.3	4.6	9.7	ND	ND	ND	**37.8**	4
DDT, total detected	6.98	27.3	17.6	25	4.2	1.7	1.3	**93.7**	12.7
Chlordane-alpha	NA	**3**	1.8	ND	ND	ND	1.1	ND	ND
Chlordane-gamma	NA	**2.2**	1.3	ND	ND	ND	ND	ND	ND
Chlordane, total detected	4.5	**5.2**	3.1	--	--	--	1.1	--	--
Dieldrin	**2.85**	ND	ND	ND	ND	ND	ND	ND	ND
Total Detected PCBs	34.1	0	0	0	0	0	0	**30.3**	0
Toxaphene	NA	ND	ND	ND	ND	ND	ND	ND	ND

[1] The prefix of each debris basin sample name represents the reach to which the debris basin discharges (i.e., 5D_DB3-13 = reach 5).

[2] Sample sites 6D_DB3-01 and 7D_DB3-17 are not shown, since no OCs were detected in samples from either debris basin.

Bolded values indicate sample sites with the highest concentration for each constituent.

Note that fourteen of the samples shown above contained concentrations that exceed the TEL numeric target for sediment. These contaminated sediments could find their way into receiving waters of the CCW via several possible scenarios, including: mobilization of the sediments due to wind or water currents, use of sediment from the debris basins for fill dirt or landscaping, or accidental spills during transport for proper disposal. Thus, a need exists to evaluate current methods for disposing of these sediments.

Atmospheric Deposition

Residues from past use of OC pesticides and PCBs are volatilized, transported, and redeposited from both local and distant sources. Present day applications of OC pesticides are responsible for some aerial deposition by means of drift from applications as well as volatilization, transport, and redepostion. Continued use in other countries of OC pesticides banned in the United States represents another active source to the atmosphere. OC pesticides and PCBs are deposited from the atmosphere during precipitation events (wet deposition) as well as from pesticide drift and settling from the atmosphere due to gravity (dry deposition).

No known studies estimate the rates of atmospheric deposition for OCs in the CCW. However, a study by Park et al. in 2001 estimated atmospheric deposition rates for PCBs and various OC pesticides to Galveston Bay, Texas (Table 46). This study yielded results that were comparable to other similar studies conducted in North America and elsewhere, including a study in the Great Lakes region (Chan et al, 1994).

Table 46. Atmospheric Deposition Rates for PCBs and OC Pesticides to Galveston Bay, Texas (Park et al., 2001)

Constituent	Wet Deposition		Dry Deposition	Total Deposition
	Dissolved	Particulate	Particulate	Dry + Wet
	µg/m²/yr	µg/m²/yr	µg/m²/yr	µg/m²/yr
tPCBs [1]	0.99	0.54	4.86	**6.40**
tHCHs [2]	1.54	0.09	0.10	**1.73**
tChlordanes [3]	0.12	0.40	0.23	**0.75**
tCyclodienes [4]	0.06	0.19	0.54	**0.79**
tDDTs [5]	0.29	1.22	0.43	**1.94**

[1] tPCBs (total PCBs, including di-, tri-, tetra-, penta-, hexa-, hepta-, octa-, nona-, deca-chlorinated congeners).
[2] tHCHs (total Hexachlorocyclohexanes, including alpha, beta, gamma, delta isomers).
[3] tChlordanes (chlordane-related compounds, including heptachlor, heptachlor epoxide, oxychlordane, alpha-chlordane, gamma-chlordane, cis-nonachlor, trans-nonachlor)
[4] tCyclodienes (total Cyclodiene pesticides, including aldrin, dieldrin, endrin).
[5] tDDTs (total DDT, including 2,4'-DDD, 4,4'-DDD, 2,4'-DDE, 4,4'-DDE, 2,4'-DDT, 4,4'-DDT).

Wet and dry deposition rates for DDT, DDE, DDE, alpha-chlordane, and gamma-chlordane were estimated for the CCW using concentrations from the Galveston and Great Lakes studies in conjunction with local data for rainfall, theoretical deposition velocity, and watershed area. Although various differences in climatic and land use conditions generate some uncertainty about the appropriateness of comparing these three areas, no other studies are know to have been completed in more comparable geographic regions. The approach is presented below.

Wet Deposition Loading (lbs/yr) calculated as:

$$C * V_{rain} * A$$

Where:

C = pesticide concentration in rain (dissolved plus particulate)[1]

V_{rain} = average annual rainfall (15 in/yr)[2]

A = Watershed Area (344 square miles)

[1] Data from Galveston and Great Lakes used to approximate concentrations in CCW

[2] Source: Ventura Countywide Stormwater Monitoring Program, 2002/03 Monitoring Report (July 2003).

Dry Deposition Loading (lbs/yr) calculated as:

$$C * V_{dep} * A$$

Where:

C = atmospheric particulate concentration [1]

V_{dep} = theoretical deposition velocity[2]

A = Watershed Area (344 square miles)

[1] Data from Galveston and Great Lakes used to approximate concentrations in CCW

[2] Vd = 0.175 cm/sec (Joshua Tree NP, CASTNet), the same value used to estimate atmospheric deposition of salts to the CCW in the Dec. 30, 2003 LWA Technical Memo.

In order to better estimate actual dry deposition in the CCW, atmospheric particulate concentrations presented in the Galveston and Great Lakes studies were normalized according to PM10 data from Galveston, Great Lakes, and Ventura County (PM10 data measures the amount of airborne particulate matter 2.5-10 micrometers in size). The method is shown below in Equation 1.

Equation 1. $\text{Dry Deposition in CCW} = [\, C_{\text{galveston, great lakes}} * PM10_{\text{ventura}} / PM10_{\text{galveston, great lakes}} \,] * V_{dep} * A_{ccw}$

The results are shown in Table 47. Notice that these estimates are reported in total pounds of deposition per year across all land and water areas of the CCW. This method over predicts the actual contribution of OCs to water resulting from aerial deposition since only a portion of all OCs deposited on land actually reach water (due to degradation which occurs before the OCs are released from terrestrial soils by erosion). The extent of this over prediction is dependant on sorption, in addition to degradation.

Table 47. Atmospheric deposition rates for DDT and chlordane compounds upon total land and water surface area in the CCW using estimates from two studies, normalized according to Ventura County PM10 data.

Constituent	Lb/yr Based on Galveston Study			Lb/yr Based on Great Lakes Study		
	Wet	Dry [1]	*Total*	Wet	Dry [1]	*Total*
4,4'-DDD	0.03	0.12	***0.15***	0.016	0.077	***0.093***
4,4'-DDE	0.013	0.076	***0.089***	0.04	0.28	***0.32***
4,4'-DDT	0.14	0.21	***0.35***	0.1	0.17	***0.27***
alpha-Chlordane	0.024	0.03	***0.054***	0.048	0.14	***0.19***
gamma-Chlordane	0.017	0.061	***0.078***	0.11	0.11	***0.22***

[1] CCW dry deposition load estimates "normalized" to Ventura Countywide 2004 Average PM10 data, as explained above. Annual arithmetic mean PM10 values used in calculations: Galveston, 22 ug/m3; Great Lakes, 28.1 ug/m3; Ventura County, 31 ug/m3 (source of PM10 data: http://www.epa.gov/air/data/).

It is somewhat misleading to consider aerial deposition upon land surfaces as a discrete source of OCs, since inputs from land-use runoff are considered for all land areas and aerial deposition is implicitly captured in those measurements. An alternate method commonly used for estimating the contribution of pollutant from atmospheric deposition is to consider only direct deposition to water. Since the surface area of all water bodies in the CCW is less than 2% of the total area, only a minute amount of the pounds per year shown above are considered as loading to water using this method.

Imported water

Imported water used in the CCW is eventually received by POTWs or used for landscaping, washing cars, and other purposes that result in runoff into storm drains or infiltration of groundwater. Drinking water and irrigation water are imported to the watershed from the State Water Project and the Freeman Diversion, respectively. The State Water Project pumps water from the San Francisco Bay Delta which originates in northern and central California, including the Central Valley. The Central Valley is cultivated extensively and OC pesticides have been used there. The concentration of OCs in the imported water is unknown, but may be estimated for some constituents using monitoring data from stations at the mouths of the Sacramento and San Joaquin Rivers, the major tributaries to the Delta. Samples collected in 1994 analyzed for toxaphene were all non-detected, 80% of endrin samples were non-detected, and total concentrations for the remaining OCs ranged from 0.000022 ug/L for heptachlor to 0.00047 ug/L for DDT (San Francisco Estuary, www.sfei.org).

Since imported water eventually finds its way into POTW effluent, urban runoff, or groundwater; this potential source is implicitly considered when land-use runoff and discharge data are examined for urban runoff, POTWs, and groundwater. Also, it is important to note that imported water undergoes treatment prior to use in homes and on lawns which removes many hydrophobic particle-associated contaminants.

Once treated, the imported water likely contains lower concentrations of contaminants than the highest values measured in the delta because many of the particles are removed during transport in the canal system and because many contaminants are transformed by chlorine or ozone during disinfection.

Pesticide Use Data

Pesticide Use Report (PUR) data from the California Department of Pesticide Regulation (DPR) provide detailed information about pesticide application rates according to crop types for each county in the state. Prior to 1990, limited use reporting requirements existed. In 1990, California began requiring full use reporting for all agricultural pesticide use and commercial pest control applications. As outlined by DPR (DPR, 2002), the following pesticide uses are considered "reported uses" requiring applicators to submit detailed use reports to the County Agricultural Commissioner:

- For the production of any agricultural commodity, except livestock.
- For the treatment of post harvest agricultural commodities.
- For landscape maintenance in parks, golf courses, and cemeteries.
- For roadside and railroad rights-of-way.
- For poultry and fish production.
- Any application of a restricted material.
- Any application of a pesticide with the potential to pollute ground water.
- Any application by a licensed pest control operator.

Exclusions from reporting requirements include industrial, institutional, and residential landscape and garden pesticide uses. These uses are collectively referred to as "unreported uses". PUR data contain extensive information about the quantities and types of pesticides used in each county, as well as information about the acreage and types of crops treated. These data are collected by county agriculture commissioners in most counties and then passed along to DPR for QA/QC and database management. Analysis of PUR data in this document examines the years 1998-2003 as a relevant timeframe for potential active sources and residual sources of OC pesticides and PCBs.

Pesticide Sales Data

Pesticide registrants, pest control dealers and pesticide brokers must report to DPR the total dollar value and total pounds or gallons of each product they sell for use in California. The active ingredient in any pesticide product is the chemical or chemicals that kill or otherwise controls target pests. Sales reporting includes only the active ingredient(s) in pesticide products and does not include their inert ingredients. When there are three or fewer registrants reporting sales of a pesticide product containing the same active ingredient, such reports are considered trade secrets and are not disclosed by DPR. Cumulative sales totals are provided for all active ingredients, disclosed and undisclosed. Included in this amount are insecticides, miticides, fumigants, nematicides, rodenticides, desiccants, defoliants, growth regulators, herbicides, bactericides, antimicrobials, algicides, and fungicides. The total pounds of active ingredients sold fluctuate from year to year, attributable to a variety of factors such as: changing weather conditions, changes in planted acreage, crop planting, pest infestations, marketing techniques, company takeovers, and sales promotions. Registration of new products may initially result in an increase of pounds of product sold. Cancellation or suspension of products may subsequently affect the sale of other products. Also, duplications in reporting may be responsible for a margin of fluctuation (if a registered product with complete use directions is sold to another registrant, who then re-labels it, both would report the sale). Pesticide sales information from DPR is only available for the years after 1991.

5.2 Land Use

There are about 344 square miles in the Calleguas Creek Watershed, approximately 51% of which is utilized by some form of human activity (DWR, 2000). About one fourth of the land is urban or urban landscape and about one fourth is used for agriculture (Figure 9). The non-utilized land is comprised almost completely of native vegetation (96%), but also includes some water areas and barren or idle lands (the terms 'native land' and 'non-utilized land' are used interchangeably in this document to describe undeveloped open space). The category 'urban landscape' includes cemeteries, golf courses, and other urban lawn areas. Agricultural lands primarily yield truck crops and citrus; with lemons, avocados, strawberries, green beans, celery, and onions being the most common crops. The term "truck crop" describes vegetables grown in furrows that go straight to market when harvested (e.g. green beans, peppers, celery, tomatoes), and the term "field crop" indicates crops such as cotton, flax, hops, and sugar beets that do not necessarily go straight to market. A detailed list of all land use types existing in the watershed by subcategory and acreage is found in Appendix III. In recent decades the CCW has experienced dramatic growth in urban residential and commercial development, but historically a much larger percentage of land was used for farming (Figure 10 - Figure 12).

Note: the figures presented in this section are best viewed in color.

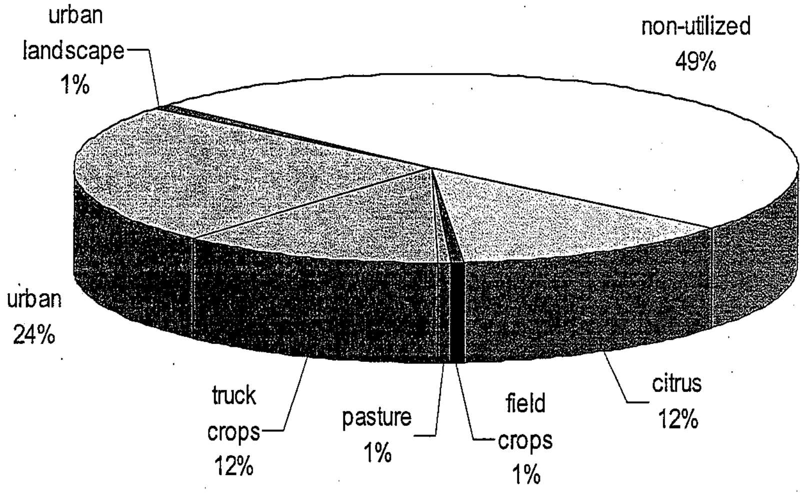


Figure 9. Land Use in CCW (DWR, 2000)

Urban Land Use

About two thirds of the urban land within the watershed is residential, situated mostly in the central to upper portions of the watershed (Table 48, Figure 13). Less than 3% of all land in the watershed is dedicated to industrial and commercial purposes combined. Since 1932, the cities of Thousand Oaks, Simi Valley, and Camarillo have grown from being isolated small towns to their current extent (Figure 10 - Figure 12).

Table 48. Breakdown of Urban Land Use in CCW (SCAG, 2000)

Urban Land Uses	Acres *	% of Urban Land Use	% of Watershed Area [1]
Residential	28,898	68%	13%
Transportation & Utilities	5,003	12%	2%
Public Facilities & Institutions	4,063	10%	2%
Industrial	2,403	6%	1%
Commercial	2,399	6%	1%

[1] The SCAG land use classification system is not identical to that of California Department of Water Resources (DWR), which is used for all other land use analysis in this document. Thus, total acreage for "urban" in this table is not the same as total urban acres shown in Appendix III. The SCAG data is presented here because it breaks urban land into subcategories (DWR does not).

Agricultural Land Use

Current agricultural land uses vary spatially according to such factors as coastal proximity, altitude, slope, and soil type. Figure 14 shows specific crop types grown in the area, according to subcategory. Citrus crops such as lemons, oranges, and avocados commonly occur in flat or gently sloping foothill areas that are slightly inland, with avocado orchards tending to exist somewhat upslope of lemon groves and oranges usually growing a bit further inland than lemons. Floodplain areas are currently predominated by a wide range of truck crops such as strawberries, peppers, green beans, celery, onions, garlic, lettuce, melons, and squash; as well as turf farms and various types of nurseries. The uppermost portions of the watershed are not cultivated extensively.

Agricultural activities in the watershed are somewhat challenging to characterize at a fine scale due to several factors. Although some changes in crop composition occur over many years (such as conversion of field crops to truck crops and the disappearance of walnut groves, both during the period 1932-1969), there are also constant changes in crop selection from year to year as farmers adjust to fluctuating market prices or strive to preserve soil by rotating their crops/fields. Additionally, many fields are used to grow successive crops during a single calendar year. This multi-cropping technique is most common in the lower parts of the watershed, adjacent to Revolon Slough and Lower Calleguas Creek (Figure 15). Fields that are multi-cropped do not always follow a time interval that begins and ends within the course of a calendar year. For example, it is common to grow three crops of strawberries in a two year period with some other crop such as barley following the first two strawberry harvests. Growers of turf often plant celery, cabbage or cauliflower in rotation with turf crops to reduce the negative effects upon soil that occur when turf is harvested (S. McIntyre, pers. comm., 2004). The twenty most common multi-crop combinations in the watershed are shown below, in Table 49. Agricultural activity within the Oxnard Plain is spatially heterogeneous with highly variable multi-cropping activity.

Table 49. Top twenty multi-cropping combinations in the Calleguas Creek Watershed by acreage, "double" and "triple" indicate the number of crops grown per year on a given piece of land (DWR, 2000).

crop types	acres	crop types	acres
Double - strawberries, strawberries	4,005	Double - beans(green), celery	199
Triple - beans(green), celery, beans(green)	474	Double - misc-truck, misc-truck	198
Double - celery, peppers	338	Triple - misc-truck, misc-truck, misc-truck	166
Triple - beans(green), celery, peppers	275	Triple - onions-garlic, celery, beans(green)	160
Double - beans(green), beans(green)	269	Triple - peppers, peppers,iD00 celery	154
Double - peppers, peppers	251	Double - peppers, celery	154
Double - peppers, beans(green)	246	Triple - beans(green), broccoli, beans(green)	148
Double - celery, beans(green)	229	Double - barley, barley	137
Triple - misc-truck, misc-truck, misc-truck	226	Double - celery, onions-garlic	134
Double - celery, celery	217	Double - onions-garlic, celery	130

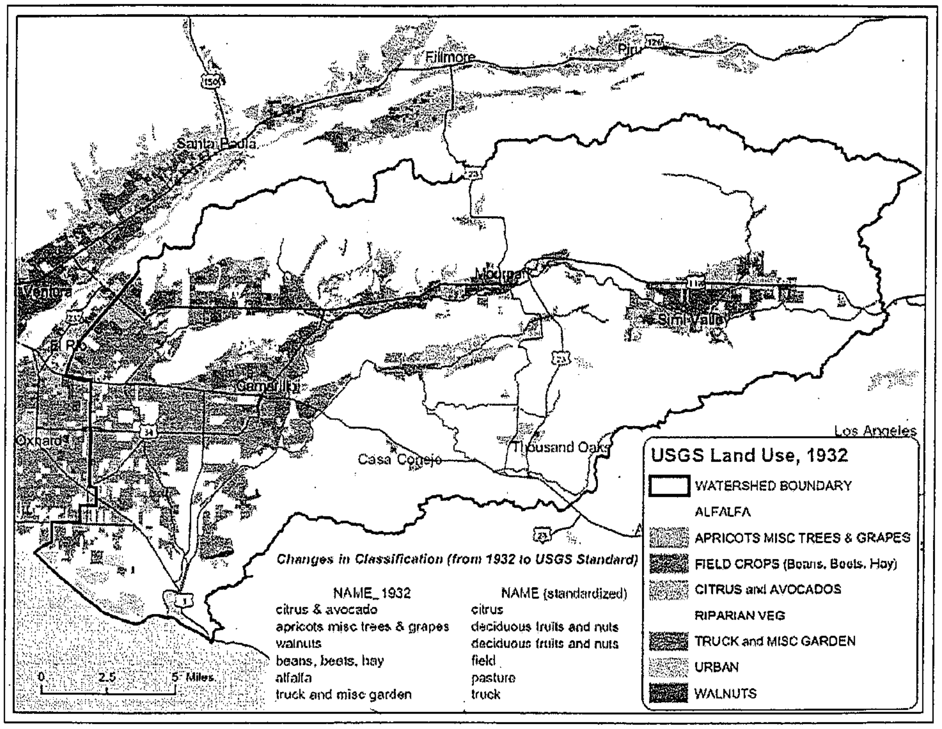


Figure 10. Land Use in the Calleguas Creek Watershed, 1932 (USGS, 2004).

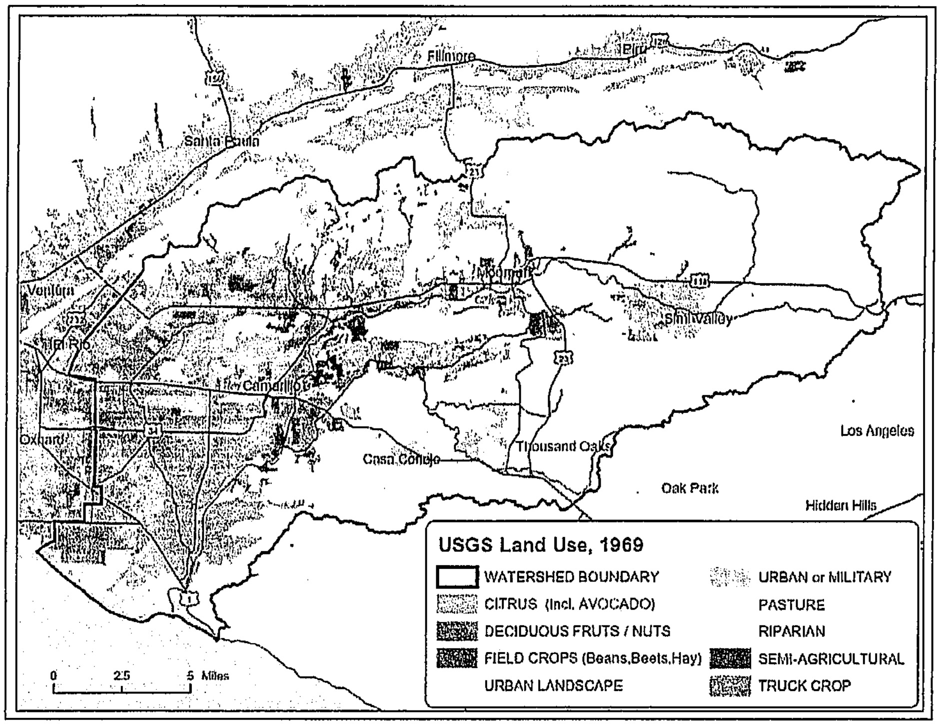


Figure 11. Land Use in the Calleguas Creek Watershed, 1969 (USGS, 2004).

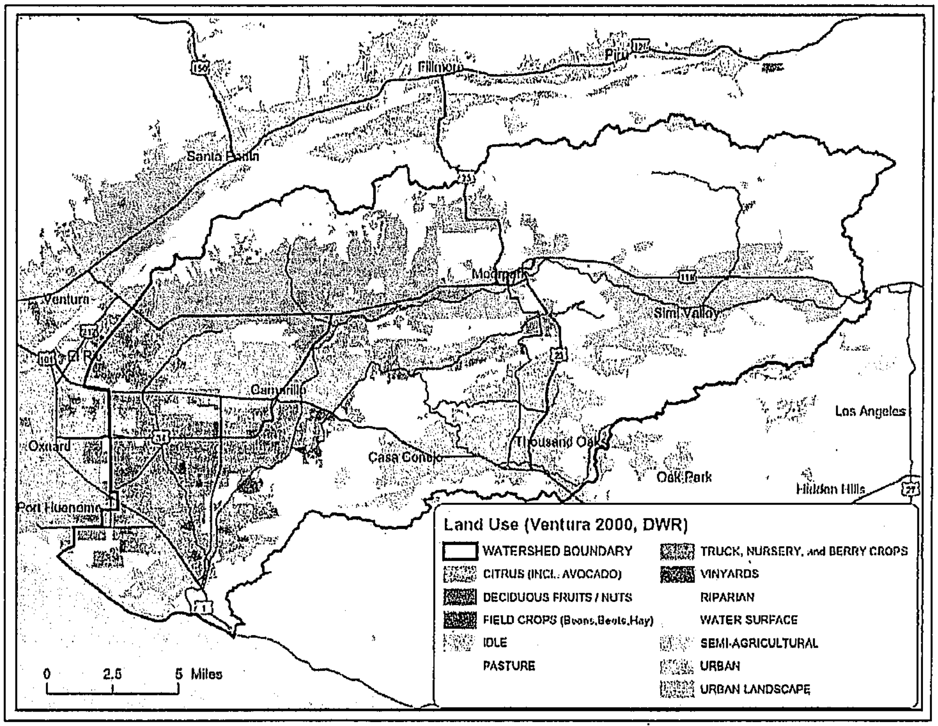


Figure 12. Land Use in the Calleguas Creek Watershed, 2000 (DWR, 2000).

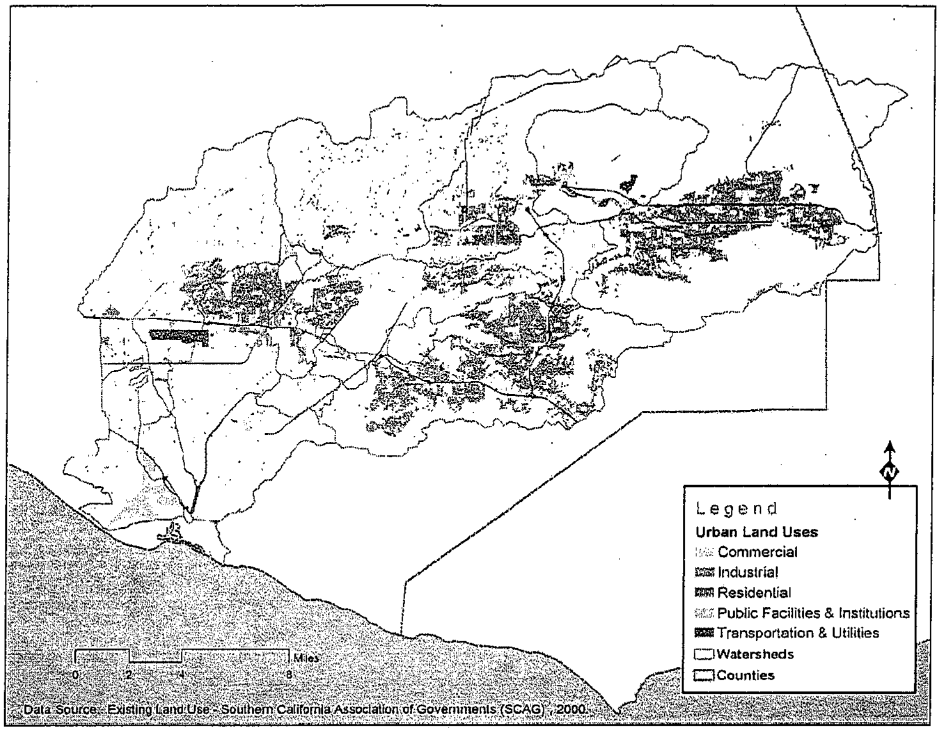


Figure 13. Urban Land Uses in the Calleguas Creek Watershed (SCAG 2000).

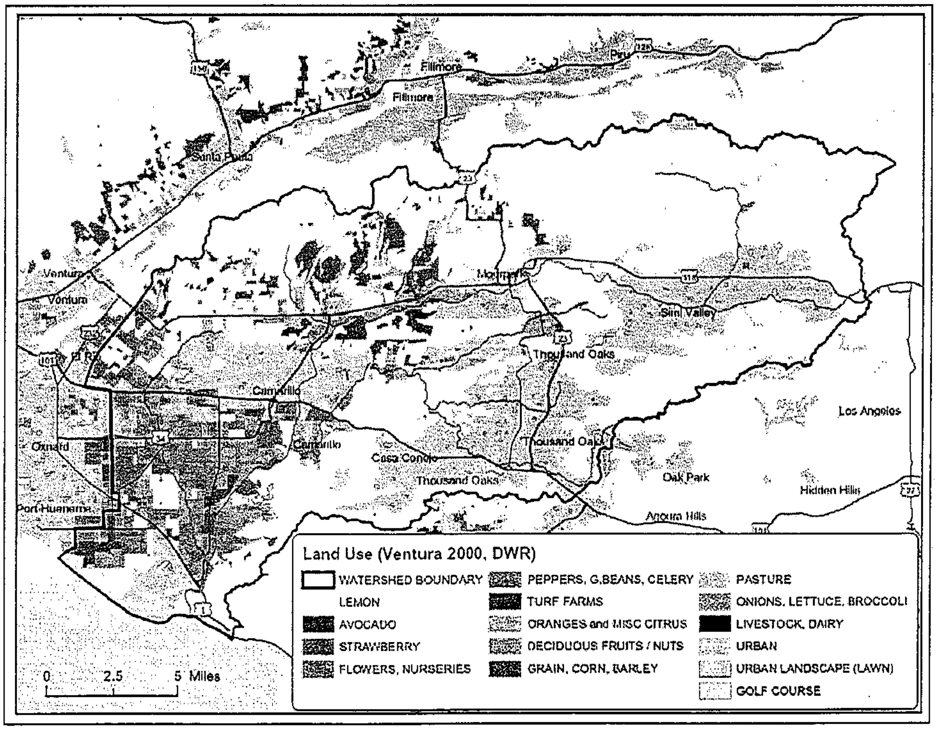


Figure 14. Land Use in the Calleguas Creek Watershed by Specific Crop, 2000 (DWR, 2000).

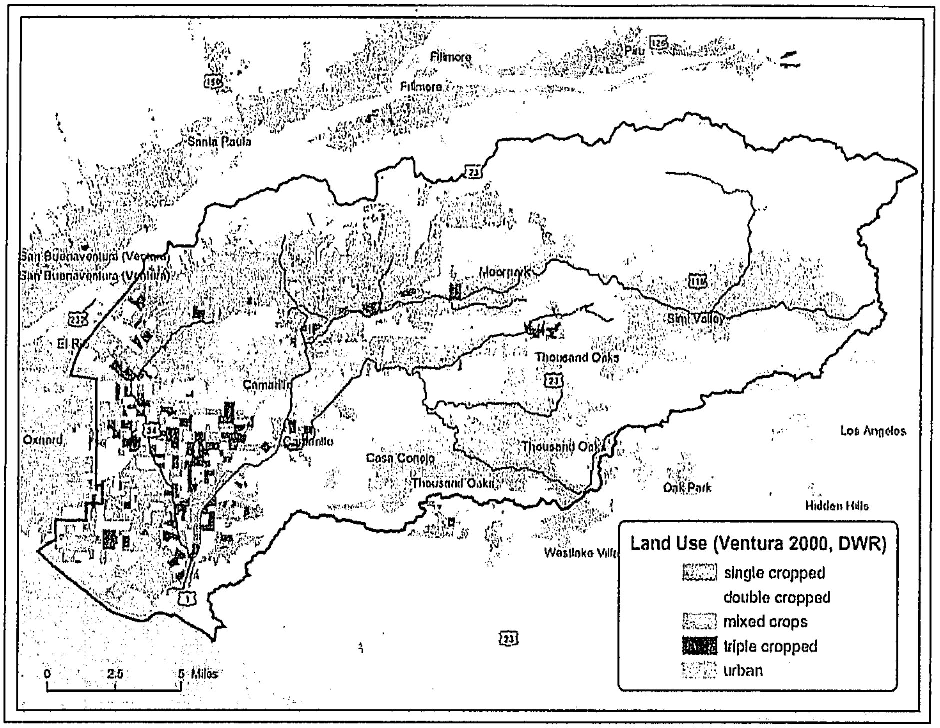


Figure 15. Multi-cropping Activity in the Calleguas Creek Watershed, 2000 (DWR, 2000).

5.3 Historical Assessment of Category-1 Constituents

This section presents information about the history of use for each category-1 constituent based upon a review of the literature, consultation with agricultural and pesticide experts, and all other available information. Given the highly persistent nature of OC Pesticides and PCBs, such information is essential for assessing the sources of these chemicals. Historical uses are described according to local spatial scales whenever possible, although such detailed information is not available in many cases.

DDT

DDT was first used as a pesticide in 1939. It was widely used to control insects in agriculture and insects that carry diseases such as malaria. During World War II (1939-1945), it was extensively employed for the control of malaria, typhus, and other insect-transmitted diseases. At its peak in 1962, DDT was used on 334 agricultural commodities. It was also used in the home as a mothproofing agent and to control lice. In 1972, 67–90% of the total US consumption of DDT was on cotton; the remainder was primarily used on peanuts and soybeans. The uses of DDT in California ranged from control of agricultural pests to control of cockroaches in residences and mosquito abatement in neighborhoods. Table 50 shows statewide reported DDT usage in California for the years 1970-1980. All uses of DDT have been banned in the USA since 1972, except for control of emergency public health problems (ATSDR, 2000a).

Table 50. **DDT Use in California from 1970 to 1980a (Mischke et al, 1985)**

Year	Pounds Used	Main Use
1970	1,164,699	agricultural
1971	111,058	agricultural
1972	80,800	agricultural
1973[b]	NUR[b,c]	--
1974	160	residential pest control (SLN)
1975-1980	less than 200 lbs per year	Vector control (SLN)

a. 1970 was the first year in which the amount of restricted pesticides used in California was reported. In 1980, the introduction of new pesticides replaced the need to use DDT for vector control.
b. Year all use banned except for special local needs (SLN)
c. NUR - no use reported

Given that DDT was banned in 1972, and that PUR data are not available before 1974; PUR data of actual DDT use are not examined. The information presented in Table 50 was probably gathered using hard copy records which are either non-existent or incomplete for Ventura County (Lichtenberger, pers. comm., 2004).

One of the largest DDT manufacturing sites in the world, the Montrose Chemical Company DDT plant, was located in the Los Angeles area about seven miles from the coast, in the City of Torrance. Waste from the facility contaminated numerous off-site locations and the coastal areas in the vicinity of Palos Verdes. There is no evidence to suggest the Calleguas Creek Watershed was contaminated by waste from the Montrose facility.

In August of 1984, the California State Assembly directed the California Department of Food and Agriculture (CDFA) to investigate possible sources of DDT and/or its breakdown products (DDTr) in the environment and to report findings to the Legislature within one year. This resolution was introduced in response to studies showing that, although its use was banned in 1972, DDTr was still being found over a decade later in California water, fish, shellfish, and produce samples. Additionally, the chemical composition of the DDTr being found indicated that it might be from recent use. CDFA investigated three possible sources of contamination by DDT and/or its breakdown products: illegal use of DDT, use of other pesticides that might be contaminated with DDTr, and long-lived residues from previous legal applications of DDT. Based on analysis of historical and empirical evidence, CDFA concluded that residues from legal applications of DDT, before its use was banned, appear to be the source of this contamination (Mischke et al, 1985). Specific findings of the study are quoted below.

1. "Before its ban, DDT was widely used in California in agriculture and for control of mosquitoes and other disease-carrying insects.
2. There was no evidence of any illegal use of DDT since its ban. In 1983, 87,000 pesticide use enforcement inspections and 3,501 investigations of possible violations were made by California County Agricultural Commissioners. None of these involved DDT. Also in 1983, about 1300 pesticide samples were analyzed to determine what chemicals they actually contained. The results show 97.5% of these samples met registration and labeling requirements. The remaining 2.5% did not involve DDT. Even before its ban, agricultural use of DDT was declining as more insects became resistant to DDT.
3. Contamination of other pesticides by DDT could not account for the residues. There have been reports that dicofol (Kelthane®) contained large amounts of DDT. Samples of dicofol sold in California

examined in 1983-84 contained very low levels of DDT, usually less than 1%, too low to account for DDT residues found.

4. Detectable levels of DDT found on some California produce were, in most cases, well below acceptable levels. Nearly all produce samples found with residues of DDTr have an edible portion which grows in or close to the ground, such as carrots, beets, lettuce, or spinach. DDTr residues found on produce are probably the result of contamination from soil containing DDTr.
5. On average, about half the DDTr detected was present as DDT in the environment. However, the composition of DDT found in soil was more stable than previously thought, therefore the kinds of DDT residues present in soil did not necessarily indicate new use.
6. Soil contaminated with DDTr may be moved into drains as a result of normal field work such as land leveling. Fish and shellfish pick up DDTr from the soil particles in the water.
7. DDTr residues were present in soil wherever DDT was used legally in the past. In 1985, CDFA collected 99 soil samples in 32 California counties from locations where DDT had been used in the past. All samples contained DDTr."

Agricultural Use

Although cotton, peanuts, and soybeans accounted for most of nationwide DDT use, there is no indication that any of these three crops have been grown in the CCW in significant amounts (according to Ventura County Crop Reports and USGS land use layers for the years 1932, 1950, 1969, and 2000). DDT is known to have been used extensively on walnut groves in the CCW, which constituted a sizable proportion of agricultural lands in the watershed before 1669. A 10/10% mixture of DDT/toxaphene was commonly used on walnuts, where it was usually applied three times per year during the "leaf period" (McIntyre, pers. comm., 2004). Acreage dedicated to walnut groves decreased from 1932 to the present (Figure 10 - Figure 12) because growers in the CCW could not produce them as cost effectively as growers in the Sacramento Valley. Beets, lima beans, and tomatoes also are known to have been treated with DDT for a number of years before it was banned in 1972. Sugar beet farming was greatly reduced in the watershed when a local sugar beet factory closed down in about 1948. At that time, many farmers started growing lima beans instead of sugar beets (McIntyre, pers. comm., 2004). It is almost certain that DDT has been applied in the CCW for other agricultural purposes besides walnuts, beets, lima beans, and tomatoes; but no information specific to CCW regarding these other uses has been found. Figure 16 shows likely historical DDT application areas; based upon USGS land use layers, Ventura County crop reports, and information related above (the degree of uncertainty associated with Figure 16 is very high). Areas of darkest red represent most recent applications and/or high cumulative applications of DDT based upon historical presence of the following land use types, in order of emphasis: 1) walnut 2) field crops 3) truck crops, urban, urban landscape, and citrus. It is important to note that this map represents nothing more than a best guess based upon available information.

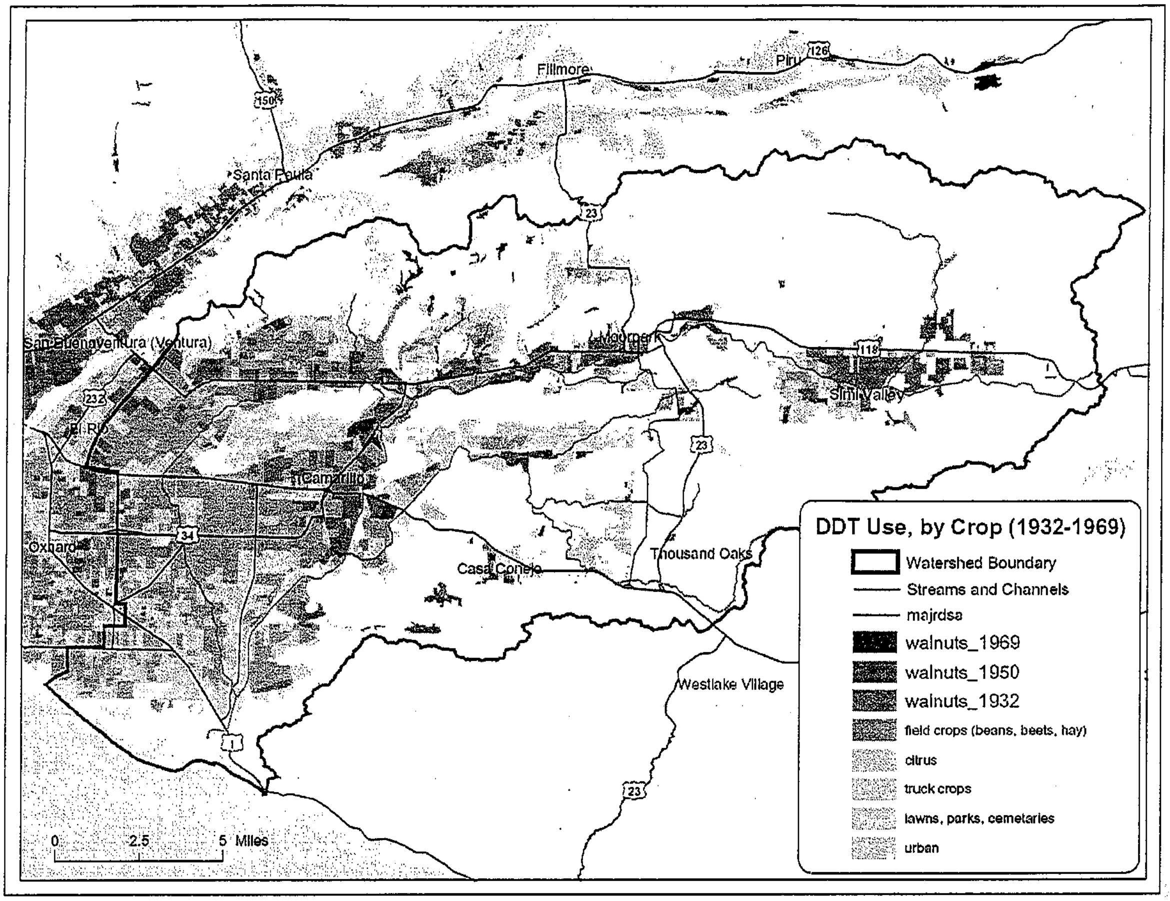


Figure 16. Predicted areas of relatively high DDT use during the time period 1932-1969 (USGS land use layers, Ventura County crop reports, interview with Sam McIntyre).

Urban Use

In many areas throughout the United States and globally, the primary non-agricultural use of DDT was for mosquito control. DDT is not known to have been used extensively for this purpose in the CCW, although it is known that Malathion was sprayed for mosquito control for many years (McIntyre, pers. comm., 2004). Ventura County Mosquito Abatement and Vector Control does not have records of any DDT use for mosquito control by that agency (Smith, pers. comm., 2004). However, a previous mosquito abatement program existed sometime before 1979 and there was a lapse period between the end of that program and startup of the current program. For many years before it was banned, DDT was commonly used by private residents for a variety of home and garden uses. However, there are no known records of such residential uses of DDT.

POTWs

Imported produce and clothing of agricultural workers from other countries may contribute DDT to influent received by POTWs in the Calleguas Creek Watershed. Due to widespread past use of DDT and the persistence and slow degradation of its breakdown products, low levels of DDE residues are still detected frequently in foods consumed in the US (Snedeker, 2001 and EIP, 1997). POTW influent may also contain

DDT originating from imported water sources as a result of terrestrial residues and atmospheric deposition in the regions from which water is drawn.

Atmospheric Deposition

Although the use of DDT is no longer permitted in the United States, it may be released to the atmosphere in other countries such as Mexico where manufacture and use continue. DDT, DDE, and DDD may also enter the air when local residues volatize from contaminated water and soil in a process referred to as gaseous evasion. Wind erosion of soils and sediments containing sorbed residues can also play a key role. This cycle of volatilization, erosion, and deposition may be repeated many times. As a result, DDT and its breakdown products can be carried long distances in the atmosphere. Although there is some deposition of DDT onto soils in North America via volatilization and atmospheric transport from countries in Central and South America that still use DDT, the magnitude of exposure through this route is considered to be small (Snedeker, 2001). In the atmosphere, about 50% of DDT is adsorbed to particulate matter and 50% exists in the vapor phase (ATSDR, 2002a). Estimated rates of atmospheric deposition for DDT are presented above in Table 46 and Table 47.

DDT in Dicofol

Dicofol is an organochlorine miticide/pesticide currently used for on cotton, apples, citrus, strawberries, beans, peppers, tomatoes, pecans, walnuts, and non-residential lawns/ornamentals. It is created from DDE (one of the breakdown products of DDT), which is reacted with chlorine to form "chlorinated DDE" and then reacted further to produce dicofol. The DDE used to make dicofol contains some DDT as a result of its own manufacturing process. The final dicofol product therefore can contain levels of DDT and "chlorinated DDE" (which can dechlorinate back to DDE in the environment). Thus, dicofol can be a direct source of both DDT and DDE. After 1987, the sum of DDT, DDE, DDD and "chlorinated DDE" allowed in dicofol products was reduced so as not to exceed 0.1% (Mischke et al, 1985). Regardless, dicofol applications are considered a potential source of DDT in the CCW.

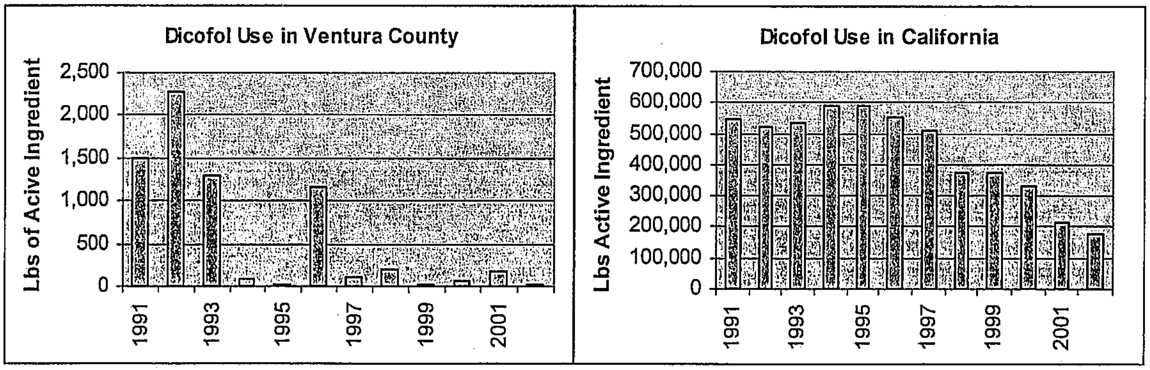


Figure 17. Dicofol use in Ventura County and statewide, 1991-2003 (DPR, 2004).

Dicofol was first registered as a pesticide in the U.S. in 1957. In 1998 manufacturers voluntarily cancelled all residential turf uses. A noticeable decrease has occurred in reported applications of dicofol in Ventura County and statewide during the 1990s (Figure 17). Allowable application levels for citrus crops have been reduced from 8 pounds of active ingredient per acre to 3 pounds per acre, and the application rate for wettable powders on strawberries has been reduced from 2.4 pounds/acre to 2 pounds/acre (EPA, 1998). Currently, 32 dicofol products are registered, including end use and manufacturing use products.

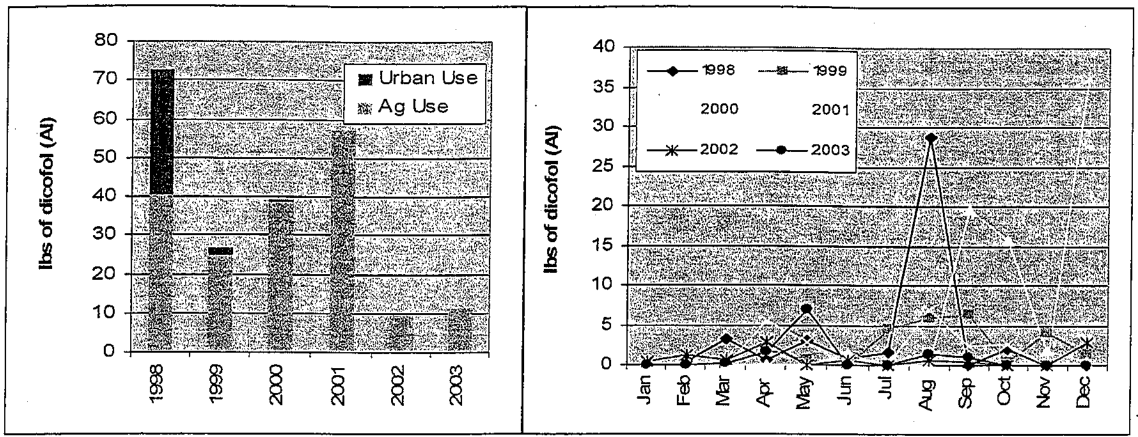


Figure 18. Dicofol use in CCW, 1998-2003 (DPR, 2004).

There were about 150 reported applications of dicofol in the CCW from 1998-2003, totaling about 216 pounds of active ingredient over that time period (Figure 18). Nursery plants and flowers received more than 95% of the agricultural applications. Although lemons, strawberries, and Christmas trees received only one or two applications each, these crops accounted for 70 of the 216 pounds applied from 1998-2002. Most of the urban uses were for landscape maintenance, although a few applications for structural pest control were reported. Two urban applications of dicofol on the same day in 1998 totaling 27 pounds account for the relatively large amount of urban use in that year. One was for structural pest control and the other for landscape maintenance.

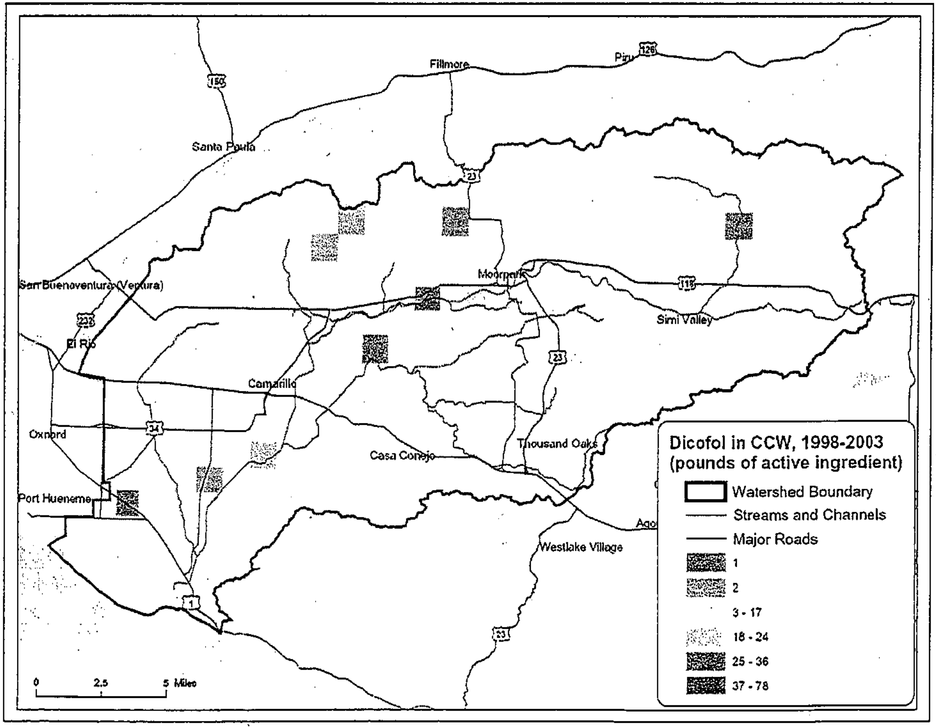


Figure 19. Dicofol use in the Calleguas Creek Watershed from 1998-2003 (DPR, 2004).

The locations and amounts of dicofol reportedly applied are shown in Figure 19. Note that all of the 150 applications occurred within a total of only 10 township/range sections. All uses of dicofol reported from 1998-2003 were applied on the ground (no aerial applications). The 216 pounds of dicofol used in the CCW from 1998-2003 would have contained about 0.2 pounds of DDT, amounting to an average of 16.3 grams of DDT per year.

Chlordane

Chlordane is a pesticide used for crops such as corn and citrus, home lawns and gardens, and termite control. It was first used in 1948. All uses except termite control were banned in 1983, and all uses were banned in 1988. The use pattern of chlordane in the US during the mid 1970s was as follows: 35% by pest control operators, mostly for termite control; 28% on agricultural crops, including corn and citrus; 30% for home lawn and garden use; and 7% on turf and ornamentals. The use of chlordane decreased noticeably in the 1970s when EPA moved to cancel all uses other than subterranean termite control. Between July 1983 and April 1988 the sole use for chlordane was to control subterranean termites. Chlordane does not degrade rapidly in soils and may persist in soil for over 20 years (ATSDR, 1994).

PUR data for the years 1974, 1979, 1984, and 1989 were examined for chlordane use in Ventura County. Use of chlordane was not reported in 1989, which is expected since all uses were banned in 1988. All reported uses of chlordane in 1984 were for the use category "federal agency". Since many of the uses reported in the 1974, 1979, and 1984 data involved liquid applications, the data for pounds of active ingredient reported in those years may contain errors and are not evaluated (DPR, 2000). The nationwide decrease in chlordane use mentioned above seems to also have occurred in the CCW, since the number of applications dropped from 468 in 1974 to 149 in 1979. Approximately 57% of the applications in 1974 and 1979 combined were agricultural and 43% for urban uses.

The main crops known to use chlordane that have historically existed in the CCW are lemons and oranges. However, the primary treatment for citrus pests over the years has been petroleum oil, which is used as a smothering agent. Turf farms also used chlordane to fight off weevils (McIntyre, pers. comm., 2004). Since the locations of citrus groves are visible in Figure 10 - Figure 12, it is possible to form a rough idea about some agricultural areas in the watershed that have received relatively greater amounts of chlordane. PUR data from 1974 and 1979 indicate that chlordane was applied to the following crops: beans, citrus, tomato, peas, peppers, celery, and cabbage. Most of the applications of chlordane were for beans and citrus in 1974 and for citrus in 1979. In the years of PUR data that were examined, there were no reported uses of chlordane for turf farms.

The amount of chlordane used for urban purposes in the CCW is unknown. During the years examined, PUR data indicate chlordane was used for the following urban uses: city agency, federal agency, other agency, recreational area, school district, state highway, and structural control (termites). All applications in 1984 and most of the applications in 1979 were for the category "federal agency". The largest number of applications in 1974 were for structural pest control. It is not possible to estimate urban use of chlordane based upon statewide sales data from DPR, because those data were not published until 1991.

Chlordane may be transported long distances and deposited by wet or dry deposition. In air, chlordane exists predominantly in the vapor phase. Vapor-phase chlordane degrades by photolysis and hydroxyl radical reaction. However, the relatively small fraction of particle-bound chlordane appears to be of major importance in atmospheric deposition. The small amount of adsorbed chlordane at ordinary temperatures appears to play an important role in atmospheric deposition. In samples collected in Texas, 98% of the chlordane scavenged rain was particle-bound chlordane, rather than vapor-phase chlordane that partitioned into rain drops. The chlordane concentration in rain was 1,900 times the concentration in air (ATSDR, 1994). Estimated rates of atmospheric deposition for total chlordanes are presented above in Table 46 and Table 47.

Dieldrin / Aldrin

Source analysis for dieldrin and aldrin is discussed here together since aldrin rapidly degrades to dieldrin in the environment (ATSDR, 200b). Dieldrin and aldrin were used extensively from the 1950s until 1970, when the U.S. Department of Agriculture canceled all uses of both pesticides. In 1972, however, EPA approved dieldrin and aldrin for killing termites. Use of the chemicals to control termites continued until 1987, when the manufacturer voluntarily canceled the registration for use in controlling termites (ATSDR, 2002b). Use of dieldrin and aldrin in the USA peaked in 1966. Decreased use after that time is attributed primarily to increased insect resistance, and development of more effective and environmentally safer pesticides (ATSDR, 2002b). Dieldrin and aldrin ranked second after DDT among agricultural chemicals used in the United States in the 1960s. Aldrin use was most concentrated in the midwest, while dieldrin was used more heavily in the south and on the west coast. Dieldrin was recommended for use on approximately 90 crops, principally corn, hay, wheat, rye, barley and oats, and orchards and vegetables. More than 50% of the dieldrin produced in 1964 was used for pest control instead of agriculture. This included soil application for termite control and mothproofing during wool carpet and clothing manufacturing. Pest control uses also included control of harvest and fire ants and for aerial spraying of spruce budworm and gypsy moths (Jorgenson, 2001).

Aldrin is estimated to have a half-life in soil of 1.5-5.2 years, depending on soil composition and other factors. Dieldrin degradation appears to vary according to its concentration in the soil, with half-lives ranging from 2.6 to 12.5 years (Jorgenson, 2001). The resistance of dieldrin and aldrin to soil leaching generally precludes their appearance in groundwater. A general absence of both chemicals from groundwater samples supports this conclusion (ATSDR, 2002b).

Atmospheric data have established that dieldrin travels very long distances from the source where it is applied. Deposition of dieldrin and aldrin can accumulate in remote areas thought to be pristine (Jorgenson, 2001). Estimated rates of atmospheric deposition for three cyclodienes, including dieldrin and aldrin, are presented above in Table 46.

PUR data for dieldrin and aldrin use in Ventura County were examined for the years 1974, 1979, 1984, and 1989. There were 14 applications of dieldrin and 3 applications of aldrin reported in 1974, all of which were for structural control. In 1979 and 1984 combined, there were 4 applications of dieldrin and 1 application of aldrin in the CCW. No use was reported for either chemical in 1989. Across all years examined uses were reported only for structural control and for "federal agency". Known limitations of PUR data from before 1990 are described in a report available from the Department of Pesticide Regulation (DPR, 2000).

Toxaphene

Toxaphene is an insecticide containing over 670 chemicals that was first used in the 1940s. EPA canceled the registrations of toxaphene for most uses as a pesticide or pesticide ingredient in 1982. Toxaphene was one of the most heavily used insecticides in the United States until that time. It was used primarily in the southern United States to control insect pests on cotton and other crops. Toxaphene was also used to control insect pests on livestock and to kill unwanted fish in lakes (ATSDR, 1996). All registered uses were banned in 1990 and existing stocks were not allowed to be sold or used in the United States. The continued use of toxaphene after 1990 shown in Figure 20 is not understood at this time. It is not known whether the 4.5 pounds of toxaphene applied in Ventura County in 1998 occurred within the CCW, since location information was not included in that record (the use was for structural pest control).

After the 1969 DDT ban, toxaphene became the most heavily used insecticide in the United States. In 1974, an estimated 44 million pounds of toxaphene used on crops in the US was distributed as follows: 85% on cotton, 7% on livestock and poultry, 5% on other field crops, 3% on soybeans, and less than 1% on sorghum (ATSDR, 1996). This national pattern of toxaphene use describes applications on crops typically not grown in the CCW. However, it is known that toxaphene was applied for many years in the CCW before 1990 onto walnut groves and some other crops in a 10/10% dust formulation of toxaphene /DDT (McIntyre, pers. comm., 2004).

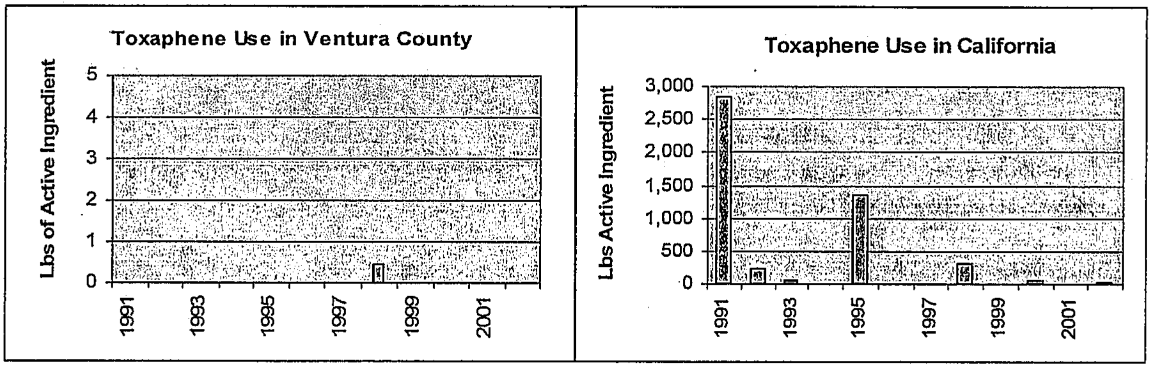


Figure 20. Toxaphene use in Ventura County and statewide, 1991-2003 (DPR, 2004).

The transport and transformation of toxaphene's many components is influenced by individual physical and chemical properties in addition to those of the mixture as a whole. The environmental fate of the mixture rather than of individual components has been studied by most investigators. A major difficulty in estimating past use of toxaphene is that, due to factors such as environmental and metabolic transformation and selective volatilization and atmospheric transport of some congeners, there is a difference in congener composition between the standard technical toxaphene and that found in environmental or biological samples. Therefore, almost all estimates of toxaphene concentration are semi-quantitative.

PUR data for toxaphene use in Ventura County were examined for the years 1974, 1979, 1984, and 1989. Known limitations of PUR data from before 1990 are described in a report available from the Department of Pesticide Regulation (DPR, 2000). There were 1,090 applications of toxaphene during the years examined, a majority of which was used to treat beans and celery (Table 51). No use was reported in 1989.

Table 51. Reported Toxaphene applications in Ventura County by Use Type in 1974, 1979, 1984, 1989 (DPR, 2004).

1974		1979		1984		1989	
bean	419	bean	65	bean	7		
celery	287	celery	51	university of California	1		
tomato	71	turf	17				
ornamental	67	tomato	15				
pepper	13	pepper	10				
lettuce, head	12	cabbage	7				
broccoli	8	flower	4				
flower	8	ornamental	4				
cabbage	6	strawberry	3				
school district	3	broccoli	2				
strawberry	3	lettuce, leaf	2				
		university of California	2				
		corn	1				
		pepper, chili	1				
		shrub	1				
total =	**897**	total =	**185**	total =	**8**	total =	**0**

PCBs

Commercial production of PCBs in the United States began in 1929. In the beginning, PCBs were used both for nominally closed applications (capacitors, transformers, heat transfer fluids, hydraulic fluids) and in open-end applications (flame retardants, inks, adhesives, paints, pesticide extenders, plasticizers, polyolefin catalyst carriers, surface coatings, wire insulators, metal coatings). Most domestic use of PCBs was restricted to nominally closed applications by 1974, and manufacture of PCBs was stopped in the USA by 1977 because of evidence that they build up in the environment and can cause harmful health effects. Aroclors were no longer used in the production of capacitors and transformers after 1979.

Atmospheric transport is the most important mechanism for long-range dispersion of PCBs. Biphenyls with 0–1 chlorine atom remain in the atmosphere, those with 1–4 chlorines gradually migrate toward polar latitudes in a series of volatilization/deposition cycles, those with 4–8 chlorines remain in mid-latitudes, and those with 8–9 chlorines remain close to the source of contamination (Wania and Mackay, 1996). Rates of atmospheric deposition for PCBs presented in a study by Park et al. in 2001, are presented in Table 46. Park et al state that atmospheric concentrations of PCBs in their study were comparable to the range of concentrations reported for other sampling sites; higher than those from Bermuda and Chesapeake Bay, but lower than those from Chicago and London. A study of dry deposition of PCBs in the Lake Michigan Air Basin conducted from 1993 to 1995 found geometric mean fluxes of total PCBs at four locations ranging from 0.057-0.21 μg/m^2-day. General atmospheric levels of PCBs were decreasing over time, although higher levels of PCBs were detected in urban sites, as compared to rural locations (Franz et al, 1998).

Although the dominant source of PCBs to surface waters is likely atmospheric deposition (both directly deposited to streams and also transported from land by runoff), desorption of sediment-bound PCBs may contribute significantly to the concentrations detected in water. PCBs in water are transported by diffusion and currents. PCBs are removed from the water column by sorption to suspended solids and sediments, by volatilization from water surfaces, and by accumulation in the tissues of biota. PCBs in soil are unlikely to migrate to groundwater because of strong binding to soil. In water, abiotic transformation processes such as hydrolysis and oxidation do not significantly degrade PCBs. Photolysis appears to be the primary abiotic degradation process in water (ATSDR, 2000). The estimated photolysis half-lives in water for various PCBs range from less than one day up to more than 200 days; dependant upon a number of factors such as water depth, sun exposure, and the degree of chlorination of the various congeners. PCBs, particularly the highly chlorinated congeners, adsorb strongly to sediment and soil where they tend to persist with half-lives on the order of months to years (ATSDR, 2000).

Accidental Spilling of PCBs

A review of the available information on sites contaminated by PCBs suggests accidental releases in the past as a common cause of PCB residues in soil (recent releases are less common since PCBs have been banned for more than twenty years). Such spills may have occurred at storage, shipping, or maintenance facilities within the watershed that handled products containing PCBs. However, no specific sites within the watershed where spills are likely to have occurred have been identified. Neither the PCB Activity Database System (PADS) nor the PCB Transformer Registration Database (both maintained by USEPA) contain records of PCB related activity in the CCW.

5.4 OC Loads in Water by Source

Concentrations of OCs in water are primarily the result of loads from nonpoint sources and discharges from point sources. The analysis in this section considers OC loads into and out of CCW subwatersheds, using DDE as a representative constituent. The numerical model developed for this purpose is characterized as:

- Empirical – Based on the statistics of the available data;
- Static – Simulating conditions as annual averages;
- Stream reach – Simulating conditions in representative stream reaches; and
- Water quality – Focused on the physical and chemical conditions in the modeled stream reaches that determine concentrations and loads of OCs in water.

Load (mass per time, L) is calculated as the product of concentration (C) and flow rate (Q):

$$L = C * Q$$

Flow rates for each land use in each subwatershed are calculated from daily mean values for water years 1990-2003 estimated by the Dynamic Calleguas Creek Modeling System, or DCCMS (LWA, 2004b). DDE concentrations from major sources to water are estimated based on the land-use runoff and discharge data summarized in Table 44.

Loads are calculated in according to two different methods. First, DDE sources from land-use runoff and point source discharges to receiving water are quantified. The sum of those loads presumably represents the total load of DDE to water. Second, actual DDE loads in water from representative reaches are quantified using receiving water data presented in the Current Conditions section. These loads should mirror the loads to water, but could vary depending on the effects of in-stream processes.

DDE Loads in Water Calculated from Land-Use Runoff and Discharge Data

Average DDE concentrations and estimated annual average loads of DDE from major land use categories are shown in Table 52. Agricultural runoff accounts for over 90% of the DDE load among these sources.

The largest load is to the Revolon Slough Subwatershed, followed by Calleguas Creek and Arroyo Las Posas Subwatersheds. Based on these load estimates and land use coverage data, unit loads are 0.54 lb/1000 acre-yr for agricultural runoff and 0.04 lb/1000 acre-yr for urban runoff.

Table 52. Estimated average annual load of DDE from major land use categories into each subwatershed. Load is calculated as flow rate multiplied by concentration and converted to appropriate units.

Subwatershed	Flow Rate (cfs)[1]					
	Urban	Native	Agric	POTWs	GW	Total
Mugu Lagoon	1.3	0.3	4.9	-	-	6.5
Calleguas Creek	5.9	0.9	9.6	4.4	5	25.9
Revolon Slough	3.1	0.7	19.9	-	-	23.6
Arroyo Las Posas	1.7	1.1	12	2	-	16.8
Arroyo Simi	17.8	8.6	3.6	14.2	4.1	48.2
Conejo Creek	15.2	2.9	3.7	16.8	2.2	40.8[2]

Concentration (ug/L)[3]	0.027	-	0.289	0.024	0.003

Subwatershed	Average Annual DDE Load (lb/yr)					
	Urban	Native	Agric	POTWs	GW	Total
Mugu Lagoon	0.07	-	2.79	-	-	2.9
Calleguas Creek	0.31	-	5.48	0.21	0.03	5.8
Revolon Slough	0.16	-	11.3	-	-	11.5
Arroyo Las Posas	0.09	-	6.84	0.09	-	6.9
Arroyo Simi	0.93	-	2.05	0.67	0.02	3
Conejo Creek	0.8	-	2.09	0.79	0.01	2.9
Total (lb/yr) =	*2.35*	--	*30.55*	*1.76*	*0.06*	*32.9*
Percent of Total	*7.1%*	--	*92.9%*	*5.3%*	*0.2%*	*100.0%*

[1] Flow rates estimated by DCCMS (LWA, 2004b).

[2] Approximately 9,000 acre-ft/yr (~12 cfs) is diverted upstream of Calleguas Creek.

[3] Average concentrations estimated from land-use runoff and discharge data.

DDE Loads in Water from Representative Reaches

Loads leaving each reach can be calculated as a comparison to the source load estimates presented above. The estimated average daily flow rates, average DDE concentrations, and resultant average annual DDE loads and unit loads in the subwatersheds are given in Table 53.

Table 53. Flow rates, DDE concentrations, and estimated DDE loads for representative reaches.

Subwatershed	Representative Reach	Average Daily Flow Rate (cfs)[1]	Average DDE Concentration (ug/L)[2]	DDE Load (lb/yr)	DDE Unit Load (lb/1000 acre-yr)
Mugu Lagoon	1	119	0.038	9.0	0.04
Calleguas Creek	3	90.4	0.019	3.4	0.02
Revolon Slough	4	23.0	0.1	6	0.1
Arroyo Las Posas	6	37.8	0.004	0.3	0.00
Arroyo Simi	7	38.0	0.015	1.1	0.01
Conejo Creek[3]	9B	33.5	0.006	0.4	0.01

[1] Flow rates estimated by DCCMS (LWA, 2004b).

[2] Average concentrations estimated from receiving water data. See accompanying text for how non-detected data were handled. Shaded cells indicate <20% detected data.

[3] The flow rate and loads are adjusted to account for the Conejo Diversion.

These load estimates should be considered approximate because of the limited available data. Calculating an average concentration based predominately on non-detected data provides only an approximation of the actual load. One check on the accuracy of these estimates is to compare the sum of land-use runoff loads to the load in the receiving water. A comparison of these values is shown in Table 54. The calculated loads in runoff exceed the loads in receiving water in every subwatershed except Mugu. One potential explanation for this discrepancy is the fact that runoff samples were collected disproportionately more frequently during storm events, which may affect source water runoff concentrations more than receiving water. Nevertheless, these estimates are on the same order of magnitude and may represent best possible estimates given the limitations of available data.

Table 54. Comparison of source runoff and receiving water load estimates for DDE.

Subwatershed	Sum of Source Loads (lb/yr)	Receiving Water Load (lb/yr)
Mugu Lagoon	2.9	9.0
Calleguas Creek	5.8	3.4
Revolon Slough	11.5	6
Arroyo Las Posas	6.9	0.3
Arroyo Simi	3.0	1.1
Conejo Creek	2.9	0.4
Total=	32.9	9.1 [1]

[1] This total is the sum of loads from Calleguas and Revolon Slough, and corroborates the estimate downstream for Mugu Lagoon.

Summary of DDE Load Estimates

These data indicate that agricultural runoff is the primary source of DDE in the watershed, primarily in the Revolon Slough Subwatershed. Urban runoff, including industrial, commercial, and residential land uses, and municipal wastewater effluent do not appear to be significant contributors of DDE in the watershed. This assessment is based on the following findings:

- Representative reaches with the majority of urbanized area and effluent discharges (Reaches 3, 6, 7, and 9B) have lower DDE concentrations on average than reaches without them (Reach 4);
- Agricultural runoff samples had detectable concentrations of DDE in 91% of samples, resulting in an average concentration over 10 times higher than in runoff from other land uses;
- Only 7% of wastewater effluent discharge samples had detectable concentrations of DDE even though analytical detection limits for these samples were generally lower than for other sample sources;
- Of the 93% of non-detected samples in wastewater effluent, most (92%) were measured using detection limits less than 0.2 ug/L.

5.5 Conclusions

Assessing sources of legacy pesticides and PCBs in the CCW is a difficult task. Detailed records of past uses for these chemicals are either scarce or non-existent. Land use mapping and GIS resources offer fewer and less detailed impressions of past conditions than present ones. Issues related to long term fate and transport create additional uncertainties. Despite these known challenges, a significant foundation of understanding has been established by reviewing the literature, analyzing all available data (such as PURs, land use layers, and crop reports) interviewing local experts. Cumulative understanding of OC pesticides and PCB sources resulting from all the above mentioned efforts guide the process of linkage analysis and determination of allocations.

6 LINKAGE ANALYSIS

The linkage analysis connects loads of OC pesticides and PCBs (OCs) to beneficial uses. Protection of beneficial uses from impairment by OCs is fundamentally about reducing OC concentrations in aquatic biota to acceptable levels, which necessitates reductions in water and sediment. The numeric targets for OCs in fish tissue define acceptable levels for protection of human health and wildlife, while numeric targets for water and sediment protect lower trophic level organisms and help trace impairment in biota back to sources.

The linkage analysis starts with the conceptual model for OC fate, transport, and effects. This model, supported by the physical and chemical properties of the OCs, is necessary to understand the central role of sediments as a storage compartment and conveyance mechanism. The conceptual model helps support the basic assumption of this TMDL analysis, which is that actions to reduce OC concentrations in sediments will reduce OC concentrations in fish tissue and in the water column.

As mentioned previously, DDE is used as a representative constituent for most of the analyses presented in this TMDL document. This is appropriate because DDE is the only constituent consistently detected and found to exceed numeric targets in water, sediment, and tissue samples (see Current Conditions section); and also because OC Pesticides and PCBs possess similar physical and chemical properties that influence their fate and transport in the environment (described below).

6.1 Conceptual Model / Fate and Transport

A general conceptual model for OC fate, transport and effects in the CCW is shown in Figure 21. The size of the arrows for each process indicates the relative importance. The dominant source of OCs is nonpoint source runoff from areas with high OC concentrations, resulting primarily from use of these chemicals in the past. Nonpoint source runoff also includes the load from atmospheric deposition, which is a much smaller contribution compared to the legacy load. As discussed in the Source Assessment (Section 5), point source inputs from water reclamation plants are a much smaller fraction of the overall load. The primary removal mechanism of OCs from the watershed is by flushing to the Pacific Ocean via Mugu Lagoon. Gaseous evasion and degradation (discussed below) are removal mechanisms, but act on much slower timescales than hydraulic inputs and outputs.

The OCs of concern in this TMDL all sorb strongly to particles. Thus, the gross movement of OCs through the watershed can be modeled as transport on the particulate phase. Although this simplifying assumption helps model watershed loads, site-specific factors that can enhance solubility (especially in pore waters) do need to be considered with regards to effects on beneficial uses.

The linkage of OCs in water and sediment to beneficial uses is uptake by organisms. Uptake by filter feeders depends on their exposure to suspended particulate OCs. Uptake by benthic detritivores is influenced primarily by OC concentrations in sediments. Dissolved OC concentrations in the interstitial waters of sediments (pore waters) may also be an important factor affecting OC uptake by benthic organisms. Fish can acquire dissolved OCs from the water column passing directly across the gills, as well as from consumption of contaminated organisms. Humans and wildlife are susceptible to consumption of organisms contaminated with OCs.

Sediment OC concentrations are important to all of these bio-uptake pathways. Filter feeders and benthic detritivores are directly affected by the OC concentrations of bottom and suspended sediments. OC concentrations in sediments indirectly affect organisms whose primary route of exposure is to dissolved OCs. Higher OC concentrations in sediments drive the adsorption-desorption equilibrium towards higher dissolved concentrations.

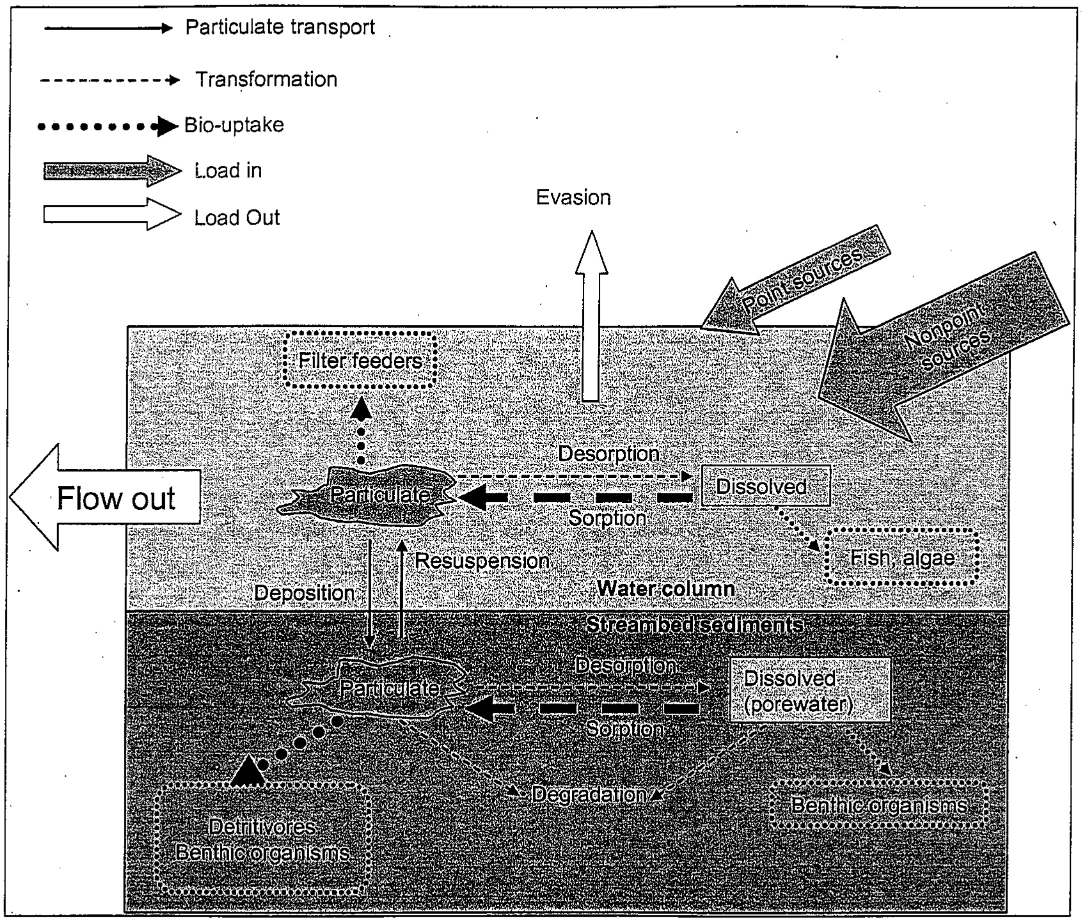


Figure 21. Conceptual model of the key transport and transformation processes of OCs in surface waters of the CCW, and entry points to the food chain.

Chemical Properties and Partitioning of OCs

Relevant chemical properties for the 303(d) listed OCs are shown in Table 55, followed by a description of these physical and chemical characteristics. Due to the hydrophobic nature of OCs they are strongly adsorbed onto silt, sediment particles, and organic matter within a water body. However, the dissolved fraction (operationally defined as the portion of a sample that passes a 1.2-μm filter) is of potential significance since it is sometimes more toxic and bioavailable. The organic carbon fraction of sediments is most commonly correlated with sorption of OCs.

Table 55. Chemical properties of OC pesticides and PCBs.

Constituent	Molecular Weight [1]	Henry's Law Constant [2] (atm-m^3/mole)	Log Kow [2]	Log Koc [2]	Log BCF [2]	Half Life in Soil, Low (days) [1]	Half Life in Soil, High (days) [1]	Water Solubility (mg/L) [2]
Aldrin	NA	1.70E-04	5.52	4.69	3.5	NA [3]	NA [3]	0.017
Chlordane	409.8	4.86E-05	NA	3.09	4.27	350	7,300	0.056
Dacthal	303.9	2.18E-06	4.19	3.81	2.96	15	100	0.5
DDD	321	4.00E-06	6.02	NA	4.9	730	2,190	0.09
DDE	319	2.10E-05	5.69	4.70	4.91	1,000	5,475	0.120
DDT	354.5	8.10E-06	6.36	5.18	4.97	1,460	5,330	0.025
Dieldrin	380.93	1.51E-05	4.55	3.92	3.65	109	4,560	0.195
Endosulfan	406.95	1.12E-05	3.83	3.82	3.02	5	150	0.45-0.51
Endrin	380.92	7.52E-06	4.56	4.06	3.17	60	5,110	0.25
HCH (Lindane)	290.85	1.40E-05	3.61	3.03	3.1	3	1,095	7.3
Heptachlor	NA	1.48E-03	4.27	3.54	3.98	180	1,200	0.18
Heptachlor Epoxide	389.2	9.50E-04	5.4	1.02	4.16	NA	NA	0.2
PCBs	200.7-453	4.0 E-04 [4]	3.9-6.7	NA	NA	730	2,190	0.004-0.91
Toxaphene	414	6.00E-06	4.68	5.32	3.49	9	5,110	0.74

Kow = octanol-water partitioning coefficient, Koc = organic carbon-normalized distribution coefficient, BCF = bioconcentration factor

[1] Sources: ATSDR website (www.atsdr.cdc.gov/toxfaq.html), EXTOXNET website (http://pmep.cce.cornell.edu/profiles/extoxnet/), Journal of Pesticide Reform website (www.pesticide.org), Mackay et al. (1997)

[2] Source: Syracuse Research Corporation, http://www.syrres.com/esc/chemfate.htm

[3] Aldrin rapidly degrades to dieldrin in the environment (ATSDR, 2002b), thus half life of dieldrin is representative.

[4] Source: Burkhard et al, 1985 (Henry's law constant for PCBs not available from Syracuse Research Corporation website).

NA = information not available.

OCs tend to bind to organic matter because of their hydrophobicity. As a result, they adsorb to silt and sediment particles and adsorb to suspended and dissolved organic matter. The distribution coefficient (K_d) of a compound describes the partitioning of the compound between the solid and liquid phase, assuming equilibrium conditions. The organic carbon-normalized distribution coefficient (K_{OC}) is a related value that accounts for the fact that partitioning to sediments by hydrophobic compounds will increase with increasing amounts of organic carbon on sediments. The relationship between K_d and K_{OC} is as follows, where f_{OC} is the fraction of organic carbon in soil or sediment:

$$K_d \cong f_{OC} \cdot K_{OC}$$

The approximate symbol is used because other sediment textural factors (e.g., surface area to volume ratios) can affect the site-specific distribution coefficient. The K_d can also vary with site-specific factors such as pH, temperature, and the concentration of the adsorbing pollutant. While the K_d is a useful property for ranking the relative affinity of different compounds for particles, equations defining the K_d should not be used too literally in modeling without site-specific information from monitoring.

A compound's potential to bioaccumulate is often measured by the ratio of its concentration in tissue to its concentration in water. This ratio is called the bioconcentration factor (BCF). The octanol: water partition coefficient (K_{ow}) is often used as a surrogate for the BCF with octanol acting as lipids (fat) and water acting as the aquatic environment. Note that the BCFs in Table 55 generally follow their K_{ow} values.

Suitability of DDE as a Representative Constituent

The use of DDE as a representative constituent for the organochlorine compounds included in this TMDL is appropriate for several reasons. As described in the Current Conditions section, it is the only constituent detected frequently enough to allow for robust analysis and modeling at varied spatial and temporal scales. It is also a suitable representative chemical because OC pesticides and PCBs have similar chemical properties, as described above.

The representative relationship is probably least appropriate for dacthal and for PCBs. There is little need for concern in the case of dacthal, since it is a category-2 constituent. In the case of PCBs, which have more widely ranging chemical properties and a significantly different use history, the compliance monitoring and adaptive management components outlined in the Implementation Plan will adequately address any issues that become apparent over time.

One additional benefit of using DDE as a representative constituent is that it is one of the most persistent OCs, which means that implementation measures and timescales set for achieving DDE targets will facilitate achievement of targets for the other OCs.

Gaseous Evasion

Evasion means the escape of OC compounds into the atmosphere. Evasion is generally considered to be significant for compounds that have Henry's Law constants (H values) greater than 10^{-4} atm-m^3/mole, although other factors such as wind speed, atmospheric concentration, and temperature also affect evasion rates. Evasion of most OCs from soil and water bodies is not considered to be a major loss mechanism. Heptachlor, heptachlor epoxide, and dieldrin all have H values above 10^{-4}, so gaseous evasion could be an important removal process for those constituents.

Seasonal variations in DDE Concentration

Water column data for each subwatershed were aggregated into wet and dry season samples and then averaged. Seasonal averages are calculated based on the average of detected values and half of the detection limit for non-detected values. The results indicate that DDE concentrations in receiving water are higher in the wet season than in the dry season for all reaches except Arroyo Las Posas (Table 56). Although the differences in the means are all statistically significant ($p<0.05$), some uncertainty is associated with the analysis of seasonality presented here because wet and dry averages are based on less than 20% detected values in three of the six subwatersheds.

No correlations between DDE and seasonality are found in sediment or tissue data.

Seasonal variation in DDE water column concentrations supports the importance of DDE loading from agricultural areas. The average DDE concentration in the water column increases by an order of magnitude during the wet season in Revolon Slough, but wet-weather increases in DDE concentrations are much more subtle in all other reaches (Table 56). The wet-weather increase in DDE concentrations in Revolon Slough is probably attributable to transport of DDE-laden sediments.

Table 56. Average DDE concentrations (ug/L) in representative TMDL reaches for wet and dry season water column samples.

Season[2]	Subwatershed [1]					
	Mugu	Calleguas	Revolon	Las Posas	Simi	Conejo
Dry	0.022	0.019	0.018	0.073	0.009	0.003
Wet	0.049	0.035	0.266	0.050	0.023	0.008

[1] Yellow shaded cells indicate less than 20% of samples had detectable levels. One-half the detection limit is used in place of non-detected values in these instances.
[2] Wet season is December-April; Dry season is May-November.

Degradation

Degradation of organochlorines can proceed by both biologically mediated and abiotic processes. Abiotic degradation mechanisms include photolysis and hydrolysis. Hydrolysis, the reaction of a water molecule with a molecular bond, is not a very important degradation pathway for most legacy OC pesticides (Mackay et al., 1997). Photolytic degradation can proceed directly when a molecular bond absorbs light, or indirectly, when photolytically produced reactive substances (e.g., superoxide radical, hydroxyl radical) attack molecular bonds. The mechanism and relative importance of photolysis (direct or indirect) depends on many factors, including the OC compound in question, the presence or absence of light-absorbing compounds (chromophores) that can produce reactive intermediates, and the degree of light penetration (in water) due to water depth and turbidity (e.g., Kulovaara et al., 1995).

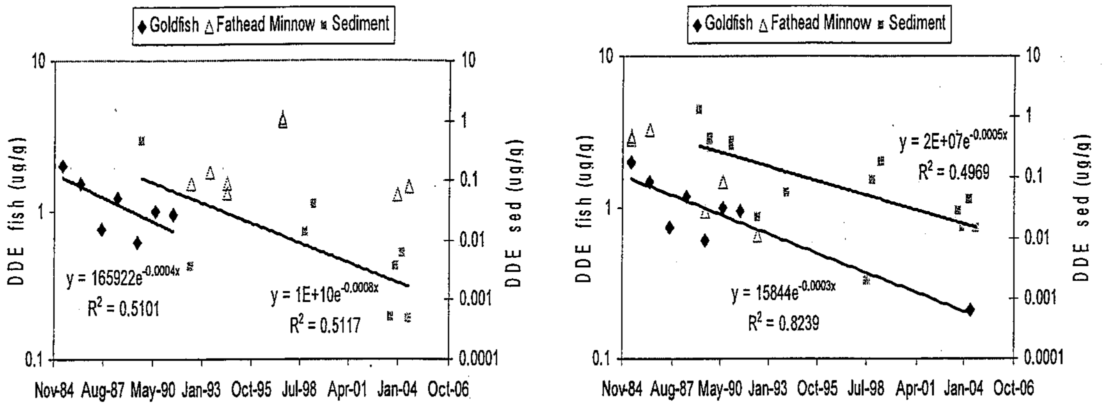
Biologically mediated degradation is generally a more important degradation pathway than hydrolysis or photolysis for OC pesticides, especially DDT and DDE (Aislabel et al, 1997). For DDT and DDE, the distribution of intermediates formed in the biotransformation process is sensitive to redox conditions. Under anaerobic conditions, microbial transformation of DDT occurs primarily by reductive dechlorination to produce DDD (1,1-dichloro-2,2-bis(p-chlorophenyl)ethane). Under aerobic conditions, DDT dechlorination produces primarily DDE and DBP (Perieira et al., 1996).

Degradation to bis(chlorophenyl)acetic acid (DDA) is a potential concern because DDA is a polar (i.e., more water soluble) degradation product (Heberer and Dünnbier, 1999). Environmental assessments often miss DDA because as a polar compound it requires a separate analytical procedure from DDT and non-polar metabolites. No data for DDA are included in the CCW database. Future monitoring efforts may wish to consider including analysis for this breakdown constituent.

The range in reported degradation rates for OCs in soils are reported as "half life" in Table 55. These values take into account all degradation reactions. Environmental monitoring data tend to indicate that degradation rates reported from controlled laboratory studies are generally faster than what is actually observed under natural conditions (Spencer et al., 1996; Zepp and Cline, 1977).

Attenuation of OCs in the CCW

Banned OC pesticides generally show a loss of concentration over time, due to a sum total effect of all the loss terms (balanced by residual, legacy loads), as illustrated by the conceptual model (Figure 21). The best example of this can be seen in the DDE concentrations of fish and sediment samples reported for Revolon Slough and Calleguas Creek (Figure 22). Streambed sediment samples collected over a relatively long period indicate a decrease in DDE content over the past 15 years. Goldfish were collected most often in earlier samples while fathead minnows have been collected most often in more recent samples. The trend for both fish species is a decrease in DDE content over the last 20 years (although the trend is less apparent in Calleguas Creek for fathead minnow samples).



a) b)

Figure 22. DDE content in streambed sediments and fish tissue for a) Calleguas Creek and b) Revolon Slough. Trend lines are shown for goldfish data; fathead minnow data are included because they have been collected more recently than goldfish in Calleguas Creek.

The decreases in DDE concentrations of sediments and biota emphasizes that natural attenuation of OCs is occurring already, due to degradation, burial, and flushing to the Ocean. A primary goal of this TMDL is to augment natural attenuation through implementation actions. The conceptual model in Figure 21 shows the action most likely to result in progress towards that goal is reduction of nonpoint source loads of OC pesticides and PCBs.

6.2 Linkage Between OC Loads, Targets, and Beneficial Uses

The conceptual model for OC fate, transformation and uptake supports four basic linkages in this TMDL Analysis, shown in Figure 23. The first linkage, that risk is proportional to pollutant concentrations in fish times consumption rates, is inherent to the target development process in section 4. The remaining three linkages are explained in detail below.

OC Concentrations in Tissue are proportional to OC concentrations in sediments.

The basic premise underlying this linkage is explained in the conceptual model presented above: OCs in sediments are taken up directly by filter feeders and benthic feeders. Organisms taking up dissolved OCs are still affected by OCs in sediment, because of adsorption-desorption equilibria. When the OC concentration of sediments in the CCW approaches zero, the OC concentration in the water column, interstitial waters, and the food chain will also approach zero.

This TMDL analysis makes the simplifying assumption that the relationship between OC concentrations in fish and sediments is linear, with the slope of the line being the overall sediment–organism bioaccumulation factor (BAF) (Figure 24-A). It is possible that a non-linear relationship between sediments and fish tissue exists (Figure 24-B, Figure 24-C). This is an acknowledged uncertainty in the TMDL analysis. However, it is important to note that the uncertainty does not prevent action, because there is reasonable certainty that lower OC concentrations in sediments will lead to lower OC concentrations in the food chain.

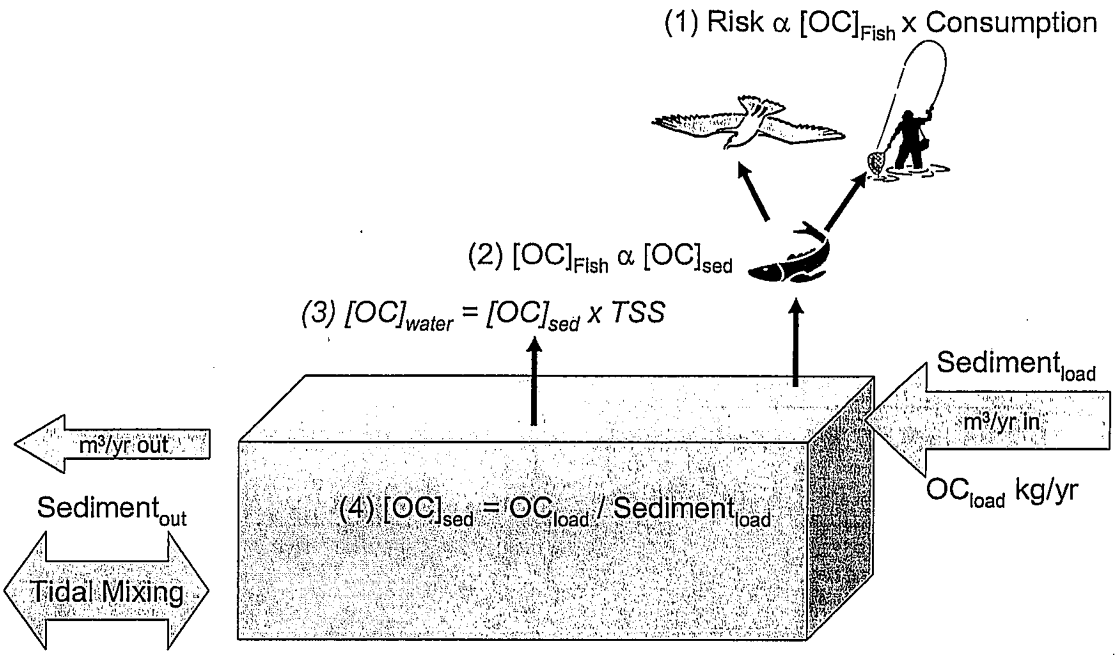


Figure 23. Conceptual illustration of the four basic linkages in this TMDL analysis: (1) Risk is proportional to OC concentration in fish times the fish consumption rate by people and wildlife; (2) OC concentrations in fish are proportional to OC concentrations in sediments; (3) OC concentrations in water are equal to OC concentrations in suspended sediments times the suspended sediment load; and (4) OC concentrations in sediments are equal to OC loads divided by sediment loads.

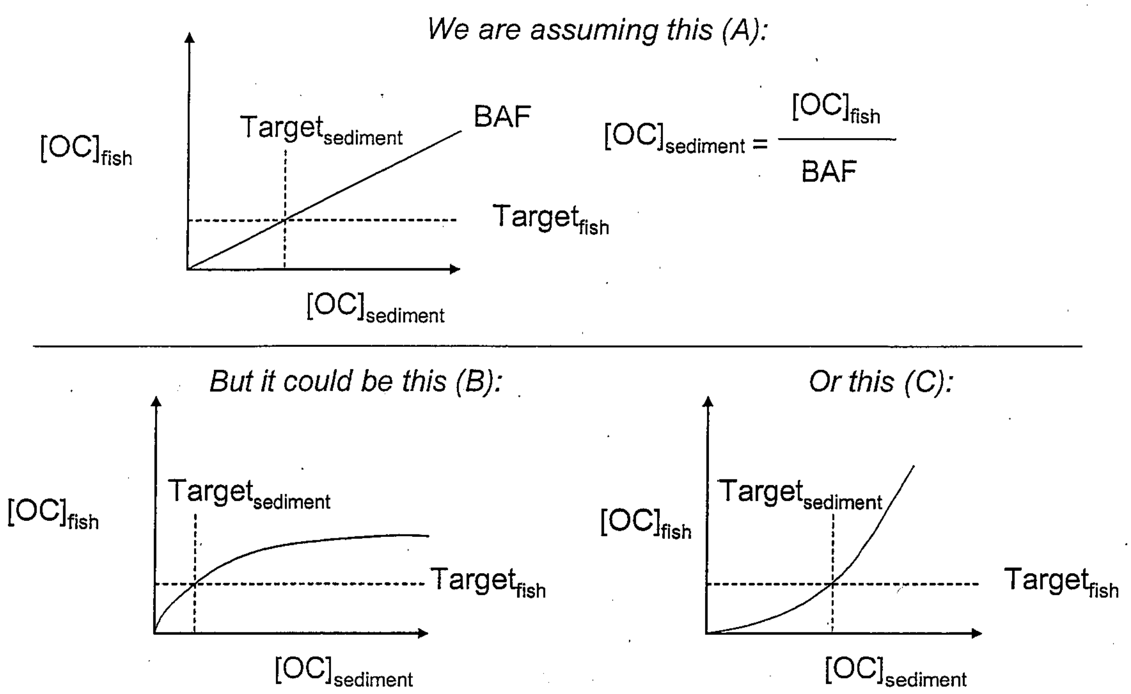


Figure 24: Comparison of the working assumption of direct proportionality between sediments and fish (A) with alternative non-linear models (B) and (C).

To better predict the expected relationship between OC concentration in sediments and OC concentrations in fish tissue, it is important to develop and populate a food web model such as the one shown in Figure 25. An assessment of all organisms present in the food web for the CCW has not been completed, but preliminary monitoring information is available.

DDE concentrations in organisms found in the CCW are shown in Table 57 and Table 58. The average concentrations of DDE do not generally increase with trophic level, as would normally be expected for bioaccumulative substances. This likely reflects an incomplete understanding of the food web. For example, the sharks in Mugu lagoon (TL 4) are not necessarily feeding on an exclusive diet of surfperch (TL3), and both organisms are free to forage outside of Mugu Lagoon. Additionally, many of the highest concentrations might be associated with specific locations where species reside (e.g., herbivores and/or detritivores living in or near agricultural discharges).

In summary, with incomplete information on the food web and OC bioaccumulation processes, proportionality between sediments and fish is assumed. Development of a detailed food web model and population of the model with matched predator-prey-sediment data could verify or refute that assumption. If a non-linear model applies, then the resulting TMDL may be lower or higher than that which is calculated by assuming a linear sediment-organism BAF. If that is discovered to be the case through assessment carried out in TMDL implementation, the TMDL can be adjusted through the TMDL review process.

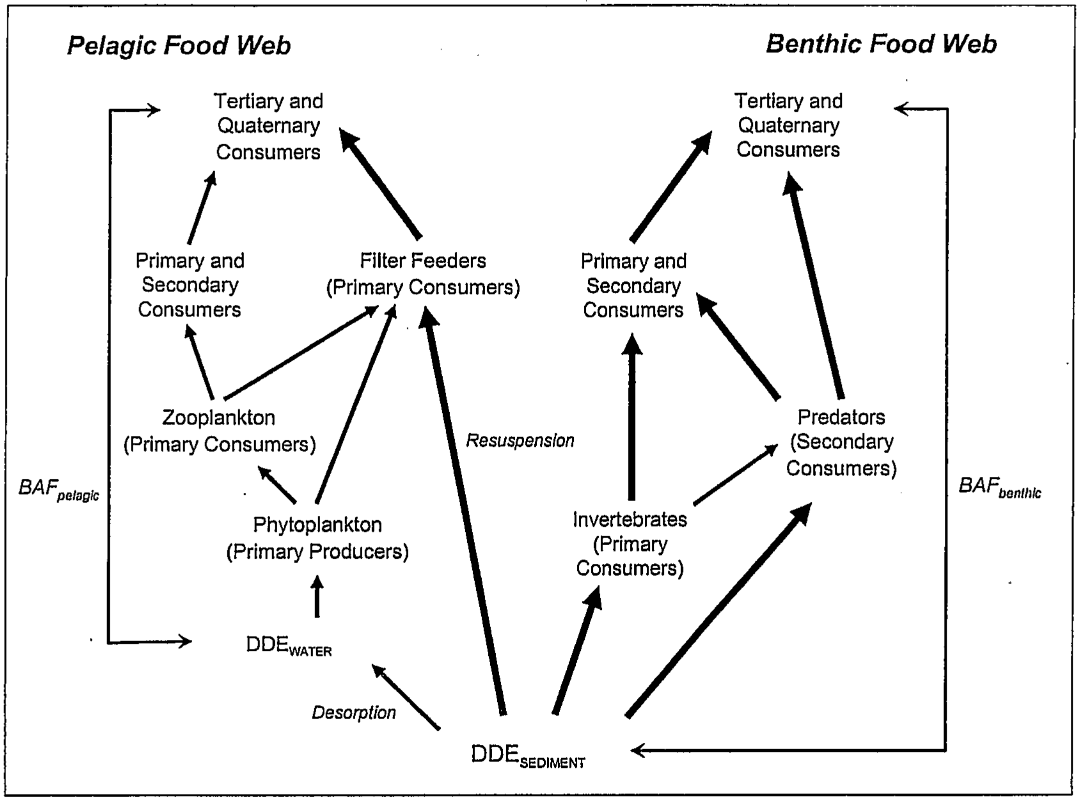


Figure 25. Basic food web model for CCW aquatic organisms, freshwater and marine.

Table 57. Marine organisms found in the CCW database (Reach 1) and average DDE tissue concentrations according to trophic level.

Trophic Level	Trophic Level Description	Organism	Linnean Classification	n	Avg DDE Concentration (ug/g)	
					Filet/Muscle	Whole Org
1	Primary Consumer (Herbivore)	Benthic invertebrate	Class Polychaeta	2	N/A	0.24
		Clam	Class Bivalvia	4		
		Mussel	Class Pelecypoda	3		
		Resident California Mussel	*Mytilus californianus*	6		
		Snails	*Melampus olivasceous*	2		
		Transplanted California Mussel	Class Pelecypoda	10		
2	Secondary Consumer (Primary Carnivore)	Crab	*Pachygrapsus crassipes*	11	0.08	0.41
		Longjaw Mudsucker	*Gillichthys mirabilis*	2		
		Shiner Perch	*Cymatogaster aggregata*	1		
		Shiner Surfperch	*Cymatogaster aggregata*	1		
		Topsmelt	*Atherinops affinis*	1		
3	Tertiary Consumer (Secondary Carnivore)	Crayfish	*Procambarus spp.*	2	N/A	0.35
4	Quaternary Consumer (Tertiary Carnivore)	Gray Smoothhound Shark	*Mustelus californicus*	7	0.11	N/A

Table 58. Freshwater organisms found in the CCW database (Reaches 2-13) and average DDE tissue concentrations according to trophic level.

Trophic Level	Trophic Level Description	Organism	Linnean Classification	n	Avg DDE Concentration (ug/g)	
					Filet/Muscle	Whole Org.
1	Primary Consumer (Herbivore)	African Clawed Frog Tadpoles	*Xenopus laevis*	1	2.57	0.64
		Goldfish	*Carassius auratus*	17		
		Transplanted Fresh Water Clam	*Corbicula spp.*	4		
2	Secondary Consumer (Primary Carnivore)	Arroyo Chub	*Gila orcutti*	15	0.84	1.52
		California Killifish	*Fundulus parvipinnis*	1		
		Carp	Family Cyprinidae	6		
		Fathead Minnow	*Pimephales promelas*	14		
		Mosquitofish	*Gambusia affinis*	7		
3	Tertiary Consumer (Secondary Carnivore)	Black Bullhead	*Ameiurus melas*	13	0.33	N/A
		Brown Bullhead	*Ameiurus nebulosus*	3		
		Bullhead	*Ameiurus spp.*	1		
		Green Sunfish	*Lepomis cyanellus*	7		
		Red Swamp Crayfish	*Procambarus clarkii*	1		

OC Concentrations in Water are a Function of OC Concentrations in Sediment

For particle-associated pollutants, the pollutant concentration in water is the TSS concentration of the water multiplied by the pollutant concentration on the TSS. This simplifying assumption is fundamental to many particle-associated TMDLs, such as the recently adopted TMDL for mercury in San Francisco Bay (SFBRWQCB, 2004). Site-specific data from the CCW show how this fact is central to understanding how reducing OC concentrations in sediments will not only lead to reduced concentrations in fish, but will attain water column targets as well.

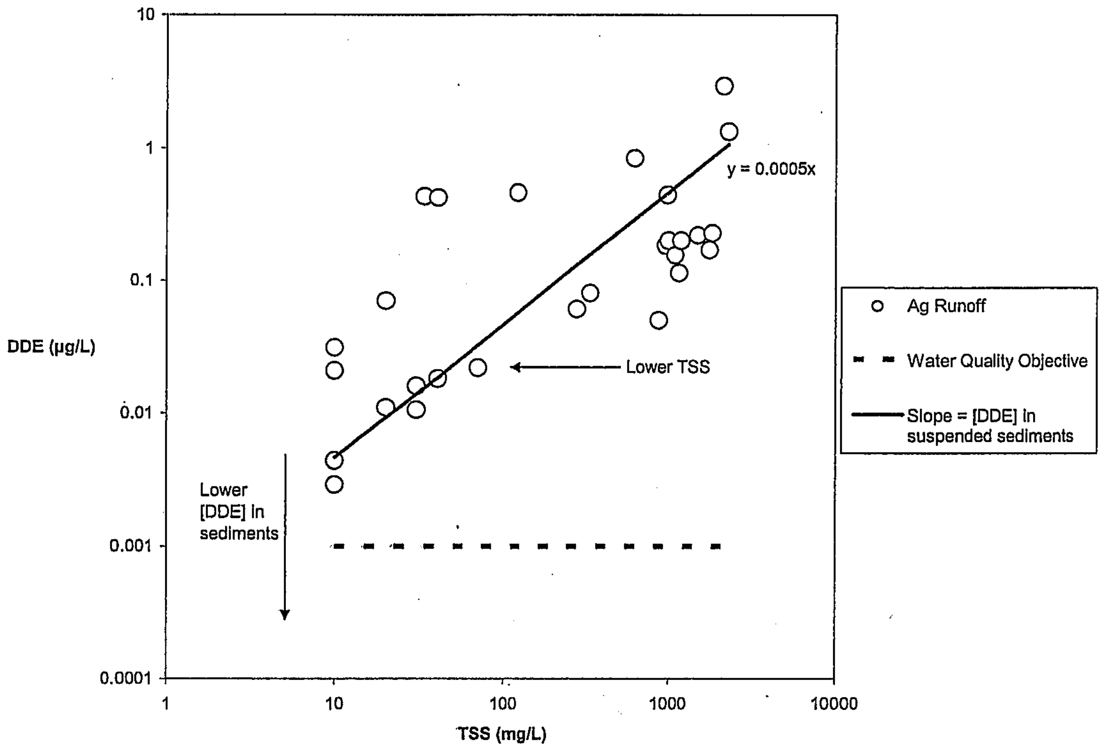


Figure 26. DDE concentrations in water increase with increasing TSS in agricultural drainage of the CCW. Note that the slope of the line gives the DDE concentration of suspended particulate matter (= 0.0005 µg DDE /mg sed or 500 ng/g).

The fact that DDE concentrations in the water column increase with increasing TSS leads to two possible strategies to attain water column targets. Reducing the TSS would lower water column DDE concentrations, but it isn't feasible to keep TSS low enough (considerably less than 10 mg/L). Rather, if the concentration of DDE in suspended particulates were reduced below the current level of 500 ppb (ng/g), then the entire line would shift downwards, making attainment of the water quality objective for DDE (0.001 µg/L) feasible at ambient TSS levels.

OC Concentrations in Sediment are a Function of OC Loading and Sediment Transport

Pollutant concentration in sediments is the master variable for attainment of beneficial uses in this TMDL analysis. OC loads are related to OC concentrations in sediment via a simple, one-box mixing model. In reality, multi-box sediment transport dynamic models are more accurate representations, but the one-box approach is often sufficient to identify the most logical next steps in TMDL implementation.

The sediments in any reach of the CCW, or in Mugu Lagoon, can be considered to be a well-mixed reservoir of a defined mass. Sediments enter from upstream, deposit, are mixed by winds, currents, tides, and organisms, and re-suspended. OC pollutants enter on sediments or, if in the dissolved phase, are scavenged onto sediments. Sediments leave the box representing a reach by either current flow or tidal action.

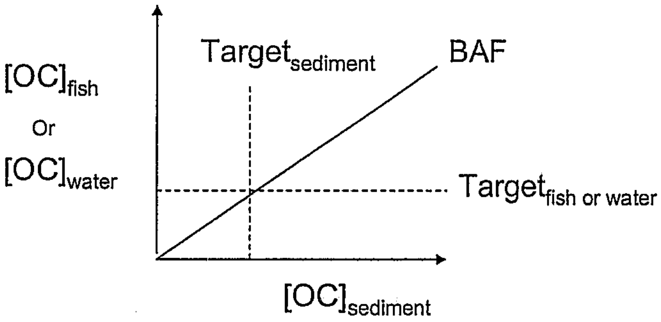
The long-term average concentration of OC pollutants in any given reach will simply be the long-term annual average OC load, divided by the long-term annual average sediment load. This becomes a reasonable basis for calculation of a Total Maximum Pollutant Load needed to attain a target concentration of an OC in sediment. The key information needed is the sediment load, which is not well known for this watershed. Therefore, an early task in the implementation plan is an assessment of sediment transport dynamics.

The importance of this concept is that it leads directly to the implementation actions needed to augment the effects of natural attenuation. The fastest way to attain the target concentrations of OCs in sediments, and therefore attain beneficial uses, is to address the largest controllable OC loads. In general, this will mean assessing OC concentrations in different land use types, and implementing BMPs to reduce soil erosion, and siltation from areas with the highest OC concentrations in sediments.

Although the basic mechanisms that transport terrestrial soils are understood (i.e., erosion from agricultural and urban soils contaminated with OCs) more specific information about the concentrations and quantities of sediment transported by runoff and erosion are not currently available, although development of such information is included in the Implementation Plan.

7 TMDL AND ALLOCATIONS

The goals of this TMDL are to reduce OC pesticide and PCB concentrations in fish tissue to levels safe for human consumption and to assure sediment and water column concentrations are protective of aquatic life. Category-2 constituents identified in the Current Conditions Section are assigned allocations equal to numeric targets for fish tissue and water, although current data suggests they are not exceeding these allocations. The TMDL for category-1 constituents is calculated as a reduction in sediment concentration, which is based upon fish tissue and water concentrations (and consideration of sediment guidelines, for reaches with sediment listings). In order to translate required reductions in fish tissue and water column concentrations into sediment concentration reductions, it is assumed that BAFs for fish tissue to sediment and water to sediment are linear, and that a given percent reduction in fish tissue or water concentration results in an equal percent reduction in sediment concentration (Figure 27). The basis for this assumption is presented in the Linkage Analysis. The validity of this assumption will be evaluated as part of the Implementation Plan and adjusted if necessary to ensure compliance with numeric targets and achievement of beneficial uses.



$$BAF = \frac{[OC]_{fish\ or\ water}}{[OC]_{sediment}}$$

$$\frac{\%\ Reduction_{fish\ or\ water}}{\%\ Reduction_{sediment}} = 1$$

Figure 27. BAF assumptions for translation of fish tissue and water concentration reductions to sediment reductions.

In order to ensure that both fish tissue and water criteria levels are attained, percent reductions in sediment concentration are set equal to the more stringent of the required fish tissue or water column reduction, as shown in Equation 2 and Equation 3.

Equation 2. When $PR_{fish} > PR_{water}$, $PR_{fish} = PR_{sed}$ --> TMDL *

Equation 3. When $PR_{water} > PR_{fish}$, $PR_{water} = PR_{sed}$ --> TMDL *

Where:

PR_{sed} = percent reduction in sediment concentration (ug/g)
PR_{fish} = percent reduction in fish tissue concentration (ug/g)
PR_{water} = percent reduction in water column concentration (ug/L)

* for reaches with sediment listings, lower of PR_{sed} or sediment guideline is applied as final TMDL concentration

Although allocations are expressed in terms of sediment concentration, TMDL progress will be measured according to achievement of all numeric targets in addition to compliance with waste load allocations and load allocations. Thus, any margin of error associated with the implicit use of BAFs and assumption of equal percent reduction across media (from fish tissue and water to sediment) might affect the validity of PR_{sed} in the short term but will not affect achievement of numeric targets in the long run.

TMDLs are comprised of a waste load allocation (WLA), a load allocation (LA), a background load (BL), and a margin of safety (MOS), as shown in Equation 4.

Equation 4 $TMDL = PR_{sed} = WLA + LA + BL + MOS$

WLAs are assigned to point source contributors of pollutants and LAs are assigned for non-point source contributions. Since OCs are not naturally occurring, the background load is set to zero. A significant implicit margin of safety is included, which is fully explained later in this section.

The allocation approach for each constituent depends upon whether or not any sediment listings exist for that constituent, the status of the constituent (category 1 versus category 2), and whether or not sediment guidelines exist for the constituent. Specific factors leading to the allocation approach for all listed constituents are shown in Figure 28.

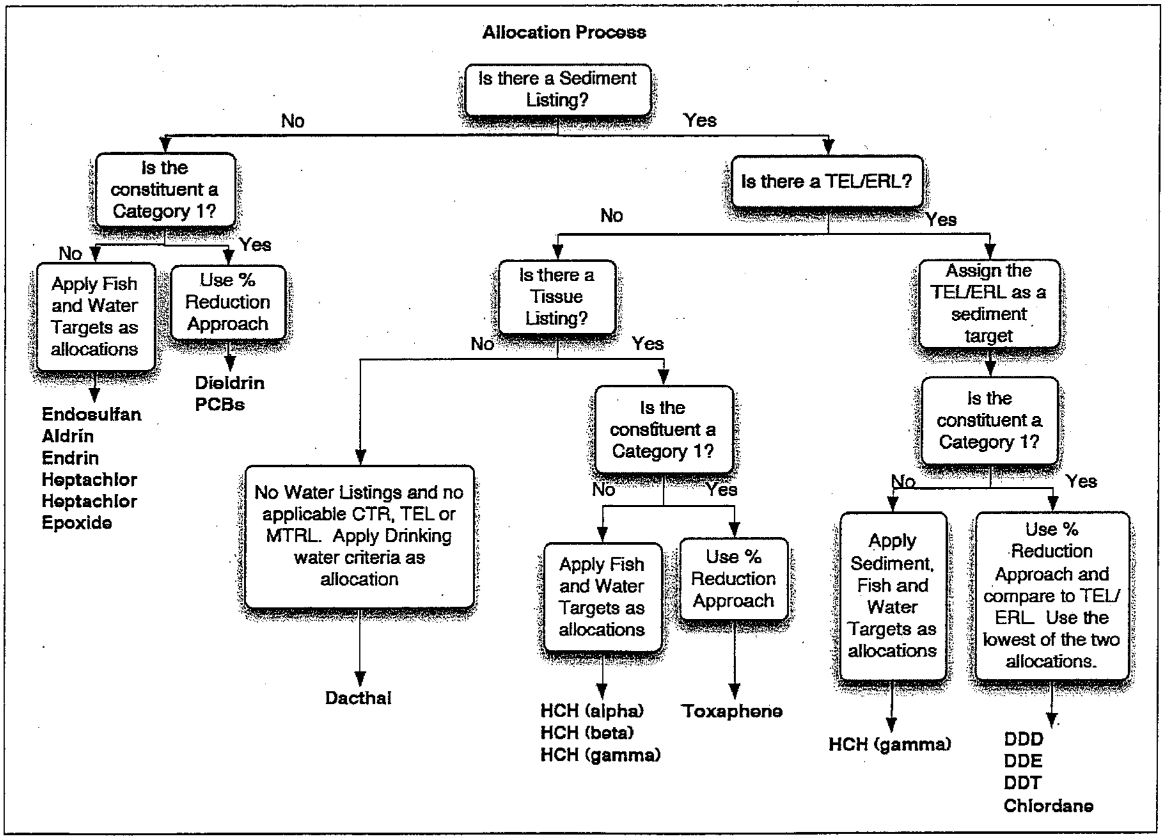


Figure 28. Approach used to develop allocations for each constituent.

The CCW Toxicity TMDL did not identify any OCs as causing toxicity in water or sediment. Any unidentified toxicity which may result from OCs is addressed in the OCs TMDL by selection of numeric targets which are protective of toxicity in water and sediment.

Alternatives Considered

WLAs and LAs expressed as loads in sediment, rather than as sediment concentrations, were considered. Deemed to be an inferior approach due to a lack of sufficient knowledge of sediment transport processes in the watershed (capability does not exist for quantifying transport of both fine and course sediment), and also because reducing total loading of sediment-borne OCs would not necessarily result in decreased concentrations of OCs in sediment.

Use of sediment guidelines, exclusively. The sediment guidelines are not adopted, not clearly protective of human health or aquatic toxicity, and no guidelines exist for many constituents.

7.1 Critical Conditions

The Clean Water Act stipulates a TMDL must take into account critical conditions and seasonal variation. OC concentrations in water, as represented by DDE in the Linkage Analysis section, are correlated with TSS and possibly correlated with flow and seasonality (wet vs. dry season). However, no correlations with flow or seasonality were found to exist in sediment or tissue data. Given that allocations for this TMDL are expressed in terms of OC concentrations in sediment, a critical condition is not identified based upon flow or seasonality.

Since the potential effects of OCs are related to bioaccumulation in the food chain over long periods of time, short term variations in concentration are not likely to cause significant impacts upon beneficial uses. Thus, average concentrations on an annual timescale are hereby defined as the critical condition.

Numeric targets selected for this TMDL are based on conservative (i.e., highly protective) values of water quality objectives, and the methodology for determining allowable concentrations employs several conservative assumptions. In combination, these factors ensure final WLAs and LAs will result in attainment of water quality objectives under all conditions of flow and loading.

7.2 Existing and Allowable Concentrations

Whenever sufficient data exist, percent reductions for category-1 constituents are calculated for fish tissue and water column concentrations by comparing data for existing conditions with the numeric targets. The percent reduction for sediment concentrations is set equal to the greater percent reduction required to meet either the fish tissue or water column target (Equation 2 and Equation 3). That percentage is used to calculate the allowable sediment concentration at the discharge point of each subwatershed, referred to as the "discharge goal." Potential downstream impacts are then considered. When the discharge goal for a given subwatershed is higher than its downstream neighbor, the final allowable concentration of the upstream subwatershed is set equal to the discharge goal of the downstream neighbor (in order to ensure protection of downstream subwatersheds from upstream inputs). This concentration is the final allowable concentration for all constituents without 303(d) listings for sediment. In the case of constituents with listings for sediment, the allowable concentration determined by percent reduction and downstream effects is compared with the sediment guideline numeric target; and the lower of the two is selected as the final allowable concentration.

Existing concentrations, percent reductions, and allowable concentrations for category-1 constituents are shown in Table 59 through Table 65. Existing concentrations are based on mean values for each constituent by subwatershed, using available receiving water data from all years. Non-detect results are quantified as half the detection limit. Italicized values shown in green shaded cells are estimated from mostly non-detected samples. Cells marked with "IDD" indicate an insufficient number of detected data to merit calculation of mean concentration. The marker "NL" is used to denote cells for which no listing exists. The column "Allowable Concentration" reflects the final allowable concentration, after consideration of all relevant factors described above.

Table 59. Existing concentrations and percent reductions required in water, fish tissue, and sediment for Chlordane.

Subwatershed	Water (ug/L)		Fish (ug/g)		Sediment (ug/g)					
	Mean	% Red.	Mean	% Red.	Mean	% Red.	Discharge Goal	Downstream Consideration	Sediment Target	Allowable Concentration
Mugu Lagoon	IDD	0%	IDD	0%	*0.0023*	0%	0.0023	--	NL	0.0023
Calleguas Creek	IDD	0%	*0.0045*	0%	*0.0006*	0%	0.0006	0.0023	NL	0.0006
Revolon Slough	*0.0078*	48%	*0.0331*	75%	*0.0054*	75%	0.0014	0.0023	0.0045	0.0014
Arroyo Las Posas	IDD^{NL}	0%	IDD^{NL}	0%	IDD^{NL}	0%	IDD^{NL}	0.0006	NL	0.0006
Arroyo Simi	IDD^{NL}	0%	IDD^{NL}	0%	IDD^{NL}	0%	IDD^{NL}	0.0006	NL	0.0006
Conejo Creek	IDD	0%	*0.0022*	0%	IDD	0%	IDD	0.0006	NL	0.0006

Table 60. Existing concentrations and percent reductions required in water, fish tissue, and sediment for 4,4'-DDD.

Subwatershed	Water (ug/L)		Fish (ug/g)		Sediment (ug/g)					
	Mean	% Red.	Mean	% Red.	Mean	% Red.	Discharge Goal	Downstream Consideration	Sediment Target	Allowable Concentration
Mugu Lagoon	0.0806	0%	*0.0063*	0%	0.0178	0%	0.0178	--	0.002	0.002
Calleguas Creek	0.0615	0%	0.0414	0%	0.0091	0%	0.0091	0.002	0.0035	0.002
Revolon Slough	*0.0254*	0%	0.1818	75%	0.0501	75%	0.0124	0.002	0.0035	0.002
Arroyo Las Posas	IDD^{NL}	0%	IDD^{NL}	0%	0.0068	0%	0.0068	0.002	0.0035	0.002
Arroyo Simi	IDD^{NL}	0%	IDD^{NL}	0%	*0.0021*	0%	0.0021	0.002	0.0035	0.002
Conejo Creek	IDD	0%	*0.0025*	0%	IDD	0%	IDD	0.002	0.0035	0.002

Table 61. Existing concentrations and percent reductions required in water, fish tissue, and sediment for 4,4'-DDE.

Subwatershed	Water (ug/L)		Fish (ug/g)		Sediment (ug/g)					
	Mean	% Red.	Mean	% Red.	Mean	% Red.	Discharge Goal	Downstream Consideration	Sediment Target	Allowable Concentration
Mugu Lagoon	*0.0382*	0%	0.1043	69%	0.0575	69%	0.0176	--	0.0022	0.0022
Calleguas Creek	0.0235	0%	0.6444	95%	0.0604	95%	0.0030	0.0022	0.0014	0.0014
Revolon Slough	0.1165	0%	1.6368	98%	0.2314	98%	0.0045	0.0022	0.0014	0.0014
Arroyo Las Posas	0.0038	0%	*0.0040*	0%	0.0396	0%	0.0396	0.0014	0.0014	0.0014
Arroyo Simi	*0.0138*	0%	IDD	0%	0.0142	0%	0.0142	0.0014	0.0014	0.0014
Conejo Creek	*0.0093*	0%	0.0229	0%	0.0026	0%	0.0026	0.0014	0.0014	0.0014

[1] no aquatic life criteria exist for DDE.

Table 62. Existing concentrations and percent reductions required in water, fish tissue, and sediment for 4,4'-DDT.

Subwatershed	Water (ug/L)		Fish (ug/g)		Sediment (ug/g)					
	Mean	% Red.	Mean	% Red.	Mean	% Red.	Discharge Goal	Downstream Consideration	Sediment Target	Allowable Concentration
Mugu Lagoon	*0.0377*	97%	IDD	0%	0.0096	97%	0.0003	--	0.0010	0.0003
Calleguas Creek	*0.0250*	96%	0.0326	2%	0.0142	96%	0.0006	0.0003	NA	0.0003
Revolon Slough	0.0516	98%	0.1933	83%	0.0791	98%	0.0015	0.0003	NA	0.0003
Arroyo Las Posas	*0.0577*	98%	IDD	0%	0.0254	98%	0.0004	0.0003	NA	0.0003
Arroyo Simi	IDD^{NL}	0%	IDD^{NL}	0%	*0.0032*	0%	0.0032	0.0003	NA	0.0003
Conejo Creek	IDD	0%	IDD	0%	*0.0081*	0%	0.0081	0.0003	NA	0.0003

Table 63. Existing concentrations and percent reductions required in water, fish tissue, and sediment for Dieldrin.

Subwatershed	Water (ug/L)		Fish (ug/g)		Sediment (ug/g)					
	Mean	% Red.	Mean	% Red.	Mean	% Red.	Discharge Goal	Downstream Consideration	Sediment Target	Allowable Concentration
Mugu Lagoon	IDD^{NL}	0%	IDD^{NL}	0%	*0.0043*	0%	0.0043	--	NL	0.0043
Calleguas Creek	IDD	0%	*0.0027*	76%	*0.0009*	76%	0.0002	0.0043	NL	0.0002
Revolon Slough	IDD	0%	0.0089	93%	0.0015	93%	0.0001	0.0043	NL	0.0001
Arroyo Las Posas	IDD^{NL}	0%	IDD^{NL}	0%	IDD^{NL}	0%	IDD^{NL}	0.0002	NL	0.0002
Arroyo Simi	IDD^{NL}	0%	IDD^{NL}	0%	IDD^{NL}	0%	IDD^{NL}	0.0002	NL	0.0002
Conejo Creek	IDD^{NL}	0%	IDD^{NL}	0%	IDD^{NL}	0%	IDD^{NL}	0.0002	NL	0.0002

Table 64. Existing concentrations and percent reductions required in water, fish tissue, and sediment for PCBs.

Subwatershed	Water (ug/L)		Fish (ug/g)		Sediment (ug/g)					
	Mean	% Red.	Mean	% Red.	Mean	% Red.	Discharge Goal	Downstream Consideration	Sediment Target	Allowable Concentration
Mugu Lagoon	IDD	0%	IDD	0%	*0.1752*	0%	0.1752	--	NL	0.1752
Calleguas Creek	IDD	0%	*0.0062*	14%	*0.1379*	14%	0.1183	0.1752	NL	0.1183
Revolon Slough	IDD	0%	IDD	0%	*0.1252*	0%	0.1252	0.1752	NL	0.1252
Arroyo Las Posas	IDD^{NL}	0%	IDD^{NL}	0%	IDD^{NL}	0%	IDD^{NL}	0.1183	NL	0.1183
Arroyo Simi	IDD	0%	IDD	0%	IDD	0%	IDD	0.1183	NL	0.1183
Conejo Creek	IDD^{NL}	0%	IDD^{NL}	0%	IDD^{NL}	0%	IDD^{NL}	0.1183	NL	0.1183

Table 65. Existing concentrations and percent reductions required in water, fish tissue, and sediment for Toxaphene.

Subwatershed	Water (ug/L)		Fish (ug/g)		Sediment (ug/g)					
	Mean	% Red.	Mean	% Red.	Mean	% Red.	Discharge Goal	Downstream Consideration	Sediment Target	Allowable Concentration
Mugu Lagoon	IDD^{NL}	0%	IDD^{NL}	0%	0.3552	0%	0.3552	--	NA	0.3552
Calleguas Creek	IDD	0%	0.3906	97%	*0.0235*	97%	0.0006	0.3552	NA	0.0006
Revolon Slough	IDD	0%	1.6647	99%	0.1637	99%	0.0010	0.3552	NA	0.0010
Arroyo Las Posas	IDD^{NL}	0%	IDD^{NL}	0%	IDD^{NL}	0%	IDD^{NL}	0.0006	NA	0.0006
Arroyo Simi	IDD	0%	IDD	0%	IDD	0%	IDD	0.0006	NA	0.0006
Conejo Creek	IDD	0%	IDD	0%	IDD	0%	IDD	0.0006	NA	0.0006

"NA" indicates that no sediment targets exist for toxaphene.

7.3 Waste Load Allocations and Load Allocations

Waste load allocations (WLAs) are assigned to point source discharges, including urban runoff from stormwater co-permittees and wastewater treatment plants (POTWs). Load allocations (LAs) are allocated to nonpoint source discharges, in this case agricultural discharges. Urban runoff, POTWs, and agricultural discharges are collectively referred to as discharges. Compliance with WLAs and LAs will be determined at the base of each subwatershed because water, fish tissue, and sediment data collected there represent cumulative inputs from the drainage area. The source analysis and linkage analysis have demonstrated the contributions of OC pesticides and PCBs to receiving waters from each of these discharges are potentially significant, depending on specifics related to each constituent.

Phased WLAs and LAs for category-1 constituents are set to allow time for reductions in OC concentrations attributable to implementation efforts and natural attenuation to occur before incorporating final WLAs and LAs into permits (the terms "phased" and "interim" are both used refer to non-final WLAs and LAs; the term "phased" is used by USEPA and "interim" by RWQCB). Phased WLAs and LAs are based on the 95th percentile value of in-stream sediment data whenever a sufficient number of detected values exist. The use of 95th percentile values to develop phased limits is consistent with current NPDES permitting methodology. When a sufficient number of detected values are not available for calculation of the 95th percentile, the highest detected value is used as the phased WLA or LA. If no detected values exist in the relevant data set, the phased limit is set according to the Minimum Level issued by SWRCB in the Statewide Implementation Plan (SIP).

WLAs and LAs are not applied for subwatershed-constituent combinations which meet all of the following conditions: the constituent is not listed for any reaches in the subwatershed, a sufficient number of data exist to determine exceedances are occurring rarely or not at all (according to the same methodology used for defining category-2 constituents in the Current Conditions section), and no potential for downstream impacts exists.

Waste Load Allocations for Urban Runoff

WLAs for category-1 constituents in urban runoff (i.e., stormwater co-permittees) are set equal to the allowable concentration for in-stream sediment, with compliance determined at the base of each subwatershed, as shown in Table 66. Should an exceedance occur at the base of a subwatershed, future source-specific sediment monitoring will attempt to identify causes of the exceedance. As explained previously, WLAs for category-2 constituents are assigned as water and fish tissue numeric targets, shown in Table 67.

Table 66. Phased/Interim and Final Sediment WLAs for MS4 Permittees for Category-1 Constituents.

Constituent	Allocation Type	Mugu Lagoon (µg/g)	Calleguas Creek (µg/g)	Revolon Slough (µg/g)	Arroyo Las Posas (µg/g)	Arroyo Simi (µg/g)	Conejo Creek (µg/g)
Chlordane	Phased/Interim Annual Allocation	0.025	0.017	0.048	0.0033[NL]	0.0033[1, NL]	0.0034
	Final Annual Average Allocation[2]	0.0033	0.0033	0.0009	0.0033[NL]	0.0033[NL]	0.0033
4,4-DDD	Phased/Interim Annual Allocation	0.069	0.066	0.40	0.29	0.014[NL]	0.0053
	Final Annual Average Allocation[2]	0.0012[3]	0.0012[3]	0.0012[3]	0.0012[3]	0.0012[3, NL]	0.0012[3]
4,4-DDE	Phased/Interim Annual Allocation	0.30	0.47	1.6	0.95	0.17[NL]	0.02
	Final Annual Average Allocation[2]	0.0021[3]	0.0014[3]	0.0014[3]	0.0014[3]	0.0014[3, NL]	0.0014[3]
4,4-DDT	Phased/Interim Annual Allocation	0.039	0.11	0.69	0.67	0.025[NL]	0.002
	Final Annual Average Allocation[2]	0.0003	0.0003	0.0003	0.0003	0.0003[NL]	0.0003
Dieldrin	Phased/Interim Annual Allocation	0.019[NL]	0.003	0.0057	0.0011[NL]	0.0011[1, NL]	0.003[1]
	Final Annual Average Allocation[2]	0.0043[NL]	0.0002	0.0001	0.0002[NL]	0.0002[NL]	0.0002
PCBs	Phased/Interim Annual Allocation	0.18	3.8	7.6	25.7[NL]	25.7[1, NL]	3.8[1]
	Final Annual Average Allocation[2]	0.18	0.12	0.13	0.12[NL]	0.12[NL]	0.12[NL]
Toxaphene	Phased/Interim Annual Allocation	22.9[NL]	0.26	0.79	0.23[NL]	0.23[1, NL]	0.26[1]
	Final Annual Average Allocation[2]	0.36[NL]	0.0006	0.001	0.0006[NL]	0.0006[NL]	0.0006

1. Phased/Interim WLAs are set equal to the Minimum Level as defined in the SIP because there are no detected values in the dataset.
2. Final allocations set equal to the sediment concentrations determined through calculating the percent reductions required to achieve fish tissue and water column targets as described in the allocation section unless otherwise noted.
3. Final allocations are set equal to the TEL or ERL, as described in Figure 28.

"NL" Subwatershed-constituent combination with no 303(d) listing. Allocations assigned based on downstream impacts.

Table 67. Final Water and Fish Tissue WLAs for MS4 Permittees for Category-2 Constituents.

Constituent	Allocation Type	Mugu Lagoon	Calleguas Creek	Revolon Slough	Arroyo Las Posas	Arroyo Simi	Conejo Creek
Aldrin	Final Monthly Average Water Allocation (μg/L)[1]	1.3[3]	3[3]	3[3]	3[3]	3[3]	3[3]
	Final Annual Average Tissue Allocation (μg/kg)[2]	0.05	0.05	0.05	0.05	0.05	0.05
Dacthal	Final Monthly Average Water Allocation (μg/L)[1]	NA	NA	3500[4]	NA	NA	NA
	Final Annual Average Tissue Allocation (μg/kg)[2]	NA	NA	NA	NA	NA	NA
Endosulfan	Final Monthly Average Water Allocation (μg/L)[1]	NA	NA	NA	NA	NA	0.056
	Final Annual Average Tissue Allocation (μg/kg)[2]	NA	NA	NA	NA	NA	64800
Endrin	Final Monthly Average Water Allocation (μg/L)[1]	0.0023	0.036	0.036	0.036	0.036	0.036
	Final Annual Average Tissue Allocation (μg/kg)[2]	3220	3220	3220	3220	3220	3220
HCH (gamma-BHC)	Final Monthly Average Water Allocation (μg/L)[1]	0.16	0.95	0.95	0.95	0.95	0.95
	Final Annual Average Tissue Allocation (μg/kg)[2]	8.2	8.2	8.2	8.2	8.2	8.2
Heptachlor	Final Monthly Average Water Allocation (μg/L)[1]	0.0036	0.0038	0.0038	0.0038	0.0038	0.0038
	Final Annual Average Tissue Allocation (μg/kg)[2]	2.4	2.4	2.4	2.4	2.4	2.4
Heptachlor Epoxide	Final Monthly Average Water Allocation (μg/L)[1]	0.0036	0.0038	0.0038	0.0038	0.0038	0.0038
	Final Annual Average Tissue Allocation (μg/kg)[2]	1.2	1.2	1.2	1.2	1.2	1.2

1. CTR chronic toxicity criteria for the protection of aquatic life are used, unless otherwise noted. Available data indicates that Category-2 constituents are not currently exceeding acute or chronic targets.
2. Tissue Threshold Residue Levels (TTRLs), derived from CTR human health criteria.
3. No chronic criteria exist. Acute criteria are used.
4. No chronic or acute criteria exist. Drinking water standard of 3500 μg/L adopted by Florida and Arizona is applied. No marine or fish tissue standards exist.

"NA" Allocations are not necessary because the constituent is Category-2, not listed for the reach to which the POTW discharges, and does not have any downstream listings or exceedances.

Waste Load Allocations for POTWs

WLAs are assigned in water for POTWs, since they discharge negligible amounts of sediment. US EPA, LARWQCB, and POTW representatives in the CCW reached consensus regarding use of this approach after considering a range of alternatives. Phased WLAs for POTWs are based on either maximum detected values or Minimum Levels from the SIP, since an insufficient number of detected values are available for calculation of 95th percentiles. Final WLAs are generated using the methodology for calculating effluent limits which is presented in section 1.4 of the SIP. The resulting WLAs are shown in Table 68.

Table 68. Phased/Interim and Final WLAs for POTWs.

Constituent	Allocation Type	Hill Canyon WWTP	Simi Valley WQCP	Moorpark WTP	Camarillo WRP	Camrosa WRP
Category 1		(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)
Chlordane	Phased/Interim WLAs[1]	2.4[2]	0.1	0.1	0.1	0.1
	Final Daily WLAs[3]	0.0012	0.0012	0.0012	0.0012	0.0012
	Final Monthly WLAs[3]	0.00059	0.00059	0.00059	0.00059	0.00059
4,4-DDD	Phased/Interim WLAs[1]	0.02[2]	0.05	0.05	0.006	0.05
	Final Daily WLAs[3]	0.0017	0.0017	0.0017	0.0017	0.0017
	Final Monthly WLAs[3]	0.00084	0.00084	0.00084	0.00084	0.00084
4,4-DDE	Phased/Interim WLAs[1]	0.26[2]	0.005[2]	0.001[2]	0.188[2]	0.05
	Final Daily WLAs[3]	0.0012	0.0012	0.0012	0.0012	0.0012
	Final Monthly WLAs[3]	0.00059	0.00059	0.00059	0.00059	0.00059
4,4-DDT	Phased/Interim WLAs[1]	0.01	0.01	0.01	0.01	0.01
	Final Daily WLAs[3]	0.0012	0.0012	0.0012	0.0012	0.0012
	Final Monthly WLAs[3]	0.00059	0.00059	0.00059	0.00059	0.00059
Dieldrin	Phased/Interim WLAs[1]	0.01	0.01	0.01	0.01	0.01
	Final Daily WLAs[3]	0.00028	0.00028	0.00028	0.00028	0.00028
	Final Monthly WLAs[3]	0.00014	0.00014	0.00014	0.00014	0.00014
PCBs	Phased/Interim WLAs[1]	0.5	0.5	0.5	0.031[2]	0.5
	Final Daily WLAs[3]	0.00034	0.00034	0.00034	0.00034	0.00034
	Final Monthly WLAs[3]	0.00017	0.00017	0.00017	0.00017	0.00017
Toxaphene	Phased/Interim WLAs[1]	0.5	0.5	0.5	0.5	0.5
	Final Daily WLAs[3]	0.00033	0.00033	0.00033	0.00033	0.00033
	Final Monthly WLAs[3]	0.00016	0.00016	0.00016	0.00016	0.00016
Category 2		(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)
Aldrin	Final Daily WLAs[3]	0.00028	0.00028	0.00028	0.00028	0.00028
	Final Monthly WLAs[3]	0.00014	0.00014	0.00014	0.00014	0.00014
Dacthal	Final Daily WLAs[3]	NA	NA	NA	NA	NA
	Final Monthly WLAs[3]	NA	NA	NA	NA	NA
Endosulfan	Final Daily WLAs[3]	0.092	NA	NA	NA	NA
	Final Monthly WLAs[3]	0.046	NA	NA	NA	NA
Endrin	Final Daily WLAs[3]	0.059	0.059	0.059	0.059	0.059
	Final Monthly WLAs[3]	0.029	0.029	0.029	0.029	0.029
HCH (gamma-BHC)	Final Daily WLAs[3]	0.13	0.13	0.13	0.13	0.13
	Final Monthly WLAs[3]	0.063	0.063	0.063	0.063	0.063
Heptachlor	Final Daily WLAs[3]	0.00042	0.00042	0.00042	0.00042	0.00042
	Final Monthly WLAs[3]	0.00021	0.00021	0.00021	0.00021	0.00021
Heptachlor Epoxide	Final Daily WLAs[2]	0.00022	0.00022	0.00022	0.00022	0.00022
	Final Monthly WLAs[2]	0.00011	0.00011	0.00011	0.00011	0.00011

1. Except where noted, Phased/Interim WLAs are set equal to Minimum Level defined in the SIP because there are no detected values in dataset.
2. Phased/Interim WLAs are set equal to the maximum value detected in discharge data.
3. Final WLAs are calculated using procedures outlined in the SIP using the CTR aquatic life and human health for organisms only criteria.

"NA" Allocations are not necessary because the constituent is Category-2, not listed for the reach to which the POTW discharges, and does not have any downstream listings or exceedances.

Load Allocations for Agricultural Runoff

LAs for category-1 constituents in agricultural runoff are set equal to the allowable concentration for in-stream sediment at the base of each subwatershed (Table 69). Should an exceedance occur at the base of a subwatershed, future source-specific sediment monitoring will attempt to identify causes of the exceedance. LAs for category-2 constituents are assigned as water and fish tissue numeric targets for each constituent (Table 70).

Table 69. Phased/Interim and Final Sediment LAs for Agriculture for Category-1 Constituents.

Constituent	Allocation Type	Mugu Lagoon (µg/g)	Calleguas Creek (µg/g)	Revolon Slough (µg/g)	Arroyo Las Posas (µg/g)	Arroyo Simi (µg/g)	Conejo Creek (µg/g)
Chlordane	Phased/Interim Annual Allocation	0.025	0.017	0.048	0.0033 [NL]	0.0033 [1, NL]	0.0034
	Final Annual Average Allocation [2]	0.0033	0.0033	0.0009	0.0033 [NL]	0.0033 [NL]	0.0033
4,4-DDD	Phased/Interim Annual Allocation	0.069	0.066	0.40	0.29	0.014 [NL]	0.0053
	Final Annual Average Allocation [2]	0.0012 [3]	0.0012[3]	0.0012[3]	0.0012[3]	0.0012 [3, NL]	0.0012[3]
4,4-DDE	Phased/Interim Annual Allocation	0.30	0.47	1.6	0.95	0.17 [NL]	0.02
	Final Annual Average Allocation [2]	0.0021[3]	0.0014[3]	0.0014[3]	0.0014 [3]	0.0014 [3, NL]	0.0014 [3]
4,4-DDT	Phased/Interim Annual Allocation	0.039	0.11	0.69	0.67	0.025 [NL]	0.002
	Final Annual Average Allocation [2]	0.0003	0.0003	0.0003	0.0003	0.0003 [NL]	0.0003
Dieldrin	Phased/Interim Annual Allocation	0.019 [NL]	0.003	0.0057	0.0011 [NL]	0.0011 [1, NL]	0.003 [1]
	Final Annual Average Allocation [2]	0.0043 [NL]	0.0002	0.0001	0.0002 [NL]	0.0002 [NL]	0.0002
PCBs	Phased/Interim Annual Allocation	0.18	3.8	7.6	25.7 [NL]	25.7 [1, NL]	3.8 [1]
	Final Annual Average Allocation [2]	0.18	0.12	0.13	0.12 [NL]	0.12 [NL]	0.12 [NL]
Toxaphene	Phased/Interim Annual Allocation	22.9 [NL]	0.26	0.79	0.23 [NL]	0.23 [1, NL]	0.26 [1]
	Final Annual Average Allocation [2]	0.36 [NL]	0.0006	0.001	0.0006 [NL]	0.0006 [NL]	0.0006

1. Phased/Interim WLAs are set equal to the Minimum Level as defined in the SIP because there are no detected values in the dataset.
2. Final allocations set equal to the sediment concentrations determined through calculating the percent reductions required to achieve fish tissue and water column targets as described in the allocation section unless otherwise noted.
3. Final allocations are set equal to the TEL or ERL as described in the allocation section.

"NL" Subwatershed-constituent combination with no 303(d) listing. Allocations assigned based on downstream impacts.

Table 70. **Final Water and Fish Tissue LAs for Agriculture for Category-2 Constituents.**

Constituent	Allocation Type	Mugu Lagoon	Calleguas Creek	Revolon Slough	Arroyo Las Posas	Arroyo Simi	Conejo Creek
Aldrin	Final Monthly Average Water Allocation (µg/L) [1]	1.3 [3]	3 [3]	3[3]	3[3]	3[3]	3[3]
	Final Annual Average Tissue Allocation (µg/kg) [2]	0.05	0.05	0.05	0.05	0.05	0.05
Dacthal	Final Monthly Average Water Allocation (µg/L)	NA	NA	3500[4]	NA	NA	NA
	Final Annual Average Tissue Allocation (µg/kg)	NA	NA	NA	NA	NA	NA
Endosulfan	Final Monthly Average Water Allocation (µg/L)	NA	NA	NA	NA	NA	0.056
	Final Annual Average Tissue Allocation (µg/kg)	NA	NA	NA	NA	NA	64800
Endrin	Final Monthly Average Water Allocation (µg/L)	0.0023	0.036	0.036	0.036	0.036	0.036
	Final Annual Average Tissue Allocation (µg/kg)	3220	3220	3220	3220	3220	3220
HCH (gamma-BHC)	Final Monthly Average Water Allocation (µg/L)	0.16	0.95	0.95	0.95	0.95	0.95
	Final Annual Average Tissue Allocation (µg/kg)	8.2	8.2	8.2	8.2	8.2	8.2
Heptachlor	Final Monthly Average Water Allocation (µg/L)	0.0036	0.0038	0.0038	0.0038	0.0038	0.0038
	Final Annual Average Tissue Allocation (µg/kg)	2.4	2.4	2.4	2.4	2.4	2.4
Heptachlor Epoxide	Final Monthly Average Water Allocation (µg/L)	0.0036	0.0038	0.0038	0.0038	0.0038	0.0038
	Final Annual Average Tissue Allocation (µg/kg)	1.2	1.2	1.2	1.2	1.2	1.2

1. CTR chronic toxicity criteria for the protection of aquatic life are used, unless otherwise noted. Available data indicates that Category-2 constituents are not currently exceeding acute or chronic targets.
2. Tissue Threshold Residue Levels (TTRLs), derived from CTR human health criteria.
3. No chronic criteria exist. Acute criteria are used.
4. No chronic or acute criteria exist. Drinking water standard of 3500 µg/L adopted by Florida and Arizona is applied. No marine or fish tissue standards exist.

"NA" Allocations are not necessary because the constituent is Category 2, not listed for the reach to which the POTW discharges, and does not have any downstream listings or exceedances.

Alternatives Considered

The following alternate approaches for assigning WLAs to POTWs were considered and discussed with US EPA, LARWQCB, and CCW stakeholders:

1. POTWs will not receive end of pipe effluent limits. Instead, receiving water concentration limits apply at discharge point of subwatershed and implementation of appropriate BMPs are required.
2. Percent reduction required for OC sediment concentration at the subwatershed discharge point is translated into equal percent reduction in effluent, and applied as end of pipe effluent limit for POTWs.
3. Sediment concentration limits for the TMDL are assigned as effluent limits for POTWs, which are measured according to streambed sediment samples taken 0-250 feet downstream of the POTW outfall.
4. All WLAs and LAs expressed as OC loads in sediment according to the product of sediment concentration limits and estimated sediment transport rates. OC loads in POTW effluent are considered equivalent to sediment loads.

Note: the State Water Resources Control Board is currently developing sediment quality guidelines. The relevant sediment quality guidelines should be incorporated into the OC Pesticides and PCBs TMDL, if appropriate.

7.4 Background Load

Background loading can be allocated to either natural sources and/or sources of loadings directly to a water body that are not attributable to a point or nonpoint source. As OC pesticides and PCBs are not naturally occurring, a background load would not be applicable under this definition. With regard to loadings that are not attributable to a point or nonpoint source, such as atmospheric and aerial deposition, as discussed in the Source Analysis Section the available studies on deposition rates could not be incorporated to determine a specific load of these sources to the CCW. As such, the background load of OC pesticides and PCBs is set equal to zero. Potential contributions from background loads are implicitly incorporated into load reductions for controllable sources.

7.5 Margin of Safety

Inclusion of a margin of safety (MOS) is necessary to ensure desired improvements in water quality are achieved. Several factors create uncertainties which could affect the accuracy of calculations made during development of this TMDL and thus the ultimate effectiveness of WLAs and LAs. The two most significant uncertainties are related to the following:

- the large proportion of non-detected values present in the CCW database, which are difficult to quantify with certainty (see Current Conditions section);
- an assumption of equal percent reduction is used for translation of fish tissue and water concentration reductions to appropriate sediment concentration reductions (see TMDL Allocation section).

A very large implicit margin of safety exists in the final WLAs and LAs for this TMDL, which results from the cumulative effect of several conservative methods employed during development of the TMDL, summarized below:

- using all years of available data for calculating required percent reductions likely over predicts current concentrations due to the effects of natural attenuation (i.e., older data reflect less degradation than newer data) -- evidence that this over prediction may be quite sizeable is presented in time series plots for the category-1 constituents (see Current Conditions section);
- selecting the greater percent reduction required of water or fish tissue concentrations as the basis for determining the percent reduction required in sediment (see TMDL Allocations section);
- ensuring protection of downstream subwatersheds from upstream inputs by reducing the allowable concentration for upstream subwatersheds where downstream allowable concentrations are lower (see TMDL Allocations section 7.2);
- selection of TELs and ERLs as numeric targets for sediment, which are the most protective of the potentially applicable sediment guidelines available (see Numeric Targets section);
- decision to use the lower of the allowable concentration (as calculated by percent reduction methodology) or the numeric target for sediment (TEL or ERL) as the WLA and LA for all reaches with 303(d) listings for sediment.

The sum total effect of these various conservative measures employed during development of the final WLAs and LAs is of sufficient magnitude that no additional MOS is required. However, compliance monitoring and special studies outlined in the Implementation Plan will examine the effectiveness of the WLAs and LAs over time, and adjustments made if necessary to ensure achievement of beneficial uses.

7.6 Attainability Analysis

Since use of all category-1 constituents considered in the OC Pesticides and PCBs TMDL has been banned and residual sources are expected to eventually degrade completely (assuming no illegal use), attainment of end goals will depend upon the magnitude of those sources which are continuous and uncontrollable, including:

1. aerial deposition from sources outside the watershed (other countries where OCs are still used);
2. residues on imported produce discharged from POTWs to local streams;
3. contaminants present in imported water;
4. continued use of dicofol, which contains ~0.1% DDT.

The following section discusses each of these sources in general terms, and then presents a likely high and low estimate for the contribution from each source (using DDT as a representative constituent).

Aerial Deposition

- Local aerial sources such as wind drift and wind erosion are in essence the same source as soil erosion to water. The difference is merely the pathway (channelized stormwater runoff versus aerial resuspension).
- DDT is still used in other countries around the globe, although the rate and effective contribution to the global atmosphere are unknown.
- Atmospheric deposition of DDT in Galveston Bay, Texas was estimated to be 1.94 ug/m^2-yr. Assuming the same deposition rate in the Calleguas Creek watershed results in a total annual deposition of 3.8 lb/yr. However, the load to water from this source in the Calleguas Creek watershed is expected to be lower for several reasons:

1. The local airshed is the Pacific Ocean, whereas the airshed for Texas includes potential DDT use areas in Mexico and the southern US.
2. The deposition rate is the gross rate, not net rate. An unquantified proportion volatilizes back into the atmosphere.
3. Much of what does not volatilize adsorbs to soil that does not erode.
4. An unknown portion of DDT degrades to compounds other than DDE and/or degrades locally before eroding to water.

Estimated Range of Contribution from Aerial Deposition:

- High estimate, assume load in Native Land runoff site (Reach 8) is entirely due to atmospheric deposition and ND is ½*DL = 0.001 ug/L * ½ * 120 cfs = 0.12 lbs/yr
- Low estimate, 2% of deposition enters water, 3.8 lb/yr * 2% = 0.08 lbs/yr

Inputs to Effluent from Imported Water and Produce

- Water imported from the State Water Project likely contains trace amounts of DDE, based on the observations that the Delta is listed as impaired for DDT, and monitoring conducted by the San Francisco Estuary Institute (see Source Assessment section). However, imported water is treated before being used in homes and on lawns, which removes hydrophobic and particle-associated contaminants.
- Residue on imported produce could contain trace amounts of DDT. The total mass of DDT from such sources cannot be reliably estimated without considerable effort. A portion of this mass conceivably also enters the wastewater system.
- POTW effluent is not considered a major contributor. POTW effluent samples throughout the watershed are 93% non-detected and do not exhibit any trend over time.

Estimated Range of Contribution from Imported Water:

- High estimate, assume effluent ND = ½*DL but exclude NDs>5 ug/L = 1.7 lbs/yr
- Low estimate, assume effluent ND is 0.0049 (1% of source water) = 0.7 lbs/yr
- Recommend effluent monitoring using low-level sampling and analytical techniques to confirm that concentrations remain low.

Dicofol Applications

- Trends in dicofol use indicates a general decrease in mass used, as shown in Figure 17 and Figure 18, in the Source Analysis Section.
- The 216 pounds of dicofol used in the CCW from 1998-2003 would have contained about 0.2 pounds of DDT. This total mass distributed over the six-year period was thus 0.03 lbs/yr. The total load in water is on the order of 30 lbs/yr, 500 times more than all of the DDT applied as dicofol.
- The actual load to water from dicofol applications is likely an order of magnitude lower owing to these factors:
  - sticks to organic material (stays in soil or harvested with plants)
  - volatilizes or wind drifts away
  - degrades naturally in soil

Estimated Range of Contribution from Dicofol Applications:

- High estimate, total mass in is total mass out = 0.03 lbs/yr

- Low estimate, assume 98% is sequestered and degraded = 0.0006 lbs/yr

Summary

The range of estimated total load in the watershed from the three main sources identified here are:

- High estimate = 0.12 $_{\text{[aerial dep]}}$ + 1.7 $_{\text{[imported water]}}$ + 0.03 $_{\text{[dicofol]}}$ = 1.85 lbs/yr
- Low estimate = 0.08 $_{\text{[aerial dep]}}$ + 0.7 $_{\text{[imported water]}}$ + 0.0006 $_{\text{[dicofol]}}$ = 0.8 lbs/yr

The average annual DDE load to water from all sources is estimated in the Source Analysis section as approximately 32 lbs/yr. The ongoing loads estimated here represent 2-6% of that total. Although DDE loading in water may need to decrease by more than 95% in several parts of the watershed, this rough estimate of ongoing uncontrollable sources suggests that attainment of TMDL targets might not be achievable. However, this estimate predicts the uncontrollable source load resulting from imported water using 1994 data and does not include consideration of the fact that imported water is treated before being used in many cases (see Source Analysis section). This is important to note, since the contribution of DDE from imported water represents a majority of both the high and low estimates of uncontrollable loads presented above. A special study included in the Implementation Plan section will seek to ascertain whether the final WLAs and LAs are attainable, and the WLAs and LAs will be reevaluated if necessary.

7.7 Future Growth

Ventura County accounts for slightly more than 2% of the state's residents with a population of 753,197 (US Census Bureau, 2000). GIS analysis of the 2000 census data yields a population estimate of 334,000 for the Calleguas Creek Watershed (CCW), which equals about 44% of the county population. According to the Southern California Association of Governments (Minjares, SCAG, 2004), growth in Ventura County averaged about 51% per decade from 1900-2000; with growth exceeding 70% in the 1920s, 1950s, and 1960s (Figure 29).

YEAR	POPLN	INCREASE
1900	14,000	--
1910	18,000	28.6%
1920	29,000	61.1%
1930	55,000	89.7%
1940	70,000	27.3%
1950	115,000	64.3%
1960	199,000	73.0%
1970	376,000	88.9%
1980	529,000	40.7%
1990	669,000	26.5%
2000	753,000	12.6%

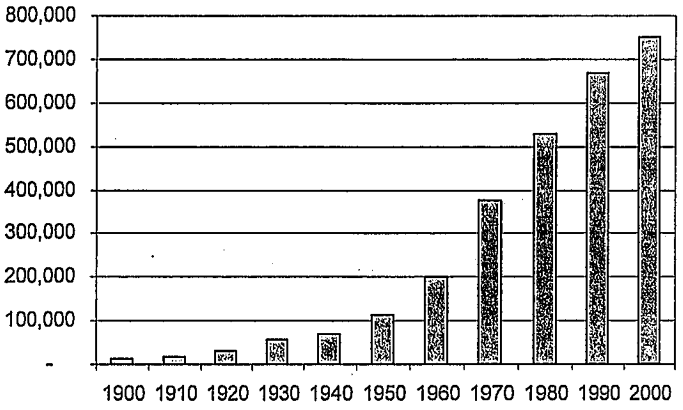


Figure 29. Population Growth in Ventura County, 1900-2000 (SCAG, www.scag.ca.gov/census/pdf/ventura.pdf)

Although Moorpark is expected to remain the smallest city as measured by population, it is also expected to have the highest growth rate from 2000-2020 (Table 71). Both Moorpark and Camarillo are predicted to experience greater than 30% growth in those years. Thousand Oaks is expected to have the lowest growth rate of the CCW cities during that same time period, and is likely to be surpassed by Simi Valley as the most populous city in the watershed by 2020 (Minjares, SCAG, 2004). In general, smaller cities in the watershed are likely to grow faster than larger cities.

Table 71. Growth Projections for CCW Cities and Region, 2000-2020 (Minjares, SCAG, 2004)

City / County / CCW	2000 Popln (July)[1]	2005 Popln (projected)	2010 Popln (projected)	2020 Popln (projected)	% Increase 2000-2010	% Increase 2000-2020
Moorpark city	31,528	37,611	42,618	43,730	35%	39%
Camarillo city	57,478	63,179	67,507	76,842	17%	34%
Simi Valley city	112,190	125,456	131,198	140,902	17%	26%
Thousand Oaks city	117,418	126,272	129,992	132,925	11%	13%
Ventura County	758,054	821,045	865,149	929,181	14%	23%
CCW [2]	336,121	364,051	383,607	411,999	14%	23%

[1] Projected values for July of 2000. Actual census values from April 2000 were slightly lower (Ventura County population was 753,197).
[2] Values in this row represent a rough estimate, calculated as 44% of the value for Ventura County (based upon the fact that current CCW population is approximately 44% of Ventura County total population).

Growth Management Efforts

Ventura County has been actively involved in growth management for several decades and continues to implement a range of growth management measures such as: urban growth boundaries, ballot-initiative zoning, and encouragement of higher density and mixed-use development. The Save Open Space and Agricultural Resources initiative (SOAR) that was passed in 1998 is one such growth management policy. Ventura County's SOAR initiative aims to preserve farmland, open-space and rural areas by establishing a City Urban Restriction Boundary beyond which urban development is controlled (Figure 30). County voter approval is required before any land located outside the City Urban Restriction Boundary can be developed for non-agricultural purposes.

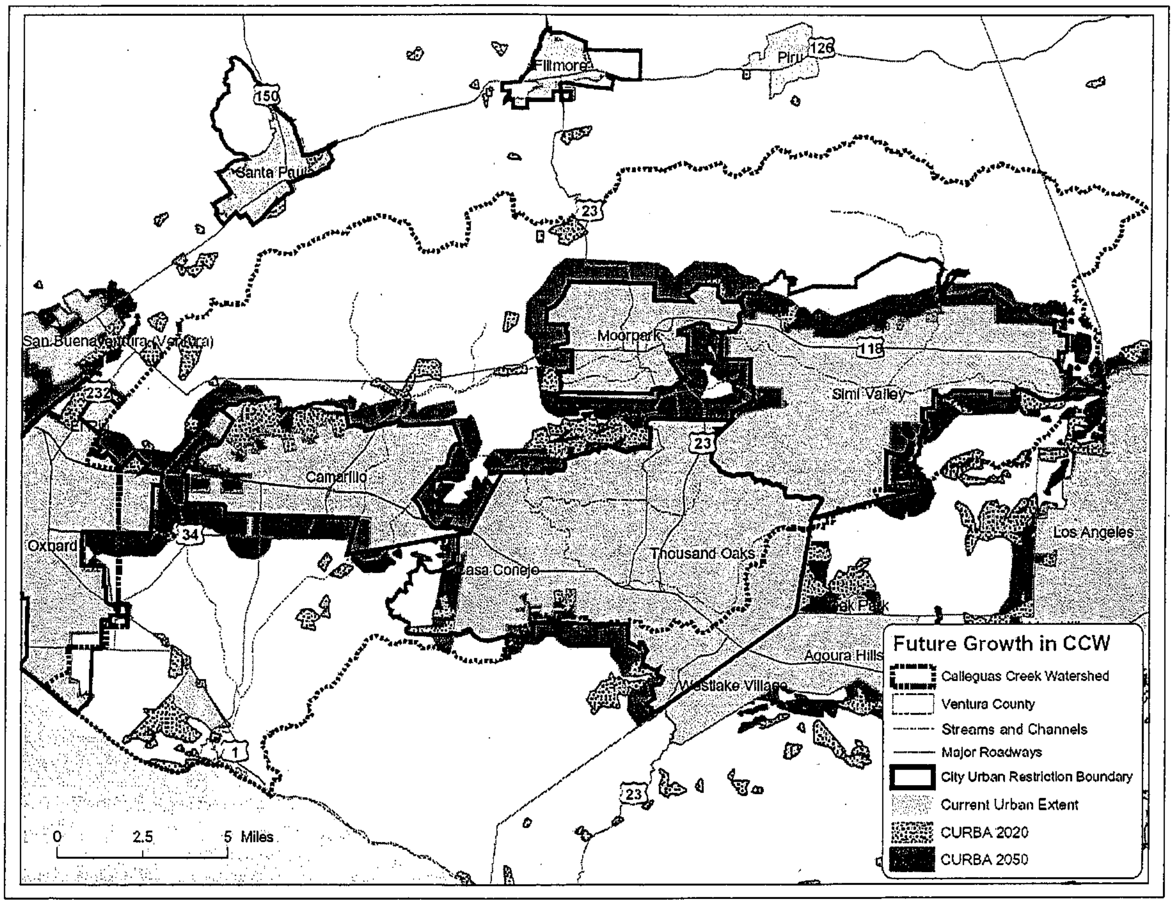


Figure 30. Potential for Urban Growth in Ventura County, based on Ventura County's City Urban Restriction Boundary and California Urban and Biodiversity Analysis (CURBA).

The results of California Urban and Biodiversity Analysis (CURBA) for lands within the Calleguas Creek Watershed for the years 2020 and 2050 are also shown in Figure 30 (Landis et al, 1998). CURBA uses an urban growth model to predict future land-use scenarios, and a habitat loss and fragmentation analysis model to estimate the effects of various land use policies upon biodiversity (only results from the urban growth model are presented here). The urban growth model calculates future urbanization probabilities for all undeveloped sites in a given area, according to such factors as: proximity to highways, proximity to city boundaries, site slope, and site development constraints. The CURBA results shown here seem to have been heavily influenced by the "development constraints" variable, as evidenced by the fact that predicted growth is highly correlated with the City Urban Restriction Boundaries established by the SOAR initiative. Since SOAR is due to expire in 2020, it does not provide permanent protection for open space or farmland.

Effects of Growth Upon OC pesticides and PCB Concentrations

Given the projections discussed in the preceding paragraphs and the presence of growth management measures such as SOAR, it seems almost certain that significant population growth will occur in and around present city limits until at least 2020. Since most of the listed OCs in the CCW have been banned, this growth shouldn't increase their use, although it might affect residual sources from past use. Urban application of those OC pesticides which are still legal (dacthal and endosulfan) might increase, but overall use could decrease because urban expansion tends to reduce total acreage of agricultural land.

Population growth may result in greater OC loading to POTW influent. The load will increase proportionally to the population increase if it is assumed that future domestic water use per person and future pesticide load per household are approximately equal to current water use and pesticide loads. Under those assumptions, the volume of wastewater discharged by POTWs would also increase proportionally to population growth. Increased flow from POTWs should not result in impairment of the CCW as long as effluent concentration standards are met for any given plant. If daily concentration limits are allowed to rise over time, a net increase in OC loading from POTWs could occur.

As urban development occurs, construction activities could have a range of effects upon OC loading to the CCW. Exposure of previously vegetated or deeply buried soil might lead to increased rates of degradation and volatilization. Grading of land to prepare for construction renders soil more vulnerable to erosion and leads to increased sedimentation of streams, which could increase OC loading into streams in the CCW since OCs are known to adhere strongly to sediment. Conversely, urbanization of open space and/or agriculture areas will effectively bury potential sources of OC laden sediments.

Future growth could result in increased OC concentrations in groundwater in the CCW. This concern is potentially relevant in the case of dacthal, which is still in use and has been found in groundwater. The effects of future growth upon PCB loads are unknown, but not likely to prove significant since atmospheric deposition and accidental spills in the past are the primary loading pathways for PCBs. Any increase of currently used OCs to the CCW that occurs as a result of population growth will be offset to some degree by decreased inputs from banned OCs as their presence attenuates due to fate and transport processes.

8 IMPLEMENTATION PLAN

California Water Code section 13360 precludes the Regional Board from specifying the method of compliance with waste discharge requirements. However, California Water Code section 13242 requires that the *Basin Plan* include an implementation plan to describe the nature of actions to be taken and a time schedule for action. This section describes the proposed implementation plan to meet numeric targets for OC pesticides and PCBs in the CCW, including BMPs which will be implemented to reduce erosion and sediment transport. The Implementation Plan includes the following elements:

- Source control activities to reduce any active sources of OC pesticides and PCBs in the watershed;
- Implementation and evaluation of agricultural best management practices (BMPs) in the watershed;
- Special studies to identify sediment transport and OC content and areas where BMP implementation may be more effective.
- Monitoring for OC pesticides and PCBs in water, fish tissue, and sediment throughout the watershed.

For the majority of constituents covered by this TMDL (including all category-1 constituents) use has been completely banned for many years. As demonstrated in the Current Conditions and Linkage Analysis sections, the trends for OC pesticides and PCBs in all media (water, sediment, and tissue) are generally decreasing in concentration over time. Consequently, these pollutants will eventually be almost completely removed from the watershed through degradation, transport to the ocean, volatilization, and other mechanisms (continuing and uncontrollable sources are discussed in Section 7.6, Attainability Analysis). The focus of this implementation plan is the identification of actions that will help accelerate this process without impacting other beneficial uses in the watershed.

Restoring impaired beneficial uses will take many years due to the large quantity of OC residues present in the watershed and the highly persistent nature of these chemicals. Additionally, implementation of BMPs to control sediment and OC transport are related to the implementation strategies for addressing siltation and the Toxicity and Nutrient TMDLs. Therefore, implementation of this TMDL will be phased to allow for evaluation of the impacts on OC concentrations from implementation of BMPs for related TMDLs and to assess the impacts of controlling sediment on streambed erosion and in-stream beneficial uses.

8.1 Waste Load Allocation Implementation

This section discusses the application of final WLAs for the municipal separate storm sewer systems (MS4s) and POTWs, the method for determining compliance with the final WLAs, implementation actions that will be undertaken to achieve the allocations, and the implementation schedule. The final WLAs will be included in NPDES permits in accordance with the compliance schedules provided in Table 73, subject to the following condition:

> WLAs may be revised prior to the dates they are placed into permits and/or prior to the dates of final WLA achievement. Any revisions to these WLAs are to be based on the collection of additional information as described in the Special Studies and Monitoring Section.

Municipal Separate Storm Sewer Systems (MS4s)

A group concentration-based WLA has been developed for MS4s. USEPA regulation allows allocations for NPDES-regulated stormwater discharges from multiple point sources to be expressed as a single categorical WLA when the data and information are insufficient to assign each source or outfall individual WLAs (40 CFR 130). The grouped allocation will apply to all NPDES-regulated municipal stormwater discharges in the CCW.

Stormwater WLAs will be incorporated into the NPDES permit as receiving water limits measured at in-stream discharge points for each subwatershed and will be achieved through the implementation of BMPs as outlined in the implementation plan. Compliance will be determined through the measurement of in-stream water quality, sediment, and fish tissue measurements at the base of each subwatershed. To facilitate stormwater co-permittees measuring compliance in all six of the subwatersheds, additional monitoring stations will be needed in four of the subwatersheds (Mugu, Conejo, Las Posas, and Arroyo Simi).

Because all of the category-1 constituents have been banned, stormwater co-permittees activities are not adding any new loads of the constituents to the watershed. Therefore, the implementation plan for MS4s includes activities that reduce the mobilization of OC pesticides and PCBs to the receiving waters. The following implementation actions will contribute to achievement of the WLAs.

Collection Program

In coordination with POTWs and the Toxicity TMDL implementation plan, stormwater co-permittees will develop and implement a collection program for all banned OC pesticides and PCBs. In other areas of the country, collection programs for OC pesticides have resulted in the proper disposal of large amounts of OC pesticides. As part of the Great Lakes Binational Toxics Strategy, 578,000 pounds of banned pesticides were collected between 1990 and 1998 in Michigan and 9700 pounds of DDT were collected in Ohio between 1993 and 1998 (USEPA, 1999). Therefore, residents in the CCW may have stored OC pesticides that could be collected through existing household hazardous waste programs. This collection program will prevent future use and improper disposal of these banned pesticides.

Construction Site BMPs

Stormwater co-permittees will continue to oversee and regulate active construction sites to minimize disturbed areas and sediment losses. If areas where relatively high concentrations of OC pesticides and/or PCBs are found within the watershed (see Special Study section), then additional activities will be undertaken to reduce erosion and transport of OCs from these areas during construction.

Evaluation and Modification of Existing Sediment Activities

Stormwater co-permittees are involved in many activities that collect, transport, and remove sediment from the watershed. The permittees will conduct an evaluation of sediment-related activities in the watershed and identify activities that might facilitate the mobilization of OC pesticides and/or PCBs to receiving waters and those that reduce the mobilization. For those activities that might facilitate mobilization, an examination of alternatives will be conducted and modifications to current processes implemented if feasible. Additionally, the increased application of activities that reduce the mobilization of pesticides and other pollutants should be considered.

Due to the persistence of OC pesticides and PCBs, concentrations of these chemicals in fish tissue and sediment are likely to persist for many years even after implementation of the activities presented above. Additional activities that could be undertaken to remove contaminated sediment from the watershed (dredging, removing topsoil) are likely to have significant impacts on wildlife and agricultural beneficial uses. Additionally, natural attenuation is occurring in the watershed and the concentrations of these pesticides are declining. Therefore, to allow time for evaluation of reductions in loadings attributable to BMP implementation from the Toxicity and Nutrient TMDLs, conduct of special studies, the implementation of additional BMPs if necessary to address OC Pesticides and PCBs, and natural attenuation to reduce concentrations, phased allocations have been assigned for MS4 discharges as shown in Table 66 in the TMDL Allocations section and an implementation schedule has been provided in Table 73.

POTWs

WLAs established for the three major POTWs in this TMDL will be implemented through NPDES permit limits. The proposed permit limits will be applied as end-of-pipe concentration-based effluent limits for POTWs. Compliance will be determined through monitoring of final effluent discharge as defined in the NPDES permit.

As discussed above for MS4 discharges, POTWs are not adding any significant new loads of OCs to the watershed. Therefore, the implementation plan for POTWs involves implementation of reasonable source control activities. The following implementation actions will contribute to achievement of the WLAs.

Source Control

POTWs will conduct a source control study to identify sources of detected OC pesticides and PCBs to POTW influent. These sources will be examined to determine reasonable activities that could be implemented to control sources to the POTW and to identify which sources are outside the control of local agencies. This study will be used as the basis for implementation of reasonable source control activities (such as the collection program discussed above) and for reevaluation of final WLAs if necessary due to the presence of sources that are outside the control of local agencies (i.e. aerial deposition from active sources outside the United States, residues on imported clothing, etc.).

To allow time for the source control study and implementation of any identified actions, conduct of special studies, and natural attenuation to reduce concentrations; phased allocations shown in (see Table 68 in the allocations section) and an implementation schedule (Table 73) have been assigned for POTWs discharges.

8.2 Load Allocation Implementation

LAs for OC pesticides and PCBs will be implemented in a manner consistent with the Porter-Cologne Water Quality Control Act. Through Porter-Cologne and the State's Nonpoint Source Pollution Control Program (NPSPCP), nonpoint source pollution (i.e. Load Allocations) is addressed through the following five key elements of the Policy for the Implementation and Enforcement of the NPSPCP (NPSPCP Implementation Policy):

1. A NPS control implementation program's ultimate purpose must be explicitly stated and at a minimum address NPS pollution control in a manner that achieves and maintains water quality objectives.
2. The NPS pollution control implementation program shall include a description of the management practices (MPs) and other program elements expected to be implemented, along with an evaluation program that ensures proper implementation and verification.
3. The implementation program shall include a time schedule and quantifiable milestones, should the RWQCB so require.
4. The implementation program shall include sufficient feedback mechanisms so that the RWQCB, dischargers, and the public can determine if the implementation program is achieving its stated purpose(s), or whether additional or different MPs or other actions are required.
5. Each RWQCB shall make clear, in advance, the potential consequences of failure to achieve an NPS implementation program's objectives, emphasizing that it is the responsibility of individual dischargers to take all necessary implementation actions to meet water quality requirements.

Under the NPSPCP Implementation Policy, the RWQCBs must regulate all nonpoint sources of pollution, using the administrative permitting authorities provided by the Porter-Cologne Act. One of the permitting authorities available to the LARWQCB is the adoption of a Conditional Waiver from Waste Discharge Requirements. The LARWQCB is currently in the process of developing and adopting a Conditional Waiver for Irrigated Lands (Conditional Waiver Program) to implement the state's NPSMP. Once adopted, the Conditional Waiver Program can be used to ensure implementation of allocations and meeting of numeric targets contained in this TMDL. However, until this program is adopted by the Regional Board, allocations can be implemented directly through a stand alone Basin Plan Amendment that is also consistent with the State's NPSPCP and includes all of the implementation provisions contained herein. In either case, reasonable assurance will be provided that the agricultural controls necessary to meet the LAs will be implemented.

Compliance with LAs will be measured at the monitoring sites approved by the Executive Officer of the Regional Board through the monitoring program developed as part of the Conditional Waiver, or through a monitoring program that is required as part of the Basin Plan Amendment in case the Conditional Waiver Program should not be adopted in a timely manner consistent with the TMDL implementation schedule. In either case, monitoring shall be consistent with the Calleguas Creek OC Monitoring Program (CCOCMP) which is currently under development.

Due to the strong affinity of OC pesticides and PCBs for sediment, the primary implementation strategies for this TMDL involve reducing the total quantity of sediment discharged into receiving waters and/or reducing the concentration of OCs in sediment discharged to receiving waters. Many of the BMPs that could be implemented are universally applicable for controlling the mobilization of pollutants. Therefore, the implementation of BMPs to achieve load allocations in the Nutrient TMDL, Toxicity TMDL and any future TMDLs will likely result in reductions in the discharge of OC pesticides as well. As such, the implementation schedule provides a phased approach that includes implementation of BMPs to address other TMDLs with additional BMPs required only if load allocations are not achieved.

Studies are currently being conducted to assess the extent of BMP implementation and provide information on the effectiveness of BMPs for agriculture. This information will be used to develop an Agricultural Water Quality Management Plan that will guide the implementation of agricultural BMPs in the CCW. Then, an agricultural education program will be developed to inform growers of the recommended BMPs and the management plan. The Association of Water Agencies of Ventura County and the Ventura County Farm Bureau are actively working on outreach to local growers to educate them on the upcoming requirements from TMDLs and the proposed Conditional Waiver Program.

The phased allocations presented in Table 69 in the Allocations Section and the implementation schedule shown in Table 73 will also provide sufficient time to:

- Allow implementation efforts from other TMDLs and natural attenuation to reduce concentrations of OC pesticides and PCBs in runoff;
- Allow for the completion of monitoring to verify the appropriateness of LAs;
- Identify and implement appropriate BMPs considering crop type, pesticide use, and site specific conditions; then monitor to evaluate effectiveness;
- Implement adaptive management strategies to employ additional BMPs or revise existing BMPs to meet LAs;
- Conduct special studies to evaluate alternative mechanisms for measuring compliance with LAs.

As compliance with the fish tissue and water targets are determined in-stream there is the potential for compliance with the targets without attainment of LAs. Additionally, reducing sediment discharge to the receiving waters could have downstream impacts, such as increasing streambed erosion. These impacts will be examined, and LAs may be revised prior to the final LA achievement dates. Any revisions to these LAs will be based on the collection of additional information developed through special studies and/or monitoring conducted as part of this TMDL.

8.3 Special Studies

The Implementation Plan sets forth special studies to address issues associated with OC pesticides and PCBs that currently require more data to resolve. The implementation schedule for these special studies is included in Table 73.

Special Study #1 - Calculation of Sediment Transport Rates

The Ventura County Watershed Protection District (VCWPD) has the capability to estimate sediment transport rates in the CCW, but their models currently consider only course grain sediment. OC pesticides and PCBs are carried in both course grain and fine grain sediment. The purpose of this special study is to determine sediment transport rates for both course and fine grain sediment. To the extent possible, the study will build upon existing work to estimate transport rates.

Additionally, the Natural Resources Conservation Service (NRCS) is considering a plan to create a comprehensive sediment transport model for the watershed, which will build upon their earlier work (NRCS, 1998). The special study of sediment transport rates proposed here will coordinate with the efforts of NRCS if/when their plan is initiated, and will occur independently if NRCS does not proceed. The knowledge gained from this special study will benefit both VCWPD and NRCS, as well as the OC Pesticides and PCBs TMDL and siltation listings for the CCW.

The results of the study will be used to further evaluate assumptions about the fate of sediment and OC pesticides and PCBs in the CCW. Additionally, if desired by the stakeholders, the study could be used to reevaluate the WLAs and LAs in the TMDL. The initial approach to assigning WLAs and LAs for the OC Pesticides and PCBs TMDL considers only the concentration of OCs in sediment. Eventually, improved understanding of sediment transport rates (for both fine and course sediment) resulting from this special study will allow for estimates of total OC loads in sediment, where:

TMDL = Total OC Load in Sediment = Sediment Transport Rate * OC Concentration in Sediment

Ultimately, calculating OC contributions from different subwatersheds, reaches, and/or land uses according to total mass load in sediment could allow for better targeting of implementation efforts toward areas responsible for the largest inputs of contaminants, better evaluation of the effectiveness of implementation actions, and improved assessments of issues related to siltation. Once sediment transport rates are better understood, WLAs and LAs could be calculated as mass loads.

Special Study #2 - Monitoring of Sediment Concentrations by Land Use Type

The OC Pesticides and PCBs TMDL assigns allocations for urban and agricultural runoff as in-stream sediment concentrations applied at the base of each subwatershed, because no sediment data exists specific to land uses or sources (urban, agriculture, POTWs, etc). Thus, proportional allocations within each subwatershed are not specified, and determination of individual contributions resulting in an exceedance at the base of a subwatershed will rely upon future monitoring efforts and the results of this special study.

The purpose of this special study is to identify sediment concentrations of OC pesticides and PCBs from representative land uses. The study will be conducted over the course of one year and will include monitoring of streambed sediment from urban, agriculture, and native land areas (although collection of terrestrial soil samples might also yield useful data, such collection is not feasible due to highly restricted access to private lands in the watershed). Once completed, this special study will provide the ability to assign proportional allocations within subwatersheds and will also advance understanding of processes and contributions related to fate and transport of OCs in the CCW.

Special Study #3 - Identification of High Concentration Areas

If specific land areas with significantly elevated concentrations of OCs are found to exist, targeting implementation resources upon those areas could reduce in-stream sediment concentrations more effectively per unit of effort than other methods requiring watershed-wide implementation. Thus, identification of any such high concentration areas (HCAs) is an important goal.

Areas within the CCW where relatively higher DDT use occurred in the past have been estimated in the Source Assessment Section of this TMDL, according to examination of historical land use layers using GIS and interviews with local agricultural experts. This initial assessment will be combined with monitoring being conducted under the ongoing PRISM monitoring program conducted by Steve Bachman on behalf of United Water. The PRISM monitoring program collects runoff data from specific land use sites throughout agricultural areas of the CCW. This data will be examined spatially for evidence of HCAs. The PRISM monitoring program and special study #2 will be the primary source of information used to identify HCAs. It is not anticipated that additional monitoring, not required by other aspects of this TMDL, will be necessary to identify HCAs. Rather, the other monitoring studies will include the identification of HCAs as a goal, and the data will be analyzed for the presence of HCAs.

Special Study #4 - Examination of Food Webs, Bioaccumulation, and Wildlife Effects

WLAs and LAs for this TMDL are based upon an assumption (explained in the TMDL and Allocations Section) that a given percent reduction in the concentration of OCs in sediment will result in an approximately equal percent reduction in fish tissue and water. This assumption is based on the notion that bioconcentration factors (BAFs) in the CCW are roughly linear, which may or may not be true. Should the implementation of this TMDL not achieve the goals of reducing concentrations in fish tissue as expected or if a reevaluation of WLAs and LAs is desired, a special study may be developed to create detailed food web models, increase understanding of the biological processes affecting uptake and accumulation of OCs in the tissue of aquatic organisms, and evaluate fish consumption rates for humans and wildlife in the watershed. Work conducted as part of this special study could result in the development of a site-specific objective for one or more of the constituents in this TMDL.

This is an optional special study to be conducted if desired by the stakeholders or determined to be necessary by the Executive Officer.

Special Study #5 – Effect of BMPs Upon Sedimentation and Siltation

Implementation of BMPs to address the OC Pesticides and PCBs, Toxicity, and Nutrient TMDLs will likely result in the reduction of sediment loads to the receiving waters of the CCW. The purpose of this special study is to quantify the amount of sediment discharge that is reduced through implementation of these BMPs. This study will be coordinated with ongoing grant-funded studies in the watershed that are working to evaluate the effectiveness of BMPs and with Special Study #1.

Special Study #6 – Concentration of OCs in Simi Valley Groundwater Discharges

Groundwater pumped from the Simi Valley dewatering wells was sampled on four occasions, of which one sample had detected concentrations of DDE, lindane, and PCBs. A NPDES permit allows the discharge of pumped groundwater from these dewatering wells to the storm drain system, for the purpose of lowering the local water table. Since four samples are likely not representative of groundwater discharges from the Simi Valley dewatering wells, a special study is mandated to determine the actual contribution of OC Pesticides and/or PCBs from these groundwater discharges.

8.4 Reevaluation of WLAs and LAs

A need to revise the numeric targets, WLAs, LAs, or other aspects of the TMDL might result from any of several factors, including but not limited to:

- Information developed through special studies and/or monitoring conducted as part of the TMDL;
- The development of sediment quality objectives by SWRCB, or other water quality criteria revisions;
- Compliance with fish tissue and water column targets prior to attainment of WLAs or LAs;

- Undesired/unexpected effects of TMDL implementation efforts (i.e. increased streambed erosion as a result of BMPs which reduce sediment delivery to receiving waters);
- Inability to attain WLAs or LAs resulting from uncontrollable sources, such as the continued use of OC pesticides in other countries or aerial deposition.

Based on consideration of such issues as described above, reevaluation of the TMDL may become necessary prior to the final WLA and LA achievement dates.

8.5 Monitoring Plan

The Monitoring Plan is designed to monitor and evaluate the implementation of this TMDL and refine the understanding of current OC pesticide and PCB concentrations in water, sediment, and fish tissue. The information presented in this section is intended to be a brief overview of the goals of the Calleguas Creek Watershed TMDL Monitoring Program (CCWTMP) which is included as Attachment A. The CCWTMP is intended to parallel efforts of the CCW Nutrients TMDL and Toxicity TMDL implementation plans.

Monitoring conducted through the forthcoming Conditional Waiver Program may meet part of the needs of the CCWTMP. To the extent monitoring required by the OCs TMDL Implementation Plan parallels monitoring required by the Conditional Waiver Program, it shall be coordinated with Conditional Waiver Program monitoring conducted by individuals and groups subject to the terms and conditions of the waiver. The goals of the CCWTMP include:

1. To determine compliance with numeric targets at monitoring stations generally located at the base of the subwatersheds and at POTW discharges.
2. To determine compliance with waste load and load allocations generally located at the base of the subwatersheds and at POTW discharges.
3. To generate additional land use runoff data (water and sediment) to better understand sources of OCs and proportional contributions from various land use types.
4. To monitor the effect of implementation actions by urban, POTW, and agricultural dischargers on in-stream water and sediment quality and fish tissue concentrations.
5. To implement the CCWTMP in a manner consistent with other TMDL implementation plans and regulatory actions within the CCW.

Estimates of current concentrations and required reductions used to develop this TMDL are based on limited data. Due to the nature of the data set, assumptions were made about outputs from the various dischargers. The collection of data through the CCWTMP will increase the resolution of current data and may indicate the need to refine the WLAs and LAs.

Compliance Monitoring

Monitoring will begin within one year of the effective date of the OC Pesticides and PCBs TMDL. In-stream water column samples will be collected quarterly for analysis of general water quality constituents (GWQC) and OC Pesticides and PCBs. In-stream water column samples will generally be collected at the base of each subwatershed (Table 72) until numeric targets are consistently met at these points. At such a time as numeric targets are consistently met at the discharge point of a subwatershed, an additional site or sites within the subwatershed will be considered for monitoring to ensure numeric targets are met throughout the subwatershed.

Additional samples will be collected concurrently with receiving water samples at representative agricultural and urban runoff discharge sites as well as at POTWs in each of the subwatersheds and analyzed for GWQC and OCs. The location of the land use stations will be determined before initiation of the CCWTMP. For OC Pesticides and PCBs, environmentally relevant detection limits will be used (i.e. detection limits lower than applicable target), if available at a commercial laboratory. All efforts will be made to include at least two wet weather-sampling events during the wet season (October through April) during a targeted storm event.

Streambed sediment samples and fish tissue samples will be collected twice a year for general sediment quality constituents (GSQC) and OC Pesticides and PCBs (Table 72). Sediment samples in Mugu Lagoon will be collected once a year for similar analysis. An annual frequency was selected for Mugu Lagoon sediment sampling due to the relatively slow sedimentation rates in the lagoon in comparison to sample collection depths as discussed in the Sample Collection section of the CCWTMP.

Table 72. Compliance Sampling Station Locations.

Subwatershed	Station ID	Station Location	Sample Media		
			Water	Sediment	Fish Tissue[1]
Mugu Lagoon	01_11_BR	11th Street Bridge	X	X	X[2]
	01_BPT_1	Located near entrance to lagoon		X	
	01_BPT_3	Located in the eastern arm of the lagoon		X	
	01_BPT_6	Located in the eastern part of the western arm		X	
	01_BPT_9	Located near 17th street in far side of western arm		X	
	01_BPT_15	Located in central part of the lagoon		X	
	01_SG_74	Located in central part of the lagoon in mudflat area		X	
Calleguas	03_CAMAR	Calleguas Creek at University Drive	X	X	X
	03D_CAMR	Camrosa Water Reclamation Plant	X		
Revolon Slough	04_WOOD	Revolon Slough East Side of Wood Road	X	X	X
Las Posas	06_SOMIS	Arroyo Las Posas off Somis Road	X	X	X
	06D_MOOR	Moorpark Wastewater Treatment Plant	X		
Arroyo Simi	07_HITCH	Arroyo Simi East of Hitch Boulevard	X	X	X
	07D_SIMI	Simi Valley Water Quality Control Plant	X		
Conejo	9A_HOWAR	Conejo Creek at Howard Road Bridge	X	X	X
	9AD_CAMA	Camarillo Water Reclamation Plant	X		
	10D_HILL	Hill Canyon Wastewater Treatment Plant	X		

1 Attempts will be made to collect fish tissue samples in the same location as water and sediment samples. However, samples may be collected elsewhere if no fish are found at pre-established sample stations.
2 Fish tissue sampling locations in Mugu will be determined in conjunction with biologists prior to sample collection.

Reporting and Modification of CCWTMP

A Monitoring Report will be prepared annually within three months after the completion of the final event of the sampling year. An adaptive management approach to the CCWTMP will be adopted as it may be necessary to modify aspects of the CCWTMP. Results of sampling carried out through the CCWTMP and other programs within the CCW may be used to modify this plan, as appropriate. These modifications will be summarized in the annual report. Possible modifications could include, but are not limited to the, following:

- The inclusion of additional land use stations to accurately characterize loadings;

- The removal of land use stations if it is determined they are duplicative (*i.e.*, a land use site in one subwatershed accurately characterize the land use in other subwatersheds);
- The inclusion of additional in-stream sampling stations;
- Discontinuation of analysis of sediment fractions; and,
- The elimination of analysis for constituents no longer identified in land use and/or in-stream samples.

If a coordinated and comprehensive monitoring plan is developed and meets the goals of this monitoring plan that plan should be considered as a replacement for the CCWTMP.

8.6 Implementation Schedule

Table 73 presents the overall implementation schedule for the Calleguas Creek Watershed OC Pesticides and PCBs TMDL. A concerted effort was made to incorporate ongoing efforts in the CCW with the overall implementation schedule. For instance, two studies assessing concentrations of pesticides in agricultural discharges and agricultural BMPs in Ventura County were initiated in the fall of 2003 and are expected to be completed in 2006. It is possible these studies will provide sufficient information to determine whether or not HCAs are present in the watershed and the quantification of sediment discharge reductions through BMP implementation.

Since the ultimate step to reduce/eliminate the discharge of most OC pesticides and PCBs, banning usage, has already occurred, the implementation schedule presented in Table 73 provides sufficient time to allow implementation measures and natural attenuation to reduce concentrations in the CCW. In addition, time is allotted for the completion of special studies and the reevaluation of the TMDL, if necessary. Finally, implementation actions being undertaken to address the Nutrient and Toxicity TMDL and siltation listings in the CCW may result in compliance with the allocations in this TMDL. Therefore, the schedule allows time for implementation and evaluation of these actions and implementation of additional activities if necessary.

Table 73. Implementation schedule for the Calleguas Creek Watershed OC Pesticides and PCBs TMDL.

Item	Implementation Action[1]	Responsible Party	Tentative Date
1	Effective date of phased OC waste load allocations.[2]	POTW Permittees, MS4 Permittees	Effective date[2]
2	Effective date of phased OC load allocations.[2]	Agricultural Dischargers	Effective date[2]
3	Implement Calleguas Creek Watershed OC Monitoring Program.	POTW Permittees, MS4 Permittees and Agricultural Dischargers	Within 1 year of effective date
4	Develop and implement source identification and control study.	POTW Permittees	Within 1-3 years of effective date.
5	Develop and implement collection program for all banned OC pesticides and PCBs.	POTW Permittees, MS4 Permittees	Within 3 years of effective date.
6	Special Study #1 – Calculation of sediment transport rates in the CCW	Agricultural Dischargers, MS4 Permittees	Within 5 years of effective date
7	Special Study #2 – Monitoring of sediment by source / land use type (SS#2 is part of SS#1 in the Basin Plan Amendment)	Agricultural Dischargers, MS4 Permittees	Within 2 years of effective date
8	Special study #3 – Identifying High Concentration Areas (HCAs)	Agricultural Dischargers, MS4 Permittees	Within 5 years of effective date.
9	If HCAs are found, implement additional erosion control measures in those areas.	MS4 Permittees	Within 7 years of effective date.
10	Evaluate sediment activities in the CCW to determine impacts on OC transport to receiving waters.	MS4 Permittees	Within 3 years of effective date.
11	If appropriate, implement changes to sediment activities in the CCW to minimize OC transport.	MS4 Permittees	Within 3 years of completion of the evaluation study
12	Identify and implement appropriate BMPs and the extent to which BMPs are currently implemented in the CCW.	Agricultural Dischargers	Within 3 years of effective date
13	Development of an Agricultural Water Quality Management Plan in conjunction with the Conditional Waiver for Irrigated Lands, or (if the Conditional Waiver is not adopted in a timely manner) the development of an Agricultural Water Quality Management Plan as part of the Calleguas Creek WMP.	Agricultural Dischargers	Within 3 years of effective date.
14	Implement educational program on BMPs identified in the Agricultural Water Quality Management Plan.	Agricultural Dischargers	Within 5 years of effective date
15	Begin implementation of BMPs appropriate for other related CCW TMDLs.	Agricultural Dischargers	Within 6 years of effective date
16	Evaluate effectiveness of those BMPs for controlling OC runoff.	Agricultural Dischargers	6 years from effective date
17	If needed, implement additional BMPs or revise existing BMPs to address any issues not covered by implementation efforts of related CCW TMDLs (Nutrients, Toxicity, siltation listings)	Agricultural Dischargers	7 years from effective date
18	Special Study #4 (optional) – Examination of food web and bioconcentration relationships throughout the watershed to ensure protection of wildlife is achieved. (SS#4 is SS#6 in BPA)	Interested Parties	To be conducted if necessary prior to the end of the implementation period
19	Special study #5 – Effects of BMPs on Sediment and Siltation	Agricultural Dischargers, MS4 Permittees	6 years from effective date
20	Based on the results of items 1-19, Regional Board will consider reevaluation of the TMDLs and WLAs and LAs if necessary.	Regional Board	Within 2 years of the submittal of information necessary to reevaluate the TMDL
21	Evaluation of degradation rates (SS#5 in BPA)	POTWs, Agricultural Dischargers, MS4 Permittees, US Naval Base	12 years
22	Achievement of Final WLAs and LAs	Agricultural Dischargers, POTW Permittees, and MS4 Permittees	2025[3]

[1] The Regional Board regulatory programs addressing all discharges in effect at the time this implementation task is due may contain requirements substantially similar to the requirements of these implementation tasks. If such requirements are in place in another regulatory program including other TMDLs, the Executive Officer may revise or eliminate this implementation task to coordinate this TMDL implementation plan with other regulatory programs.

[2] Interim WLAs and Interim LAs are effective immediately upon TMDL Adoption. WLAs will be placed in POTW NPDES permits as effluent limits. WLAs will be placed in stormwater NPDES permits as in-stream limits. LAs will be implemented using applicable regulatory mechanisms.

[3] Date of achievement of WLAs and LAs based on the estimated timeframe for educational programs, special studies, implementation of appropriate BMPs, and predicted trends of natural attenuation. The conditional waiver will set the timeframes for the BMP management plans.

8.7 Adaptive Management

Implementation of the OC Pesticides and PCBs TMDL will operate within an adaptive management framework where compliance monitoring, special studies, and stakeholder interaction guide the process as it develops through time. Compliance monitoring will generate information critical for measuring progress toward achievement of WLAs and LAs, and may suggest the need for revision of those allocations in some instances. Additionally, data from ongoing monitoring could reveal necessary adjustments to the implementation timeline and may serve to initiate reevaluation when appropriate. Special studies will increase understanding of specific conditions/processes in the watershed, allowing for more accurate prediction of results expected from various implementation efforts. Thus, adaptive management allows this TMDL to be an ongoing and dynamic process, rather than a static document.

Leadership of the adaptive management program will involve individuals from a range of groups. The LARWQCB will oversee compliance monitoring and any potential need for reevaluation of this TMDL. Individual stakeholders or stakeholder groups may contribute time and expertise to special studies. The Ventura County Watershed Protection District has significant resources and personnel dedicated to improving the understanding of sediment transport in watersheds of the region, including the CCW. United Water is involved in a program to monitor effects upon water quality from various agricultural land uses, which will likely generate information beneficial for the efficacy of the Implementation Plan. Many stakeholders have been working together since 1996 toward the development of a Watershed Management Plan for Calleguas Creek. The purpose of the Watershed Management Plan is to develop a strategy for addressing a variety of needs in the watershed, including: flood control, erosion and sedimentation, water quality, water resources, and habitat. When developed, this plan should identify mechanisms for addressing the water quality issues within the watershed, including 303(d)-listed pollutants. As such, the plan will serve as the ultimate implementation plan for all of the TMDLs within the watershed.

8.8 Economic Analysis of Implementation

Water Code Section 13000 requires the State and Regional Boards to regulate so as to achieve the highest water quality that is reasonable, based on consideration of economics and other public interest factors. Water Code Section 13141 requires that prior to the implementation of any agricultural water quality control program; an estimate of the total cost of the program and identification of potential sources of financing shall be included in any applicable regional water quality control plan. An analysis of the impacts of implementing these TMDLs with respect to costs, benefits, and other public interests factors is presented below.

The WLA Implementation Plan focuses on education, collection, water conservation, and monitoring to expedite the removal of OC Pesticides and PCBs from the watershed. Table 74 summarizes the goals of the education/collection program as well as estimated costs for the WLA implementation actions.

Table 74. Waste Load Allocation Implementation Plan actions and Cost Estimates

Implementation Action and Goals	Estimated Cost
Develop and implement urban educational and collection program. The goals of this program are: 1. Provide information on: • Bans and restrictions on use of OC pesticides and PCBs. • The harmful effects of OC pesticides and PCBs. • The proper use and disposal of pesticides. • Alternative pest control techniques including integrated pest management. • Methods for reducing urban water use and runoff. • Household hazardous waste collection program to collect any remaining OC pesticide and PCB stocks. 2. Assess effectiveness of program for achieving WLAs.	$150,000/year for a minimum of three years
Develop and implement source identification and control program	$10,000 for source identification. Additional costs could arise from actions to control identified controllable sources.
If identified, implement additional construction controls in HCAs.	$2400/yr [1]
Evaluate and if identified, implement changes to sediment activities in watershed.	$10,000 for evaluation of sediment activities. Additional

[1] Estimated based on 4 hours of inspection time at $60/yr at 10 construction sites.

As presented in the LA Section, BMPs will likely be necessary to reduce agricultural loads to achieve LAs. The LA Implementation Plan focuses on education, water conservation, and implementation of BMPs. Table 75 summarizes the goals of the programs and studies as well as estimated costs. Since the implementation plan for the OC Pesticides and PCBs TMDL has a much longer timeline for completion than other related TMDLs in the CCW (Nutrients, Toxicity, Sediment), implementation actions put in place by the other TMDLs will likely accomplish many or even all of the necessary goals for the OCs TMDL. The estimates of cost shown in Table 75 are the costs of the full program of implementation. It is expected that these costs will cover implementation for all of the related TMDLs and are therefore not separate costs to be added together for each TMDL.

Table 75. Load Allocation Implementation Plan Actions and Cost Estimates

Implementation Action and Goals	Estimated Cost [1]
Develop and implement an Agricultural Water Quality Management Plan. The goal of this action is to develop a management plan to address identified water quality impairments and meet water quality objectives.	$700,000
Identify appropriate BMPs and the extent to which BMPs are currently implemented in the CCW. The goal of this action is to complete studies to determine the most appropriate BMPs for the CCW given crop type, pesticide, site specific conditions, as well as the critical conditions as well as the current BMPs utilized in the CCW and the extent to which they are currently implemented.	This work is currently being conducted and will not require additional funding.
Develop and implement agricultural BMP education program. The goals of this program are to: 1. Provide information on: • BMPs identified in the aforementioned studies as well as other BMPs deemed to be effective at reducing runoff to water bodies given crop type, pesticide, site specific conditions, as well as the critical conditions. • Bans and restrictions on use of OC pesticides and PCBs. • The harmful effects of OC pesticides and PCBs. • The proper use and disposal of pesticides. • Alternative pest control techniques including integrated pest management. • Methods for reducing water use and runoff. 2. Assess effectiveness of program.	$75,000/year for a minimum of three years
Implement BMPs. The goal of this action is to implement BMPs to address OC pesticides and PCBs and to assess their effectiveness for achieving LAs.	$3,300,000 - $140,000,000

1 All of the costs presented in this table represent the costs of the entire program. In many cases the implementation actions are similar for other CCW TMDLs. These are considered total costs and are not independent costs to be added for each TMDL.

Table 76 summarizes the estimated unit costs and watershed wide costs associated with implementing a wide range of possible agricultural BMPs. Currently it is unclear which BMPs have been implemented in the CCW or the extent to which those BMPs have been implemented. Because of this, in developing the estimated cost for implementing BMPs it was assumed that 1) no BMPs are implemented in the CCW and 2) BMPs are required on all agricultural lands. Cost estimates were developed by selecting the least and most expensive options by category for the low and high cost estimates, respectively. The range of estimates is likely high given the broad assumptions used.

Table 76. Estimated Costs for Applicable Agricultural Best Management Practices (BMPs) for Reducing Pesticide Loading[1,2]

Agricultural BMP	Units	Cost Range Per Unit		Cost Range For Watershed	
		Low	High	Low	High
Conservation Tillage					
No Till	acre	-$11.50	$5.70	-$227,800	$112,900
Mulch Till	acre	$11.50	$22.90	$227,800	$453,600
Contour Farming	acre	$9.20	$114.60	$96,600	$1,203,300
Contour Orchard and Other Fruit Area	acre	$114.60	$149.00	$1,203,300	$1,564,500
Crop Residue Use					
Chopping and Chopping Waste	acre	$28.70	$68.80	$568,500	$1,362,800
Mulching using min. Tillage	acre	$11.50	$28.70	$227,800	$568,500
Filter Strip					
Filter Strip (10-20 ft wide)	acre	$430	$14,326	$80,500	$2,682,500
Filter Strip (20-40 ft wide)	acre	$430	$14,326	$161,000	$5,364,900
Filter Strip (40-60 ft wide)	acre	$430	$14,326	$321,900	$10,729,900
Buffer Strip (20-30 ft wide)	acre	$487	$1,948	$182,400	$729,600
Landscaping (20-30 ft wide)	acre	$516	$4,011	$193,100	$1,502,200
Grassed Waterway	acre	$430	$14,326	$403,400	$13,412,300
Hillside Bench	acre	$40	$2,120	$421,050	$22,262,100
Irrigation Systems					
Irrigation System: Sprinkler	acre	$401	$1,261	$7,945,000	$24,971,950
Irrigation System: Trickle					
Microspray System	acre	$974	$3,667	$19,296,050	$72,643,900
Drip Irrigation	acre	$2,120	$4,126	$41,996,900	$91,723,850
Irrigation System					
Tailwater Recovery	each	$5,157	$28,652	NC	NC
Irrigation Water Management	acre	$57	$28,652	$1,135,000	$17,025,000
Runoff Management system					
Sediment Basin	each	$802	$1,150,000	NC	NC
Infiltration Trench	per foot	$17	$86	NC	NC
Sediment Trap, Box Inlet	each	$212	$974	NC	NC
			Total[3]	**$3,300,000**	**$140,000,000**

NC Not calculated as there was not a clear method for estimating the total units needed.

[1] From: Calleguas Creek Watershed Erosion and Sediment Control Plan for Mugu Lagoon (NRCS, 1995).

[2] Costs adjusted from 1995 to 2000 using Engineering News Record Construction Cost Index.

[3] The total for the Low Cost Range determined by selecting the least expensive BMP from each subgroup. The total for the High Cost Range determined by selecting the most expensive BMP from each subgroup.

9 REFERENCES

40 Code of Federal Regulations (40 CFR) Part 130 (TMDL Rule). 2000. United States Environmental Protection Agency (USEPA).

Abrol, S., Augustenborg, C., Madden, C., Suffet, M. 2003. Development of a TMDL for Organochlorine Pesticides for the Calleguas Creek Watershed. Prepared for the Los Angeles Regional Water Quality Control Board. Contract No. 01-172-140-0. September 2003.

Agency for Toxic Substances and Disease Registry (ATSDR). 1994. Toxicological Profile for Chlordane, U.S. Department of Health and Human Services. May 1994

Agency for Toxic Substances and Disease Registry (ATSDR). 1996. Toxicological Profile for Toxaphene. U.S. Department of Health and Human Services. August 1996.

Agency for Toxic Substances and Disease Registry (ATSDR). 2000. Toxicological Profile for Polychlorinated Biphenyls (PCBs). U.S. Department of Health and Human Services. November 2000

Agency for Toxic Substances and Disease Registry (ATSDR). 2002a. Toxicological Profile for DDT. U.S. Department of Health and Human Services. September 2002

Agency for Toxic Substances and Disease Registry (ATSDR). 2002b. Toxicological Profile for Aldrin/Dieldrin. U.S. Department of Health and Human Services. September 2002

Anderson, B.S. et al. 2002. Causes of Ambient Toxicity in the Calleguas Creek Watershed of Southern California, Environmental Monitoring and Assessment, 78: 131-151-2002.

Aislabie, J.M., Richards, N.K., Boul, H.L. 1997. Microbial Degradation of DDT and its Residues – a Review. New Zealand Journal of Agricultural Research 40: 269 – 282.

Anderson, B.S.; Vlaming, V. DE; Larsen, K.; Deanovic, L.S.; Birosik, S.; Smith, D.J.; Hunt J.W.; Phillips B.M.; and Tjeerdema R.S. 2002. Causes of Ambient Toxicity in the Calleguas Creek Watershed of Southern California. Environmental Monitoring and Assessment. 78, 131-151.

Barron, M.G.; Heintz, R.; and Krahn, M.M. 2003. Contaminant Exposure and Effects in Pinnipeds: Implications for Steller Sea Lion Declines in Alaska. Science of the Total Environment, 311(1-3): 111-133.

Braune, B. et al., 1999. Spatial and Temporal Trends of Contaminants in Canadian Arctic Freshwater and Terrestrial Ecosystems: a Review. Science of the Total Environment, 230(1-3): 145-207.

Buchman. 1999. NOAA Screening Quick Reference Table, NOAA HAZMAT Report 99-1, Seattle, WA, Coastal Protection and Restoration Division, National Oceanic and Atmospheric Administration, 12 pages.

Burkhard, Lawrence; Armstrong, David; and Andren, Anders. 1985. Henry's Law Constants for the Polychlorinated Biphenyls. Environmental Science & Technology 19 (7): 590-596 1985.

California Resources Agency. 1997. CWIS Mugu Lagoon. California Environmental Resources Evaluation System (CERES). Website: http://ceres.ca.gov/wetlands/geo_info/so_cal/mugu_lagoon.html.

Chan, C.H.; Bruce, G.; and Harrison, B. 1994. Wet Deposition of Organochlorine Pesticides and Polychlorinated Biphenyls to the Great Lakes. Journal of Great Lakes Research, 20 (3): 546-560.

California Department of Pesticide Regulation (DPR). 2000. DPR Pesticide Use Reporting; An Overview of California's Unique Full Reporting System. Published May 2000. Downloaded from DPR website, March 2004.

California Department of Pesticide Regulation (DPR). 2004. Pesticide Use Report Data for 1991-2003. Data acquired from Linda Lichtenberger, March 2004, llichtenberger@cdpr.ca.gov.

California Department of Water.Resources (DWR). 2000. Land use survey GIS data. Website visited April 2004: http://www.landwateruse.water.ca.gov/basicdata/landuse/landusesurvey.cfm .

Cox, Caroline. 1991. Pesticides and Birds: From DDT to Today's Poisons. Journal Of Pesticide Reform / Winter, 1991 / VOL. 11, NO. 4.

EIP Associates. 1997. Organochlorine Pesticides Source Identification. Prepared for Palo Alto Regional Water Quality Control Plant by EIP Associates. October 28, 1997.

Franz, T.P.; S.J. Eisenreich; and T.M. Holsen. 1998. Dry deposition of particulate PCBs and PAHs to Lake Michigan. Environmental Science and Technology. 1998, 32: 3681-3688. Cited in ATSDR 2000. Toxicological Profile for Polychlorinated Biphenyls (PCBs). US Department of Health and Human Services Public Health Service Agency for Toxic Substances and Disease Registry. November 2000.

Granade, Steve. 2003. Environmental Engineer, Naval Base Ventura County, steve.granade@navy.mil. Personal communication with C. Minton, August 4, 2003.

Grigorian, Grigor. 2001. Personal Communication with Ashli Cooper. January 18, 2001.

Heberer, T, and Dunnbier, U. 1999. DDT Metabolite Bis(Chlorophenyl)acetic acid: the Neglected Environmental Contaminant. Environmental Science and Technology 33: 2346-2351.

Helsel D.R. and R.M. Hirsch. 1992. Statistical Methods in Water Resources, Elsevier Science B.V., Amsterdam.

Helsel, D.R. and T.A. Cohn. 1988. Estimation of Descriptive Statistics for Multiply Censored Water Quality Data, Water Resour. Res. Vol. 24, No. 12, pp. 1997-2004.

Helsel, Dennis. 1990. Less than Obvious, Statistical Treatment of Data Below the Detection Limit. Environmental Science and Technology, Vol 24, No 12.

Hothem, R.L. and Powell, A.N. 2000. Contaminants in Eggs of Western Snowy Plovers and California Least Terns: Is There a Link to Population Decline? Bulletin of Environmental Contamination and Toxicology, Volume 65, Pages: 42 – 50.

Jorgenson, J. Lisa. 2001. Aldrin and Dieldrin: A Review of Research on Their Production, Environmental Deposition and Fate, Bioaccumulation, Toxicology, and Epidemiology in the United States, Environmental Health Perspectives Supplements, Volume 109, Number S1. March 2001.

Kulovaara, M., Backlund, P. and Corin, N. 1995. Light-induced degradation of DDT in humic water. Science of the Total Environment, 170(3): 185-191.

Landis, John D. PhD. 1998. Development and Pilot Application of the California Urban and Biodiversity Analysis Model. Forthcoming in Computers, Environment, and Urban Systems, http://gis.esri.com/library/userconf/proc98/PROCEED/TO600/PAP571/P571.htm.

Larry Walker Associates (LWA). 1999. Calleguas Creek Characterization Study, Surface Water Element, 1998-1999.

Larry Walker Associates (LWA). 2004a. Calleguas Creek Watershed Database. Accessed December 2004.

Larry Walker Associates (LWA). 2004b. Progress Report on Efforts to Address Salts on the Calleguas Creek Watershed. Submitted to Calleguas Creek Watershed Management Plan, pp. 105, June 30, 2004.

Lichtenberger, Linda. 2004. California Dept of Pesticide Regulation (DPR), llichtenberger@cdpr.ca.gov . Personal communication to Michael Casterline, April 2004.

Los Angeles Regional Water Quality Control Board (LARWQCB). 2002. Draft Staff Report – 2002 Update: Clean Water Act Section 305(b) Report and Section 303(d) List of Impaired Waters – LA Region. January 29, 2002.

Los Angeles Regional Water Quality Control Board (LARWQCB). 2003. 2002 Clean Water Act Section 303(d) List of Water Quality Limited Segments; Calleguas Creek Listings.

Long ER, Field LJ, MacDonald DD. 1998. Predicting toxicity in marine sediments with numerical sediment quality guidelines. Environ Toxicol Chem 17: 714-727.

MacDonald, DD. 1994. Approach to the Assessment of Sediment Quality in Florida Coastal Waters. Volume 1 – Development and Evaluation of Sediment Quality Assessment Guidelines.

Mackay, D., W. Shiu, and K. Ma. 1997. Illustrated Handbook of Physical-chemical Properties and Environmental Fate for Organic Chemicals. Volume V: Pesticide chemicals. Lewis Publishers, Boca Raton, FL.

McIntyre, Sam. 2004. Pesticide Advisor, Somis Ag Management Inc. sompacag@aol.com . Personal communication to Michael Casterline, May 2004.

Minjares, Javier. 2004. Southern California Association of Governments, Population Growth by City for SCAG Region for 2000-2030 (pre-website release of population projections), minjares@scag.ca.gov.

Mischke, Tom; Brunetti, K; Acosta, V; Weaver, D; Brown, Mary. 1985. Agricultural Sources of DDT Residues in California's Environment. California Department of Food and Agriculture (Environmental Hazards Assessment Program). http://www.cdpr.ca.gov/docs/ipminov/ddt/ddt.htm. September 1985

Muir, D. et al. 1999. Spatial and Temporal Trends and Effects of Contaminants in the Canadian Arctic Marine Ecosystem: a Review. Science of the Total Environment, 230(1-3): 83-144.

National Oceanic and Atmospheric Administration (NOAA). 1999. Sediment Quality Guidelines Developed for the National Status and Trends Program. Office of Response and Restoration, National Ocean Service. Updated 6/28/99.

Park, J.S.; Wade, T.L. 2001. Atmospheric Deposition of Organochlorine Contaminants to Galveston Bay, Texas. Atmospheric Environment, 35: 3315-3324.

Pereira, W.E., Hostettler, F.D. and Rapp, J.B. 1996. Distributions and Fate of Chlorinated Pesticides, Biomarkers and Polycyclic Aromatic Hydrocarbons in Sediments Along a Contamination Gradient from a Point-source in San Francisco Bay, California. Mar. Environ. Res, 41(3): 299-314.

Saillant, Catherine. 2004. Land Tax to Go on Ballot. Los Angeles Times, April 28th 2004. www.latimes.com/news/local/ventura.

San Francisco Bay Regional Water Quality Control Board (SFBRWQCB). January 2004. PCBs in San Francisco Bay, Total Maximum Daily Load Report.

San Francisco Bay Regional Water Quality Control Board (SFBRWQCB). 2004. Mercury in San Francisco Bay Total Maximum Daily Load (TMDL) Proposed Basin Plan Amendment and Staff Report. September 2, 2004.

Smith, Randy. 2004. Ventura County Mosquito Abatement and Vector Control, randy.smith@mail.co.ventura.ca.us. Personal communication to Michael Casterline, March 2004.

Southern California Association of Governments (SCAG). 2004. Urban land use GIS data. Website visited June 2004: http://rtmisweb.scag.ca.gov/data_gis/.

Shumway,Robert; Azari, Rahman; Kayhanian, Masoud. 2002. Statistical Approaches to Estimating Mean Water Quality Concentrations with Detection Limits. Environmental Science and Technology, Vol 36.

Snedeker, Suzanne M. March 2001. Pesticides and Breast Cancer Risk: A Review of DDT, DDE, and Dieldrin. Environmental Health Perspectives, Volume 109, Supplement 1.

Spencer W.F., Singh G., Taylor C.D., LeMert R.A., Cliath M.M., and Farmer W.J. July-August 1996. DDT Persistence and Volatility as Affected by Management Practices after 23 Years. Journal of Environmental Quality, Volume. 25.

State Water Resources Control Board (SWRCB). 1997. Proposed Decision Regarding Application 29408 and Wastewater Change Petition No. 6 of the City of Thousand Oaks and Availability of Unappropriated Water for Applications 29816, 29819, 29581, 29959, 300317, 30092, and 30194--Arroyo Conejo, Conejo Creek, and Calleguas Creek in Ventura County. Sacramento, California. August 1997.

State Water Resources Control Board (SWRCB). 2004a. State Mussel Watch Program (SMWP) website visited August 2004: http://www.swrcb.ca.gov/programs/smw/index.html .

State Water Resources Control Board (SWRCB). 2004b. Toxic Substances Monitoring Program (TSMP) website visited August 2004: http://www.swrcb.ca.gov/programs/smw/index.html .

State Water Resources Control Board (SWRCB). 2004c. Water Quality Control Policy For Developing California's Clean Water Act Section 303(D) List. September 30th, 2004

United States Census Bureau (USCB). Website visited May 2004: http://www.census.gov/population/projections/state/stpjpop.txt .

United States Navy. 2000. Unpublished data from Steve Granade, Environmental Engineer, Naval Base Ventura County, steve.granade@navy.mil .

United States Department of Agriculture, Natural Resources Conservation Service (USDA, NRCS). 1995. Calleguas Creek Watershed Erosion and Sediment Control Plan for Mugu Lagoon. USDA Report prepared by Water Resources Planning Staff.

United States Environmental Protection Agency (US EPA). 1980. Ambient Water Quality Criteria for Aldrin/Dieldrin. Office of Water Regulations and Standards Criteria and Standards Division. (other criteria documents available at USEPA website: http://www.epa.gov/waterscience/pc/ambient2.html).

United States Environmental Protection Agency (US EPA). 1980. Ambient Water Quality Criteria for Chlordane. Office of Water Regulations and Standards Criteria and Standards Division. (other criteria documents available at USEPA website: http://www.epa.gov/waterscience/pc/ambient2.html).

United States Environmental Protection Agency (US EPA). 1980. Ambient Water Quality Criteria for DDT. Office of Water Regulations and Standards Criteria and Standards Division. (other criteria documents available at USEPA website: http://www.epa.gov/waterscience/pc/ambient2.html).

United States Environmental Protection Agency (US EPA). 1998. Reregistration Eligibility Decision: Dicofol. EPA 738-R-98-018. November 1998. R.E.D. Facts: Dicofol. November 1998

United State Environmental Protection Agency (USEPA). 1999. The Road to Zero? U.S. Federal and State Regulatory Support for the Great Lakes Binational Toxics Strategy, Report to the U.S. Environmental Protection Agency.

United States Environmental Protection Agency (US EPA). 1991. Guidance for Water Quality-based Decisions: the TMDL Process. Office of Water. Washington, D.C. EPA 440/4-91-001. April, 1991. http://www.epa.gov/OWOW/tmdl/decisions/ .

United States Environmental Protection Agency (US EPA). 2002. Total Maximum Daily Loads for Toxic Pollutants – San Diego Creek and Newport Bay, California. US Environmental Protection Agency, Region 9. Established June 14, 2002.

United States Geological Survey (USGS). 2004. Website visited May 2004: http://ca.water.usgs.gov/archive/reports/ofr96_629/geog.html#1.5 .

Ventura County (website), May 2004, http://www.countyofventura.org/visitor/visitor.asp.

Wandji, Serge-Alain, Ph.D.; Gandhi, Renu, Ph.D.; Snedeker, Suzanne, Ph.D. October 1998. Critical Evaluation of Chlordane's Breast Cancer Risk. Cornell University, Sprecher Institute for Comparative Cancer Research, Program on Breast Cancer and Environmental Risk Factors. http://envirocancer.cornell.edu/ .

Wania and Mackay *in litt* 1996. Cited in ATSDR 2000. Toxicological Profile for Polychlorinated Biphenyls (PCBs). US Department of Health and Human Services Public Health Service Agency for Toxic Substances and Disease Registry. November 2000.

Zepp, R.G., and D.M. Cline. 1977. Rates of direct photolysis in aquatic environment. Environmental Science and Technology, 11(4): 359-366.

Appendix I – Planning Species for the Calleguas Creek Watershed Evaluation Study (www.calleguascreek.org)

Common Name	Scientific name	Federal/State Status
BIRDS		
Cooper's hawk	*Accipiter cooperii*	- -/CSC
Sharp-shinned hawk	*Accipiter gentilis*	- -/CSC
Tri-colored blackbird	*Agelaius tricolor*	FSC/CSC
Southern California rufous-crowned sparrow	*Aimophila ruficeps canescens*	FSC/CSC
Bell's sage sparrow	*Amphispiza belli belli*	FSC/CSC
Golden eagle	*Aquila chrysaetos*	- -/CFP
Burrowing owl	*Athene cunicularia*	FSC/CSC
Western snowy plover	*Charadrius alexandrinus nivosus*	FT/CSC
Mountain plover	*Charadrius montanus*	FSC/CSC
Northern harrier	*Circus cyaeneus*	CSC
Yellow warbler	*Dendroica petechia brewsteri*	- -/CSC
White-tailed kite	*Elanus leucurus*	- -/CFP
Southwestern willow flycatcher	*Epimodonax traillii extimus*	FE/CE
California horned lark	*Eremophila alpestris actia*	- -/CSC
Prairie falcon	*Falco mexicanus*	- -/CSC
Merlin	*Falco columbarius*	CSC
Yellow-breasted chat	*Icteria virens auricollis*	- -/CSC
Loggerhead shrike	*Lanius ludovivianus*	FSC/CSC
Long-billed curlew	*Numenius americanus*	- -/CSC
Belding's savannah sparrow	*Passerculus sandwichensis beldingi*	FSC/CE
California brown pelican	*Pelecanus occidentalis californicus*	FE/CE
Double-crested cormorant	*Phalacrocorax auritus*	- -/CSC
Coastal cactus wren	*Campylorhynchus brunneicapillus cousei*	FSC/CSC
Coastal California gnatcatcher	*Polioptila californica californica*	FT/CSC
Light-footed clapper rail	*Rallus longirostris levipes*	FE/CE
Bank swallow	*Riparia riparia*	- -/CT
California least tern	*Sterna antillarum browni*	FE/CE
Least Bell's vireo	*Vireo bellii pusillus*	FE/CE
MAMMALS		
Ringtail	*Bassariscus astutus*	--/CFP
Coyote	*Canis latrans*	- -/- -
Yuma myotis	*Myotis yumanensis*	FSC/CSC
California mastiff bat	*Eumops perotis californicus*	FSC/CSC
Mountain lion	*Felis concolor*	- -/- -
Bobcat	*Felis rufus*	- -/- -
San Diego black-tailed jackrabbit	*Lepus californicus bennetti*	FSC/CSC
San Diego desert woodrat	*Neotoma lepida intermedia*	FSC/CSC
American badger	*Taxidea taxus*	- -/- -
Black bear	*Ursa americanus*	- -/- -

FT – Federally Threatened; FE – Federally Endangered; FSC – Federal Species of Concern (formerly Category 2 or Category 3 candidate or proposed for federal listing); CE – State Endangered; CT – State Threatened; CFP – State Fully Protected; CSC – State Species of Special Concern.

Appendix II – Least Tern and Clapper Rail Data from Point Mugu Navy Base

Unpublished data from the U.S. Navy contains information about OC pesticides and PCB concentrations in California Least Tern chicks (dead from unknown causes), California Least Tern eggs (abandoned and unhatched), Light Footed Clapper Rail chicks (dead from unknown causes), Light Footed Clapper Rail eggs (abandoned and unhatched), and fish recovered from abandoned nests found on the Point Mugu Navy Base (U.S. Navy, 2000). A range of OCs were considered, including: DDD, DDE, DDT, PCBs (five aroclors), aldrin, HCH (including lindane), chlordane, dieldrin, endosulfan, endrin, heptachlor, heptachlor epoxide, and toxaphene. DDD, DDE, and HCH (beta-BHC) were the only constituents detected; and about 90% of those detections were for DDE. Those DDE data are shown in Table 77.

Table 77. DDE content in chicks and eggs of California Least Terns, Light Footed Clapper Rails, and fish found in abandoned nests on the Point Mugu Navy Base (U.S. Navy, 2000).

Client-ID	Collected	n (total)	n (detected)	Result	Units	Average Reporting Limit	Average Detected Concentration
Least Tern Chick	8/7/2000	13	13	1.3	ug/g	0.258	1.41
Least Tern Egg Contents	8/7/2000	6	6	0.48	ug/g	0.157	0.61
Fish	8/8/2000	3	1	0.12	ug/g	0.060	0.12
Clapper Rail Chick	8/7/2000	1	1	1.9	ug/g	0.083	1.90
Clapper Rail Egg Contents	8/7/2000	5	5	0.29	ug/g	0.017	0.33

Egg shell thickness of the unhatched eggs was also measured. A comparison of egg shell thickness and DDE concentration is shown in Figure 31. A relationship seems to exist between DDE concentration and egg shell thickness (although more samples are needed to provide statistical certainty), consistent with findings in the literature that thinning of eggshells may result when birds eat fish and/or other organisms contaminated by DDE, DDE, or DDT (Cox, 1991).

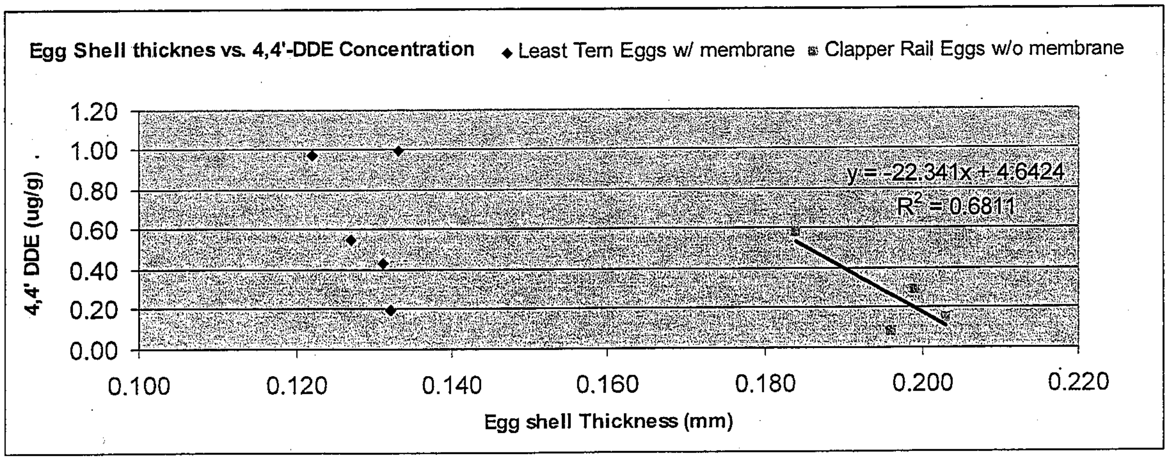


Figure 31. Plot of egg shell thickness vs. 4,4' DDE concentration in Least Tern and Clapper Rail eggs from Mugu Lagoon (U.S. Navy, 2000). All but one of the Least Tern eggs included measurable membrane and all but one of the Clapper Rail eggs did not include measurable membrane.

Appendix III - Land Use in the Calleguas Creek Watershed by Subcategory (DWR, 2000 Land Use Layer)

Name (class1,subclass1)	Acres in CCW	% of CCW	Acres of Utilized Land	% of Utilized Land
native veg	103,689.95	47.1%	--	--
urban	52,723.13	24.0%	52,723.13	47.1%
lemons	17,647.92	8.0%	17,647.92	15.8%
avocados	7,913.95	3.6%	7,913.95	7.1%
strawberries	5,261.21	2.4%	5,261.21	4.7%
peppers	3,048.93	1.4%	3,048.93	2.7%
beans(green)	2,938.90	1.3%	2,938.90	2.6%
celery	2,643.34	1.2%	2,643.34	2.4%
no data	2,491.16	1.1%	--	--
misc truck	2,307.12	1.0%	2,307.12	2.1%
flowers,nursery,xmas tree	2,295.47	1.0%	2,295.47	2.1%
onions, garlic	1,520.59	0.7%	1,520.59	1.4%
turf farms	1,424.69	0.6%	1,424.69	1.3%
golf course	1,276.71	0.6%	1,276.71	1.1%
lawn area, irr	1,132.84	0.5%	1,132.84	1.0%
mixed(4)	1,091.30	0.5%	1,091.30	1.0%
lettuce	1,039.00	0.5%	1,039.00	0.9%
citrus (misc)	846.87	0.4%	846.87	0.8%
melon,squash,cuc	818.42	0.4%	818.42	0.7%
riparian	815.14	0.4%	--	--
oranges	676.46	0.3%	676.46	0.6%
corn (field and sweet)	650.51	0.3%	650.51	0.6%
truck crops (misc)	626.95	0.3%	626.95	0.6%
water	610.72	0.3%	--	--
broccoli	512.11	0.2%	512.11	0.5%
misc field	482.23	0.2%	482.23	0.4%
cabbage	464.71	0.2%	464.71	0.4%
barley	373.14	0.2%	373.14	0.3%
tomatoes	346.09	0.2%	346.09	0.3%
mixed pasture	340.96	0.2%	340.96	0.3%
livestock feed lots	321.04	0.1%	321.04	0.3%
barren	290.32	0.1%	--	--
bush berries	244.12	0.1%	244.12	0.2%
cole crops	217.13	0.1%	217.13	0.2%
cauliflower	177.42	0.1%	177.42	0.2%
spinach	119.46	0.1%	119.46	0.1%
grain (misc)	105.67	0.0%	105.67	0.1%
sudan	73.79	0.0%	73.79	0.1%
artichoke	66.99	0.0%	66.99	0.1%
idle	121.63	0.1%	--	--
carrots	53.97	0.0%	53.97	0.0%
vinyard	41.14	0.0%	41.14	0.0%
farmsteads	38.42	0.0%	38.42	0.0%
pasture (misc)	27.52	0.0%	27.52	0.0%
pistachios	11.61	0.0%	11.61	0.0%
poultry	9.75	0.0%	9.75	0.0%
grapefruit	9.68	0.0%	9.68	0.0%
walnuts	8.19	0.0%	8.19	0.0%
misc subtropical fruit	6.63	0.0%	6.63	0.0%
wheat	5.76	0.0%	5.76	0.0%
cemetary, irr	5.47	0.0%	5.47	0.0%
total =	**219,966.22**	**100.0%**	**111,947.30**	**100.0%**

California Regional Water Quality Control Board
Los Angeles Region
Recipient of the 2001 *Environmental Leadership Award* from Keep California Beautiful

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Agency Secretary

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Arnold Schwarzene
Governor

TO: Calleguas Creek Watershed Management Plan

FROM: Elizabeth Erickson
Associate Engineering Geologist

Samuel Unger
Senior Water Resources Control Engineer Engineer, TMDL Unit #2
LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD

DATE: February 11, 2005

SUBJECT: TECHNICAL COMPONENTS OF A DUCK POND AGRICULTURAL DRAIN/MUGU DRAIN/ OXNARD DRAIN #2 OC PESTICIDE, TOXICITY AND SEDIMENT TOXICITY TMDL FOR CALLEGUAS CREEK

1. Introduction

This memorandum addresses impairments of the Duck Pond/Mugu/Oxnard Drain #2 (Duck Pond/Drain #2) by pesticides, toxicity and sediment toxicity, which are part of Analytical Units #2 and #5 in the March, 1999, consent decree for Heal the Bay Inc., et al. v. Browner, Case No. 98-4825SBA. Most of the listings in Unit #5 were analyzed by the Calleguas Creek Watershed Management Plan (CCWMP), in collaboration with the US Environmental Protection Agency (EPA) and the Regional Board. However, the Duck Pond/Drain #2 TMDLs in both units were not developed by the CCWMP. This memorandum addresses these listings and is organized according to the major TMDL elements. The Regional Board staff will present this analysis to the CCWMP and other stakeholders, and will address the comments received.

2. Problem Statement

2.1 Overview

Mugu Lagoon is located entirely within the Point Mugu Naval Base, which was established shortly after WWII. Historically, a wetlands/marsh/delta surrounded Mugu Lagoon, portions of which were drained for agricultural and recreational purposes during the last century. Pesticide use by farmers, combined with Naval Base activities, increased contamination in the water and sediments, and led to elevated levels of pesticides in fish tissue. Several water segments were first listed on the EPA 1994 303(d) list for pesticides and sedimentation and remained on the 2002 303(d) list for Chem A,[1] DDT, chlordane, toxaphene, toxicity and sediment toxicity. The

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[1] According to the National Academy of Sciences, the definition of Chem A is aldrin, dieldrin, endrin, heptaclor, heptachlor epoxide, total chlordane, hexachlorocyclohexane (including lindane), total endosulfan and toxaphene. These constituents cannot exceed the recommended guidelines either individually or in combination.

1999 consent decree established a timetable for the development of TMDLs, including two for the Duck Pond/Drain #2 within Unit #5, and one within Unit #2, both due by March, 2005.

2.2 Water Quality Standards

There are twelve existing and potential beneficial uses for Mugu Lagoon, which are impaired due to elevated levels of pesticides and unknown toxicity. The Duck Ponds/Drain #2 share these uses through the Tributary Rule, which assigns the beneficial uses of major rivers to their tributaries. Existing beneficial uses include the preservation of biological habitats (BIOL), the preservation of estuarine, wetland and marine habitats (EST, WET, MAR), and the enhancement of habitats for wildlife (WILD) and for rare, threatened or endangered species (RARE). Additional beneficial uses include the migration of aquatic organisms (MIGR), the preservation of habitat for spawning (SPWN), the use of water for non-contact activities (REC2), commercial and sport fishing (COMM), and the navigation of vessels (NAV). Use of water for contact activities (REC-1) is a potential impairment.

The Basin Plan (Section 3) contains the following applicable water quality objectives:

> Bioaccumulation: Toxic pollutants shall not be present at levels that will bioaccumulate in aquatic life to levels which are harmful to aquatic life or human health.
>
> Pesticides: No individual pesticide or combination of pesticides shall be present in concentrations that adversely affect beneficial uses. There shall be no increase in pesticide concentrations found in bottom sediments or aquatic life.
>
> Toxicity: All waters shall be maintained free of toxic substances in concentrations that are toxic to, or that produce detrimental physiological responses in human, plant, animal or aquatic life.

Under Toxicity, the Basin Plan also determined compliance with this objective "by use of indicator organisms, analyses of species diversity, population density, growth anomalies, bioassays of appropriate duration or other appropriate methods as specified by the State or Regional Board." Separate tests for acute and chronic toxicity are also specified.

3. Current Conditions

The large number of drainage ditches across the Oxnard plain has lead to confusion about the names of the waterways and which waterways were impaired. Correct locations of the Duck Ponds, Oxnard Drain #2, Mugu Lagoon, Revolon Slough and Calleguas Creek are labeled in Figure 1. For the purposes of this TMDL, Drain #2 is assumed to be contiguous, connected by culverts underneath the Naval Base runway.[2]

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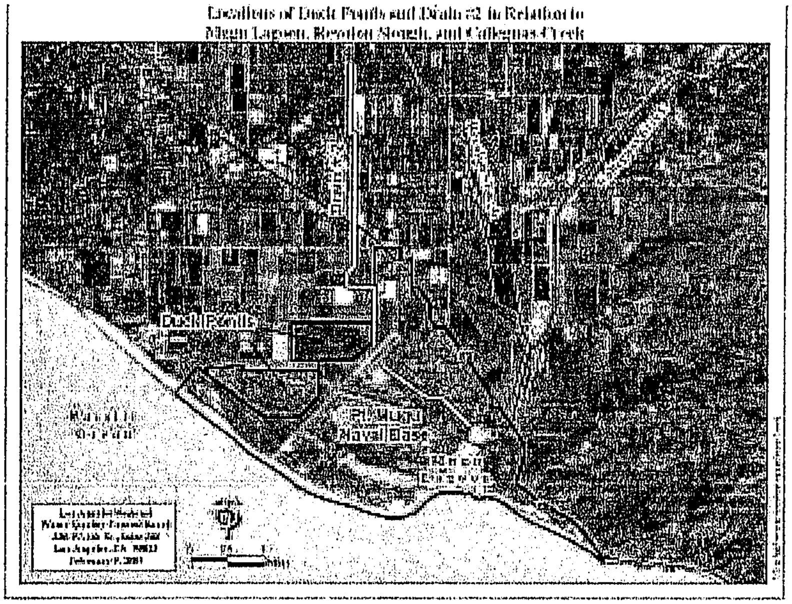
[2] The segment connecting Drainage #2 to Mugu Lagoon is labeled on the EPA Enviromapper as Oxnard Drain #3.

Figure 1: The location of the Duck Ponds and Oxnard Drain #2, in relation to Mugu Lagoon, Calleguas Creek, and Revolon Slough.



This TMDL addresses impairments in the Duck Ponds and Oxnard Drain #2. Less extensive water quality sampling occurred in these water segments, compared to Revolon Slough, which was included in watershed-wide sampling by the CWMP. Sampling of the Duck Pond/Drain #2 is included in the implementation plan for this TMDL, to verify similarities between the Drain #2 and Revolon Slough.

4. Numeric Targets and Allocations:

Numeric targets for the Duck Pond/Drain #2 are for sediments and water, for both known and unknown sources of toxicity. Targets are similar to those outlined for water segments in the Calleguas Watershed. Table 1 lists numeric targets for known sources, including ChemA, DDT, chlordane, and toxaphene. Targets are also set for DDD and DDE, since the parent constituent, DDT, degrades rapidly.

Table 1. Numeric targets for known sources of toxicity in water and fish tissue, which are used to derive targets for sediments, from Table 39 pg 50, Calleguas Creek Watershed OC Pesticide and PCBs TMDL (CCWMP, 1/31/05)

Constituent	CTR** Water Quality Targets (ug/L)		Fish Tissue Targets, TTRLs** (ug/Kg)	Sediment Guidelines (ug/dry Kg)	
	Freshwater	Marine		Freshwater TEL**	Marine TEL**
Aldrin	3.0*	1.3*	0.050	NA	NA
Dieldrin	0.056	0.0019	0.65	2.9	0.72
Endrin	0.036	0.0023	3200	2.7	NA
Heptachlor	0.0038	0.0036	2.4	NA	NA
Heptachlor Epoxide	0.0038	0.0036	1.2	0.6	NA
HCH (alpha-BHC)	NA	NA	1.7	NA	NA
HCH (bets-BHC)	NA	NA	6.0	NA	NA
HCH (delta-BHC)	NA	NA	NA	NA	NA
HCH (gamma BHC)	0.95*	0.16*	8.2	0.94	NA
Endosulfan	0.056	0.0087	65,000	NA	NA
DDD	NA	NA	45	3.5	1.2
DDE	NA	NA	32	1.4	2.07
DDT	.001	.001	32	NA	1.19
Chlordane	0.0043	0.0040	8.3	4.5	2.3
Toxaphene	.00020	.00020	9.8	NA	NA

*No chronic criteria exist; acute criteria (based on Criteria Maximum Concentration) are used instead.
** CTR=California Toxics Rule, TTRL= Tissue Threshold Residue Level, TEL=Threshold Effect Level

To address toxicity of unknown causes in water, the No-Observed-Effects Concentration (NOEC) is used, where NOEC is defined as the highest concentration of toxicant to which organisms are exposed, that causes no observable effect on survival and no observable effect on growth and reproduction. This means there is no significant difference between the test solution and the control, as determined by hypothesis testing.

To address toxicity of unknown causes in sediments, the sediment quality triad is recommended. This approached was used by the Water Resources Control Board Bay Protection and Toxics Cleanup program (BPTCP) (SWRCB, 1998). The State Water Resources Board has used this methodology to develop sediment quality objectives for enclosed bays and estuaries. As the name implies, this analysis is three-fold, and includes tests for sediment toxicity, sediment chemistry and a measure for the health of the biological community.[3] Results are compared to a reference site, or to a clean control (the latter is more conservative).

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[3] For the BPTCP study, biological assessment focused on the benthic infaunal community, and was evaluated using a Relative Benthic Index (Ibid.)

Table 2. Numeric targets for unknown toxicity

Location	Substrate and Units	
Duck/Mugu/Ox#2	water	NOEC
Duck/Mugu/Ox#2	sediment	Use the sediment quality triad, and compare to reference site

5. Source Analysis

6. Linkage Analysis

For Source Analysis and Linkage Analysis, please see Sections 5 and 6 in both of the following documents:

Larry Walker Associates. (2004). Interim Draft, Calleguas Creek Watershed Toxicity TMDL, December, 2004.

Larry Walker Associates. (2005). Draft, Calleguas Creek Watershed OC Pesticides and PCBs TMDL, Jan. 31, 2005.

7. TMDL and Allocations

Sources for most pesticides and contaminants in the Duck Pond/Drain #2 include agricultural and urban runoff. Allocations are provided for each, which are comparable to those applied to Revolon Slough (see Table 3). Phased and final allocations are used, to account for natural attenuation and implementation efforts. There are no POTWs near the Duck Pond/Drain #2; therefore, there are no separate allocations for POTWs. Also, there are no sediment allocations for some of the ChemA constituents, which were listed as "Category-2" in the TMDL (pg 29, Ibid.). Due to the low or non-detect levels found during the watershed-wide sampling, these constituents do not cause impairment of beneficial uses, and only water and fish tissue targets were assigned (pg. 99, Ibid.).

Table 3. Wasteload allocations for agricultural and urban runoff for pesticides in sediments (ug/g). (Table 66, 69 pg. 101, 104 OC Pesticide and PCBs TMDL, 1/31/2005)

Constituent	Chlordane	DDD	DDE	DDT	Dieldrin	Toxaphene
	Phased Final	Phased Final	Phased Final	Phased Final	Phased Final	Phased Final
Duck/Mugu/Ox#2	.048 .0009	.399 .0012	1.595 .0014	.685 .0003	.00057 .0001	.7852 .0010

Table 4. Final water and fish tissue load allocations for agriculture and urban runoff for Category-2 constituents. (Table 67, 70 pg. 102, 105 OC Pesticide and PCBs TMDL, 1/31/2005)

Constituent	Aldrin	Endosulfan	Endrin	HCH (gamma BHC)	Heptachlor	Heptachlor epoxide
Final Annual Avg. Water (ug/L)	3*	NA	0.036	0.95	0.0038	0.0038

Final Annual Avg. Fish Tissue (ug/Kg)	0.05	NA	3220	8.2	2.4	1.2

* No chronic criteria exist, so criteria for acute criteria are used.

Table 5. Wasteload allocations for agricultural and urban runoff for unknown toxicity in water and sediments.

Location	Substrate and Units	
Duck/Mugu/Ox#2	water	NOEC
Duck/Mugu/Ox#2	sediment	Use the sediment quality triad, and compare to reference site

8. Implementation Plan

(1) Year 1:

Monitoring: The monitoring plan outlined in the Calleguas Creek OC Pesticide and PCBs TMDL will be extended to include the Duck Ponds, and the results will be compared to conditions in Revolon Slough. Monitoring plans described in the Conditional Waiver for Irrigated Lands, the MS4 urban runoff permit for Oxnard and stormwater monitoring by the Ventura County Watershed Protection District (VCWPD), will be expanded to include this assessment.

Sediment Toxicity and Habitat study support: The assessment of sediment toxicity will be completed in the Duck Ponds by either the CMWP, Oxnard MS4 or VCWPD, to evaluate impairments. Results from the Mugu Lagoon habitat assessment will be combined with these results on the Duck Ponds to determine whether impairments are sufficiently addressed.

(2) Years 2-5:

Linkage Assessment: If monitoring results reveal differences between the Duck Ponds and Revolon Slough, a recommendation to review the TMDL numeric targets, allocations and implementation plan will be presented to the Regional Board.

(3) Year 5

Objective Attainment Assessment: If monitoring results do not show improvement, a recommendation/work plan will be prepared for the Regional Board demonstrating how standards may be achieved within the following year.

(4) Year 6

Attainment of Water Quality Objectives in Duck Pond Agricultural Drain/Mugu Drain/Oxnard Drain #2

References

California State Water Resources Control Board (SWRCB), California Los Angeles Regional Water Quality Control Board, California Department of Fish and Game, University of California, Santa Cruz, San Jose State University. (1998). Sediment Chemistry, Toxicity, and Benthic Community Conditions in Selected Water Bodies of the Los Angeles Region. August, 1998.

Larry Walker Associates. (2004). Interim Draft, Calleguas Creek Watershed Toxicity TMDL, December, 2004.

Larry Walker Associates. (2005). Draft, Calleguas Creek Watershed OC Pesticides and PCBs TMDL, Jan. 31, 2005.

D. Hoffman, B. Rattner, G.A. Burton, Jr., and J.Cairns, Jr. *Handbook of Ecotoxicology, 2nd Edition.* CRC-Lewis. Boca Raton, FL, 2002.

Receiving Water Impacts Associated with Urban Runoff

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Introduction

The main purpose of treating stormwater is to reduce its adverse impacts on receiving water beneficial uses. Therefore, it is important in any urban stormwater study to assess the detrimental effects that runoff is actually having on a receiving water. Urban receiving waters may have many beneficial use goals, including:

- stormwater conveyance (flood prevention)
- biological uses (warm water fishery, biological integrity, etc.)
- non-contact recreation (linear parks, aesthetics, boating, etc.)
- contact recreation (swimming)
- water supply

Two joint research projects recently funded by the EPA[145, 146] examined the historical development of stormwater management programs and modifications that should be incorporated into future design procedures. The projects found that with full development in an urban watershed and with no stormwater controls, it is unlikely that any of the above listed uses can be fully obtained. With less development and with the application of stormwater controls, some uses may be possible. It is important that unreasonable expectations not be placed on urban waters, as the cost to obtain these uses may be prohibitive. With full-scale development and lack of adequate stormwater controls, severely degraded streams will be common. However, stormwater conveyance and aesthetics should be the basic beneficial use goals for all urban waters. Biological integrity should also be a goal, but with the realization that the natural stream ecosystem will be severely modified with urbanization. Certain basic controls, installed at the time of development, plus protection of stream habitat, may enable partial use of some of these basic goals in urbanized watersheds. Careful planning and optimal utilization of stormwater controls are necessary to obtain these basic goals in most watersheds. Water contact recreation, consumptive fisheries, and water supplies are not appropriate goals for most urbanized watersheds. However, these higher uses may be possible in urban areas where the receiving waters are large and drain mostly undeveloped areas.

Water Environment & Technology[1] reported that the latest National Water Quality Inventory released by the EPA only showed a slight improvement in the attainment of beneficial uses in the nations waters. Urban runoff was cited as the leading source of problems in estuaries, with nutrients and bacteria as the leading problems. Problems in rivers and lakes were mostly caused by agricultural runoff, with urban runoff the third ranked source for lakes, and the fourth ranked source for rivers. Bacteria, siltation, and nutrients were the leading problems in the nations rivers and lakes. Borchardt and Statzner[2] stressed that many conditions may affect receiving waters from stormwater, specifically physical factors (such as shear stress) and chemical factors (such as oxygen depletion and/or non-ionized ammonia).

In general, monitoring of urban stormwater runoff has indicated that the biological beneficial uses of urban receiving waters are most likely affected by habitat destruction and long-term exposures to contaminants (especially to macroinvertebrates via contaminated sediment), while documented effects associated from acute exposures of toxicants in the water column are rare[3-5]. Receiving water contaminant concentrations resulting from runoff events and typical laboratory bioassay test results have not indicated many significant short-term receiving water problems. As an example, Lee and Jones-Lee[6] state that exceedences of numeric criteria by short-term discharges do not necessarily imply that a beneficial use impairment exists. Many toxicologists and water quality expects have concluded that the relatively short periods of exposures to the toxicant concentrations in stormwater are not sufficient to produce the receiving water effects that are evident in urban receiving waters, especially considering the relatively large portion of the toxicants that are associated with particulates[7]. Lee and Jones-Lee[7] conclude that the biological problems evident in urban receiving waters are mostly associated with illegal discharges and that the sediment bound toxicants are of little risk. Mancini and Plummer[8] have long been advocates of numeric water quality standards for stormwater that reflect the partitioning of the toxicants and the short periods of exposure during rains. Unfortunately, this approach attempts to isolate individual runoff events and does not consider the accumulative adverse effects caused by the frequent exposures of receiving water organisms to stormwater[9-11]. Recent investigations have identified acute toxicity problems associated with moderate-term (about 10 to 20 day) exposures to adverse toxicant concentrations in urban receiving streams [12]. However, the most severe receiving water problems are likely associated with chronic exposures to contaminated sediment and to habitat destruction.

Pathogens in stormwater are also a significant concern potentially affecting human health. The use of indicator bacteria is controversial for stormwater, as well as the assumed time of typical exposure of swimmers to contaminated receiving waters. However, recent epidemiological studies has shown significant health effects associated with stormwater contaminated marine swimming areas. Protozoa pathogens, especially associated with likely sewage-contaminated stormwater, is also of public health concem.

Evaluating a receiving water and understanding the potential role that urban wet weather flows may have on its beneficial uses is a complex and time consuming activity. Burton and Pitt[13] have produced a comprehensive book describing the development of effective monitoring strategies, including selection of parameters, development of the experimental design, and detailed guidance on sampling, analyses, and data interpretation.

Urban runoff has been found to cause significant receiving water impacts on aquatic life[3,4,13]. The effects are obviously most severe for receiving waters draining heavily urbanized watersheds. However, some studies have shown important aquatic life impacts for streams in watersheds that are less than ten percent urbanized[19,22].

In order to best identify and understand these impacts, it is necessary to include biological monitoring, using a variety of techniques, and sediment quality analyses, in a monitoring program. Water column testing alone has been shown to be very misleading. Most aquatic life impacts associated with urbanization are probably related to long-term problems caused by polluted sediments and food web disruption. Transient water column quality conditions associated with urban runoff probably rarely cause significant aquatic life impacts.

The underlying theme of these researchers is that an adequate analysis of receiving water biological impacts must include investigations of a number of biological organism groups (fish, benthic macroinvertebrates, algae, rooted macrophytes, etc.) in addition to studies of water and sediment quality[13]. Simple studies of water quality alone, even with possible comparisons with water quality criteria for the protection of aquatic life, are usually inadequate to predict biological impacts associated with urban runoff.

Duda, *et al.*[14] presented a discussion on why traditional approaches for assessing water quality, and selecting control options, in urban areas have failed. The main difficulties of traditional approaches when used with urban runoff are: the complexity of contaminant sources, wet weather monitoring problems, and limitations when using water quality standards to evaluate the severity of wet weather receiving water problems. They also discuss the difficulty of meeting water quality goals in urban areas that were promulgated in the Water Pollution Control Act.

Relationships between observed receiving water biological effects and possible causes have been especially difficult to identify, let alone quantify. The studies reported in this paper have identified a wide variety of possible causative agents, including sediment contamination, poor water quality (low dissolved oxygen, high toxicants, etc.), and factors effecting the physical habitat of the stream (high flows, unstable streambeds, absence of refuge areas, etc.). It is expected that all of these factors are problems, but their relative importance varies greatly depending on the watershed and receiving water conditions. Horner[15], as an example, notes that many watershed, site, and organism specific factors must be determined before the best combination of runoff control practices to protect aquatic life can be determined.

The time scale of biological impacts in receiving waters affected by stormwater must also be considered. Snodgrass, *et al.*[16] reported that ecological responses to watershed changes may take between 5 and 10 years to equilibrate. Therefore, receiving water investigations conducted soon after disturbances or mitigation may not accurately reflect the long-term conditions that will eventually occur. They found that the first changes due to urbanization will be to stream and groundwater hydrology, followed by fluvial morphology, then water quality, and finally the aquatic ecosystem. They also reported that it is not possible to predict biological responses from in-stream habitat changes or conditions, although they, along with many other researchers[26, 62-67, 77, 80-82, 85-88, 99, 102, 103, 105-108] have found that habitat changes are among the most serious causes of the aquatic biological problems associated with urbanization of a watershed.

Gross Indicators of Acute Aquatic Organism Stress in Urban Receiving Waters

Dissolved Oxygen Depletion Investigations

Dissolved oxygen stream levels have historically been used to indicate receiving water problems associated with point source contaminant discharges and with combined sewer overflows. Therefore, early investigations of the effects of stormwater discharges mostly focused on in-stream dissolved oxygen conditions downstream from outfalls. Of course, DO levels are also being evaluated in most current receiving water investigations also, but the emphasis has shifted more towards elevated nutrient and toxicant concentrations, plus numerous other indicators of aquatic organism stress, as described later.

An early study of DO in urban streams only affected by stormwater was conducted by Ketchum[17] in Indiana. Sampling was conducted at nine cities and the project was designed to detect significant dissolved oxygen deficits in streams during periods of rainfall and runoff. The results of this study indicated that wet weather DO levels generally appear to be similar or higher than those observed during dry weather conditions in the same streams. They found that significant wet weather DO depletions were not observed, and due to the screening nature of the sampling program, more subtle impacts could not be measured. Heaney, *et al.*[18], during their review of studies that examined continuous dissolved oxygen (DO) monitoring stations downstream from urbanized areas, indicated that the worst dissolved oxygen levels occurred after the storms in about one-third of the cases studied. This lowered DO could be due to urban runoff moving downstream, combined sewer overflows and/or resuspension of benthic deposits. Resuspended benthic deposits could have been previously settled urban runoff settleable solids. They also found that worst case conditions do not always occur during the low flow periods following storms. As noted below, adverse dissolved oxygen conditions associated with urban runoff are likely to occur a substantial time after the runoff event and downstream from the discharge locations.

Figure 1 illustrates a problem that may be common to DO predictions in urban receiving waters. Pitt[19] conducted three long-term BOD experiments with stormwater collected from a residential area in San Jose, CA. These were conventional BOD tests, using approved procedures published in the then current version of *Standard Methods.* Basically, many BOD bottles were prepared for each sample, representing replicates for each day for the observations, and for several different dilutions. The bottles were seeded with an activated sludge seed to provide a starting microbial population. As seen, the observed BOD curves do not have a conventional shape. The BOD_5 values are about 25 mg/L, typical to what is commonly reported for most stormwater. However, the BOD curves are seen to rapidly increase throughout the 20-day test period, instead of leveling off at about 7 to 10 days, as expected for municipal wastewaters. These curves illustrate the common problem of acclimation of a wastewater to the microorganisms that are present in the test solution. Stormwater has relatively low levels of nutrients and easily assimilated organic material, but moderate levels of toxicants. It is possible that the activated sludge seed requires extra time for the microbial population to shift to a population dominated by organisms capable of effectively degrading the organics in stormwater. Alternatively (or in addition), the more refractory organics in stormwater may simply require a longer period of time for degradation. In any case, the ultimate BOD/BOD_5 ratio for stormwater is much greater than for conventional municipal wastewaters, making simple use of observed BOD_5 values in receiving water models problematic. Urban stream sediments are commonly anaerobic, likely caused by the deposition of the slowly decaying stormwater organic compounds. Stormwater effects on short-term stream DO levels may be minimal, but sediment interaction (including scour) with the water can have adverse effects long after the stormwater event that discharged the decaying material. Therefore, the misuse of the classical BOD_5 test for stormwater can lead to poor conclusions concerning urban DO conditions, one of the more commonly used indicators of ecological health.

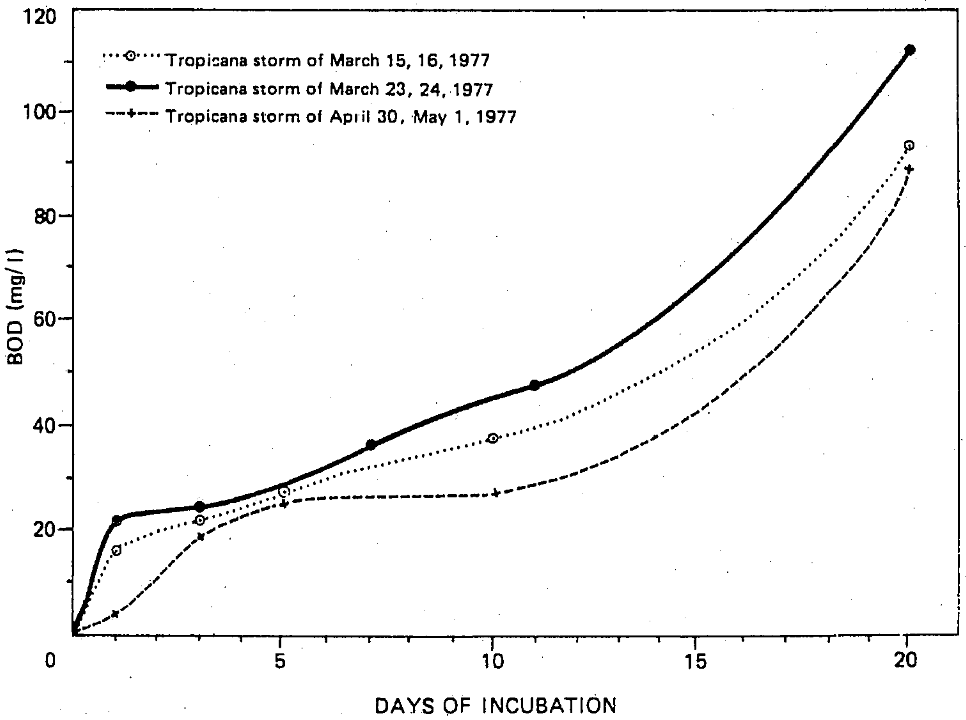


Figure 1. Long-term BOD tests for stormwater[19].

Urban Runoff Effects on Receiving Water Contaminant Concentrations

Numerous data are available characterizing stormwater chemical characteristics. This discussion summarizes a few example cases where in-stream measurements found significant changes in quality as a function of land use. These studies usually sampled streams as they passed through urban areas, from upstream relatively uncontaminated areas through and past urban areas. Both wet and dry weather sampling was also usually conducted.

In the southeast, many urban lakes in developing areas are typically characterized by high turbidity levels caused by high erosion rates of fine grained clays. There has been conflicting evidence on the role of these elevated turbidity levels on eutrophication processes and resulting highly fluctuating DO levels. Because of the high sediment loads, these urban lakes are quite different compared to most studied impoundments. Burkholder, *et al.*[20] described a series of enclosure experiments they conducted in Durant Reservoir, near Raleigh, North Carolina. The experimental design allowed investigating the effects of different levels of sediment and nutrients on algal productivity. They found that the effects (reduction of light reduction and coflocculation of clay and phosphate) of low (about 5 mg/L) and moderately high clay (about 15 mg/L) loadings added every 7 to 14 days did not significantly reduce the algal productivity simulation caused by high phosphate loadings. However, they noted that other investigators using higher clay loadings (about 25 mg/L added every 2 days) did see depressed effects of phosphorus enrichment on the test lake. They concluded that dynamically turbid systems, such as represented in southeastern urban lakes, have complex interacting mechanisms between discharged clay and nutrients that make simple predictions of the effects of eutrophication much more difficult than in the more commonly studied clear lakes. In general, they concluded that increased turbidity will either have no effect, or will have a mitigating effect, on the cultural eutrophication process.

Field and Cibik[21] summarized some potential urban runoff effects reported in other studies. Two studies of a reservoir near Knoxville, Tennessee, showed that the quality of the contributing streams were degraded to a small extent by urban runoff and that the reservoir itself experienced a significant change in DO, pH, BOD_5, conductivity, temperature, total solids, and total coliform bacteria during short storm events. In another study at the Christina River in Newark, Delaware, cadmium and lead concentrations several miles below the urban area remained at elevated values up to 48 hours after storm periods. The quality of runoff from similar non-urbanized watersheds was compared with this urbanized area's runoff. They found that concentrations of nitrates, phosphorus, heavy metals and pesticides were considerably higher in the urbanized areas than in the forested regions. Field and Cibik[21] also reported on a study conducted in Virginia, where water, sediment, detritus, caddisflies, snails and crayfish were analyzed for iron, manganese, nickel, lead, cadmium, zinc, chromium and copper. The sampling areas were exposed to wastewater effluent and urban runoff. The found that concentrations increased immediately below stormwater discharge locations. They also reported on a study from Hawaii which indicated that receiving water conditions were designated as hazardous because of very high concentrations of suspended solids, heavy metals and bacterial pathogens.

During the Coyote Creek, San Jose study, dry weather concentrations of many constituents exceeded expected wet weather concentrations by factors of two to five times[22]. During dry weather, many of the major constituents (e.g., major ions, total solids, etc.) were significantly greater in both the urban and nonurban reaches. These constituents were all found in substantially lower concentrations in the urban runoff and in the rain. The rain and the resultant runoff apparently diluted the concentrations of these constituents in the creek during wet weather. Within the urban area, many constituents were found in greater concentrations during wet weather than during dry weather (Chemical Oxygen Demand, organic nitrogen, and especially heavy metals - lead, zinc, copper, cadmium, mercury, iron, and nickel). Lead concentrations were found to be more than seven times as great in the urban reach than in the nonurban reach during dry weather, with a confidence level of 75 percent. Other significant increases in urban area concentrations occurred for nitrogen, chloride, orthophosphate, Chemical Oxygen Demand, specific conductance, sulfate, and zinc. The dissolved oxygen measurements were about 20 percent less in the urban reach than in the nonurban reach of the creek.

Bolstad and Swank[23] examined the in-stream water quality at 5 sampling stations in Cowetta Creek in western North Carolina over a 3 year period. The watershed is 4350 ha and is relatively undeveloped (forested) in the area above the most upstream sampling station and becomes more urbanized at the downstream sampling station. Baseflow water quality was good, while most constituents increased during wet weather. Bacteria values increased substantially during wet weather, with total and fecal coliforms, and fecal streptococci increasing by two to three times during storms. Water quality was compared to building density for the different monitoring stations, with increasing stormwater contaminant concentrations (especially for turbidity, bacteria, and some inorganic solutes) with increasing building densities. Baseflow concentrations also typically increased with density, but at a much lower rate. In addition, the highest concentrations observed during individual events corresponded to the highest flow rates.

Reported Fish Kill Information

Urban runoff impacts are sometimes difficult for many people to appreciate in urban areas. Fish kills are the most obvious indication of water quality problems for many people. However, because urban receiving water quality is usually so poor, the aquatic life in typical urban receiving waters is usually limited in abundance and diversity, and quite resistant to poor water quality. Sensitive native organisms have typically been displaced, or killed, long ago. It is also quite difficult to identify the specific cause of a fish kill in an urban stream. Ray and White[24], for example, stated that one of the complicating factors in determining fish kills related to heavy metals is that the fish mortality may lag behind the first toxic exposure by several days, and is usually detected many miles downstream from the discharge location. The actual concentrations of the water quality constituents that may have caused the kill could then be diluted beyond detection limits, making probable sources of the toxic materials impossible to determine in many cases.

Heaney, *et al.*[18] reviewed fish kill information reported to government agencies during 1970 to 1979. They found that less than three percent of the reported 10,000 fish kills were identified as having been caused by urban runoff. This is less than 30 fish kills per year nationwide. A substantial number of these 10,000 fish kills were not identified as having any direct cause. They concluded that many of these fish kills were likely caused by urban runoff, or a combination of problems that could have been worsened by urban runoff.

During the Bellevue, Washington, receiving water studies, some fish kills were noted in the unusually clean urban streams[25]. The fish kills were usually associated with inappropriate discharges to the storm drainage system (such as cleaning materials and industrial chemical spills) and not from "typical" urban runoff. However, as noted later, the composition of the fish in the urban stream was quite different, as compared to the control stream[26].

Fish kill data have therefore not been found to be a good indication of receiving water problems caused by urban runoff. However, as discussed previously, the composition of the fisheries and other aquatic life taxonomic indicators are sensitive indicators of receiving water problems in urban streams.

Toxicological Effects of Stormwater

Even though acute toxicity of stormwater on most aquatic organisms has been relatively rare, short-term toxicity tests are still commonly conducted as part of some whole effluent toxicity (WET) tests required by some state regulatory agencies and by some stormwater researchers[147].

The need for endpoints for toxicological assessments using multiple stressors was discussed by Marcy and Gerritsen[27]. They used five watershed-level ecological risk assessments to develop appropriate endpoints based on specific project objectives. Dyer and White[28a] also examined the problem of multiple stressors affecting toxicity assessments. They felt that field surveys rarely can be used to verify simple single parameter laboratory experiments. They developed a watershed approach integrating numerous databases in conjunction with *in-situ* biological observations to help examine the effects of many possible causative factors. Toxic effect endpoints are additive for compounds having the same "mode of toxic action", enabling predictions of complex chemical mixtures in water, as reported by *Environmental Science & Technology*[28b]. They reported that EPA researchers at the Environmental Research Laboratory in Duluth, MN, identified about five or six major action groups that contain almost all of the compounds of interest in the aquatic environment. Much work still needs to be done, but these new analytical methods may enable the in-stream toxic effects of stormwater to be better predicted.

Ireland, *et al.*[29] found that exposure to UV radiation (natural sunlight) increased the toxicity of PAH contaminated urban sediments to *C. dubia*. The toxicity was removed when the UV wavelengths did not penetrate the water column to the exposed organisms. Toxicity was also reduced significantly in the presence of UV when the organic fraction of the stormwater was removed. Photo-induced toxicity occurred frequently during low flow conditions and wet weather, but was reduced during turbid conditions.

Johnson, *et al.*[30] and Herricks, *et al.*[10, 11] describe a structured tier testing protocol to assess both short-term and long-term wet weather discharge toxicity that they developed and tested. The protocol recognizes that the test systems must be appropriate to the time-scale of exposure during the discharge. Therefore, three time-scale protocols were developed, for intra-event, event, and long-term exposures. The use of standard whole effluent toxicity (WET) tests were found to over-estimate the potential toxicity of stormwater discharges.

The effects of stormwater on Lincoln Creek, near Milwaukee, WI, were described by Crunkilton, *et al.*[12]. Lincoln Creek drains a heavily urbanized watershed of 19 mi^2 that is about nine miles long. On-site toxicity testing was conducted with side-stream flow-through aquaria using fathead minnows, plus in-stream biological assessments, along with water and sediment chemical measurements. In the basic tests, Lincoln Creek water was continuously pumped through the test tanks, reflecting the natural changes in water quality during both dry and wet weather conditions. The continuous flow-through mortality tests indicated no toxicity until after about 14 days of exposure, with more than 80% mortality after about 25 days, indicating that the shorter-term toxicity tests likely underestimate stormwater toxicity. The biological and physical habitat assessments also supported a definitive relationship between degraded stream ecology and urban runoff.

Rainbow[31] presented a detailed overview of heavy metals in aquatic invertebrates. He concluded that the presence of a metal in an organism cannot tell us directly whether that metal is poisoning the organism. However, if compared to concentrations in a suite of well-researched biomonitors, it is possible to determine if the accumulated concentrations are atypically high, with a possibility that toxic effects may be present. Allen[32] also presented an overview of metal contaminated aquatic sediments. This book presents many topics that would enable the user to better interpret measured heavy metal concentrations in urban stream sediments.

One of the key objectives of the Chesapeake Bay restoration effort is to reduce the impacts of toxicants, for which stormwater is a recognized major source for the area. Hall, *et al.*[33] describe the *Toxics Reduction Strategy*, based on water column and sediment chemical analyses, benthic community health, and fish body burdens. More than 40% of the sites have displayed some degree of water column toxicity, and about 70% of the sites have displayed sediment toxicity. Garries, *et al.*[34] further describe how the list of *Toxics of Concern* is developed for Chesapeake Bay.

Sediment contaminated by stormwater discharges has a detrimental effect on the receiving water biological community. Schueler[35] summarized *in-situ* assessment methods of stormwater-impacted sediments. The use of *in-situ* test chambers, using *C. dubia*, eliminates many of the sample disruption problems associated with conducting sediment toxicity tests in the laboratory. Love and Woolley[36] found that stormwater was alarmingly more toxic than treated sewage and that treatment before reuse of residential area stormwater may be needed.

Pitt[37] reported a series of laboratory toxicity tests using 20 stormwater and CSO samples. He found that the most promising results are associated with using several complementary tests, instead of any one test method. However, simple screening toxicity tests (such as using the Azur Microtox test) are useful during preliminary assessments or for treatability tests.

Huber and Quigley[38] studied highway construction and repair materials (e.g. deck sealers, wood preservatives, waste-amended pavement, etc.) for their chemical and toxicological properties and leaching characteristics. *Daphnia magna* (a water flea) and the algae *Selenastrum capricornutum* were used for the toxicity tests. Leaching was evaluated as a function of time using batch tests, flat plate tests and column tests, as appropriate for the end-use of the highway material. These comprehensive tests identified a number of maintenance and construction materials that should be avoided for use near aquatic environments due to their elevated toxicity.

Kosmala, *et al.*[40] used *C. dubia* in laboratory toxicity tests in combination with field analysis of the *Hydropsychid* life cycle to assess the impact of both the wastewater treatment plant effluent and the stormwater overflow on the receiving water. They found that the results seen in the laboratory toxicity tests and in the *in-situ* biological measurements were due to nutrient and micropollutant loadings. Marsalek, *et al.*[41] used several different toxicity tests to assess the various types of toxicity in typical urban runoff and in runoff from a multi-lane highway. The tests included traditional toxicity analysis using *Daphnia magna*, the Microtox® toxicity test, sub-mitochondrial particles, and the SOS Chromotest for genotoxicity. Marsalek and Rochfort[42] also investigated the toxicity of urban stormwater and CSO. Acute toxicity, chronic toxicity and genotoxicity of stormwater and CSO were studied at 19 urban sampling sites in Ontario, Canada, using a battery of seven bioassays. Most frequent responses of severe toxicity were found in stormwater samples (in 14% of all samples), particularly those collected on freeways during the winter months. Compared to stormwater, CSO displayed lower acute toxicity (7% of the samples were moderately toxic, and none of the samples was severely toxic).

Skinner, *et al.*[43] showed that stormwater runoff produced significant toxicity in the early life stages of medaka (*Oryzias latipes*) and inland silverside (*Menidia beryllina*). Developmental problems and toxicity were strongly correlated with the total metal content of the runoff and corresponded with exceedences of water quality criteria of Cd, Cu, W, and Zn.

Tucker and Burton[44] compared *in-situ* versus laboratory conditions for toxicity testing of nonpoint-source runoff. They found that NPS runoff from urban areas was more toxic to the organisms in the laboratory while the agricultural runoff was more toxic to the organisms exposed *in-situ*. The differences seen between the two types of toxicity tests demonstrated the importance of *in-situ* assays in assessing the effects of NPS runoff. Hatch and Burton[45], using field and laboratory bioassays, demonstrated the impact of the urban stormwater runoff on *Hyalella azteca*, *Daphnia magna*, and *Pimephales promelas* survival after 48 hours of exposure. The significant toxicity seen at the outfall site was attributed to the contaminant accumulation in the sediments and the mobilization of the top layers of sediment during storm events.

Bickford, *et al.*[46] described the methodology developed and implemented by Sydney Water in Australia to asses s the risk to humans and aquatic organisms in creeks, rivers, estuaries and ocean waters from wet weather flows (WWFs). The model used in this study was designed to predict concentrations of various chemicals in WWFs and compare the values to toxicity reference values. Brent and Herricks[47] proposed a methodology for predicting and quantifying the toxic response of aquatic systems to brief exposures to pollutants such as the contaminants contained in stormwater runoff. The method contains an event-focused toxicity method, a test metric (ETU, event toxicity unit) to represent the toxicity of intermittent events, and an event-based index that would described the acute toxicity of this brief exposure. The toxicity metric proposed (PE-LET50 [post-exposure lethal exposure time]) was the exposure duration required to kill 50% of the population during a pre-specified, post-exposure monitoring period. Colford, *et al.*[48] proposed three methods of analytically evaluating the impact of storm sewer and combined sewer outflows on public health, especially in areas that may receive through deposition the harmful agents in sewage and combined sewage.

Subtle (Chronic) Effects of Stormwater Discharges on Aquatic Life

Many studies have shown the severe detrimental effects of urban runoff on receiving water organisms. These studies have generally examined receiving water conditions above and below a city, or by comparing two parallel streams, one urbanized and another nonurbanized. The researchers usually carefully selected the urbanized streams to minimize contaminant sources other than urban runoff. However, few studies have examined direct cause and effect relationships of urban runoff for receiving water aquatic organisms [49]. The following paragraphs briefly describe a variety of urban receiving water investigations.

Klein[50] studied 27 small watersheds having similar physical characteristics, but having varying land uses, in the Piedmont region of Maryland. During an initial phase of the study, they found definite relationships between water quality and land use. Subsequent study phases examined aquatic life relationships in the watersheds. The principal finding was that stream aquatic life problems were first identified with watersheds having imperviousness areas comprising at least 12 percent of the watershed. Severe problems were noted after the imperviousness quantities reached 30 percent.

Receiving water impact studies were also conducted in North Carolina[51-53]. The benthic fauna occurred mainly on rocks. As sedimentation increased, the amount of exposed rocks decreased, with a decreasing density of benthic macroinvertebrates. Data from 1978 and 1979 in five cities showed that urban streams were grossly polluted by a combination of toxicants and sediment. Chemical analyses, without biological analyses, would have underestimated the severity of the problems because the water column quality varied rapidly, while the major problems were associated with sediment quality and effects on macroinvertebrates. Macroinvertebrate diversities were severely reduced in the urban streams, compared to the control streams. The biotic indices indicated very poor conditions for all urban streams. Occasionally, high populations of pollutant-tolerant organisms were found in the urban streams, but would abruptly disappear before subsequent sampling efforts. This was probably caused by intermittent discharges of spills or illegal dumpings of toxicants. Although the cities studied were located in different geographic areas of North Carolina, the results were remarkably uniform.

During the Coyote Creek, San Jose, California, receiving water study, 41 stations were sampled in both urban and nonurban perennial flow stretches of the creek over three years. Short and long-term sampling techniques were used to evaluate the effects of urban runoff on water quality, sediment properties, fish, macroinvertebrates, attached algae, and rooted aquatic vegetation[22]. These investigations found distinct differences in the taxonomic composition and relative abundance of the aquatic biota present. The non-urban sections of the creek supported a comparatively diverse assemblage of aquatic organisms including an abundance of native fishes and numerous benthic macroinvertebrate taxa. In contrast, however, the urban portions of the creek (less than 5% urbanized), affected only by urban runoff discharges and not industrial or municipal discharges, had an aquatic community generally lacking in diversity and was dominated by pollution-tolerant organisms such as mosquitofish and tubificid worms.

A major nonpoint runoff receiving water impact research program was conducted in Georgia[54]. Several groups of researchers examined streams in major areas of the state. Benke, *et al.*[55] studied 21 stream ecosystems near Atlanta having watersheds of one to three square miles each and land uses ranging from 0 to 98 percent urbanization. They measured stream water quality but found little relationship between water quality and degree of urbanization. The water quality parameters also did not identify a major degree of pollution. In contrast, there were major correlations between urbanization and the number of species found. They had problems applying diversity indices to their study because the individual organisms varied greatly in size (biomass). CTA[56] also examined receiving water aquatic biota impacts associated with urban runoff sources in Georgia. They studied habitat composition, water quality, macroinvertebrates, periphyton, fish, and toxicant concentrations in the water, sediment, and fish. They found that the impacts of land use were the greatest in the urban basins. Beneficial uses were impaired or denied in all three urban basins studied. Fish were absent in two of the basins and severely restricted in the third. The native macroinvertebrates were replaced with pollution tolerant organisms. The periphyton in the urban streams were very different from those found in the control streams and were dominated by species known to create taste and odor problems.

Pratt, *et al.*[57] used basket artificial substrates to compare benthic population trends along urban and nonurban areas of the Green River in Massachusetts. The benthic community became increasing disrupted as urbanization increased. The problems were not only associated with times of heavy rain, but seemed to be affected at all times. The stress was greatest during summer low flow periods and was probably localized near the stream bed. They concluded that the high degree of correspondence between the known sources of urban runoff and the observed effects on the benthic community was a forceful argument that urban runoff was the causal agent of the disruption observed.

Cedar swamps in the New Jersey Pine Barrens were studied by Ehrenfeld and Schneider[58]. They examined nineteen wetlands subjected to varying amounts of urbanization. Typical plant species were lost and replaced by weeds and exotic plants in urban runoff affected wetlands. Increased uptakes of phosphorus and lead in the plants were found. It was concluded that the presence of stormwater runoff to the cedar swamps caused marked changes in community structure, vegetation dynamics, and plant tissue element concentrations.

Medeiros and Coler[59] and Medeiros, *et al.*[60] used a combination of laboratory and field studies to investigate the effects of urban runoff on fathead minnows. Hatchability, survival, and growth were assessed in the laboratory in flow-through and static bioassay tests. Growth was reduced to one half of the control growth rates at 60 percent dilutions of urban runoff. The observed effects were believed to be associated with a combination of toxicants.

The University of Washington[25,61-67] conducted a series of studies to contrast the biological and chemical conditions in urban Kelsey Creek with rural Bear Creek in Bellevue, Washington. The urban creek was significantly degraded when compared to the rural creek, but still supported a productive, but limited and unhealthy salmonid fishery. Many of the fish in the urban creek, however, had respiratory anomalies. The urban creek was not grossly polluted, but flooding from urban developments had increased dramatically in recent years. These increased flows dramatically changed the urban stream's channel, by causing unstable conditions with increased stream bed movement, and by altering the availability of food for the aquatic organisms. The aquatic organisms were very dependent on the few relatively undisturbed reaches. Dissolved oxygen concentrations in the sediments depressed embryo salmon survival in the urban creek. Various organic and metallic priority pollutants were discharged to the urban creek, but most of them were apparently carried through the creek system by the high storm flows to Lake Washington. The urbanized Kelsey Creek also had higher water temperatures (probably due to reduced shading) than Bear Creek. This probably caused the faster fish growth in Kelsey Creek.

The fish population in the urbanized Kelsey Creek had adapted to its degrading environment by shifting the species composition from Coho salmon to less sensitive cutthroat trout and by making extensive use of less disturbed refuge areas. Studies of damaged gills found that up to three-fourths of the fish in Kelsey Creek were affected with respiratory anomalies, while no cutthroat trout and only two of the Coho salmon sampled in the forested Bear Creek had damaged gills. Massive fish kills in Kelsey Creek and its tributaries were also observed on several occasions during the project due to the dumping of toxic materials down the storm drains.

There were also significant differences in the numbers and types of benthic organisms found in urban and forested creeks during the Bellevue research. Mayflies, stoneflies, caddisflies, and beetles were rarely observed in the urban Kelsey Creek, but were quite abundant in the forested Bear Creek. These organisms are commonly regarded as sensitive indicators of environmental degradation. One example of degraded conditions in Kelsey Creek was shown by a species of clams (*Unionidae*) that was not found in Kelsey Creek, but was commonly found in Bear Creek. These clams are very sensitive to heavy siltation and unstable sediments. Empty clam shells, however, were found buried in the Kelsey Creek sediments indicating their previous presence in the creek and their inability to adjust to the changing conditions. The benthic organism composition in Kelsey Creek varied radically with time and place while the organisms were much more stable in Bear Creek.

Urban runoff impact studies were conducted in the Hillsborough River near Tampa Bay, Florida, as part of the U.S. EPA's Nationwide Urban Runoff Program (NURP)[68]. Plants, animals, sediment, and water quality were all studied in the field and supplemented by laboratory bioassay tests. Effects of salt water intrusion and urban runoff were both measured because of the estuarine environment. During wet weather, freshwater species were found closer to the Bay than during dry weather. In coastal areas, these additional natural factors made it even more difficult to identify the cause and effect relationships for aquatic life problems. During another NURP project, Striegl[69] found that the effects of accumulated contaminants in Lake Ellyn (Glen Ellyn, Ill.) inhibited desirable benthic invertebrates and fish and increased undesirable phyotoplankton blooms.

The number of benthic organism taxa in Shabakunk Creek in Mercer County, New Jersey, declined from 13 in relatively undeveloped areas to four below heavily urbanized areas[70,71]. Periphyton samples were also analyzed for heavy metals with significantly higher metal concentrations found below the heavily urbanized area than above.

Stewart, *et al.*[72] collected diatoms (*Bacillariophyta*) and water quality samples from three streams that drain the Great Marsh in the Indiana Dunes National Lakeshore. They found that diatom species diversity could be used as indicators of water quality, which could then be linked to land use in a watershed. Diatom species diversity was most variable in areas with poorer water quality and was directly correlated to the total alkalinity, total hardness and specific conductance of the water in the stream.

A number of papers presented at the 7th International Conference on Urban Storm Drainage, held in Hannover, Germany, described receiving water studies that investigated organic and heavy metal toxicants. Handová, *et al.*[73] examined the bioavailability of metals from CSOs near Prague. They compared these results with biomonitoring. The metals were ranked according to their mobility as: Cd (95%), Zn (87%), Ni (64%), Cr (59%), Pb (48%), and Cu (45%). The mobile fraction was defined as the metal content that was exchangeable, bound to carbonates, bound to iron and manganese oxides, and bound to organic matter. Boudries, *et al.*[74] and Estèbe, *et al.*[75] investigated heavy metals and organics bound to particulates in the River Seine near Paris. The Paris CSOs caused a significant increase in the aliphatic and aromatic hydrocarbons bound to river sediments. The high flows during the winter were associated with lower heavy metal associations with the sediment, compared to the lower summer flow conditions. These differences were found to be due to dilution of the CSOs in the river and to the changing contributions of rural versus urban suspended solids during the different seasons.

The Northeastern Illinois Planning Commission[76] compared comprehensive fish survey information from over 40 northeastern Illinois small to moderate-sized streams and rivers to demographic data for the contributing watershed areas. The streams had watershed areas ranging from about 12 to 222 square miles and had population densities ranging from about 30 to more than 4,500 people per square mile. The fish data was used in the index of biotic integrity (IBI) to identify the quality of the fish populations. Table 1 lists the fish data that is used in the IBI and Table 2 shows the different scores for the quality categories. Factors necessary for good and excellent quality fish communities include the presence of diverse and reproducing fish and other aquatic organisms, including a significant percentage of intolerant species (such as darters and smallmouth bass).

Table 1. Index of Biotic Integrity (IBI) Metrics[76]

Category	Metric
Species richness and composition	Total number of fish species
	Number and identity of darter species
	Number and identity of sunfish species
	Number and identity of sucker species
	Number and identity of intolerant species
	Proportion of individuals as green sunfish
Trophic composition	Proportion of individuals as omnivores
	Proportion of individuals as hybrids
	Proportion of individuals as piscivores
Fish abundance and condition	Number of individuals in sample
	Proportion of individuals as hybrids
	Proportion of individuals with disease, tumors, fin damage, and skeletal anomalies

Table 2. Illinois Environmental Protection Agency (IEPA) Biological Stream Characterization (BSC) and Index of Biotic Integrity (IBI) Classifications and Criteria[76]

IBI Score	Stream Class	BSC Category	Biotic Resource Quality
51 – 60	A	Unique	Excellent
41 – 50	B	Highly Valued	Good
31 – 40	C	Moderate	Fair
21 – 30	D	Limited	Poor
≤ 20	E	Restricted	Very Poor

The more commonly used imperviousness-based indicator of development was not used due to a lack of available data and the difficulty of acquiring good quality current imperviousness data, let alone estimating historical imperviousness data. In contrast, population data was readily available and thought to be an adequate indicator of the extent and density of urbanization in the watersheds. They found that nearly all streams in urban and suburban watersheds having population densities greater than about 300 people per square mile showed signs of considerable impairment to their fish communities (being in fair to very poor condition). In contrast, nearly all rural streams supported fish communities that were rated good or excellent. They identified both point and nonpoint sources as major contributors to these impairments. However, the point source discharges and CSO discharges have substantially decreased over the past 20 years, while the nonpoint source discharges have increased significantly with increased development, and the fisheries are still declining in many areas. In stable areas that were mostly affected by point sources and CSOs, documented dramatic improvements in some water quality indicators (especially DO and ammonia), and the fish populations, have occurred. In similar areas, but having continued urban development, the fisheries have continued to decline.

They concluded that although rural watersheds have known water quality problems (especially agricultural chemicals and erosion, plus manure runoff), these issues did not prevent the attainment of mostly high quality fisheries in these areas. Similar conclusions were noted in the comparison study by the USGS in North Carolina[77] of forested, agricultural, and urban streams. Although the forested streams were of the best quality, the streams in the agricultural areas were of intermediate quality and had significantly better biological conditions than the urban stream (which had poor macroinvertebrate and fish conditions, poor sediment and temperature conditions, and fair substrate and nutrient conditions).

Habitat Effects Caused by Stormwater Discharges

Some of the most serious effects of urban runoff are on the aquatic habitat of the receiving waters. These habitat effects are in addition to the pollutant concentration effects. Numerous papers already referenced found significant sedimentation problems in urban receiving waters. The major effects of urban sediment on the aquatic habitat include silting of spawning and food production areas and unstable bed conditions[78]. Other major habitat destruction problems include rapidly changing flows and the absence of refuge areas to protect the biota during these flow changes. Removal of riparian vegetation can increase water temperatures and a major source of large organic debris that are important refuge areas. The major references on stream geomorphology that many of the following researchers based their work on were by Leopold, *et al.*[79], Brookes[80], and Rosgen[81]. These fundamental references should be consulted for excellent descriptions of the many natural processes affecting streams in transition. Brookes also specifically examines urbanization effects on stream morphology. Knowledge of these basic processes will better enable an understanding of local stream changes occurring with watershed urbanization. This understanding will, in turn, enable more efficient rehabilitation efforts of degraded streams and the use of watershed controls to minimize these effects.

Brookes[80] has documented many cases in the U.S. and Great Britain of stream morphological changes associated with urbanization. These changes are mostly responsible for habitat destruction that are usually the most significant detriment to aquatic life. In many cases, water quality improvement would result in very little aquatic life benefits if the physical habitat is grossly modified. The most obvious habitat problems are associated with stream "improvement" projects, ranging from removal of debris, to straightening streams, to channelization projects. Brookes[80,82] presents a number of ways to minimize habitat problems associated with stream channel projects, including stream restoration.

Wolman and Schick[83] observed deposition of channel bars, erosion of channel banks, obstruction of flows, increased flooding, shifting of channel bottoms, along with concurrent changes in the aquatic life, in Maryland streams affected by urban construction activities.

Pess and Bilby[84] identified Coho salmon (*Oncorhynchus kisutch*) distribution and abundance in Puget Sound rivers and explained the distribution by using both stream-reach and watershed-scale habitat characteristics, including the influence of urban areas on the habitat. In the Puget Sound region of the U.S. Pacific Northwest, Greenberg, *et al.*[85] developed and evaluated the Urban Stream Baseline Evaluation Method to characterize baseline habitat conditions for salmonids. The methodology, based on assessment of geomorphic suitability, fish distribution and habitat alteration, was recommended for use to prioritize recovery actions.

Bragg and Kershner[86] investigated the impact on the habitats of aquatic life and they found that coarse woody debris in riparian zones can be used successfully to maintain the integrity of these ecosystems. Larson[87] evaluated the effectiveness in urban areas of these habitat restoration activities using large woody debris and found that in urban areas, the success of restoration may be hindered by the high sediment loads and increased flow associated with urbanization. Markowitz, *et al.*[88] documented the CSO Long Term Control Plan implemented by the City of Akron, Ohio which focused on habitat preservation and aquatic life use of the receiving waters. The plan included these non-traditional alternatives: riparian setbacks in undeveloped areas, stream restoration, linear parks or greenways and artificial riffles for stream aeration, and were found to cost less than five percent of the typical cost of controlling CSO flows. A methodology to investigate the chronic and cumulative degradation of the river Orne due to CSO and urban runoff was presented by Zobrist, *et al.*[89], with the results being used to evaluate management activities. Xu, *et al.*[91] reported on the improvement plan being used for a river passing through the downtown area of a city in Western Japan and the problems that were inherent with developing a compromise strategy between flood control and mitigation and the desire to have an attractive waterway through the city. The final improvement plan recommended construction of a new flood drain tunnel and a new underground flood control reservoir.

Cianfrani, *et al.*[92] used a GIS system to document the results of a comprehensive inventory of the natural resources of the Fairmount Park (Philadelphia, Pennsylvania) stream system, including vegetation communities, fish, aquatic and terrestrial insects, birds, mollusks, amphibians, reptiles, and streams. The stream assessment also included the characterization of stream reaches by in-stream habitat, geomorphology and riparian zone. This GIS inventory then was used in planning the restoration of sites in the Fairmount Park system. Derry, *et al.*[93] reported on the habitat management strategies implemented by the City of Olympia, Washington, to control the degradation of aquatic habitats by urban stormwater runoff. These management strategies provided a basis for resolving the conflict between growth and the protection of aquatic resources. Ishikawa, *et al.*[94] reported on the efforts to restore the hydrological cycle in the Izumi River Basin in Yokohama, Japan while Saeki, *et al.*[95] have documented the efforts of the Tokyo Metropolitan Government and its Basin Committee to restore the natural water cycle in the Kanda River. Kennen[96] investigated the relationship between selected basin and water-quality characteristics in New Jersey streams and the impact on the macroinvertebrate community and its habitat. He found that urban areas had the greatest probability of having impacted stream areas, with the amount of urban land and the total flow of treated sewage effluent being the strongest explanatory variables for the impact. He also found that levels of impairment were significantly different between the Atlantic Coastal Rivers drainage area and the Lower Delaware River drainage area.

Increased Flows from Urbanization

Increased flows are the probably the best know example of impacts associated with urbanization. Most of the recognition has of course focused on increased flooding and associated damages. This has led to numerous attempts to control peak flows from new urban areas through the use of regulations that limit post development peak flows to pre development levels for relatively large design storms. The typical response has been to use dry detention ponds. This approach is limited, and may actually increase downstream flows. In addition to the serious issue of flooding, high flows also cause detrimental ecological problems in receiving waters. The following discussion presents several case studies where increased flows were found to have serious effects on stream habitat conditions.

The aquatic organism differences in urbanized and control streams found during the Bellevue Urban Runoff Program were probably most associated with the increased peak flows. The increased flows in the urbanized Kelsey Creek resulted in increases in sediment carrying capacity and channel instability of the creek[61-65]. Kelsey Creek had much lower flows than the control Bear Creek during periods between storms. About 30 percent less water was available in Kelsey Creek during the summers. These low flows may also have significantly affected the aquatic habitat and the ability of the urban creek to flush toxic spills or other dry weather contaminants from the creek system[66,67]. Kelsey Creek had extreme hydrologic responses to storm. Flooding substantially increased in Kelsey Creek during the period of urban development; the peak annual discharges almost doubled in the last 30 years, and the flooding frequency also increased due to urbanization[66, 67]. These increased flows in urbanized Kelsey Creek resulted in greatly increased sediment transport and channel instability.

Bhaduri, *et al.*[97] also quantified the changes in streamflow and associated decreases in groundwater recharge associated with urbanization. They point out that the most widely addressed hydrologic effect of urbanization is the peak discharge increases that cause local flooding. However, the increase in surface runoff volume also represents a net loss in groundwater recharge. They point out that urbanization is linked to increased variability in volume of water available for wetlands and small streams, causing "flashy" or "flood-and-drought" conditions. In northern Ohio, urbanization at a study area was found to cause a 195% increase in the annual volume of runoff, while the expected increase in the peak flow for the local 100-yr event was only 26% for the same site. Although any increase in severe flooding is problematic and cause for concern, the much larger increase in annual runoff volume, and associated decrease in groundwater recharge, likely has a much greater effect on in-stream biological conditions.

Snodgrass, *et al.*[16] reported that in the Toronto, Ontario, area, flows causing bankfull conditions occur with a return frequency of about 1.5 years. Storms with this frequency are in general equilibrium with resisting forces that tend to stabilize the channel (such as vegetation and tree root mats), with increased flows overcoming these resisting forces causing channel enlargement. Infrequent flows can therefore be highly erosive. With urbanization, the flows that were bankfull flows during historical times now occur much more frequently (about every 0.4 years in Toronto). The channel cross-sectional area therefore greatly increases to accommodate the increased stream discharges and power associated with the "new" 1.5 year flows that are trying to re-establish equilibrium.

Booth and Jackson[98] examined numerous data from lowland streams in western Washington and concluded that development having about 10% imperviousness caused a readily apparent degradation of aquatic life in the receiving waters. They linked the association between increased imperviousness and biological degradation to increases in flows and sediment discharges. They concluded that conventional methods to size stormwater mitigation measures (especially detention ponds) were seriously inadequate. They felt that without a better understanding of the critical processes that lead to degradation, some downstream damage to the aquatic ecosystem is likely inevitable, without unpopular restrictions to the extent of development in the watershed corresponding to <10% imperviousness. The stream channels were generally stable if the effective impervious areas remained below 10% of the complete watershed. This level of development corresponds to a 2-year developed condition flow being less than the historical 10-year pre-developed flow condition. They found that the classical goal of detention ponds to maintain predevelopment flows was seriously inadequate because there is no control on the duration of the peak flows. They showed that a duration standard to maintain post development flow durations for all sediment-transporting discharges to predevelopment durations will avoid many receiving water habitat problems associated with stream instability. Without infiltration, the amount of runoff will obviously still increase with urbanization, but the increased water could be discharged from detention facilities at flow rates below the critical threshold causing sediment transport. The identification of the threshold discharge below which sediment transport does not occur, unfortunately, if difficult and very site specific. A presumed threshold discharge of about one-half of the pre-development 2-year flow was recommended for gravel bedded streams. Sand-bedded channels have sediment transport thresholds that are very small, with inevitable bed load transport likely to occur for most levels of urbanization.

Channel Modifications due to Urban Wet Weather Flow Discharges

Changes in physical stream channel characteristics can have a significant effect on the biological health of the stream. These changes in urban streams have been mostly related to changes in the flow regime of the stream, specifically increases in peak flow rates, increased frequencies and durations of erosive flows, and channel modifications made in an attempt to accommodate increased stormwater discharges.

Schueler[99] stated that channel geometric stability can be a good indicator of the effectiveness of stormwater control practices. He also found that once a watershed area has more than about 10 to 15% effective impervious cover, noticeable changes in channel morphology occur, along with quantifiable impacts on water quality, and biological conditions. Stephenson[100] studied changes in streamflow volumes in South Africa during urbanization. He found increased stormwater runoff, decreases in the groundwater table, and dramatically decreased times of concentration. The peak flow rates increased by about two-fold, about half caused by increased pavement (in an area having only about 5% effective impervious cover), with the remainder caused by decreased times of concentration (related to the increased drainage efficiency of artificial conveyances).

Richey[64] made some observations about bank stabilities in Kelsey and Bear Creeks as part of the Bellevue, WA, NURP project[25]. She notes that the Kelsey Creek channel width had been constrained during urban development. Thirty-five percent of the urbanized Kelsey Creek channel mapped during these projects was modified by the addition of some type of stabilization structure. Only eight percent of non-urbanized Bear Creek's length was stabilized. Most of the stabilization structures in Bear Creek were low walls in disrepair while more than half of the structures observed along Kelsey Creek were large riprap or concrete retention walls. The necessity of the stabilization structures was evident from the extent and severity of erosion cuts and the number of deposition bars observed along the Kelsey Creek stream banks. Bridges and culverts were also frequently found along Kelsey

Creek; these structures further act to constrict the channel. As discharges increased and the channel width is constrained, the velocity increases, causing increases in erosion and sediment transport.

The use of heavy riprapping along the creek seemed to worsen the flood problems. Storm flows are unable to spread out onto the flood plain and the increased velocities are evident downstream along with increased sediment loads. This rapidly moving water has enough energy to erode unprotected banks downstream of riprap. Many erosion cuts along Kelsey Creek downstream of these riprap structures were found. Similar erosion of the banks did not occur in Bear Creek. Much of the Bear Creek channel had a wide flood plain with many side sloughs and back eddies. High flows in Bear Creek could spread onto the flood plains and drop much of their sediment load as the water velocities decreased.

The University of Washington studies also examined sediment transport in urbanized Kelsey and non-urbanized Bear Creeks. Richey[64] found that the relative lack of debris dams and off-channel storage areas and sloughs in Kelsey Creek contributed to the rapid downstream transit of water and materials. The small size of the riparian vegetation and the increased stream power probably both contributed to the lack of debris in the channel. It is also possible that the channel debris may have been cleared from the stream to facilitate rapid drainage. The high flows from high velocities caused the sediments to be relatively coarse. The finer materials were more easily transported downstream. Larger boulders were also found in the sediment but were probably from failed riprap or gabion structures.

Maxted[101] examined stream problems in Delaware associated with urbanization. He found an apparent strong correlation between habitat score and biology score from 40 stream study locations. He found that it is not possible to have acceptable biological conditions if the habitat is degraded. The leading contributor to habitat degradation was found to be urban runoff, especially the associated high flows and sediment accumulations.

A number of presentations concerning aquatic habitat effects from urbanization were made at the *Effects of Watershed Development and Management on Aquatic Ecosystems* conference held in Snowbird, UT, in August of 1996, sponsored by the Engineering Foundation and the ASCE. MacRae[102] presented a review of the development of the common zero runoff increase (ZRI) discharge criterion, referring to peak discharges before and after development. This criterion is commonly met using detention ponds for the 2 yr storm. MacRae shows how this criterion has not effectively protected the receiving water habitat. He found that stream bed and bank erosion is controlled by the frequency and duration of the mid-depth flows (generally occurring more often than once a year), not the bank-full condition (approximated by the 2 yr event). During monitoring near Toronto, he found that the duration of the geomorphically significant pre-development mid-bankfull flows increased by a factor of 4.2 times, after 34% of the basin had been urbanized, compared to before development flow conditions. The channel had responded by increasing in cross-sectional area by as much as 3 times in some areas, and was still expanding. Table 3 shows the modeled durations of critical discharges for predevelopment conditions, compared to current and ultimate levels of development with "zero runoff increase" controls in place. At full development and even with full ZRI compliance in this watershed, the hours exceeding the critical mid-bankfull conditions will increase by a factor of 10, with resulting significant effects on channel stability and the physical habitat.

Table 3. Hours of Exceedence of Developed Conditions with Zero Runoff Increase Controls Compared to Predevelopment Conditions[102]

Recurrence Interval (yrs)	Existing Flowrate (m3/s)	Exceedence for Predevelopment Conditions (hrs per 5 yrs)	Exceedence for Existing Development Conditions, with ZRI Controls (hrs per 5 yrs)	Exceedence for Ultimate Development Conditions, with ZRI Controls (hrs per 5 yrs)
1.01 (critical mid-bankfull conditions)	1.24	90	380	900
1.5 (bankfull conditions)	2.1	30	34	120

MacRae[102] also reported other studies that found that channel cross-sectional areas began to enlarge after about 20 to 25% of the watershed was developed, corresponding to about a 5% impervious cover in the watershed. When the watersheds are completely developed, the channel enlargements were about 5 to 7 times the original cross-sectional areas. Changes from stable streambed conditions to unstable conditions appear to occur with basin imperviousness of about 10%, similar to the value reported previously for serious biological degradation. He also summarized a study conducted in British Columbia that examined 30 stream reaches in natural areas, in urbanized areas having peak flow attenuation ponds, and in urbanized areas not having any stormwater controls. The channel widths in the uncontrolled urban streams were about 1.7 times the widths of the natural streams. The streams having the ponds also showed widening, but at a reduced amount compared to the uncontrolled urban streams. He concluded that an effective criterion to protect stream stability (a major component of habitat protection) must address mid-bankfull events, especially by requiring similar durations and frequencies of stream power (the product of shear stress and flow velocity, not just flow velocity alone) at these depths, compared to satisfactory reference conditions.

Much research on habitat changes and rehabilitation attempts in urban streams has occurred in the Seattle area of western Washington over the past 20 years. Sovern and Washington[103] described the in-stream processes associated with urbanization in this area, as part of a paper describing a recommended approach for the rehabilitation of urban streams. They were concerned that many "restoration" attempts of urban streams were destined to failure because of a lack of understanding of the actual changes occurring in streams as the watersheds changed from forested to urban land uses. They presented a concept of the "new urban stream" that attempts to correct several of the most important changes to better accommodate the native Pacific Northwest fish, instead of the unrealistic goal of trying to totally restore the steams to predevelopment conditions. The important factors that affect the direction and magnitude of the changes in a steam's physical characteristics due to urbanization include:

- the depths and widths of the dominant discharge channel will increase directly proportional to the water discharge. The width is also directly proportional to the sediment discharge. The channel width divided by the depth (the channel shape) is also directly related to sediment discharge.
- the channel gradient is inversely proportional to the water discharge rate, and is directly proportional to the sediment discharge rate and the sediment grain size.
- the sinuosity of the stream is directly proportional to the stream's valley gradient and is inversely proportional to the sediment discharge.
- bed load transport is directly related to the stream power and the concentration of fine material, and inversely proportional to the fall diameter of the bed material.

In their natural state, small streams in forested watersheds in Western Washington have small low-flow channels (the aquatic habitat channel) with little meandering[103]. The stream banks are nearly vertical because of clayey bank soils and heavy root structures, and the streams have numerous debris jams from fallen timber. The widths are also narrow, generally from 3 to 6 feet wide. Stable forested watersheds also support about 250 aquatic plant and animal species along the stream corridor. Pool/riffle habitat is dominant along streams having gradients less than about 2 percent slope, while pool/drop habitat is dominant along streams having gradients from 4 to 10 percent. The pools form behind large organic debris (LOD) or rocks. The salmon and trout in Western Washington have evolved to take advantage of these stream characteristics. Sovern and Washington[103] point out that less athletic fish species (such as chum and pink salmon) cannot utilize the steeper gradient, upper reaches, of the streams. Coho, steelhead and cutthroat can use these upper areas, however.

Urbanization radically affects many of these natural stream characteristics. Pitt and Bissonnette[25] reported that the Coho salmon and cutthroat trout were affected by the increased nutrients and elevated temperatures of the urbanized streams in Bellevue, as studied by the University of Washington as part of the U.S. EPA's NURP project[104]. These conditions were probably responsible for accelerated growth of the fry which were observed to migrate to Puget Sound and the Pacific Ocean sooner than their counterparts in the control forested watershed that was also studied. However, the degradation of sediments, mainly the decreased particle sizes, adversely affected their spawning areas in streams that had become urbanized. Sovern and Washington[103] reported that, in Western Washington, frequent high flow rates can be 10 to 100 times the predevelopment flows in urbanized areas, but that the low flows in the urban streams are commonly lower than the predevelopment low flows. They have concluded that the effects of urbanization on western Washington streams are dramatic, in most cases permanently changing the stream hydrologic balance by: increasing the annual water volume in the stream, increasing the volume and rate of storm flows, decreasing the low flows during dry periods, and increasing the sediment and contaminant discharges from the watershed. With urbanization, the streams increase in cross-sectional area to accommodate these increased flows and headwater downcutting occurs to decrease the channel gradient. The gradients of stable urban streams are often only about 1 to 2 percent, compared to 2 to 10 percent gradients in natural areas. These changes in width and the downcutting result in very different and changing stream conditions. The common pool/drop habitats are generally replaced by pool/riffle habitats, and the stream bed material is comprised of much finer material, for example. Along urban streams, fewer than 50 aquatic plant and animal species are usually found. They have concluded that once urbanization begins, the effects on stream shape are not completely reversible. Developing and maintaining quality aquatic life habitat, however, is possible under urban conditions, but it requires human intervention and it will not be the same as for forested watersheds.

Other Seattle area researchers have specifically examined the role that large woody debris (LWD) has in stabilizing the habitat in urban streams. Booth, *et al.*[105] found that LWD performs key functions in undisturbed streams that drain lowland forested watersheds in western Washington. These important functions include: energy dissipation of the flow energy, channel bank and bed stabilization, sediment trapping, and pool formation. Urbanization typically results in the almost complete removal of this material. They point out that logs and other debris have long been removed from channels in urban areas for many reasons, especially because of their potential for blocking culverts or to form jams at bridges, they may increase bank scour, and many residents favor "neat" stream bank areas (a lack of woody debris in and near the water and even with mowed grass to the waters edge). Booth, *et al.*[105] present and modify the stream classification system originally developed by Montgomery and Buffington[106] that recognizes LWD as an important component of Pacific northwest streams that are being severely affected by urbanization.

The role of LWD varies in each channel type, and the effects of its removal also varies. The channel types are described as follows. The upper colluvial channels are wholly surrounded by colluvium (sediment transported by creep or landsliding, and not by stream transport) and generally lie at the top of the channel network. The cascade channels are the steepest of the alluvial channels and are characterized as having tumbling flows around individual boulders that dissipate most of the energy of the flowing water. Only very small pools are in cascade channels. The step-pool channels have accumulations of debris that form a series of steps that are one to four channel widths apart. The steps separate small pools that accumulate fine sediment. The fine sediment can be periodically flushed downstream during rare events. "Free" step-pool channels are characterized by steps that are made of alluvium that can be periodically transported downstream during high flows, while "forced" step-pool channels are characterized by steps that are made of immovable obstructions (large logs or bedrock). The removal of LWD from a forced step-pool stream in the Cascade Range could be naturally compensated by the common occurrence of large boulders that also form forced steps. However, in the lowlands near Puget Sound, the available sand and gravel stream deposits are too small to form stable steps, and the removal of LWD would have a much more severe effect on the channel stability. Plane-bed channels have long and channel-wide reaches of uniform riffles and do not have pronounced meanders and associated pools. Pool-riffle channels are the most common lowland stream channels in western Washington. These streams have pronounced meanders with pools at the outside of the bends and corresponding bars on the inside of the bends. Riffles form in the relatively straight stretch between the pools. There are also "free" and "forced" pool-riffle channels. Forced riffle-pool channels are typically formed with obstructions, such as LWD, and their removal would generally lead to a plane-bed channel characteristic. Forced riffle-pool channels form due to natural meanders and the inertial forces of the water. Dune-ripple channels have beds mostly made of sand where the character of the bed material changes in response to the flows.

The role of LWD is also highly dependent on the width of the stream. In narrow channels (high gradient colluvial and cascade channels), much of the LWD can be suspended above the flows, rarely being submerged and not available as a fish refuge, a sediment trap, or to dissipate the water's energy. In wide channels (dune-ripple channels), the LWD may be significantly shorter than the channel width, with minimal stable opportunities to provide steps in the channel. Therefore, LWD plays a much more important role in channels having medium widths (lowland streams having plane-bed and pool-riffle channels), where the timber can become tightly lodged in the common flow channel. The removal of the LWD in these streams, especially in streams having few boulder steps, would have significant effects. Fish populations decline rapidly and precipitously following the removal of LWD in these critical streams [105].

Horner, *et al.*[107] described an extensive study in the Pacific Northwest where 31 stream reaches were examined since 1994 for a variety of in-stream and watershed characteristics. They felt that the most severe in-stream biological changes were most likely associated with changes in habitat, especially increased frequencies and magnitudes of high flows. These flow changes were therefore thought to most related to watershed factors affecting runoff, especially the amount of impervious areas in the watershed. They felt that the most rapid changes in ecological conditions were most likely to occur for urbanizing streams at relatively low levels of development, conditions representing most of the selected study sites.

Horner, *et al.*[107] found a rapid decline in biological conditions as total imperviousness area increases to about 8% in the watershed. The rate of decline is less for higher levels of urbanization. Eight study areas had better biological conditions than expected and were associated with higher amounts of intact wetlands along the riparian corridors than other sites, indicating a possible significant moderating effect associated with preserving stream corridors in their natural condition. The less tolerant Coho salmon is much more abundant than the more tolerant cutthroat trout only for very low levels of urbanization. Stormwater concentrations of zinc were also seen to increase steadily with increasing impervious areas. However, the concentrations are well below the critical water quality criteria until the impervious cover reaches about 40%, a level much greater than when significant biological effects are noted. Similar conclusions were made with other metal concentrations and contaminant concentrations in the sediment. They interpreted these findings to imply that contaminant conditions were much less important than habitat destruction when affecting in-stream biological conditions. They concluded that the preponderance of physical and biological evidence indicated rapid in-stream biological conditions at early stages of urbanization. However, chemical contaminants did not appear to significantly affect biological conditions in the early stages of urbanization, but may have at very high levels of urbanization. Based on their results, they developed a preliminary summary of the conditions that would allow high levels of biological functions in the Puget Sound area:

- total impervious areas less than 5% of the watershed area, unless mitigated by extensive riparian protection, management efforts, or both;
- 2-year peak flow/winter baseflow ratio of <20;
- greater than 60% of the upstream buffer should be greater than 30 m wide; and
- less than 15% of the sediment in the stream bed should be less than 0.85 mm.

Habitat evaluations are commonly and justifiably recognized as critical components of stream and watershed studies. However, Poole, *et al.*[108] caution users concerning their use to quantify aquatic habitat or channel morphology in an attempt to measure the response of individual streams to human activities. Their concern is the subjectivity of habitat surveys and the lack of repeatability, precision, and transferability of the measurement techniques. The measurement parameters are also assigned relatively arbitrary nominal values that are not easily statistically evaluated. They feel that the typical use of habitat unit classifications encourages the focus on direct manipulation or replacement of habitat structures (such as in stream "restoration" activities) while neglecting the long-term maintenance of habitat-forming biophysical processes (such as controlling the energy distribution of stream discharges and the discharges of sediment into the streams).

Therefore, the use of habitat unit classifications as an indicator of watershed health may be most appropriately used for only very large differences or changes, when conducted over a large portion of a watershed being studied, and only if a sufficiently large number of observations and replicates are made to compensate for the high inherent measurement variations. Many current habitat surveys are being conducted on small scales within a short period of time and with few observations, and without adequate statistical evaluations of the data. The results of these surveys are therefore of questionable value. As for all indicators, it is important that methods be developed and tested to improve the accuracy of the tool, and that additional supplemental measurement methods also be used to confirm observations and conclusions, especially when evaluating cause and effect relationships in watersheds.

Stormwater Contamination of Sediments and Increased Sediment Discharges in Urban Streams

Many of the observed biological effects associated with urban runoff may be caused by polluted sediments and associated benthic organism impacts. The EPA[109] prepared a four volume report to Congress on the incidence and severity of sediment contamination in the surface waters of the U.S. This report was required by the Water Resources Development Act of 1992. This Act defines contaminated sediment as "sediment containing chemical substances in excess of appropriate geochemical, toxicological or sediment quality criteria or measures; or otherwise considered to pose a threat to human health or the environment." In the national quality survey, the EPA examined data from 65% of the 2,111 watersheds in the U.S. and identified 96 watersheds that contain areas of probable concern. In portions of these waters, benthic organisms and fish may contain chemicals at levels unsafe for regular consumption. Areas of probable concern are located in regions affected by urban and agricultural runoff, municipal and industrial waste discharges, and other contaminant sources. When the fourth volume is completed, much more detailed information will become available concerning the relative role that urban stormwater contributes to national contaminated sediment problems. Sediment quality criteria is an emerging area, with slowly emerging general guidance available to compare locally observed conditions to "standards." In most cases, local reference conditions have been most effectively used to indicated if the observed conditions constitute a problem[13].

Examples of elevated heavy metal and nutrient accumulations in urban sediments are numerous. DePinto, *et al.*[110] found that the cadmium content of river sediments can be more than 1,000 times greater than the overlying water concentrations and the accumulation factors in sediments are closely correlated with sediment organic content. They reported that sediments were also able to adsorb phosphorus in proportion to the phosphorus concentrations in the overlaying waters during aerobic periods, but that the sediments released phosphorus during anaerobic periods. Heaney[111] found that long-term impacts of urban runoff related to the resuspension of previously deposited polluted benthos material may be more important than short-term discharges of contaminants from potential "first-flushes."

Another comprehensive study on polluted sediment was conducted by Wilber and Hunter[112] along the Saddle River in New Jersey where they found significant increases in sediment contamination with increasing urbanization. They found large variations in metal concentrations for different sediment particle sizes in the urban river. The sediment particle size distribution was the predominant influencing factor for total metal concentrations in the sediments. Areas having fine sediments had a substantially greater concentration of heavy metals than those areas having coarse sediments.

In another study, Pitt and Bozeman[22] observed concentrations for many contaminants in the urban area sediments of Coyote Creek (San Jose, California) that were much greater than those from the nonurban area. Orthophosphates, TOC, BOD_5, sulfates, sulfur, and lead were all found in higher concentrations in the sediments from the urban area stations, as compared with those from the upstream, non-urban area stations. The median sediment particle sizes were also found to be significantly smaller at the urban area stations, reflecting a higher silt content.

Several of the University of Washington projects and the Seattle METRO project investigated physical and chemical characteristics of the Kelsey and Bear Creeks sediments as part of the Bellevue, WA, NURP projects[25]. Perkins[63] found that the size and composition of the sediments near the water interface tended to be more variable and of a larger median size in Kelsey Creek than in Bear Creek. These particle sizes varied in both streams on an annual cycle in response to runoff events. Larger particle sizes were more common during the winter months when the larger flows were probably more efficient in flushing through the finer materials. Pedersen[61] also states that Kelsey

Creek demonstrated a much greater accumulation of sandy sediments in the early spring. This decreases the suitability of the stream substrates for benthic colonization. Scott, *et al.*[26] state that the level of fines in the sediment samples appears to be a more sensitive measure of substrate quality than the geometric mean of the particle size distribution. Fines were defined as all material less than about 840 microns in diameter. METRO[113] also analyzed organic priority pollutants in 17 creek sediments including several in Kelsey and Bear Creeks. Very few organic compounds were detected in either stream with the most notable trend being the much more common occurrence of various PAHs in Kelsey Creek while none were detected in Bear Creek.

Scott, *et al.*[65] state that streambed substrate quality can be an important factor in the survival of salmonid embryos. Richey[64] describes sediment bioassay tests which were performed using Kelsey and Bear Creeks sediments. She found that during the four-day bioassay experiment, no mortalities or loss of activities were observed in any of the tests. She concluded that the chemical constituents in the sediment were not acutely toxic to the test organism. However, the chronic and/or low level toxicities of these materials was not tested.

The University of Washington project and the Seattle METRO project analyzed interstitial water for various constituents. These samples were obtained by inserting perforated aluminum stand pipes into the creek sediment. This water is most affected by the sediment quality and affects in turn the benthic organisms much more than the creek water column. Scott, *et al.*[65] found that the interstitial water pH ranged from 6.5 to 7.6 and did not significantly differ between the two streams but did tend to decrease during the spring months. The lower fall temperatures and pH levels contributed to reductions in ammonium concentrations. The total ammonia and unionized ammonia concentrations were significantly greater in Kelsey Creek than in Bear Creek. They also found that the interstitial dissolved oxygen concentrations in Kelsey Creek were much below those concentrations considered normal for undisturbed watersheds. These decreased interstitial oxygen concentrations were much less than the water column concentrations and indicated the possible impact of urban development. The dissolved oxygen concentrations in the interstitial waters and Bear Creek were also lower than expected potentially suggesting deteriorating fish spawning conditions. During the winter and spring months, the interstitial oxygen concentrations appeared to be intermediate between those characteristic of disturbed and undisturbed watersheds.

The University of Washington[64] also analyzed heavy metals in the interstitial waters, focusing mostly on the more readily detected lead and zinc measurements compared to the low, or undetectable, copper and chromium concentrations. The urban Kelsey Creek interstitial water had concentrations of heavy metals approximately twice those found in the rural Bear Creek interstitial water. They expect that most of the metals were loosely bound to fine sediment particles. Most of the lead found was associated with the particulates, with very little soluble lead found in the interstitial waters. The interstitial samples taken from the stand pipe samplers were full of sediment particles which could be expected to release lead into solution following the mild acid digestion for exchangeable lead analyses. They also found that the metal concentrations in Kelsey Creek interstitial water decreased in a downstream direction. They felt that this might be caused by stream scouring of the benthic material in that part of the creek. The downstream Kelsey Creek sites were more prone to erosion and channel scouring while the most upstream station was relatively stable.

Variable interstitial water quality may cause variations in sediment toxicity with time and location. Seattle METRO[113] monitored heavy metals in the interstitial waters in Kelsey and Bear Creeks. They found large variations in heavy metal concentrations depending upon whether the sample was obtained during the wet or the dry season. During storm periods, the interstitial water and creek water heavy metal concentrations approached the stormwater values (200 μg/L for lead). During non-storm periods, the interstitial lead concentrations were typically only about 1 μg/L. They also analyzed priority pollutant organics in interstitial waters. Only benzene was found and only in the urban stream. The observed benzene concentrations in two Kelsey Creek samples were 22 and 24 μg/L, while the reported concentrations were less than 1 μg/L in all other interstitial water samples analyzed for benzene.

A number of recent investigations have examined sediment quality in conjunction with biological conditions in urban receiving waters in attempts to identify causative agents affecting the biological community. Arhelger, *et al.*[114] examined conditions in the upper Houston Ship Channel that receives drainage from the metropolitan Houston area. The channel has been dredged to allow large vessels access to the upper reaches of what used to be a relatively small channel. The dredging has increased the cross-sectional area by about 20 times, with attendant significant decreases in flushing flows. This has allowed efficient sedimentation of suspended material discharged from the 500 mi^2 urban watershed. The sediments have undergone extensive chemical, physical, and toxicity testing, with frequent indications of toxicity. The tests have indicated that the toxicity is most likely caused by the high sediment oxygen demand and associated low dissolved oxygen conditions. Toxicity testing of *Ampelisca* under varied DO conditions showed significant decreases in survival when the bottom DO is less than 3 mg/L, for example. Even though the point source BOD loads have been reduced by more than 90% since the 1970s, receiving water and sediment oxygen levels are very low, presumably caused by uncontrolled stormwater sources.

Previous studies near Auckland, New Zealand have shown that sediment concentrations of many constituents near stormwater outfalls, especially in industrial areas, often exceed guidelines intended to protect bottom-dwelling animals. Guidelines used were as presented by Long, *et al.*[115] and were as follows (along with sediment concentrations from two locations near Auckland):

mg/kg	Copper	Lead	Zinc
Effects range - low	34	47	150
Effects range - median	270	218	410
Hellyers/Kaipatiki	17 – 36	13 – 95	58 – 192
Pakuranga	14 – 65	22 – 112	108 – 345

Lead, zinc, and organochlorine were the most widespread potential problems. Field surveys and laboratory toxicity tests had shown circumstantial evidence of chronic toxicity associated with stormwater. Detailed field surveys, by Morrisey, *et al.*[116], were therefore conducted to better understand actual toxicity problems in the local marine estuaries that are influenced by complex natural factors. These complicating factors include strong gradients in salinity, sediment texture, currents, and wave action, all radically affecting the natural distribution of benthic fauna. In slowly growing areas or in relatively low density urban areas, the relatively small rate of accumulation of contaminated sediments from nonpoint sources may take many years to accumulate to levels that may produce detectable impacts in the receiving waters. In addition, changing urban conditions and changing weather from year to year make the rate of accumulation highly variable. These factors all make it difficult to conduct many types of field experiments that rely on before and after observations, or other short-term observations that assume steady conditions. They therefore relied on a "weight-of-evidence" approach considering many different and reinforcing/confirming procedures (such as the sediment quality triad and the effects range tests, both of which rely on distribution of contaminants and organisms in the field and from laboratory toxicity tests). They also applied their results to the Abundance Biomass Comparison index proposed by Warwick[117]. This index is a relative measure of biomass vs. abundance and has been shown to work well for individual sites where control sites are difficult to identify and study, especially if available "control" sites already impacted. Pore water chemistry, sediment quality, and benthic community composition were included in the field analyses. Statistical analyses identified the strongest correlations between pH and iron content of the pore water and the sediment texture, with benthic composition. The pH and iron pore water conditions may affect the bioavailability of the sediment heavy metals. Current and future work includes similar studies in non-urbanized estuaries, the development of chronic toxicity tests using local indigenous organisms, and studies of recolonization of heavily impacted sites. .

Watzin, *et al.*[118] examined sediment contamination in Lake Champlain near Burlington, VT, to compare several toxicity endpoints with sediment characteristics. They measured sediment pore water toxicity using *Ceriodaphania dubia*, *Chironomus tentans*, and *Pimephales promelas*, benthic community composition, and many physical and chemical characteristics at 19 locations. Four major storm drains and the secondary sewage treatment plant all discharged to the harbor. Boat traffic and historical petroleum handling facilities also affected some of the sampling locations. They found variable levels of toxicity at the different sites, but effects of acid-volatile sulfides on heavy metal toxicity was not demonstrated. However, they did find strong associations between metal and organic carbon levels and toxicity, indicating possible metal-organic matter complexation reducing metal availability. The sediment toxicity tests did indicate a moderate level of concern, but the macroinvertebrate community was apparently not significantly affected during these tests. They propose the use of a weight-of-evidence approach that uses multiple indicators of problems and possible sources of the problems, plus repeated observations over seasonal cycles, before management recommendations are developed.

Equilibrium partitioning of sediment-based fluoranthene and critical bioaccumulation levels was used to predict toxicity to amphipods by Driscoll and Landrum[119]. The equilibrium partitioning theory (EqP) has been used to predict effects of organic toxicants found in sediments, using an organic carbon-normalized sediment concentration of the hydrophobic organic compound (used for PAHs and pesticides) and resulting estimated pore-water concentrations. They report that toxicity bioassays with benthic invertebrates have, in general, confirmed this approach. However, certain test organisms and sediments have not been well predicted using this approach. Driscoll and Landrum tested a complementary method: the critical body residue (CBR) approach. This method measures the actual body burdens of a compound in relation to toxic effects. They found that the CBR approach is a useful complement to the EqP approach for the prediction and assessment of toxicity associated with contaminated sediments.

Rhoads and Cahill[120] studied the elevated concentrations of chromium, copper, lead, nickel and zinc that were found in sediments near storm sewer outfalls. They noted that copper and zinc concentrations were greater in the bedload compared to the bed material and therefore were more likely to be mobilized during runoff events.

Crabill, *et al.*[121] presented their analysis of the water and sediment in Oak Creek in Arizona, which showed that the sediment fecal coliform counts were on average 2200 times greater than that in the water column. Water quality standards for fecal coliforms were regularly violated during the summer due to the high recreational activity and animal activity in the watershed, as well as the storm surges due to the summer storm season.

Vollertsen, *et al.*[122] characterized the biodegradability of combined-sewer organic matter based on settling velocity. Fast settling organic matter, which represents the largest fraction of the organic material, was found to be rather slowly biodegradable compared to the slow settling organic fraction. The biodegradability of sewer sediments was argued to be taken into account for detailed characterization when dealing with CSO impacts. Vollertsen and Hvitved-Jacobsen[123] studied the stoichiometric and kinetic model parameters for predicting microbial transformations of suspended solids in combined sewer systems.

The effects of large discharges of relatively uncontaminated sediment on the receiving water aquatic environment were summarized by Schueler[124]. These large discharges are mostly associated with poorly controlled construction sites, where 30 to 300 tons of sediment per acre per year of exposure may be lost. These high rates can be 20 to 2,000 times the unit area rates associated with other land uses. Unfortunately, much of this sediment reaches urban receiving waters, where massive impacts on the aquatic environment can result. Unfortunately, high rates of sediment loss can also be associated with later phases of urbanization, where receiving water channel banks widen to accommodate the increased runoff volume and frequency of high erosive flow rates. Sediment is typically listed as one of the most important pollutants causing receiving water problems in the nations waters. Schueler[124] listed the impacts that can be associated with suspended sediment:

"• abrades and damages fish gills, increasing risk of infection and disease
• scouring of periphyton from streams (plants attached to rocks)
• loss of sensitive or threatened fish species when turbidity exceeds 25 NTU
• shifts in fish communities toward more sediment tolerant species
• decline in sunfish, bass, chub, and catfish when monthly turbidity exceed 100 NTU
• reduces sight distance for trout, with reduction in feeding efficiency
• reduces light penetration that causes reduction in plankton and aquatic plant growth
• reduces filtration efficiency of zooplankton in lakes and estuaries
• adversely impacts aquatic insects which are the base of the food chain
• slightly increases stream temperature in summer
• suspended sediments are a major carrier of nutrients and metals
• turbidity increases probability of boating, swimming, and diving accidents
• increased water treatment to meet drinking water standards

- increased wear and tear on hydroelectric and water intake equipment
- reduces anglers chances of catching fish
- diminishes direct and indirect recreational experience of receiving waters".

He also listed the impacts that can be associated with deposited sediment:

"• physical smothering of benthic aquatic insect community
- reduced survival rates for fish eggs
- destruction of fish spawning areas and redds
- 'imbedding' of stream bottom reduces fish and macroinvertebrate habitat value
- loss of trout habitat when fine sediments are deposited in spawning or riffle-runs
- sensitive or threatened darters and dace may be eliminated from fish community
- increase in sediment oxygen demand can deplete DO in lakes or streams
- significant contributing factor in the alarming decline of freshwater mussels
- reduced channel capacity, exacerbating downstream bank erosion and flooding
- reduced flood transport capacity under bridges and through culverts
- loss of storage and lower design life for reservoirs, impoundments, and ponds
- dredging costs to maintain navigable channels and reservoir capacity
- spoiling of sand beaches
- deposits diminish the scenic and recreational value of waterways"

Sediment Contamination Effects and Criteria

There is much concern and discussion about contaminated sediments in urban receiving waters. Many historical discussions downplayed the significance of contaminated sediments, based on their assumed "low-availability" to aquatic organisms. However, many of the previously described receiving water studies found greatly disturbed benthic organism populations at sites with contaminated urban sediments, compared to uncontaminated control sites. More specifically, ***in-situ*** sediment toxicity tests in urban receiving waters (such as those conducted by Burton and Stemmer[125]; Burton[126, 128-129]; Burton, *et al.*[127], Burton and Scott[130]; and Crunkilton, *et al.*[12]) have illustrated the direct toxic effects associated with exposure to contaminated urban sediments, to problems associated with their scour, and to decreases in toxicity associated with their removal from stormwater.

The fate of contaminated sediments, especially mechanisms that expose contaminants to sensitive organisms, can determine the overall and varied effects that the sediments may have. Scour of fine-grained sediments during periods of high flows in streams and rivers, or due to turbulence from watercraft in shallow waterbodies, has frequently been encountered. In addition, contaminant remobilization may also occur through bioturbation from sediment-dwelling organisms, or from nest-building fish. These mechanisms may resuspend contaminants, making them more available to organisms. Burrowing organisms can also transport deeply buried contaminants to surface layers, thereby increasing surface contamination levels, while the surface scouring mechanisms would tend to decrease the concentrations in the surface sediment. Bioturbation has been reported to strongly influence the fate of contaminants and that sediment-bound contaminants can be remobilized by biological activity[131].

Lee and Jones-Lee[6] reviewed the significance of chemically contaminated sediments and associated impacts. They are especially concerned about the development of sediment contamination criteria based on simple chemical tests. They feel that is has been well demonstrated that the toxic-available form of chemical constituents present in the sediment is the dissolved form present in the interstitial waters. Historically, the EPA assumed that the dissolved form of certain organic toxicants could be estimated based on an equilibrium partitioning model based on the particulate organic carbon present. Likewise, the dissolved forms of heavy metals were assumed to be controlled by metal sulfide precipitates. Lee and Jones-Lee feel that the EPA's overly simplistic two component box model used to predict dissolved forms of toxicants should never be used alone without concurrent well-established toxicity measurements. They are also concerned about the use of toxicity co-occurrence data bases used to relate measured sediment chemical conditions with observed biological conditions that are also sometimes used to establish sediment criteria. These data bases have not considered some of the most important possible causes of toxicity at the test sites, namely low dissolved oxygen, and high ammonia and hydrogen sulfide concentrations. They outlined the components of sediment toxicity tests that they feel are necessary:

- Non-chemically based "toxicity" can be caused by factors such as sediment grain size.
- Natural vs. authropogenically caused sediment toxicity also needs to be separated. They mention several instances where sediments are naturally toxic according to laboratory toxicity tests, but still support healthy and high-quality sport fisheries in overlying waters. The most obvious natural cause of sediment toxicity is low oxygen levels in the interstitial water. High levels of ammonia and hydrogen sulfide may also then occur. They state that "the presence of highly toxic conditions in sediments from natural causes, which decimates the benthic organism populations for a considerable part of the year, does not preclude the presence of an outstanding sports fishery."
- The sensitivity of the test organisms to ammonia toxicity should be considered. Several commonly used toxicity test organisms are much less sensitive to ammonia than many naturally occurring aquatic life forms of interest. Some researchers also strip ammonia from the sediments before testing, treating ammonia as a test interference. They feel that nutrient-derived toxicity (algal decomposition effects on sediment oxygen demand, and the resulting reducing conditions, low dissolved oxygen levels, and high ammonia and hydrogen sulfide levels) may be the most important cause of toxicity in aquatic sediments. An appropriate toxicity investigation evaluation (TIE) should be conducted to identify the cause of any identified toxicity problems. The use of acid volatile sulfide and heavy metal concentrations and TOC normalized sediment organic concentrations can be used as part of a TIE to rule out metals or certain organics as the potential cause of toxicity, but the reverse is not reliable (these methods cannot predict toxicity).
- Selecting reference sites is critical. A suite of test toxicity organisms (at least two or three) must be used, along with a suite of reference sites. Multiple references sites is needed to help understand the role of natural causes of toxicity. In addition, investigations should be conducted at least twice in a year during important times for the aquatic organisms.

They feel that the best approach in developing sediment quality evaluations should use a best professional judgment (BPJ), weight-of-evidence approach. This approach involves an integrated assessment of the aquatic life toxicity test results, assessment of the bioaccumulations of hazardous chemicals in edible portions of aquatic life, knowledge of chemical characteristics of the sediments and associated waters, and investigations of the aquatic life assemblages in the sediments of concern compared to appropriate reference sites.

Bioassessments and other Watershed Indicators as Components of Receiving Water Evaluations

Kuehne[132] studied the usefulness of using various aquatic organisms during stream taxonomic surveys as indicators of pollution. He found that invertebrates can reveal pollution for some time after a water pollution event, but they cannot give accurate indications of the nature of the contaminants. He stated that in-stream fish studies had not been employed as biological indicators much before 1975, but that they are comparable in many ways to invertebrates as quality indicators and can be more easily identified. However, because of better information pertaining to invertebrates and due to their limited mobility, certain species may be useful as sensitive indicators of minor changes in water quality. Fish can be highly mobile and cover large sections of a stream, as long as their passage is not totally blocked by adverse conditions. Fish disease surveys were also used during the Bellevue, Washington, urban runoff studies as an indicator of water quality problems[25, 65]. McHardy, *et al.*[133] also examined heavy metal uptake in green algae (*Cladophora glomerata*) from urban runoff for use as a biological monitor of specific metals.

Burton, *et al.*[127], during tests conducted at polluted stream and landfill sites, found that a battery of laboratory and in-situ bioassay tests were most useful when determining aquatic biota problems. The test series included microbial activity tests, along with exposures of microfaunal organisms, zooplankton, amphipods, and fathead minnows to the test water. The newly developed microbial tests correlated well with *in-situ* biological test results. Bascombe, *et al.*[134] also reported on the use of *in-situ* biological tests, using an amphipod exposed for five to six weeks in urban streams, to examine urban runoff receiving water effects. Ellis, *et al.*[135] examined bioassay procedures for evaluating urban runoff effects on receiving water biota. They concluded that an acceptable criteria for protecting receiving water organisms should not only provide information on concentration and exposure relationships for *in-situ* bioassays, but also consider body burdens, recovery rates, and sediment related effects.

A number of stormwater researchers have recently presented bioassessment and other "watershed indicators" that they have found as useful tools to quantify local receiving water problems. Many of these schemes were presented at the *Assessing the Cumulative Impacts of Watershed Development in Aquatic Ecosystems and Water Quality* conference held in Chicago in March of 1996, sponsored by the Northeastern Illinois Planning Commission, and at the *Effects of Watershed Development and Management on Aquatic Ecosystems* conference held in Snowbird, UT, in August of 1996, sponsored by the Engineering Foundation and the ASCE. Several papers from those conferences are summarized below, by location.

U.S. National Perspective of Bioassessments

Barbour[136] reviewed many of the state programs throughout the U.S. that are using biological assessments as part of their water resources programs. Most of the active state bioassessment programs started since 1990, after the publication of the EPA's *Rapid Bioassessment Protocols*[137] and the *Program Guidance for Biocriteria*[138] manuals. By 1996, numeric biocriteria were in place in Ohio and Florida (and promulgated in Maine) and under development in 13 other states. Although the majority of the states had not used biocriteria, nearly ¾ had used bioassessment data to measure the attainment of their aquatic uses. Almost all states were using benthic macroinvertebrates (all but 3 states) and fish (all but 14 states). Seven states were also using algae in their bioassessment programs.

An important aspect of the biocriteria approach is that local and regional expectations be considered in setting specific objectives. In addition, local reference sites representing specific ecoregions are also used to calibrate observations. The basic components of a bioassessment include:

- study objectives (typically the determination of biological conditions for different watershed characteristics),
- site classification (identification of homogeneous areas within a watershed, typically using various biological metrics),
- reference condition (relatively undisturbed areas for comparison and calibration of the metrics),
- standardized protocols (training and the use of consistent methods),
- data analysis (selection of several complementary metrics based on local relevancy),
- habitat assessment (physical habitat structure evaluations, generally a visual technique), and
- quality assurance (assign responsibility, establish protocols, etc. to ensure repeatability).

Watershed Indicators of Receiving Water Problems

The EPA[139] published a list of 18 indicators to track the health of the nation's aquatic ecosystems. These indicators are intended to supplement conventional water quality analyses in compliance monitoring activities. The use of broader indicators of environmental health is increasing. As an example, 12 states are currently using biological indicators, and 27 states are developing local biological indicators, according to Pelley[140]. Because of the broad nature of the nation's potential receiving water problems, this list is more general than typically used for specific stormwater issues. These 18 indicators are[139]:

1) population served by drinking water systems violating health-based requirements.
2) population served by unfiltered surface water systems at risk from microbiological contamination.
3) population served by communities by community drinking water systems exceeding lead action levels.
4) drinking water systems with source water protection programs.
5) fish consumption advisories.
6) shellfish-growing waters approved for harvest for human consumption.
7) biological integrity of rivers and estuaries.
8) species at risk of extinction.
9) rate of wetland acreage loss.
10) designated uses: drinking water supply, fish and shellfish consumption, recreation, aquatic like.
11) groundwater pollutants (nitrate).

12) surface water pollutants.
13) selected coastal surface water pollutants in shellfish.
14) estuarine eutrophication conditions.
15) contaminated sediments.
16) selected point source loadings to surface water and groundwater.
17) nonpoint source sediment loadings from crop land.
18) marine debris.

These environmental indicators cover a wide range of problems and many are for specific local uses. Most, however, are applicable to stormwater problems in urban areas.

Claytor[141, 142] summarized the approach developed by the Center for Watershed Protection as part of their EPA sponsored research on identifying watershed indicators that can be used to assess the effectiveness of stormwater management programs [143]. The indicators selected are direct or indirect measurements of conditions or elements which indicate trends or responses of watershed conditions to stormwater management activities. Categories of these environmental indicators are shown in Table 4, ranging from conventional water quality measurements to citizen surveys. Biological and habitat categories are also represented. Table 5 lists the 26 indicators, by category. It is recommended that appropriate indicators be selected from each category for a specific area under study. This will enable a better understanding of the linkage of what is done on the land, how the sources are regulated or managed, and the associated receiving water problems. The indicators were selected to: 1) measure stress or the activities that lead to impacts on receiving waters, 2) assess the resources itself, and 3) measure the regulatory compliance or program initiatives. Claytor[142] presented a framework for using stormwater indicators, as shown below:

Level 1 (Problem Identification):

1) establish management sphere (who is responsible, other regulatory agencies involved, etc.)
2) gather and review historical data
3) identify local uses which may be impacted by stormwater (flooding/drainage, biological integrity, non-contact recreation, drinking water supply, contact recreation, and aquaculture).
4) inventory resources and identify constraints (time frame, expertise, funding and labor limitations)
5) assess baseline conditions (use rapid assessment methods).

Table 4. Stormwater Indicator Categories[142]

Category	Description	Principle element being assessed
Water Quality	Specific water quality characteristics	Receiving water quality
Physical/Hydrological	Measure changes to, or impacts on, the physical environment	Receiving water quality
Biological	Use of biological communities to measure changes to, or impacts on, biological parameters	Receiving water quality
Social	Responses to surveys or questionnaires to assess social concerns	Human activity on the land surface
Programmatic	Quantify various non-aquatic parameters for measuring program activities	Regulatory compliance or program initiatives
Site	Indicators adapted for assessing specific conditions at the site level	Human activity on the land surface

Table 5. Environmental Indicators[142]

Indicator Category	Indicator Name
Water Quality Indicators	Water quality pollutant constituent monitoring Toxicity testing Non-point source loadings Exceedence frequencies of water quality standards Sediment contamination Human health criteria
Physical and Hydrological Indicators	Stream widening/downcutting Physical habitat monitoring Impacted dry weather flows Increased flooding frequency Stream temperature monitoring
Biological Indicators	Fish assemblage Macro-invertebrate assemblage Single species indicator Composite indicators Other biological indicators
Social Indicators	Public attitude surveys Industrial/commercial pollution prevention Public involvement and monitoring User perception
Programmatic Indicators	Illicit connections identified/corrected BMPs installed, inspected, and maintained Permitting and compliance Growth and development
Site Indicators	BMP performance monitoring Industrial site compliance monitoring

The selection of the indicators to assess the baseline conditions should be based on the local uses of concern, as shown on Table 6. Most of the anticipated important uses are shown to require indicators selected for each of the categories.

The Level 2 assessment strategy is for examining the local management program and is outlined below:

1) state goals for program (based on baseline conditions, resources, and constraints)
2) inventory prior and on-going efforts (including evaluating the success of on-gong efforts)
3) develop and implement management program
4) develop and implement monitoring program (more quantitative indicators than typically used for the level 1 evaluations above)
5) assess indicator results (does the stormwater indicator monitoring program measure the overall watershed health?)
6) re-evaluate management program (update and revis e management program based on measured successes and failures)

Table 6. Selection of Indicators for Evaluating Baseline Conditions, by Receiving Water Use[142]

	Water quality	Physical/ hydrological	Biological indicators	Social indicators	Programmatic indicators	Site indicators
Flooding/drainage		X		X	X	X
Biological integrity	X		X	X	X	X
Non-contact recreation	X	X	X	X	X	X
Water supply	X		X	X	X	X
Contact recreation	X	X	X	X	X	X
Aquaculture	X	X	X	X	X	X

Cave[144] described how environmental indicators are being used to summarize the massive amounts of data being generated by the Rouge River National Wet Weather Demonstration Project in Wayne County (Detroit area), MI. This massive project is examining existing receiving water problems, the performance of stormwater and CSO management practices, and receiving water responses in a 438 mi^2 watershed having more than 1.5 million people in 48 separate communities. The baseline monitoring program has now more than 4 years of continuous monitoring of flow, pH, temperature, conductivity, and DO, supplemented by automatic sampling for other water quality constituents, at 18 river stations. More than 60 projects are examining the effectiveness of stormwater management practices and 20 projects are examining the effectiveness of CSO controls, each also generating large amounts of data. Toxicants are also being monitored in sediment, water, fish tissue, and with semipermeable membranes to help evaluate human health and aquatic life effects. Habitat surveys were conducted at 83 locations along more than 200 miles of waterway. Algal diversity and benthic macroinvertebrate assessments were also conducted at these survey locations. Electrofishing surveys were conducted at 36 locations along the main river and in tributaries. Several computer models were also used to predict sources, loadings, and wet weather flow management options for the receiving waters and for the drainage systems. A geographic information system was used to manage and provide spatial analyses of the massive amounts of data collected. However, there was still a great need to simply present the data and findings, especially for public presentations. Cave described how they developed a short list of 35 indicators, based on the list of 18 from EPA and with discussions with state and national regulatory personnel. They then developed seven indices that could be color-coded and placed on maps to indicate areas of existing problems and projected conditions based on alternative management scenarios. These indices are described as follows:

Condition Quality Indicators:
1) dissolved oxygen. Concentration and % saturation values (ecologically important)
2) fish consumption index. Based on advisories from the Michigan Dept. of Public Health.
3) river flow. Significant for aquatic habitat and fish communities.
4) bacteria count. *E. coli* counts based on Michigan Water Quality Standards, distinguished for wet and dry conditions.

Multi-Factor Indices:
1) aquatic biology index. Composite index based on fish and macroinvertebrate community assessments (populations and individuals)
2) aquatic habitat index. Habitat suitability index, based on substrate, cover, channel morphology, riparian/bank condition, and water quality.
3) aesthetic index. Based on water clarity, color, odor, and visible debris.

These seven indicators represent 30 physical, chemical, and biological conditions what directly impact the local receiving water uses (water contact recreation, warmwater fishery, and general aesthetics). Cave presented specific descriptions for each of the indices and gave examples of how they are color-coded for map presentation.

The use of reference sites is common to many bioassessment approaches. As indicated above, reference sites typically are selected as representing as close to natural conditions as possible. However, it is not possible to identify such pristine locations representing varied habitat conditions in most areas of the country. Ohio, for example, has numerous reference sites throughout the state representing a broad range of conditions, but few are completely unimpacted by modifications or human activity in the watersheds. Schueler[77] reviewed a USGS report prepared by Crawford and Leant that examined the differences between streams located in forested, agricultural, and urban watersheds in North Carolina. He points out that in many cases, a completely natural forested area is not a suitable benchmark for current conditions before urbanization. In many areas of the country, agricultural land is being converted to urban land, and the in-stream changes expected may be better compared to agricultural conditions. The USGS study found that the stream impacted by agricultural operations was intermediate in quality, with higher nutrient and worse substrate conditions than the urban stream, but better macroinvertebrate and fish conditions. The forested watershed had the best conditions (good quality conditions for all categories), except for somewhat higher sediment heavy metal concentrations than expected. Even though the agricultural watershed had little impervious area, it had high sediment and nutrient discharges, plus some impacted stream corridors. The urban stream had poor macroinvertebrate and fish conditions, poor sediment and temperature conditions, and fair substrate and nutrient conditions.

Summary of Assessment Tools

Almost all states using bioassessment tools have relied on the EPA reference documents as the basis for their programs. Common components of these bioassessment programs (in general order of popularity) include:

- macroinvertebrate surveys (almost all programs, but with varying identification and sampling efforts)
- habitat surveys (almost all programs)
- some simple water quality analyses
- some watershed characterizations
- few fish surveys
- limited sediment quality analyses
- limited stream flow analyses
- hardly any toxicity testing
- hardly any comprehensive water quality analyses

Normally, numerous metrics are used, typically only based on macroinvertebrate survey results, which are then assembled into a composite index. Many researchers have identified correlations between these composite index values and habitat conditions. Water quality analyses in many of these assessments are seldom comprehensive, a possible over-reaction to conventional very costly programs that have typically resulted in minimally worthwhile information. Burton and Pitt[13] have recommended a more balanced assessment approach, using toxicity testing and carefully selected water and sediment analyses to supplement the needed biological monitoring activities. A multi-component assessment enables a more complete evaluation of causative factors and potential mitigation approaches.

Summary of Urban Runoff Effects on Receiving Waters

The effects of urban runoff on receiving water aquatic organisms or other beneficial uses is very site specific. Different land development practices create substantially different runoff flow characteristics. Different rain patterns cause different particulate washoff, transport and dilution conditions. Local attitudes also define specific beneficial uses and, therefore, current problems. There is also a wide variety of water types receiving urban runoff, and these waters all have watersheds that are urbanized to various degrees. Therefore, it is not surprising that urban runoff effects, though generally dramatic, are also quite variable and site specific.

Previous attempts to identify urban runoff problems using existing water quality data have not been conclusive because of differences in sampling procedures and the common practice of pooling data from various sites, or conditions[4]. It is therefore necessary to carefully design comprehensive, long-term studies to investigate urban runoff problems on a site-specific basis. Sediment transport, deposition, and chemistry play key roles in urban receiving waters and need additional research. Receiving water aquatic biological conditions, especially compared to unaffected receiving waters, should be studied as a supplement to laboratory bioassays. In-stream taxonomic surveys are sensitive to natural variations of pollutant concentrations, flows, and other habitat affects. However, laboratory studies are necessary to help understand potential cause and effect relationships because of their ability to better control exposure variables.

These specific studies need to examine beneficial uses directly, and not rely on published water quality criteria and water column measurements alone. Published criteria are usually not applicable to urban runoff because of the slug nature of urban runoff and the unique chemical speciation of its components. Typical natural water pollutant characteristics (especially chemical mixtures and exposure pulses) are difficult to interpret, compared to simpler artificial systems having continuous discharges of more uniform characteristics.

The long-term aquatic life effects of urban runoff are probably more important than short-term effects associated with specific events, and are related to site specific conditions associated with dilution, size of the watershed, and size of the stream. The long-term effects are probably related to habitat degradation, deposition and accumulation of toxic sediments, or the inability of the aquatic organisms to adjust to repeated exposures to high concentrations of toxic materials or high flow rates.

References

1 *Water Environment & Technology*. "News Watch: U.S. water quality shows little improvement over 1992 inventory." Vol. 8, no. 2, pp. 15 - 16. Feb. 1996a.

2 Borchardt, D. and B. Statzner. "Ecological impact of urban stormwater studied in experimental flumes: Population loss by drift and availability of refugial space." *Aquatic Sciences*. Vol. 52, No. 4. pp. 299-314. 1990.

3 Field, R., and R. Pitt. "Urban storm-induced discharge impacts: US Environmental Protection Agency research program review." *Water Science and Technology*. Vol. 22, No. 10/11. 1990.

4 Pitt, R. E. "Biological effects of urban runoff discharges." in: *Effects of Urban Runoff on Receiving Systems: An Interdisciplinary Analysis of Impact, Monitoring, and Management,* Engineering Foundation Conference, Mt. Crested Butte, CO. ASCE, NY. 1991.

5 Pitt, R. "Effects of Urban Runoff on Aquatic Biota." In: *Handbook of Ecotoxicology* (Edited by D.J. Hoffman, B.A. Rattner, G.A. Burton, Jr. and J.Cairns, Jr.). Lewis Publishers/CRC Press, Boca Raton, pp. 609-630. 1995.

6 Lee, G.F. and A. Jones-Lee. "Evaluation of the water quality significance of the chemical constituents in aquatic sediments: Coupling sediment quality evaluation results to significant water quality impacts." *WEFTEC '96, Surface Water Quality and Ecology, parts 1 and 2*. 1996 Water Environment Federation Technical Exposition and Conference, Dallas, TX. WEF, Alexandria, VA. 1996.

7 Lee, G.F. and A. Jones-Lee. "Deficiencies in stormwater quality monitoring." in: *Stormwater NPDES Related Monitoring Needs.* Edited by H.C. Torno. Proceedings of an Engineering Foundation Conference, Mt. Crested Butte, CO. August 1994. ASCE, NY. 1995.

8 Mancini, J. and A. Plummer. "Urban runoff and water quality criteria." In: *Urban Runoff Quality – Impact and Quality Enhancement Technology.* Edited by B. Urbonas and L.A. Roesner. Engineering Foundation Conference, Henniker, Hew Hampshire. ASCE, NY. pp. 133-149. June 1986.

9 Davies, P.H. "Factors in controlling nonpoint source impacts." Engineering Foundation/ASCE conference held in 1991 in Mt. Crested Butte, Colorado: *Stormwater Runoff and Receiving Systems: Impact, Monitoring and Assessment* (edited by E.E. Herricks). Lewis/CRC Press. Boca Raton. pp. 53 – 64. 1995.

10 Herricks, E.E, I. Milne, and I. Johnson. "A protocol for wet weather discharge toxicity assessment." Volume 4, pg. 13 - 24. *WEFTEC'96: Proceedings of the 69th Annual Conference & Exposition.* Dallas, Texas. 1996.

11 Herricks. E.E., editor. *Stormwater Runoff and Receiving Systems: Impact, Monitoring and Assessment.* Conference of the Engineering Foundation/ASCE held in 1991 in Mt. Crested Butte, Colorado. Lewis/CRC Press. Boca Raton. 458 pgs. 1995.

12 Crunkilton, R., J. Kleist, J. Ramcheck, W. DeVita, and D. Villeneueve. "Assessment of the response of aquatic organisms to long-term *in-situ* exposures to urban runoff." Presented at the *Effects of Watershed Developments and Management on Aquatic Ecosystems* conference. Snowbird, UT, August 4 – 9, 1996. Edited by L.A. Roesner. ASCE, New York. 1997.

13 Burton, G.A. Jr., and R. Pitt. *Stormwater Effects Handbook: A Tool Box for Watershed Managers, Scientists, and Engineers*. CRC Press, Inc., Boca Raton, FL. August 2001. 1085 pgs.

14 Duda, A.M., D.R. Lenat, and D. Penrose. "Water quality in urban streams - What we can expect." *Journal Water Pollution Control Federation.* Vol. 54, No. 7. pp. 1139- 1147. July 1982.

15 Horner, R.R. "Toward ecologically based urban runoff management." In: *Effects of Urban Runoff on Receiving Systems: An Interdisciplinary Analysis of Impact, Monitoring, and Management.* Engineering Foundation Conference. Mt. Crested Butte, CO. ASCE, NY. 1991.

16 Snodgrass, W.J., B.W. Kilgour, L. Leon, N. Eyles, J. Parish, and D.R. Barton. "Applying ecological criteria for stream biota and an impact flow model for evaluation sustainable urban water resources in southern Ontario." In: *Sustaining Urban Water Resources in the 21st Century.* Proceedings of an Engineering Foundation Conference. Edited by A.C. Rowney, P. Stahre, and L.A. Roesner. Malmo, Sweden. Sept. 7 – 12, 1997. To be published by ACSE, New York. 1998.

17 Ketchum, L.H., Jr. *Dissolved Oxygen Measurements in Indiana Streams During Urban Runoff.* EPA-600/2-78-135, U.S. Environmental Protection Agency, Cincinnati, Ohio. August 1978.

18 Heaney, J.P., W.C. Huber, M.E. Lehman. *Nationwide Assessment of Receiving Water Impacts from Urban Storm Water Pollution*. U.S. Environmental Protection Agency, Cincinnati, Ohio, April 1980.

19 Pitt, R. E. *Demonstration of Nonpoint Pollution Abatement Through Improved Street Cleaning Practices*, EPA-600/2-79-161, U.S. Environmental Protection Agency, Cincinnati, Ohio, August 1979.

20 Burkholder, J.M., L.M. Larsen, H.B. Glasgow, Jr., K.M. Mason, P. Gama, and J.E. Parsons. "Influence of sediment and phosphorus loading on phytoplankton communities in an urban piedmont reservoir." *Journal of Lake and Reservoir Management*. Vol. 14, no. 1, pp. 110 – 121. January 1998.

21 Field, R., and C. Cibik. "Urban runoff and combined sewer overflows." *Journal of Water Pollution Control Federation*. Vol. 52. No. 6. pp.1290-1307. June 1980.

22 Pitt, R. and M. Bozeman. *Sources of Urban Runoff Pollution and Its Effects on an Urban Creek*, EPA-600/52-82-090, U.S. Environmental Protection Agency, Cincinnati, Ohio, December 1982.

23 Bolstad, P.V. and W.T. Swank. "Cumulative impacts of landuse on water quality in a southern Appalachian watershed." *Journal of the American Water Resources Association*. Vol. 33, no. 3, pp. 519 – 533. June 1997.

24 Ray, S., and W. White. "Selected aquatic plants as indicator species for heavy metal pollution." *Journal of Environmental Science and Health*, A11, 717, 1976.

25 Pitt, R.E., and P. Bissonnette. *Bellevue Urban Runoff Program, Summary Report*. PB84 237213. Water Planning Division, U.S. Environmental Protection Agency, Washington, D.C., December 1983.

26 Scott, J.B., C.R. Steward, and Q.J. Stober. "Effects of urban development on fish population dynamics in Kelsey Creek, Washington." *Trans. Amer. Fisheries Society*. Vol. 115, No. 4. pp. 555-567. July 1986.

27 Marcy, S. and J. Gerritsen. "Developing deverse assessment endpoints to address multiple stressors in watershed ecological risk assessment." Abstract Book: *SETAC 17th Annual Meeting*. pg. 96. Washington, D.C., Nov. 17 - 21, 1996.

28a Dyer, S.D. and C.E. White. "A watershed approach to assess mixture toxicity via integration of public and private databases." Abstract Book: *SETAC 17th Annual Meeting*. pg. 96. Washington, D.C., Nov. 17 - 21, 1996.

28b ES&T *(Environmental Science & Technology)*. "Toxicity of aquatic mixtures yielding to new theoretical approach.". Vol. 30, no. 4, pp. 155a - 156a. April 1996a.

29 Ireland, D.S., G.A. Burton, Jr., and G.G. Hess. "In-situ toxicity evaluations of turbidity and photoinduction of polycyclic aromatic hydrocarbons." *Environmental Toxicology and Chemistry*. Vol. 15, no. 4, pp. 574 - 581. April 1996.

30 Johnson, I., E.E. Herricks, and I. Milne. "Application of a test battery for wet weather discharge toxicity analyses." Volume 4, pg. 219 - 229. *WEFTEC'96: Proceedings of the 69th Annual Conference & Exposition*. Dallas, Texas. 1996.

31 Rainbow, P.S. "Chapter 18: Heavy metals in aquatic invertebrates." *In: Environmental Contaminants in Wildlife; Interpreting Tissue Concentrations*. Edited by W.N. Beyer, G.H. Heinz, and A.W. Redmon-Norwood. CRC/Lewis Press. Boca Raton. pp. 405 - 425. 1996.

32 Allen, H.E. (editor). *Metal Contaminated Aquatic Sediments*. Ann Arbor Press. Chelsea, MI. 350 pgs. 1996.

33 Hall, L.W., Jr., M.C. Scott, W.D. Killen, Jr., and R.D. Anderson. "The effects of land-use characteristics and acid sensitivity on the ecological status of Maryland coastal plain streams." *Environmental Toxicology and Chemistry*. Vol. 15, no. 3, pp. 384 – 394. 1996.

34 Garries, M.J., T. Barron, R. Batiuk, K. Eisenman, J. Gregory, L. Hall. A. Hart, P. Jiapizian, W. Rue, J. Savitz, M.E. Setting, and C. Stoll. "Derivation of Chesapeake Bay toxics of concern." Abstract Book: *SETAC 17th Annual Meeting*. pg. 105. Washington, D.C., Nov. 17 - 21, 1996.

35 Schueler, T. (editor). "*In-situ*, nonbenthic assessment of stormwater-impacted sediments." *Watershed Protection Techniques*. Vol. 2, no. 2, pp. 351 - 353. Spring 1996b.

36 Love, E., and Woolley, B . Environmentally Sustainable Stormwater Quality. *Proc. the Eighth International Conference on Urban Storm Drainage*. August 30 – September 3, 1999, Sydney, Australia. Edited by IB Joliffe and JE Ball. The Institution of Engineers Australia, The International Association for Hydraulic Research, and The International Association on Water Quality. 50. 1999.

37 Pitt, R. "Urban stormwater toxic pollutant assessment, sources, and treatability - closure." *Water Environment Research*. Vol. 68, no. 5, pp. 953 - 955. July/Aug. 1996.

38 Huber, W.C., and Quigley, M.M . Simplified Fate and Transport Model of Runoff From Highway Construction and Repair Materials. *Proc. the Eighth International Conference on Urban Storm Drainage*. August 30 – September 3, 1999, Sydney, Australia. Edited by IB Joliffe and JE Ball. The Institution of Engineers Australia, The International Association for Hydraulic Research, and The International Association on Water Quality, 1209. 1999.

39 Doherty, F.G.; Qureshi, A.A.; and Razza, J.B . Comparison of the *Ceriodaphnia dubia* and Microtox® Inhibition Tests For Toxicity Assessment of Industrial and Municipal Wastewaters. *Environ. Toxicol*. **14**, 4, 375. 1999.

40 Kosmala, A.; Charvet, S.; Roger, M.C.; and Faessel, B . Impact Assessment of a Wastewater Treatment Plant Effluent Using Instream Invertebrates and the *Ceriodaphnia dubia* Chronic Toxicity Test. *Water Res.* (G.B.), **33**, 1, 266. 1999.

41 Marsalek, J.; Rochfort, Q.; Brownlee, B.; Mayer, T.; and Servos, M . Exploratory Study of Urban Runoff Toxicity. *Water Sci. and Tech.*(G.B.), **39**, 12, 33. 1999.

42 Marsalek J., and Rochfort, Q . Toxicity of Urban Wet-weather Pollution Sources: Stormwater and CSOs. *Proc. the Eighth International Conference on Urban Storm Drainage*. August 30 – September 3, 1999, Sydney, Australia. Edited by IB Joliffe and JE Ball. The Institution of Engineers Australia, The International Association for Hydraulic Research, and The International Association on Water Quality, 1575. 1999.

43 Skinner, L.; de Peyster, A.; and Schiff, K . Developmental Effects of Urban Storm Water in Medaka (*Oryzias latipes*) and Inland Silverside (*Menidia beryllina*). *Arch. Environ. Contam.Toxicol.*. 37, 2, 227. 1999.

44 Tucker, K.A., and Burton, G.A . Assessment of Nonpoint-Source Runoff in a Stream Using In-Situ and Laboratory Approaches. *Environ. Toxicol. Chem.*. **18**, 12, 2797. 1999.

45 Hatch, A.C., and Burton, G.A . Sediment Toxicity and Stormwater Runoff in a Contaminated Receiving System: Consideration of Different Bioassays in the Laboratory and Field. *Chemosphere*, **39**, 6, 1001. 1999.

46 Bickford, G.; Toll, J.; Hansen, J.; Baker, E.; and Keessen, R . Aquatic Ecological and Human Health Risk Assessment of Chemicals in Wet Weather Discharges in the Sydney Region, New South Wales, Australia. *Mar. Pollut. Bull.*. **39**, 1-2, 335. 1999.

47 Brent, R.N., and Herricks, E.E . A Method for the Toxicity Assessment of Wet Weather Events. *Water Res.* (G.B.), **33**, 10, 2255. 1999.

48 Colford, J.M.; Tager, I.; Byers, L.F.; Ricci, P.; Hubbard, A.; and Horner R . Methods for Assessing the Public Health Impact of Outflows from Combined Sewer Systems. *J. Air Waste Manage. Assoc.*. **49**, 4, 454. 1999.

49 Heaney, J.P. and W.C. Huber. "Nationwide assessment of urban runoff impact on receiving water quality." *Water Resources Bulletin*. Vol. 20. No. 1. pp. 35-42. February 1984.

50 Klein, R.D. Urbanization and Stream Quality Impairment. *Water Resources Bulletin*. Vol. 15. No. 4. August 1979.

51 Lenet, D.R., D.L. Penrose, and K. Eagleson. *Biological Evaluation of Non-Point Sources of Pollutants in North Carolina Streams and Rivers*. North Carolina Division of Environmental Management, Biological Series #102. North Carolina Dept. of Natural Resources and Community Development, Raleigh, North Carolina. 1979.

52 Lenet, D. and K. Eagleson. *Ecological Effects of Urban Runoff on North Carolina Streams*. North Carolina Division of Environmental Management, Biological Series #104. North Carolina Dept. of Natural Resources and Community Development, Raleigh, North Carolina. 1981.

53 Lenet, D.R., D.L. Penrose, and K.W. Eagleson. "Variable effects of sediment addition on stream benthos." *Hydrobiologia*. Vol. 79. pp. 187-194. 1981.

54 Cook, W.L., F. Parrish, J.D. Satterfield, W.G. Nolan, and P.E. Gaffney. *Biological and Chemical Assessment of Nonpoint Source Pollution in Georgia: Ridge-Valley and Sea Island Streams*. Department of Biology, Georgia State University. Atlanta, Georgia. 1983.

55 Benke, A.C., G.E. Willeke, F.K. Parrish,and D.L. Stites. *Effects of Urbanization on Stream Ecosystems*. School of Biology, Environmental Resources Center, Report No. ERC 07-81. Georgia Institute of Technology. Atlanta, Georgia. 1981.

56 CTA, Inc. *Georgia Nonpoint Source Impact Assessment Study: Blue Ridge/Upland Georgia Cluster, Piedmont Cluster, and Gulf Coastal Plain Cluster*. Georgia Envir, Protection Division, Dept. of Natural Resources, Atlanta, Georgia. 1983.

57 Pratt, J.M., R.A. Coler and P.J. Godfrey. "Ecological effects of urban stormwater runoff on benthic macroinvertibrates inhabiting the Green River, Massachusetts." *Hydrobiologia*. Vol. 83. pp. 29-42. 1981.

58 Ehrenfeld, J.G. and J.P. Schneider. *The Sensitivity of Cedar Swamps to the Effects of Non-Point Pollution Associated with Suburbanization in the New Jersey Pine Barrens*. U.S. Environmental Protection Agency. Office of Water Policy. PB8-4-136779. Washington, D.C. Sept. 1983.

59 Medeiros, C. and R.A. Coler. *A Laboratory/Field Investigation into the Biological Effects of Urban Runoff*. Water Resources Research Center, University of Massachusetts. Amherst, Massachusetts. July 1982.

60 Medeiros, C., R.A. Coler, and E.J. Calabrese. "A laboratory assessment of the toxicity of urban runoff on the fathead minnow (*Pimephales promelas*)." *Journal of Environmental Science Health*. Vol. A19. No. 7. pp. 847-861. 1984.

61 Pedersen, Edward Robert. *The Use of Benthic Invertebrate Data for Evaluating Impacts of Urban Stormwater Runoff.* Masters thesis submitted to the College of Engineering, University of Washington, Seattle, 1981.

62 Richey, Joanne Sloane, Michael A. Perkins, and Kenneth W. Malueg. "The effects of urbanization and stormwater runoff on the food quality in two salmonid streams." *Verh. Internat. Werein. Limnol.* Vol. 21, Pages 812-818, Stuttgart, October 1981.

63 Perkins, M. A. *An Evaluation of Instream Ecological Effects Associated with Urban Runoff to a Lowland Stream in Western Washington.* U.S. Environmental Protection Agency, Corvallis Environmental Research Laboratory, Corvallis, Oregon, July, 1982.

64 Richey, Joanne Sloane. *Effects of Urbanization on a Lowland Stream in Western Washington.* Doctor of Philosophy dissertation, University of Washington, Seattle, 1982.

65 Scott, J.B., C.R. Steward, and Q.J. Stober. *Impacts of Urban Runoff on Fish Populations in Kelsey Creek, Washington.* Contract No. R806387020, U.S. Environmental Protection Agency, Corvallis Environmental Research Laboratory, Corvallis, Oregon, May 1982.

66 Ebbert, J.C., J. E. Poole, and K.L. Payne. *Data Collected by the U.S. Geological Survey During a Study of Urban Runoff in Bellevue, Washington, 1979-82.* Preliminary U.S. Geological Survey Open-File Report, Tacoma, Washington, 1983.

67 Prych, Edmund A. and J.C. Ebbert. *Quantity and Quality of Storm Runoff from Three Urban Catchments in Bellevue, Washington.* Preliminary U.S. Geological Survey Water Resources Investigations Report, Tacoma, Washington, undated.

68 Mote Marine Laboratory. *Biological and Chemical Studies on the Impact of Stormwater Runoff upon the Biological Community of the Hillsborough River, Tampa, Florida.* Stormwater Management Division, Dept. of Public Works. Tampa, Florida. March 1984.

69 Striegl, R.G. *Effects of Stormwater Runoff on an Urban Lake, Lake Ellyn at Glen Ellyn, Illinois.* USGS open file report 84-603. Lakewood, Colorado. 1985.

70 Garie, H.L. and A. McIntosh. "Distribution of benthic macroinvertebrates in a stream exposed to urban runoff." *Water Resources Bulletin*, Vol. 22. No. 3. pp. 447-455. 1986.

71 Garie, H.L. and A. McIntosh. "Distribution of benthic macroinvertebrates in a stream exposed to urban runoff." *Water Science and Technology.* Vol. 22, No. 10/11. 1990.

72 Stewart, P.M.; Butcher, J.T.; and Gerovac, P.J . Diatom (*Bacillariophyta*) Community Response to Water Quality and Land Use. *Natural Areas Journal.* **19**, 2, 155. 1999.

73 Handová, Z., Z. Konícek, M. Liska, J. Marsálek, J. Matena, and J. Sed'a. "CSO impacts on receiving waters: Heavy metals in sediments and macrozoobenthos." 7th *International Conference on Urban Storm Drainage.* Hannover, Germany. Sept. 9-13, 1996. Edited by F. Sieker and H-R. Verworn. IAHR/IAWQ. SuG-Verlagsgesellschaft. Hannover, Germany. pp. 485-492. 1996.

74 Boudries, H., C. Broguet, J-M. Mouchel, and D.R. Thévenot. "Urban runoff impact on composition and concentration of hydrocarbons in River Seine suspended solids." 7th *International Conference on Urban Storm Drainage.* Hannover, Germany. Sept. 9-13, 1996. Edited by F. Sieker and H-R. Verworn. IAHR/IAWQ. SuG-Verlagsgesellschaft. Hannover, Germany. pp. 569-574. 1996.

75 Estèbe, A., G. Belhomme, S. Lecomte, V. Videau, J-M. Mouchel, and D.R. Thévenot. "Urban runoff impacts on particulate metal concentrations in River Seine: suspended solid and sediment transport." 7th *International Conference on Urban Storm Drainage.* Hannover, Germany. Sept. 9-13, 1996. Edited by F. Sieker and H-R. Verworn. IAHR/IAWQ. SuG-Verlagsgesellschaft. Hannover, Germany. pp. 575-580. 1996.

76 Dreher, D.W. "Watershed urbanization impacts on stream quality indicators in northeastern Illinois." Presented at the *Assessing the Cumulative Impacts of Watershed Development on Aquatic Ecosystems and Water Quality* conference. March 20 – 21, 1996. Northeastern Illinois Planning Commission. pp. 129 – 135. Chicago, IL. 1997.

77 Schueler, T. (editor). "Comparison of forest, urban and agricultural streams in North Carolina." *Watershed Protection Techniques.* Vol. 2, no. 4, pp. 503 - 506. June 1997b.

78 Cordone, A.J. and D.W. Kelley. "Influences of inorganic sediments on aquatic life of streams." *Californica Fish and Game.* Vol. 47. pp. 189-228. 1961.

79 Leopold, L.B., M.G. Wolman, and J.P. Miller. *Fluvial Processes in Geomorphology.* W.H. Freeman and Co. San Francisco. 522 pgs. 1964.

80 Brookes, A. *Channelized Rivers: Perspectives for Environmental Management.* John Wiley and Sons. 1988.

81 Rosgen, D.L. *A Classification of Natural Rivers.* Catena, Elsiver Science. Amsterdam. 1994.

82 Brookes, A. "Design issues." In: *Effects of Urban Runoff on Receiving Systems: An Interdisciplinary Analysis of Impact, Monitoring, and Management.* Engineering Foundation Conference. Mt. Crested Butte, CO. ASCE, NY. 1991.

83 Wolman, M.G. and A.P. Schick. "Effects of construction on fluvial sediment, urban and suburban areas of Maryland." *Water Resources Research.* Vol. 3. No. 2. pp. 451-464. 1967.

84 Pess, G.R., and Bilby, R.E . Stream-reach and Watershed-scale Variables and Salmonid Spawning Distribution and Abundance in the Puget Sound Region. *Proc. AWRA's 1999 Annual Water Resources Conference - Watershed Management to Protect Declining Species*, December 1999, Seattle, WA. American Water Resources Association, 397. 1999.

85 Greenberg, E.S.; Gagner, M.R.; and Reiser, D.R . An Approach For Evaluating Baseline Habitat Conditions Within Urban/Urbanizing Streams With Application to Prioritization of Recovery Efforts. *Proceedings: AWRA's 1999 Annual Water Resources Conference - Watershed Management to Protect Declining Species*, December 1999, Seattle, WA. American Water Resources Association, 409. 1999.

86 Bragg, D.C., and Kershner, J.L . Coarse Woody Debris in Riparian Zones - Opportunity for Interdisciplinary Interaction. *J. Of For.*. **97**, 4, 30. 1999.

87 Larson, M.G . Effectiveness of LWD in Stream Rehabilitation Projects in Urban Basins. *Proceedings: AWRA's 1999 Annual Water Resources Conference - Watershed Management to Protect Declining Species*, December 1999, Seattle, WA. American Water Resources Association, 377. 1999.

88 Markowitz, D.V.; Gsellman, P.; and Bronowsk, J . Thinking Outside the Pipe: Non-traditional Solutions for Water Quality Improvement. *Proc. Water Environ. Fed. 72nd Annu.Conf. Exposition*, [CD-ROM], New Orleans, LA. 1999.

89 Zobrist, C.; Cencie, N.; and Demortier, G . Methodological Study of CSO's Impact: Application to the River Orne. *Proc. the Eighth International Conference on Urban Storm Drainage.* August 30 – September 3, 1999, Sydney, Australia. Edited by IB Joliffe and JE Ball. The Institution of Engineers Australia, The International Association for Hydraulic Research, and The International Association on Water Quality, 403. 1999.

90 O'Meara, J.; Murray, J.; and Ridgway, J . Restoration of an Urban Lake: the Newburgh Lake Project. *Proc. Water Environ. Fed. 72nd Annu.Conf. Exposition*, [CD-ROM], New Orleans, LA . 1999.

91 Xu, S.; Higashijima, R.; Shingu, T.; Amakata, M.; and Sakai, T . Improvement Plan of Y River Going Through Downtown of F City. *Proc. the Eighth International Conference on Urban Storm Drainage.* August 30 – September 3, 1999, Sydney, Australia. Edited by IB Joliffe and JE Ball. The Institution of Engineers Australia, The International Association for Hydraulic Research, and The International Association on Water Quality, 218. 1999.

92 Cianfrani, C.; Hession, W.C.; McBride, M.; and Pizzuto, J.E . Urban Streams in Fairmount Park, Philadelphia, PA: Assessment and Restoration. *Proceedings: AWRA's 1999 Annual Water Resources Conference - Watershed Management to Protect Declining Species*, December 1999, Seattle, WA. *Am. Water Resour. Assoc.*, 393. 1999.

93 Derry, W.E.; Haub, A.; Dobey, E.; and Hoey, J . City of Olympia Aquatic Habitat Evaluation and Management Study. *Proceedings: AWRA's 1999 Annual Water Resources Conference - Watershed Management to Protect Declining Species*, December 1999, Seattle, WA. American Water Resources Association, 323. 1999.

94 Ishikawa, T.; Irie, M.; Terashima, T.; and Ozawa, K . Restoration of the Hydrological Cycle in the Izumi River Basin in Yokohama. *Proc. the Eighth International Conference on Urban Storm Drainage.* August 30 – September 3, 1999, Sydney, Australia. Edited by IB Joliffe and JE Ball. The Institution of Engineers Australia, The International Association for Hydraulic Research, and The International Association on Water Quality, 530. 1999.

95 Saeki, K.; Houjoh, Y.; Inoyae, I.; Shinoda, Y.; Watanabe, S.; and Nakanishi, Y . Rehabilitation of the Water Cycle at the Basin of the Kanda River. *Proc. the Eighth International Conference on Urban Storm Drainage.* August 30 – September 3, 1999, Sydney, Australia. Edited by IB Joliffe and JE Ball. The Institution of Engineers Australia, The International Association for Hydraulic Research, and The International Association on Water Quality, 522. 1999.

96 Kennen, J.G . Relation of Macroinvertebrate Community Impairment to Catchment Characteristics in New Jersey Streams. *J. Am. Water Resour. Assoc.*. **35**, 4, 939. 1999.

97 Bhaduri, B., M.Grove, C. Lowry and J. Harbor. "Assessing long-term hydrologic effects of land use change." *Journal AWWA*. Vol. 89, No. 11, pg. 94 – 106. Nov. 1997.

98 Booth, D.B., C.R. Jackson. "Urbanization of aquatic systems: Degradation thresholds, stormwater detection, and the limits of mitigation." *Journal of the American Water Resources Association*. Vol. 33, no. 5, pp. 1077 – 1090. October 1997.

99 Schueler, T. (editor). "Stream channel geometry used to assess land use impacts in the Pacific Northwest." *Watershed Protection Techniques*. Vol. 2, no. 2, pp. 345 - 348. Spring 1996a.

100 Stephenson, D. "Evaluation of effects of urbanization on storm runoff." *7th International Conference on Urban Storm Drainage*. Hannover, Germany. Sept. 9-13, 1996. Edited by F. Sieker and H-R. Verworn. IAHR/IAWQ. SuG-Verlagsgesellschaft. Hannover, Germany. pp. 31-36. 1996.

101 Maxted, J.R. "The use of percent impervious cover to predict the ecological condition of wadable nontidal streams in Delaware." Presented at the *Assessing the Cumulative Impacts of Watershed Development on Aquatic Ecosystems and Water Quality* conference. March 20 – 21, 1996. Northeastern Illinois Planning Commission. pp. 123 – 127. Chicago, IL. 1997.

102 MacRae, C.R. "Experience from morphological research on Canadian streams: Is control fo the two-year frequency runoff event the best basis for stream channel protection?" Presented at the *Effects of Watershed Developments and Management on Aquatic Ecosystems* conference. Snowbird, UT, August 4 – 9, 1996. Edited by L.A. Roesner. ASCE, New York, 1997.

103 Sovern, D.T. and P.M. Washington. "Effects of urban growth on stream habitat." Presented at the *Effects of Watershed Developments and Management on Aquatic Ecosystems* conference. Snowbird, UT, August 4 – 9, 1996. Edited by L.A. Roesner. pp. 163 – 177. ASCE, New York, 1997.

104 EPA (U.S. Environmental Protection Agency). *Results of the Nationwide Urban Runoff Program.* Water Planning Division, PB 84-185552, Washington, D.C., December 1983.

105 Booth, D.B., D.R. Montgomery, and J. Bothel. "Large woody debris in urban streams of the Pacific Northwest" Presented at the *Effects of Watershed Developments and Management on Aquatic Ecosystems* conference. Snowbird, UT, August 4 – 9, 1996. Edited by L.A. Roesner. ASCE, New York, 1997.

106 Montgomery, D.R. and J.M. Buffington. *Channel Classification, Prediction of Channel Response, and Assessment of Channel Conditions.* Washington State Department of Natural Resources. Report TFW-SH10-93-002. 84 pgs. 1993.

107 Horner, R.R, D.B. Booth, A. Azous, and C.W. May. "Watershed determinants of ecosystem functioning." Presented at the *Effects of Watershed Developments and Management on Aquatic Ecosystems* conference. Snowbird, UT, August 4 – 9, 1996. Edited by L.A. Roesner. ASCE, New York, 1997.

108 Poole, G.C., C.A. Frissell, and S.C. Ralph. "In-stream habitat unit classification: Inadequacies for monitoring and some consequences for management." *Journal of the American Water Resources Association*. Vol. 33, no. 4, pp. 879 – 896. August 1997.

109 EPA (U.S. Environmental Protection Agency). Report to Congress: *The Incidence and Severity of Sediment Contamination in Surface Waters of the United States*, Volume 1: *National Sediment Quality Survey* (EPA 823-R-97-006), Volume 2: *Data Summary for Areas of Probable Concern (APC)* (EPA 823-R-98-007), Volume 3: *National Sediment Contaminant Point Source Inventory* (EPA 823-R-98-008), Volume 4 (under development): *National Sediment Contaminant Nonpoint Source Inventory.* National Center for Environmental Publications and Information. Cincinnati, Ohio. 1998.

110 DePinto, J.V., T.C. Young and S.C. Martin. "Aquatic sediments." *Journal of Water Pollution Control Federation*. Vol. 52. No. 6. pp 1656-70. June 1980.

111 Heaney, J.P. *Nationwide Assessment of Receiving Water Impacts from Urban Storm Water Pollution: First Quarterly Progress Report*. Environmental Engineering Sciences, University of Florida, Gainesville, Florida, 1978.

112 Wilber, W. G., and J. V. Hunter. *The Influence of Urbanization on the Transport of Heavy Metals in New Jersey Streams*, Water Resources Research Institute, Rutgers University, New Brunswick, New Jersey, 1980.

113 Galvin, David D. Richard K. Moore. *Toxicants in Urban Runoff, METRO Toxicant Program Report #2.* U.S. Environmental Protection Agency Grant #P-000161-01, Lacey, Washington, December, 1982.

114 Arhelger, M., P. Jensen. Amd Y-C. Su. "Houston ship channel sediments and their relation to water quality." Volume 4, pg. 329 - 337. *WEFTEC'96: Proceedings of the 69th Annual Conference & Exposition*. Dallas, Texas. 1996.

115 Long, E.R., D.D. MacDonald, S.L. Smith, and F.D. Calder. "Incidence of adverse biological effects within ranges of chemical concentrations in marine and estuarine sediments." *Environmental Management*. Vol. 19, pp. 81 – 97. 1996.

116 Morresey, D.J., D.S. Roper, and R.B. Williamson. "Biological effects of the build-up of contaminants in sediments in urban estuaries." Presented at the *Effects of Watershed Developments and Management on Aquatic Ecosystems* conference. Snowbird, UT, August 4 – 9, 1996. Edited by L.A. Roesner. ASCE, New York, pp. 1 – 20. 1997.

117 Warick, R.M. "A new method for detecting pollution effects on marine macrobenthic communities." *Marine Biology*. Vol. 92, pp. 557 – 562. 1986.

118 Watzin, M.C., A.W. McIntosh, E.A. Brown, R. Lacey, D.C. Lester, K.L. Newbrough, and A.R. Williams. "Assessing sediment quality in heterogeneous environments: A case study of a small urban harbor in Lake Champlain, Vermont, USA." *Environmental Toxicology and Chemistry*. Vol. 16, No. 10. pp. 2125 – 2135. 1997.

119 Driscoll, S.K., and P.F. Landrum. "A comparison of equilibrium partitioning and critical body residue approaches for predicting toxicity of sediment-associated fluoranthene to freshwater amphipods." *Environmental Toxicology and Chemistry*. Vol. 16, no. 10, pp. 2179 – 2186. 1997.

120 Rhoads, B.L., and Cahill, R.A . Geomorphological Assessment of Sediment Contamination in an Urban Stream System. *Applied Geochemistry*. **14**, 4, 459. 1999.

121 Crabill, C.; Donald, R.; Snelling, J.; Foust, R.; and Southam, G . The Impact of Sediment Fecal Coliform Reservoirs on Seasonal Water Quality in Oak Creek, Arizona. *Water Res.* (G.B.), **33**, 9, 2163. 1999.

122 Vollertsen, J.; Hvitved-Jacobsen, T.; McGregor, I.; and Ashley, R. (1999b) Aerobic Microbial Transformations of Pipe and Silt Trap Sediments from Combined Sewers. *Water Sci. Technol.* (G.B.). **39**, 2, 233. 1999.

123 Vollertsen , J., and Hvitved-Jacobsen, T . Stoichiometric and Kinetic Model Parameters for Microbial Transformations of Suspended Solids in Combined Sewer Systems. *Water Res.* (G.B.). **33**,14, 3127. 1999.

124 Schueler, T. (editor). "Impact of suspended and deposited sediment." *Watershed Protection Techniques*. Vol. 2, no. 3, pp. 443. February 1997a.

125 Burton, G.A., Jr., B.L. Stemmer, and K. L. Winks. "A multitrophic level evaluation of sediment toxicity in Waukegan and Indiana Harbors," *Environ. Toxicol. Chem.* 8:1057-1066. 1989.

126 Burton, G.A., Jr. "Evaluation of seven sediment toxicity tests and their relationships to stream parameters." *Toxicity Assess.* 4:149-159. 1989.

127 Burton, G.A., Jr., B.L. Stemmer, and K. L. Winks. "A multitrophic level evaluation of sediment toxicity in Waukegan and Indiana Harbors," *Environ. Toxicol. Chem.* 8:1057-1066. 1989.

128 Burton, G.A., Jr. "Assessing freshwater sediment toxicity." *Environ. Toxicol. Chem.* 10(12).1991.

129 Burton, G.A., Jr., Ed. *Sediment Toxicity Assessment.* Boca Raton, FL. Lewis Publishers. 1992.

130 Burton, G.A., Jr., and J. Scott. "Sediment toxicity evaluations," *Environ. Sci. Technol.* Vol. 25. 1992.

131 ES&T *(Environmental Science & Technology)*. "News –Sediments: Pollutant remobilization." Vol. 31, no. 12, pg. 536a. 1997.

132 Kuehne, R.A. *Evaluation of Recovery in a Polluted Creek After Installment of New Sewage Treatment Procedures*. University of Kentucky Water Resources Research Institute, Lexington, Kentucky. May 1975.

133 McHardy, B.M., J.J. George, and J. Salanki (editors). "The uptake of selected heavy metals by the green algae *Cladophora glomerata*." In: *Proceedings of Symposium on Heavy Metals in Water Organisms*. Tihany, Hungary. Akademiai Kiado, Budapest, Hungary. *Symp. Biol. Hung.*, Vol. 29. pp. 3-20. 1985.

134 Bascombe, A.D., J.B. Ellis, D.M. Revitt, and R.B.E. Shutes. "Development of ecotoxicological criteria in urban catchments." *Water Science and Technology*. Vol. 22, No. 10/1, pp. 173-179. 1990.

135 Ellis, J.B., R.B. Shutes, and D.M. Revitt. "Ecotoxicological approaches and criteria for the assessment of urban runoff impacts on receiving waters." In: *Effects of Urban Runoff on Receiving Systems: An Interdisciplinary Analysis of Impact, Monitoring, and Management*. Engineering Foundation Conference. Mt. Crested Butte, CO. ASCE, NY. 1991.

136 Barbour, M.T. "Measuring the health of aquatic ecosystems using biological assessment techniques: A national perspective." Presented at the *Effects of Watershed Developments and Management on Aquatic Ecosystems* conference. Snowbird, UT, August 4 – 9, 1996. Edited by L.A. Roesner. ASCE, New York, pp. 18 – 33. 1997.

137 Plafkin, J.L., M.T. Barbour, K.D. Porter, S.K. Gross, and R.M. Hughes. *Rapid Bioassessment Protocols for use in Streams and Rivers: Benthic Macroinvertebrates and Fish*. EPA-440-4-89-001. U.S. Environmental Protection Agency. Office of Water Regulations and Standards. Washington, D.C. 1989.

138 EPA (U. S. Environmental Protection Agency). *Biological Criteria: National Program Guidance for Surface Waters*. EPA-440-5-90-004. U.S. Environmental Protection Agency. Office of Water Regulations and Standards. Washington, D.C. 1990.

139 EPA (U.S. Environmental Protection Agency). *Environmental Indicators of Water Quality in the United States*. Office of Water, U.S. Environmental Protection Agency. EPA 841-F-96-002. Washington, D.C., June 1996.

140 Pelley, J. "National 'environmental indicators' issued by EPA to track health of U.S. waters." *Environmental Science & Technology*, Vol. 31, no. 9, pg. 381a. Sept. 1996.

141 Claytor, R.A. "An introduction to stormwater indicators: an urban runoff assessment tool." *Watershed Protection Techniques*. Vol. 2, no. 2, pp. 321 - 328. Spring 1996a.

142 Claytor, R.A. "An introduction to stormwater indicators: Urban runoff assessment tools." Presented at the *Assessing the Cumulative Impacts of Watershed Development on Aquatic Ecosystems and Water Quality* conference. March 20 – 21, 1996. Northeastern Illinois Planning Commission. pp. 217 – 224. Chicago, IL. April 1997.

143 Claytor, R.A. and W. Brown. *Environmental Indicators to Assess the Effectiveness of Municipal and Industrial Stormwater Control Programs*. Prepared for the U.S. EPA, Office of Wastewater Management. Center for Watershed Protection, Silver Spring, MD. 210 pgs. 1996.

144 Cave, K.A., "Receiving water quality indicators for judging stream improvement." In: *Sustaining Urban Water Resources in the 21st Century*. Proceedings of an Engineering Foundation Conference. Edited by A.C. Rowney, P. Stahre, and L.A. Roesner. Malmo, Sweden. Sept. 7 – 12, 1997. To be published by ACSE, New York. 1998.

145 Pitt, R., M. Lilburn, S. Nix, S.R. Durrans, S. Burian, J. Voorhees, and J. Martinson *Guidance Manual for Integrated Wet Weather Flow (WWF) Collection and Treatment Systems for Newly Urbanized Areas (New WWF Systems)*. U.S. Environmental Protection Agency. 612 pgs. Expected publication in 2001.

146 Heaney, J.P., R. Pitt, and R. Field. *Innovative Urban Wet-Weather Flow Management Systems*. ISBN 1-56676-914-0. Technomics, Lancaster, PA. 535 pgs. June 2000.

147 Burton, G.A., Jr., R. Pitt, and S. Clark. "The role of whole effluent toxicity test methods in assessing stormwater and sediment contamination." *CRC Critical Reviews in Environmental Science & Technology*. 30: 413-447. 2000.

Nonpoint Source

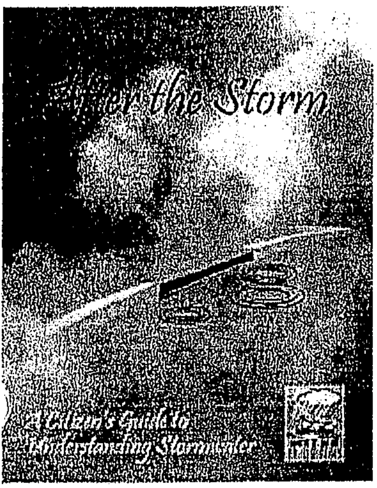
News-Notes

August 2004, #73

The Condition of the Water-Related Environment
The Control of Nonpoint Sources of Water Pollution
The Ecological Management & Restoration of Watersheds

Notes on the National Scene

EPA Partners with The Weather Channel for Runoff Education



A companion educational brochure is available at epa.gov/weatherchannel.

A half-hour television special about watersheds and stormwater runoff is now being seen throughout the nation on The Weather Channel. Co-produced by the Environmental Protection Agency and The Weather Channel, "After the Storm" explores how polluted runoff threatens the nation's waters. The program premiered on The Weather Channel on February 4, 2004; an additional showing is scheduled for Saturday, September 18, 2004 (8:00 pm and 11:00 pm EST). Information about the program is available at www.epa.gov/weatherchannel.

"I encourage everyone to tune in to learn more about the threats facing our nation's waters from polluted runoff," said Acting Assistant Administrator for Water, Benjamin Grumbles. "After the Storm shows the connection between weather and watersheds and the importance of watershed protection. We all live in a watershed and we all have an impact on our environment."

The program reminds viewers that a finite amount of fresh water exists on the planet, and that everyone needs to take actions to protect water resources. "Over the last thirty years, the nation has done a tremendous job in tracking pollution from large factories and sewage treatment plants," said Grumbles. "Remaining threats are much more difficult to regulate. When it rains or when snow melts, pollutants from city streets, suburban lawns, and farms may run off into our nation's streams, lakes, wetlands and coastal waters."

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EPA Partners with The Weather Channel for Runoff Education (continued)

The show highlights three case studies—Santa Monica Bay, the Mississippi River Basin/Gulf of Mexico, and New York City—where polluted runoff threatens watersheds highly valued for recreation, commercial fisheries and navigation, and drinking water. Key scientists, water quality experts, and citizens involved in local and national watershed protection efforts provide insight into the problems as well as solutions to today's water quality crisis.

Acting Assistant Administrator Grumbles added, "EPA was pleased to team up with The Weather Channel on this educational special. Broadcast meteorologists are considered trusted and effective spokespersons for conveying complex environmental and scientific information to the American public, and millions of viewers tune in to The Weather Channel daily for the latest weather updates. Weather events—like droughts, floods, and rain—directly impact the quality of our water resources. They offer a perfect opportunity for meteorologists to discuss connections between weather and watersheds."

In addition to illustrating the environmental implications of weather events, the special provides useful tips on how people can help make a difference. "After the Storm" explains simple things people can do to protect their local watershed—such as picking up after one's dog and recycling household hazardous wastes. It also shows how some communities and private companies are getting involved through low impact development—utilizing rain gardens and green roofs to minimize stormwater runoff.

An "After the Storm" educational brochure is available for download and as a hard copy from EPA (information is available at www.epa.gov/weatherchannel). The brochure provides tips on preventing runoff from residential and commercial properties, farms, construction sites, automotive facilities, forestry operations, and others.

Want to Air the Program in Your Classroom?

VHS copies of the "After the Storm" program are available free for education and communication purposes in classrooms, at conferences, etc. However, the tape should not be reproduced, distributed, broadcast or cablecast, without the express written permission of EPA. If you have any questions, please send them to EPA at weatherchannel@epa.gov. The VHS copies of "After the Storm" will include captioning so the program is accessible to those who are deaf or hard of hearing. To order, call the National Service Center for Environmental Publications (NSCEP) at 513-489-8190 or 800-490-9198 or send an e-mail to ncepimal@one.net (request "After the Storm" (VHS), EPA 840-V-04-001).

Want to Air the Program in Your Town?

After Aug. 5, 2004, EPA will have full rights to the "After the Storm" program and will be making high quality Beta SP copies of the program available to cable and other television stations for their use. EPA is taking orders now for delivery AFTER Aug. 5, 2004. You may order on the Web site, or by calling NSCEP at 513-489-8190 or 800-490-9198 or e-mailing them at ncepimal@one.net (request "After the Storm" (Beta SP), EPA 841-V-04-001).

New EPA Technical Support Center Lends a Hand

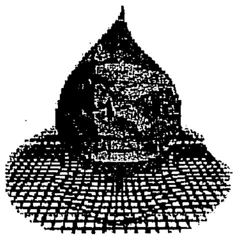
EPA recently established a Watershed and Water Quality Modeling Technical Support Center to provide assistance to EPA regions, state, and local governments, and their contractors in the implementation of the Clean Water Act. The Center, which is part of EPA's Office of Research and Development (ORD), is committed to providing access to technically defensible tools and approaches that can be used in the development of Total Maximum Daily Loads (TMDL), waste load allocations, and watershed protection plans.

What Kind of Technical Support is Offered?

The Center will provide the following types of assistance and technical support:

- Review of proposed TMDLs—provides a technical review and comments for proposed or pre-proposed TMDLs

New EPA Technical Support Center Lends a Hand (continued)



- Task Order Manager—serves as Task Order Manager for EPA's National Watershed Contract, providing technical oversight to ensure consistency and quality in the approaches taken to develop TMDLs
- Technical Advisory Group—Center staff participate as technical advisors
- Model Application—takes the lead in the application of models used in the development of TMDLs, implementation, waste load allocation
- Data Analysis—provides assistance in data acquisition and analysis
- Post TMDL Implementation—provides assistance in the development of TMDL implementation
- Best Management Practice Analysis—provides assistance in the selection and placement of BMPs in the watershed
- Research to develop and improve models for regulatory applications

What Tools are Available?

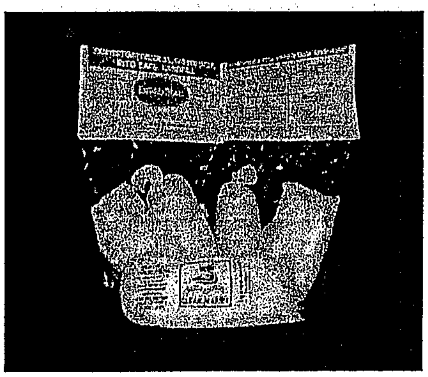
The Center provides access to a wide variety of tools and mathematical models that can be used to support the development of TMDLs, waste load allocations, and watershed protection plans. Most of the tools offered, including watershed models and hydrodynamic and water quality models, were developed and are being upgraded to serve the needs of the regulatory community better. Most of these tools have been enhanced to meet the needs of the TMDL program.

The Center also provides self-paced training on-line, sponsors specialty conferences, and offers regularly scheduled training classes around the county to educate people about the watershed and water quality models. Materials from these training classes will be available at the Center's Web site. For more information about the Center, see www.epa.gov/athens/wwqtsc, or contact Tim Wool by phone at 706-355-8312 or by e-mail at wool.tim@epa.gov.

News from State, Tribes, and Localities

Free Socks Put a Stop to Oily Bilge Water

Going boating in Massachusetts? Don't forget your socks. In 2002 the Massachusetts Office of Coastal Zone Management Marina Assistance Program distributed free bilge socks to more than 18,000 boaters to promote the use of these nonpoint source pollution-reducing tools. The bilge socks contain absorbent material that binds with petroleum products from a boat's bilgewater, preventing the release of these pollutants to the marina's waters when the bilges are pumped out. Last year the managers began an education program for boaters that reinforces the message to use bilge socks.



Bilge socks are long fabric tubes filled with absorbent material.

The type of tube-like bilge socks used are two feet long and three inches in diameter, and are placed directly in a boat's bilge compartment. A boat's bilge is found inside the hull at the very bottom of the boat. The bilge collects water and other fluids that are spilled on the interior sections of the deck, plus any water or petroleum products that leak from the engine. Boats typically have automatic bilge pumps that turn on and discharge the bilge water overboard once it accumulates to a particular level.

"Clean bilge water discharges will not harm coastal waters," explained Robin Lacey, program manager for the

Free Socks Put a Stop to Oily Bilge Water (continued)

Massachusetts Marina Assistance Program. "However, it is illegal to discharge bilge if it contains petroleum products or other pollutants. Since the bilge water pump is automatic, many people don't think about what is in the water that is being pumped overboard. Our giveaway program was an easy way to educate boaters about the impact bilgewater can have on the environment."

Building on Past Success

The program began in 2000 when the coastal program funded an effort by the Buzzards Bay National Estuary Program to distribute bilge socks to bay boaters. The program was so successful coastal managers decided to take it statewide. Organizers sought funding under Section 6217 of the Coastal Zone Act Reauthorization Amendments (CZARA), which requires a State to "develop and implement management measures for nonpoint source pollution to restore and protect coastal waters ..." Section 6217 requires states to establish coastal nonpoint source programs, which are then subject to federal approval.

Using implementation money received after the 2001 federal approval of their Coastal Zone Management Plan, Lacey says they went to vendors specifically looking for bilge socks made out of hydrocarbon-absorbing polymers, which can absorb 2.5 quarts of petroleum products per sock. "The polymers permanently bind the oil and solidify it so the oil can't be squeezed out, and won't even drip out. This way, you don't have a disposal issue. It can just be tossed out with the household trash." The sock manufacturer notes that a bilge sock should last one boating season, assuming the boat engine is well-maintained.

In early 2002, Lacey worked with regional coastal staff to develop a distribution plan for 10,000 socks, which retail for about $12 each. Harbormasters, watershed associations, and environmental groups all agreed to hand out the bilge socks to coastal boat owners. To save time and money, the vendor sent boxes of 50 socks directly to those who agreed to distribute them. "That way we didn't have to bring them in-house and then ship them back out," he says. The first 10,000 socks were distributed by the end of April 2002. With harbormasters asking for more, the program staff ordered an additional 8,200. Each sock distributed included a waterproof education tag with instructions, clean boating tips, and information about why the use of bilge socks is important (see www.enviro-bond.com/pub/bilgetag.pdf). The project cost $75,000, which included socks and educational tags.

The distribution program made an impact, noted Lacey. "Approximately 150,000 boats are registered in the state of Massachusetts, so we equipped more than 10 percent of them with bilge socks." Lacey estimates that the 18,200 socks distributed have the potential of removing 11,000 gallons of petroleum products from the state's coastal waters.

Putting the Best Socks Forward

While the bilge sock distribution was a one-time event, Lacey says they are currently building on the program by working to educate boaters and marina owners. The coastal program staff is creating written materials that can be distributed at marinas, and is also encouraging marina owners to require boats in their slips to have bilge socks, adds Lacey. "The marinas have an interest in keeping their waters clean. Requiring boats to have bilge socks is a step in the right direction." But not all boaters keep their boats in marinas. In the near future Lacey hopes to get the clean boating message out to additional boaters at boating events, boating safety classes, and in boat registration materials. "As we help boaters become more aware of their potential contribution to coastal water pollution, I expect to see more voluntary widespread use of products like bilge socks."

[For more information, contact Robin Lacey, Massachusetts Office of Coastal Zone Management Marina Assistance Program, 251 Causeway Street, Suite 900, Boston, MA 02114-2138. Phone: 617-626-1220; e-mail: Robin.Lacey@state.ma.us. This article was reprinted in part from the November/December 2002 issue of Coastal Services, *a National Oceanographic and Atmospheric Administration publication found at www.csc.noaa.gov/magazine/2002/06/mass.html.]*

Where Mitigation Really Works

Planning to impact a wetland or stream in North Carolina? According to state law, if you are impacting more than an acre of wetland or more than 150 linear feet of stream you must compensate for its loss. All states have similar rules; however, North Carolina is taking a unique approa to better ensure that the compensation equals the loss suffered. Often, projects that replace lost wetlands or damaged riparian areas do not function as effectively as the original site and therefore result in an overall reduction in watershed health. To prevent such losses, North Carolina's Ecosystem Enhancement Program (EEP), formally known as the Wetlands Restoration Program, has initiated a targeted mitigation effort. Rather than requiring developers to mitigate for small projects individually, the EEP collects mitigation dollars into a Wetlands Trust Fund. These dollars are then applied to selected large-scale wetland and riparian restoration projects that the state has identified as having the greatest potential to provide ecological health benefits.

The EEP is an innovative, non-regulatory program established by the North Carolina General Assembly in 1996 to restore wetlands, streams, and riparian areas throughout the state. As part of this task, the EEP is responsible for providing a consistent and streamlined approach to address compensatory mitigation requirements associated with Clean Water Act Section 401 and 404 permits issued by the North Carolina Division of Water Quality (DWQ) and the U.S. Army Corps of Engineers. For more information about these permits, see www.wetlands.com/regs/tlpge02a.htm.

Developing Plans Statewide

The EEP has developed Watershed Restoration Plans (WRP) for each of the state's 17 major river basins to help direct compensatory mitigation and restoration projects. These plans target specific watersheds within each river basin where restoration projects could contribute significantly to the goal of protecting and enhancing overall watershed functions. To develop the Watershed Restoration Plans, the EEP assesses the location and condition of natural resources using multiple information sources such as the NC Division of Water Quality's Basinwide Water Quality Plans, rare plant and animal lists, and wildlife management plans. The EEP reviews and revises these plans a rotating 5-year schedule.

The EEP is also developing more detailed Local Watershed Plans (LWP), which are developed at a much finer scale. Through a 1999 agreement with the NC Department of Transportation (DOT), the DOT committed to provide $17.5 million over seven years to fund the development of 30 LWPs within cataloging units where DOT anticipates compensatory mitigation needs. This original agreement was with the EEP, but detailed watershed planning is an activity that has been embraced with the development of the EEP. Examples of completed plans and the locations of ongoing plans can be accessed through the EEP Web site: h2o.enr.state.nc.us/wrp.

To develop a LWP, the EEP conducts a detailed assessment of the watershed and involves the local community in identifying and implementing solutions to water quality and quantity problems. At a minimum, a LWP identifies potential stream and wetland restoration projects to help meet DOT's future compensatory mitigation needs. "The LWPs allow us to compare the probable benefits of one potential project in a watershed against another—to ensure that we get the greatest ecological benefit for the dollars spent," explained Suzanne Klimek, manager of the EEP Planning Section. Ideally, by developing a LWP, these restoration projects can be linked to other water quality and habitat improvement efforts initiated at the local level, such as stormwater management projects, water supply protection strategies, land use planning guidelines, and best management practice installation. Although they are being developed with DOT funds, the LWPs can provide targeting assistance for all restoration projects in the watershed.

Putting the Plans to Work

The WRPs (and LWPs where available) allow EEP to choose the best location for its wetland, stream or riparian buffer restoration efforts, including compensatory mitigation-related projects implemented for DOT and other government and private clients. "When developers must mitigate for planned wetland or riparian impacts, they have three options in North Carolina: install a mitigation project themselves, purchase credits from a private mitigation bank, or pay into the Wetlands Restoration Fund," explained Klimek. EEP is tasked with using the funds paid into the Wetlands Restoration Fund to restore sites identified in the plans.

Because they consolidate the mitigation requirements of multiple small projects, the EEP can implement large-scale watershed restoration efforts that address significant water quality problems. "Rather than having small restoration efforts be spread over the landscape where their benefit is diluted, we focus our restoration efforts in certain key watersheds and increase the likelihood of having a significant benefit to ecological health," explained Klimek. "We try to implement projects in the same subwatersheds where the impacts occurred. If that is not possible, we always implement the projects within the same 8-digit hydrologic unit."

Over the past 5 years, EEP has accepted the compensatory mitigation requirements of 273 Section 404 permits and Section 401 Water Quality certifications. These cumulative mitigation requirements total 220,238 linear feet of streams and 252.34 acres of wetlands in 13 river basins. During FY02 (July 1, 2001 through June 30, 2002), 81 of the Section 401 Water Quality Certifications issued required wetland or stream mitigation. Of those, 69 percent were satisfied through payment to the EEP compensatory mitigation requirements, while seven percent were satisfied through payment to private mitigation banks. The applicants conducted the remaining 23 percent of the required compensatory mitigation on site.

The plans help EEP fulfill another of its important roles: providing compensation for wetland and stream impacts that are permitted but fall below the regulatory threshold requiring compensatory mitigation (wetland impacts less than one acre or stream impacts of less than 150 feet). These losses can be significant—approximately 53 wetland acres in FY02. To offset these losses, EEP completes restoration projects using appropriated funds, interest earned by the Wetlands Trust Fund, and grant awards. By planning ahead, EEP ensures that its restoration efforts will make a difference.

[For more information, contact Suzanne Klimek, Planning Supervisor, North Carolina Department of Environmental and Natural Resources, Ecosystem Enhancement Program, 1652 Mail Service Center, Raleigh, NC 27699-1652. Phone: 919-715-1835; e-mail: suzanne.klimek@ncmail.net.]

Notes on Watershed Management

Putting Pressure on Pressure Washing Pollution

"We dissolve nature's scourge away to restore the full beauty of your home and deck," reads an advertisement for a commercial pressure washing company. But where does the "scourge" go? And what about the cleansing agents used to remove it? Pressure-washing activities can pose pollution risks to nearby waterways if proper management techniques are not used. Fortunately, many local governments have stormwater ordinances that prohibit discharges of non-stormwater, such as wastewater from pressure washing, but compliance by businesses and individuals often remains an issue. One California region is taking steps to help residents and businesses comply with

Why is Pressure Washing a Problem?

Pressure washing involves using a stream of pressurized water, sometimes containing cleansing agents, to remove contaminants from surfaces. Pressure washing is typically used to clean surfaces such as pressure treated decks, sidewalks, parking lots, buildings, trash dumpster areas, and vehicles. The wastewater from washing these areas might contain pollutants such as detergents, oils, grease, sediment, trash, and heavy metals. If not properly contained, the pressure washing wastewater can flow into storm drains and directly into local waterways.

Putting Pressure on Pressure Washing Pollution (continued)

its existing ordinance by providing a best management practice (BMP) manual and creating an incentive program to encourage compliance.

As part of its effort to comply with its Phase I stormwater permit requirements, the Sacramento Stormwater Management Program (SMP), which includes the County of Sacramento and the cities of Citrus Heights, Elk Grove, Folsom, Galt, Rancho Cordova, and Sacramento, is turning its attention to an often-overlooked source of non-stormwater discharges to storm drains—mobile pressure washers. "Many of these folks are not aware that storm drains lead directly to local creeks and rivers and not to sanitary treatment facilities. They don't realize that the detergents and pollutants coming off of the surfaces are actually ending up in local waterways," explained Patrick Sanger, with the City of Sacramento's Department of Utilities. "We are working to educate mobile pressure washing business owners about the proper way to manage pressure washing wastewater."

The SMP offers educational resources to help pressure washing businesses learn about and take advantage of BMPs to comply with stormwater regulations. In November 2002, the SMP partnered with the Business Environmental Resource Center (BERC), and the Sacramento Regional County Sanitation District to release *Best Management Practices for Pressure Washers* (available for download at www.sacstormwater.org), which explains the steps that pressure washer operators should take before, during, and after a job.

What Can Pressure Washer Operators Do to Minimize Impacts?

Pressure washer operators, including homeowners, should adhere to the following key practices at a minimum:

- Plan ahead (identify sites and methods, obtain necessary permits and authorizations)
- Pre-clean (sweep debris and remove existing liquid contaminants using absorbents)
- Minimize water used
- Choose least-toxic cleaning products
- Collect wastewater (using vacuum pumps, booms/berms, portable containment areas, weighted storm drain covers, inflatable plumber's plugs, oil/water separators, holding tanks, portable sump pumps, hoses, and/or absorbents)
- Discharge collected waste water to sanitary sewer (or, if the water contains hazardous materials or compounds, through a licensed hazardous waste hauler)
- Discharge onto the land surface only permitted with the property owner's permission and only when the wastewater does not create a nuisance condition, flow into the storm drain system, and/or contaminate soil with hazardous waste.

A full list of practices recommended by the Sacramento Stormwater Management Program is available in *Best Management Practices for Pressure Washers* (available for download at www.sacstormwater.org).

In June 2003, the partners held a workshop for the local pressure washing companies. BERC mailed workshop invitations to 250 organizations that described the workshop content and mentioned the availability of the BMP manual. More than 40 people attended the workshop and learned about regulations, best management practices, sanitary sewer discharge permits, and the opportunity to participate in the Clean Water Business Partners (CWBP) program. "We were pleased with the turnout," said Sanger. "We discovered that many of the attendees are already using some of the BMPs outlined in the manual. We also received great feedback about which BMPs work best for them." Other similar outreach efforts are planned for the future.

Putting Pressure on Pressure Washing Pollution *(continued)*

Promoting Pressure Washers through CWBP

Beginning in Summer 2003, the SMP included mobile pressure washers in its CWBP program and is relying on this program as a long-term outreach and education tool. The CWBP is an incentive-based program that rewards local businesses for promoting clean water awareness and implementing BMPs. The SMP initiated the CWBP in 1998 for carpet cleaners—another mobile business that generates polluted wastewater. In 2001, the CWBP expanded to include landscaping companies. Mobile pressure washing is the third industry targeted by CWBP. "The businesses who are helping to keep our waterways healthy should promote it to their customers. Our program rewards them for doing that," said Sanger.

The CWBP program offers many benefits to participating businesses, including:

- Promotion through the extensive CWBP program advertising campaign on radio, television, and utility bill inserts and other print formats
- Promotion on the CWBP web page
- CWBP brochures and door hangers
- Stormwater pollution prevention fact sheets
- Recognition by the public as a company that cares about local water quality

"In exchange for these benefits, the businesses agree to follow all the necessary BMPs and help us spread an environmental message." Businesses hand out brochures and other educational materials to their customers. The brochures include a tear-out survey on which the customer is asked to report where the employee disposed of wastewater (storm drain, sanitary sewer, or transported it away). Returned surveys are entered into drawings for prizes such as a free carpet cleaning. "Occasionally someone will report improper disposal by CWBP participants. We follow up and let the business owner know that they need to better educate their employees. We have 60 businesses represented in the program so far and we've only had to remove two for not complying with the terms of the program."

The pressure washer CWBP program currently has over a dozen members. Sanger anticipates that more will follow as they realize the benefits. "The returned surveys indicate that more and more consumers are choosing a business based on whether it is environmentally responsible. We've had several companies sign up for the program because they didn't want to lose business to the CWBP members." The most recent biennial public awareness survey conducted by the SMP in March 2004 showed that 84 percent of the population is willing to pay at least 5 percent more for services supplied by environmental friendly companies, and 64 percent of respondents are willing to pay 15 percent more.

That is the idea behind the CWBP, Sanger adds. "Our goal with the program is two-fold: educate the public and educate the businesses. When both happen together, then the businesses can use their environmentally friendly practices as a marketing tool and a more enviro-savvy public can demand it of their service providers. The hope is that normal business economics will encourage those companies that choose to not obey the laws and continue to illegally discharge to the storm drain system to either change their practices or find another line of work."

Not a CWBP Participant? You Still Must Comply with the Ordinance!

Although the SMP's stormwater ordinance prohibits non-storm discharges, they do not have the staff to monitor all potential offenders. "The industry is still mostly self-regulated," explained Sanger. "We have stormwater inspectors, building inspectors, and other staff who will report illegal discharges if they see them, but we don't have anyone out patrolling the streets for mobile pressure washers or carpet cleaners. We rely quite a bit on the general public—they do a good job of reporting violations using our stormwater hotline." SMP staff follows up on reports and issues fines as necessary.

Putting Pressure on Pressure Washing Pollution (continued)

Spread the News

The success of the CWBP Program has attracted the interest of other communities dealing with stormwater issues, noted Sanger. "I frequently receive calls and e-mails from people throughout the U.S. and beyond. They want to hear about our program and learn how they can start a similar one in their area." The key to the CWBP's success is the mutually beneficial nature of the program, added Sanger. "We help the businesses and they help us."

[For more information, contact Patrick Sanger, City of Sacramento, Department of Utilities, 1395 35th Avenue, Sacramento, California 95822. Phone: 916-264-0126; e-mail: psanger@cityofsacramento.org.]

"Builders for the Bay" Leads to Consensus on Codes

During the summer of 2003 in Harford County, Maryland, a diverse group consisting of local government planners, builders, county engineers, environmental groups, real-estate developers, and lawyers completed a negotiation and consensus-building process that paves the way for changes in the layout and construction of new development. The diverse group explored subdivision regulations and municipal and road codes to identify and overcome obstacles in current codes that unduly restrict on-site construction practices to the detriment of environmental protection goals.

The end-product of the 'roundtable' as the negotiation was officially called, was a consensus document that lays out recommendations for 22 separate development principles designed to help protect open space, reduce impervious cover, and minimize the negative impacts of stormwater runoff associated with new residential and commercial development. The document further includes explicit language for changes in county codes that would support the principles. Participation of county staff from the Harford County Department of Planning and Zoning, familiar with the intricacies of current county codes, was key in enabling the successful formulation of potential new codes.

Lying within the watershed of the environmentally-sensitive Chesapeake Bay, Harford County's water pollution mitigation efforts were supported by the "Builders for the Bay" partnership, established in December 2001 to promote sound land use development throughout the Bay watershed. The Harford County roundtable is the first of twelve planned for the entire Chesapeake Bay Watershed under Builders for the Bay, which is sponsored by the Center for Watershed Protection (CWP), the Alliance for the Chesapeake Bay (ACB), and the National Association of Home Builders (NAHB). Harford County's roundtable was supported in part by the Abell Foundation, the Cafritz Foundation, and the Chesapeake Bay Trust.

The CWP completed its second Builders for the Bay Roundtable in November 2003 in south central Pennsylvania. For more information about this effort see the December 5, 2003 issue of Watershed Weekly (www.pawatersheds.org/Wweekly) printed by the Pennsylvania Organization for Watersheds and Rivers.

What Will Code Changes Achieve?

Code changes recommended by the roundtable are intended to make it easier for developers to create more open space and include more flexible features in the design of residential and commercial sites. Developments created using 'better site design' principles incorporate less impervious cover, conserve more natural areas, and produce less stormwater runoff, ultimately helping to minimize the construction- and development-impact on the Chesapeake Bay and its tributaries. In addition to being more environmentally sensitive, residential communities constructed with better site design have the potential to be seen as more attractive and livable, and may accrue higher market values.

Examples of the changes recommended by the roundtable include:

- establishing minimum and maximum parking ratios that may reduce impervious pavement

"Builders for the Bay" Leads to Consensus on Codes (continued)

- reducing home setback requirements in order to preserve more open space, preserve natural hydrology, natural stream trajectories, and continuous patches of forest
- allowing flexible standards for sidewalks to allow alternative pedestrian routes that help to limit paving on sensitive areas
- preventing private lots from encroaching on county-designated Natural Resource District protection areas

For a complete listing of the recommendations, see www.cwp.org/Harford_consensus.pdf.

Harford County's document focuses on site-based efforts to mitigate building and paving impacts on water quality. "Many communities are struggling with issues of where development should occur, but how we design the sites already designated for growth is also critical in protecting our water resources," explained Anne Kitchell, a watershed planner with the Center for Watershed Protection. "If every community in the Chesapeake Bay region were to do what Harford County has done, it would be a big step in minimizing the impact of future growth on the Bay."

Environmentalists and developers alike are excited about the success of the Harford County roundtable project. Susan Davies of the Home Builders Association of Maryland (HBAM) was impressed with both the process and the product. "How encouraging that all different interest groups were able to coordinate and work together on what ended up as a fairly comprehensive document," she said. Enthusiastic about recommendations that she sees as readily achievable, she added that "there's a potential for good changes in the not-too-distant future."

HBAM President Don Sample echoed Davies' optimism. "We're very enthusiastic ... it'll help property owners derive more value, and help the environment—what could be better? We were really pleased that CWP and the ACB were willing to not just talk about the problems, but really do something that makes a difference."

Building on early successes with Builders for the Bay Roundtables, CWP intends to sponsor other Bay watershed counties, townships, and localities in their efforts to revise municipal and building code and manage growth in an environmentally sensitive manner.

[For more information on Builders for the Bay or the Harford County Roundtable, contact the Center for Watershed Protection, 8391 Main Street, Ellicott City, Maryland 21043; Phone: 410-461-8323; e-mail: ack@cwp.org; Web: www.buildersforthebay.net.]

News in Agriculture

Innovative Pest Control Curtails Runoff-Prone Chemicals

As members of the agricultural community strive to move away from the use of chemicals, they turn more frequently to innovative practices, including natural biological pest controls. The first article explains how nuisance rodent populations in vineyards are being held in check by encouraging proliferation of the pest's natural predator—owls. The second article describes how pecan orchard yield and quality are being increased by growing trap crops that lure stink bug pests away from the pecan crop. In both cases, innovative farmers are saving money, reducing dependence on chemical pesticides, and improving the environment. This theme of innovative pest control practices continues into the Technical Notes section immediately following these articles. (See "Army Uses GPS Targeting to Win Golf Course Bug Battle.")

Owls Control Vineyard Gophers

Using rodenticides to control rodent pests? Try owls instead! A new nonprofit group, called Habitat for Hooters (HFH), is promoting the use of owls as a sustainable, environmentally-friendly method of controlling vineyard rodents in Napa Valley, California. To encourage owls to hunt in and around vineyards, HFH and its partners have been working for the past 3 years to improve owl habitat, primarily through the placement and maintenance of owl houses. HFH provides free consultations, bird banding, and box maintenance to HFH members, taking that opportunity to gather data for future analysis.

Owls Control Vineyard Gophers (continued)

Why Not in Vineyards?

The program is the brainchild of Janet Barth, a teacher and wildlife rehabilitation volunteer. "I had heard of a group that was using barn owls to decrease rodent populations in sugar cane fields. I thought 'why not in vineyards?'" Napa Valley vineyards are popular with pocket gophers, who enjoy building tunnels in the loose cultivated soil, drinking from the irrigation lines, and eating grapevines. They eat the vine's new growth and will sometimes kill the vines by girdling them underground.

Barth mentioned her owl idea to the local Resource Conservation District (RCD) and the Habitat for Hooters (HFH) project was born. She received a $2,500 grant from the City of Napa to fund the program development. Several vineyards also donated money to offset her start up costs. Officially launched in 2000, the organization focuses on distributing and maintaining owl boxes, educating vineyard owners and community members about owls and owl habitat, and collecting information about the local owl population.

HFH relies on membership fees from vineyards and private citizens for annual support, and applies for grants from the wine industry to support special projects and equipment needs. Members receive a discount on owl houses, and receive free consultation services for owl banding and house placement and maintenance.

To attract members, Barth initially mailed a brochure and order form to all Napa Valley vineyards. The response was overwhelming. "It took us almost a year to fill all the box orders that we received from that first mailing." Since then, Barth has given many presentations to school groups, civic groups, and environmental groups. The program has also received media coverage in a local newspaper and several newsletters. Barth publishes an annual newsletter that reports the project's progress and lists all members. Membership (now at almost 150 members) continues to rise and box orders continue to come in as people hear about the program during a presentation, from friends, or learn about it from the media. Community members and vineyard owners have installed almost 500 boxes since the program began.

Is the Project Making a Difference?

"Unfortunately, we didn't have a base population count when we began the program, so we don't know for sure whether we have increased the population," explained Barth. "However, the owls were certainly looking for places to live. In one vineyard we placed 6 boxes the first year. Within 2 weeks, all were occupied. Last year we placed 15 more boxes, 90 percent of which are now occupied. That tells me that nesting sites are at a premium, which is not surprising given the ongoing loss of forest in the Napa Valley area."

According to the Napa RCD, a barn owl will eat an average of 155 pocket gophers per year. "The vineyard owners can see the result of the owls' appetites," said Barth. "When I clean out the owl boxes each year we usually find about 12 inches of owl pellets. The vineyard owners are thrilled because they know the owls are earning their keep." If the owls successfully keep rodent populations down, the vineyard owners will be less likely to resort to other methods of rodent control that are toxic to the environment.

Building Boxes Yield Profits

Building and distributing owl boxes is a key component of the HFH program. HFH arranged with the wood shop in the Vintage High School Agriculture Department's Resource Occupation Program to build most of its owl boxes. The wood shop uses the profits to invest in supplies and equipment. Customers are asked to donate $40 per box, $10 of which is used to cover materials and $30 of which is provided to the box builders. The students made $8000 for the wood shop during the program's first two years. When demand is high or the students are on summer vacation, other organizations such as boy scouts and environmental groups earn some money by helping to build boxes.

Owls Control Vineyard Gophers (continued)

The Future

Barth has been banding and monitoring owls since the program began. "Our focus is now shifting from selling boxes to gathering data. We hope to do more educational outreach, using the data as a tool," explained Barth. HFH plans to conduct research on the effectiveness of the owl box program by tracking the owl populations and studying diet composition and dispersal and migration patterns. She recently partnered with the local high school's biology department to have students conduct a one-time owl pellet dissection and analysis lab. Pleased with the results, she plans to apply for a grant that will allow her to pay students to conduct a comprehensive prey study.

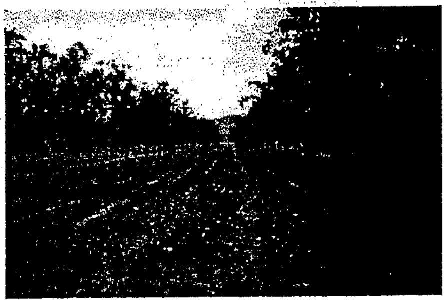
Barth is also mentoring a group in nearby San Raphael that plans to conduct controlled studies to see whether owl habitat improvement can definitively yield natural reductions in rodent populations. "A study like this is needed—currently all available supporting information is purely anecdotal." In the meantime, HFH will continue to use its available data to open the public's eyes about the benefits of owls as a natural pest control.

[For more information, contact Janet Barth, Habitat for Hooters, Mailing Address: Napa County Resource Conservation District, 1303 Jefferson Street, Suite 500B, Napa, CA 94559. Phone: 707-224-3464; e-mail: wesaw1@mindspring.com; Web: www.naparcd.org/habitatforhooters.htm]

Trapping Stink Bugs the Natural Way

Kyle Brooksheir, a West Texas pecan grower, has been able to produce higher grade pecans while reducing pesticide application. While every orchard is different, and more study needs to be done, integrated pest management may prove to be a superior method for pest control.


Pecans damaged by stink bugs.


Rows of black-eyed peas lure stink bugs away from pecan trees.

Adult stink bugs lay eggs on weeds and crops like pecans, and their populations increase in summer. As crops are harvested and weeds dry up, adults fly to pecans to feed. Stink bugs suck sap from developing pecan nuts, causing the nutlets to fall from the tree. Feeding after shell hardening causes brown or black spots on the kernel, which gives the nut a bitter taste and reduces the cash value of the crop. Because stink bugs can feed directly through the hard shell, producers are faced with the problem that the pecans can be damaged up to the day of harvest, and even after harvest, while the nuts are being taken to the shelling plant. Due to human health concerns, effective insecticides cannot be applied within three to four weeks of harvest.

For many years, growers minimized pest damage to pecans by spraying insecticides combined with a zinc spray. However, applying insecticides has had to be reevaluated because fewer effective insecticides are available due to high re-registration costs, lack of new insecticides, poor insecticide control, secondary pest outbreaks, and renewed concerns about the effects of insecticides on humans and the environment. Routinely using insecticides leads to pesticide resistance, destroys natural enemies of pecan pests, and increases production costs.

Setting a Trap

Trap cropping is a technique where a producer deliberately plants a second type of plant that the pest desires more than the cash crop. For pecan producers, black-eyed peas can serve as an effective trap crop to draw stink bugs away from valuable pecan trees. A Sustainable Agriculture

Trapping Stink Bugs the Natural Way (continued)

Research and Education Program grant-funded study was conducted during 1994 and 1995 at a West Texas pecan orchard and suggested advantages of trap cropping.

When the research team compared stink bug damage losses between site/years with trap crops and those without trap crops, they noted a $29.29 per acre benefit from trap crops on average. For each dollar spent in establishing and maintaining the trap crops, the team observed a nine dollar benefit on average.

Brooksheir reports that before trap cropping he lost between 10 and 11 percent on his crop every year. After trap cropping, his losses fell to less than 2 percent. He notes, “It was clear very quickly that it was a profitable practice for us.”

$ Loss/Acre from Stink Bugs

	1993	1994	1995
Orchard #1 (650 acres)	12.54*	0.62	2.21
Orchard #2 (400 acres)	9.45*	21.26*	79.40*

*No trap crop.

Brooksheir plants black-eyed peas between the rows of pecan trees at the ratio of one acre of peas for every 20 acres of pecans. Starting around the first of July, he plants a section of peas every two weeks to keep maturing pods always available for the bugs. Since the bugs prefer the peas, they stay away from the trees. Because Brooksheir does not need to spray the peas, his family has fresh peas for the table all summer.

Besides getting more cash for his crop, trap cropping saves Brooksheir money on pesticide, reduces the possibility of polluted runoff, and, as he laughingly remarked, “We enjoy eating the fresh peas.”

[For more information, contact Kyle Brooksheir, Box 216, Van Horn, TX 79855. Phone (915) 283-2506; e-mail kylenina@telestar1.com. Alternatively, contact Bill Ree, Extension Agent Pest Management - Pecan-IPM, P.O. Box 2150, Bryan, TX 77806-2150. Phone: 979-845-6800; e-mail: w-ree@tamu.edu; Web: http://pecankernel.tamu.edu.]

National Agricultural NPS Pollution Management Measures Now Available

EPA has released the updated *National Management Measures to Control Nonpoint Source Pollution from Agriculture*, a technical guidance and reference document for use by State, local, and tribal managers in the implementation of nonpoint source pollution management programs. This guidance document is intended to provide technical information on the best available, economically achievable means of reducing NPS pollution of surface and ground water from agriculture. The guidance provides background information about agricultural NPS pollution, where it comes from and how it enters the nation's waters, discusses the broad concept of assessing and addressing water quality problems on a watershed level, and presents up-to-date technical information about how to reduce agricultural NPS pollution.

The causes of agricultural NPS pollution, specific pollutants of concern, and general approaches to reducing the impact of such pollutants on aquatic resources are discussed in the Overview (Chapter 2). A general discussion of best management practices (BMPs) and the use of combinations of individual practices (BMP systems) to protect surface and ground water is provided in Chapter 3. Management measures for nutrient management; pesticide management; erosion and sediment control; managing facility wastewater, manure and runoff from animal feeding operations; grazing management; and irrigation water management are described in Chapter 4. Also in Chapter 4 are discussions of BMPs that can be used to achieve the management measures, including cost and effectiveness information. Chapter 5 summarizes watershed planning principles, and Chapters 6 and 7 offer overviews of nonpoint source monitoring and pollutant load estimation, respectively. For more information, or to download a copy of the manual, see www.epa.gov/nps/agmm.

Technical Notes

Army Uses GPS Targeting to Win Golf Course Bug Battle

Cutting-edge science solved an environmental problem for an age-old game. In the mid-1990s Ruggles Golf Course on Maryland's Aberdeen Proving Ground had a serious June bug problem. The June bug population grew so large that after intense spraying in the fall of 1995, dead June bug larvae made such a stink and so thickly covered the fairways and greens that the course had to be closed. To make matters worse, birds were dying after eating the dead larvae. Adding insult to injury was the possibility of long-lasting pesticide leaching into the groundwater, and of surface runoff carrying pesticides into Chesapeake Bay. Something had to be done.

The Right Idea

Enter the Army's Center for Health Promotion and Preventive Medicine, Entomological Sciences Program, which has a long-term working relationship with the Agricultural Research Service (ARS) of the U.S. Department of Agriculture. Beginning in the 1970s, the ARS had recommended identifying areas where pests live and breed at maximum concentrations and targeting those areas for treatment. This would greatly reduce the amount of pesticide necessary to control the pests while also reducing the environmental impact.

Going High Tech

In the 1990s, the advancement of the global positioning system (GPS) and geographic information systems (GIS) provided ARS with a new technology to locate and map the areas with the highest concentrations of pests. In 1996, ARS received funding from the Strategic Environmental Research and Development Program (SERDP), a partnership between the Department of Defense, the Department of Energy, and the Environmental Protection Agency, to develop new software and conduct pilot projects using GPS and GIS to pinpoint concentrations of pests.

In 1998 a partnership between the U.S. Army Environmental Center, the ARS, and the SERDP was formed to test the new methods using GPS and GIS at several military sites. Army golf courses were some of the first of these sites. ARS used GPS and GIS to locate and map the areas with the highest concentrations of pests. After successful testing on the golf course on Fort Meade, the technology was applied the next year to a pilot project on the 18th hole at Ruggles.

Attacking the Invaders

ARS began the June bug eradication effort in August 1999. By that late in the summer the larvae had grown large enough that their location was evident by mounds and tunnels on the surface of the ground. ARS located areas of greatest concentration on the 18th fairway and entered the coordinates into the GPS system. These key areas turned out to cover only 20 percent of the fairway and surrounding rough. ARS then targeted these areas for pesticide application.

Spraying in the morning with a quick-acting, low-environmental-persistence pesticide resulted in dead larvae by the afternoon. The spraying was as effective as broadcast spraying in reducing the larvae infestation and resulted in significant time and cost savings. The rest of the course was then mapped and sprayed with similar success, and Ruggles Golf Course did not have significant recurrence of larvae in the following years. Thus, the long-term effectiveness of the targeted application was better than the broadcast spraying that had been conducted the previous 6 years, was less expensive, and posed a reduced environmental risk.

Researchers also determined that soil moisture and thickness of thatch could predict areas with a high probability of June bug larvae and other types of grubs. Based on this information, the recommended method was application of pesticides only to areas with sufficient moisture and depth of thatch in the early summer when the larvae are small. This reduces the need to broadcast persistent pesticides over the golf course early in the spring, avoids the damage associated with tunneling activities of the larger grubs, and reduces problems of high numbers of large, dead larvae on the golf course.

Army Uses GPS Targeting to Win Golf Course Bug Battle (continued)

The program achieved 95 percent control of the green June bug larvae. The cost of investing in the technology was paid back after only two years by the savings from reduced pesticide use and labor. Other benefits included the ability to use pesticides with less persistence in the environment, less worker and golfer exposure to chemicals, and a golf course that stays open during June bug season. Additional project details are outlined in a report developed by the Mid-Atlantic Integrated Assessment, available at www.epa.gov/maia/html/junebug.html.

Expanding the Program

The program's success has not gone unnoticed. The project team received the inaugural "Pollution Prevention Project of the Year" award in December 1999 from the Strategic Environmental Research and Development Service. The Department of Defense is now implementing similar efforts at some if its other facilities. The Ruggles Golf Course may even be more chemical-free soon—the course superintendent sees the benefits of the technology and hopes to expand its use to target and treat invasive weeds such as clover and nutsedge.

[For information contact Richard Brenner, USDA ARS, 5601 Sunnyside Avenue, GWCC-BLTSVL, Beltsville, MD 20705-5131. Phone: 301-504-6905; e-mail: richard.brenner@nps.ars.usda.gov; Web: www.apgmwr.com/recreation/golf.html or www.epa.gov/maia/html/junebug.html.]

Recycling to Reduce Runoff: Compost on Road Cuts

Compost is gaining popularity as a tool for revegetating steep slopes. A section of the Blue Ridge Parkway near Asheville, North Carolina was affected by a rock- and soil-slide in late May 2002, closing the parkway. While the road was being repaired, the slope of the road cut had to be restored and stabilized quickly to prevent excessive runoff from heavy summer rains. To do this, the Federal Highway Administration (FHWA), which manages highways on Federal lands, aimed to establish vegetation on the repaired slope. On this site, traditional approaches to stabilization, such as hydroseeding and root reinforcement systems, were challenged by fickle May temperatures, rocky and poor soils, and very steep slopes. After reviewing available options the FHWA decided to apply a combination of compost blankets and netting to the slope.

The Compost Advantage

Research and field trials show that compost works effectively in stabilizing steep slopes and preventing erosion. Although hydroseeding—a grass-planting process that consists of spraying a mixture of hay, straw, fiber mulch, water, fertilizer, agricultural lime, grass seed, and a tackifier—helps control runoff, it is found to be less erosion-resistant than compost on the kind of tricky terrain that the Blue Ridge Parkway section presented.

Composted organic material such as mixtures of peat moss, bark, processed wood chips, lawn grass clippings, manure, and other materials stimulate the chemical, physical, and biological characteristics of soil. The result is healthy vegetation growth: compost improves root growth, and enhances the germination of grass or other vegetation that reinforces the slope.

Absorbency is an additional bonus in helping control runoff. This benefit is important on steep slopes where the soil is too poor and nonabsorbent for vegetation to become established. Compost can absorb as much as the first half inch of a rainfall.

In this project the compost method was found to be more economical than hydroseeding. The cost of this technique ranged from 20 to 50 cents per square foot, depending on the accessibility and steepness of the slope. The cost included seed, 1 to 3 inches of compost, turf reinforcement netting, compost filter berms around the perimeter, and the berms applied in increments on the contours across the slope.

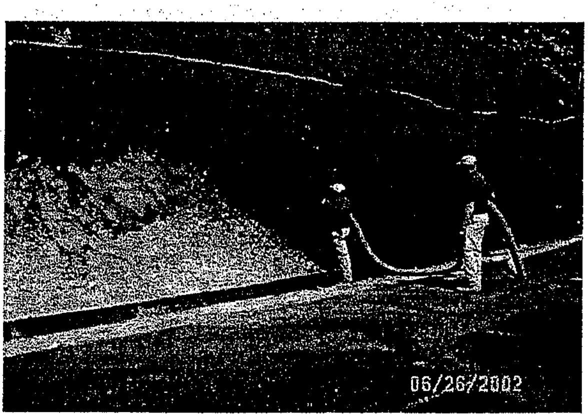
Although the cost of hydroseeding is typically about seven to 10 cents per square foot, the vulnerability to erosion on such a steep slope may be higher than with the compost technique. This area was more rock than soil, so a growing medium was needed for the vegetation, and the compost provides that medium. To use hydroseeding on steep slopes would require a root systen reinforcement mat placed prior to seeding, along with at least some soil/seed mixture with a temporary rolled mat on top to prevent erosion. The seven to 10 cents includes only the hydroseed application. Compared with the hydroseeding method, including the two mats and soil/seed mixture, the compost method is more economical.

Applying Compost and Making it Stick

The bulk of the time spent on the project consisted of clearing and grubbing the area and removing the slide material. During excavation operations, the substrate was roughed parallel with the contours of the slope using backhoe teeth. While grading the slope, the contractor made a point of avoiding "slicking off" (i.e., smoothing down to a hard surface) and avoiding making vertical claw marks that would have channeled water. Instead, the machinery was used to create indentations or imprints every few feet to prepare the substrate for a seedbed.

Prior to applying the compost, rock climbers rappelled down the slope to place lockdown netting to increase the strength of the root system and reduce the risk of a blanket root system failure. As the grass roots penetrate the compost netting, they bind and tie the compost blanket and berms to the ground surface. The netting served to increase shear strength long enough for the seed to germinate and begin to grow before the compost could slide down the slope. A biosolids-based compost was mixed with nutrient-enhanced leaf compost and wood fibrous-composted mulch and then was blown using blower-truck technology to form a blanket of compost over the netting.

Heavy equipment clears the slide material to prepare for compost application.



The contractor used a pneumatic blower to apply the compost.

Vegetation was reestablished on the slope within 5 months of the slide.

To break up the flow of water and prevent it from concentrating, mesh tubes filled with compost and grass seed were laid and staked across the entire slope. After the grass is established, they biodegrade and act as a biofilter.

It Worked!

On the second-to-last day of the compost installation, a storm brought rainfall of 3 inches per hour. Although a small breech and some rilling occurred, the breech self-healed, and the rilling stopped. The rainstorm's timing proved fortuitous, enabling FHWA to observe the performance of this technology under a heavy rain.

The FHWA completed the work on June 28, 2002. The next major test was the drought during summer 2002. Although the dry conditions caused the vegetation to grow less densely than was

Recycling to Reduce Runoff: Compost on Road Cuts (continued)

desirable, adequate vegetation was established. The compost with the seed prescription was designed to account for such seasonal climatic conditions. Although the grass germinated and then dried up, the seed in the compost mixture enabled the grass to regerminate when the growing conditions were right.

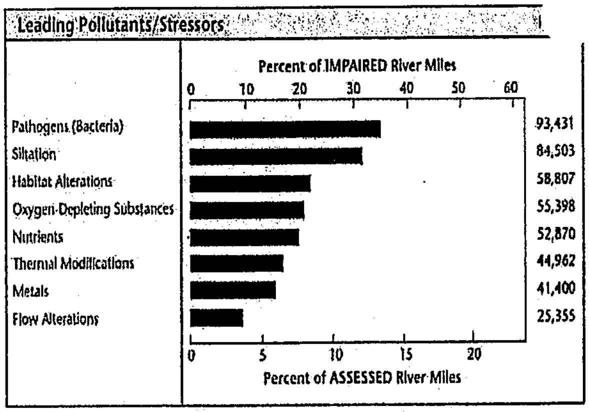
As the process-knowledge of using compost in highway construction evolves, FHWA may consi adopting this method as a best management practice. As a method, composting can be used for temporary erosion and sediment control during construction phases and permanent erosion and sediment control through establishing sustainable vegetation. Not only does compost appear to be as good as or better than conventional erosion control methods, but it also offers the environmental benefit of recycling biodegradable wastes that might otherwise end up in landfills.

[This article was abridged and reprinted with permission from the March/April 2003 issue of Public Roads *(Vol 66 - Number 5), located on-line at www.tfhrc.gov/pubrds/03mar.* Public Roads *is published twice monthly by the U.S. Department of Transportation Federal Highway Administration. For feedback on the magazine contents, contact Martha Soneira via e-mail at Martha.Soneira@fhwa.dot.gov or by phone at 202-493-3468. For further details on the project contact Mitch King, Project Engineer, FHWA Eastern Federal Lands Construction Division, 112 Industrial Park Drive, Sevierville, TN 37862. Phone: 865-453-7123.]*

Removing Bacteria from Runoff: An Overview of Strategies

How serious is the problem of unhealthy levels of bacteria in our nation's waterways? In terms of both the number and miles of waters identified as impaired under the latest Clean Water Act (CWA) 303(d) listings, pathogens are identified as the most commonly violated category of water quality standard (see graph). Thus, high bacteria levels in U.S. waters account for the single greatest obstacle to achieving full compliance with the Clean Water Act's "fishable and swimmable" goals. While it is impossible to be certain how much is attributable to point sources, much—perhaps most—is associated with nonpoint sources from both urban and agricultural sources.

In Virginia, approximately half of the stream miles listed as not meeting water quality standards are impaired by bacteria. Other states are only now getting around to listing bacteria-impaired waters. A review of Virginia's waters impaired by bacteria and the 92 bacteria Total Maximum Daily Load (TMDL) studies Virginia has developed to date, reveal that these impairments are associated with high population densities of either people or livestock.



Pathogens are the most commonly cited cause of water quality impairment (U.S. EPA 305(b) 2000 Report, released September 2002).

Although states are developing TMDLs to allocate loads among various point and nonpoint sources, including a growing number that are informed by high-tech bacteria source tracking, increased knowledge and awareness is needed to help program managers develop mitigation and protection strategies for pathogens. Two main strategies may be followed simultaneously: source control and in-drainage mitigation. Below is an annotated list of options for each strategy. Other options may exist, as well.

Source Control Strategies:

- Low impact development (LID) techniques—A low impact development is one that seeks to mimic a site's predevelopment hydrology by reducing impervious surfaces and taking advantage of opportunities to infiltrate, filter, retain, evaporate, and slow down runoff close to its source. LID techniques can be applied to new and existing development using decentralized micro-scale or lot-level controls to manage rainfall and runoff. Reducing th

Removing Bacteria from Runoff: An Overview of Strategies (continued)

volume of runoff decreases the potential for bacteria to be transported into storm drains. For example, a downspout can be designed or modified to redirect runoff from rooftops with bird droppings toward pervious areas capable of infiltrating the runoff. Likewise, any pet waste left near a rain garden or bio-infiltration cell is less likely to pollute nearby streams than pet waste left along a roadside ditch. See www.epa.gov/nps/lid for more information on low impact development.

- Riparian buffering—Vegetated or forested riparian zones can be used to provide buffers between impacted land uses and water resources in both urban and agricultural areas. The riparian zones help in two ways. First, they physically separate high concentrations of humans and domesticated animals from waterways. Second, the riparian zones serve as overland filters for treating animal waste to the extent that these zones are directly downslope of the impacted land use. Virginia recently issued guidance on implementing TMDLs that contain estimates that bacteria can be reduced by 43 percent to 57 percent by implementing proper riparian buffers, especially in agricultural watersheds (*Guidance Manual for Total Maximum Daily Load Implementation Plans*, Virginia Department of Conservation and Recreation and Department of Environmental Quality, July 2003).

- Street sweeping—A 1993 study by Roger Bannerman with the Wisconsin Department of Natural Resources identified streets and parking lots as significant sources or carriers for bacteria and other urban pollutants. Bacteria have an affinity for attaching themselves to fine sediments, and can form biofilms on gutters, both of which can be swept away. It is important to use sweepers that have good efficiencies for removing the tiniest particles. A new generation of high efficiency vacuum street sweepers has reversed the criticisms that earlier types of sweepers performed poorly in the Nationwide Urban Runoff Program studies of the early 1980s (see *News-Notes* Issue #56, February 1999, "State-of-the-art Street Sweepers Could Reduce Suspended Solids in Receiving Waters"). However, research to quantify a bacteria load reduction benefit from street sweepers is lacking.

- Pooper scooper enforcement, public campaigns, and the free market—While many localities have some form of legal code banning pet waste in public areas, most localities put little or no effort into enforcement. A combination of ratcheting up enforcement and public education campaigns has been effective from New York to Texas. The Texas Commission on Environmental Quality recently developed and distributed public outreach materials to encourage more owners to pick up after Fido. New billboards and magnets that show a Shar-Pei dog and the message "Please pick up my poop" are helping to garner public attention to this issue. Another idea is to issue warning tickets that explain the problems associated with pet waste. Finally, with names like "Doody Calls" (www.doodycalls.com) and "Wholly Crap" (www.whollycrap.com), some entrepreneurs are getting into a new business that's really "picking up."

Pet waste campaign message from the Texas Commission on Environmental Quality developed in 2002.

- Dog parks as BMPs—An environmentally friendly dog park is one that is sited away from environmentally sensitive features, such as floodplains, and provides a safe off-leash fenced area, public education signage, free pooper scooper bags, and sanitary trash receptacles. Such dog parks function as social crucibles for transferring the conscientious behavior of responsible pet owners who pick up after their pets to less conscientious owners, and thus helping to establish a new social norm. According to Judy Green, Executive Director of the Northern Virginia Dog Park Coalition, if the dog park is set up correctly, "the peer pressure on newcomers to pick up after their pets really works." Sponsorship and acceptance

Removing Bacteria from Runoff: An Overview of Strategies (continued)

of responsibility by a local dog group for each dog park helps ensure accountability and success.

- GeesePeace techniques—By humanely decreasing nuisance resident geese populations, a ne organization called GeesePeace is reducing the amount of bacteria-laden geese droppings i particular areas. This organization is "dedicated to building better communities though innovative, effective, and humane solutions to wildlife conflicts." The GeesePeace solution is a site-specific recipe of integrated programs that may include egg addling (which requires a permit from the U.S. Fish and Wildlife Service), vegetative barriers around waterbodies, border collie patrols, goose repellants (such as the safe, all-natural grape compound Methyl Anthranilate, or MA for short), and publicly signed and enforced "no feed" zones. While GeesePeace focuses on strategies specific to nuisance waterfowl populations, the concepts of humane and effective solutions may be applicable to other animals with unnaturally high populations or exotic invasive species such as raccoons, nutria, rats, and other animals that have adapted to man-made environments in population densities far greater than would be found naturally. For more on GeesePeace and its approaches, visit www.geesepeace.org.
- Illicit discharge detection and elimination—Dye tests, smoke tests, mobile TV inspections through storm sewer systems, flow monitoring, and remote sensing are some of the tools that can be used to detect and eliminate illicit discharges that may contain human waste or other pathogens. These are presented in an EPA fact sheet online at cfpub.epa.gov/npdes/stormwater/menuofbmps/illi_2.cfm. Optical brightener monitoring is a variation on dye testing that can detect persistent ultraviolet man-made dyes common to laundry detergent in storm sewer systems or downstream of failing septic systems. When the optical brighteners are detected in the environment or storm sewer system they indicate the presence of laundry effluent, which is a component of human sewage. See *News-Notes* Issue #63 (www.epa.gov/owow/info/NewsNotes/issue63/63_issue.pdf) or the Summer 2003 issue of *The Volunteer Monitor* (www.epa.gov/owow/monitoring/volunteer/issues.htm) for more information on optical brightener monitoring.
- Cattle/livestock fencing, alternative water sources, and livestock waste management—Cost-share programs through soil and water conservation districts (SWCDs) are often available to assist farmers who are concerned that excluding cattle and other livestock from nearby streams means an end to a cheap and convenient source of water for their livestock. Alternative watering systems may be supplied via solar pasture pumps, electric pumps, and even animal-operated pasture pumps. A growing number of states have successfully restored bacteria-impaired streams in agricultural watersheds by fencing out livestock from excessive stream access. Other agricultural BMPs that have been shown to be effective for reducing bacteria runoff include constructing roofs over concentrated feeding areas, stabilizing livestock access areas, and constructing animal waste storage facilities. See also *News-Notes* Issue #71 for an example of effective equine waste management.

In-drainage Mitigation Strategies:

- UV disinfection—At least three applications of ultraviolet (UV) light disinfection of urban runoff have been installed in the U.S., and others may soon follow. So far, all are located in southern California. In 2002, a UV treatment system was installed at a storm drain outfall along Moonlight Beach in the City of Encinitas. The city spent $438,000 to design, construct, and install the multi-stage UV light disinfection system within a 9-foot by 24-foot box culvert. The system is designed to treat baseflow, up to 150 gallons of flow per minute (0.3 cfs); significant wet weather events trigger an automatic shut-off and bypass the treatment unit. System maintenance is limited to periodic cleaning and UV lamp replacement every nine months to a year. So far, bacteria counts are being reduced from levels in the 100s, 1000s, and 10,000s of colony-forming units (cfu) per 100 milliliters (ml) of water going into the UV unit to just 2 cfu/100 ml for most of the baseflow periods leaving the treatment unit. This experimental project is profiled in the May/June 2003 issue of *Stormwater Magazine*, available online at www.forester.net/sw_0305_moonlight.html. In

July 2003, Orange County installed a UV unit capable of treating 140 gallons per minute at an outfall to Aliso Creek near Aliso Viejo. And this spring, Orange County, California, installed two UV treatment units inside a double box culvert that feeds a creek channel and drains to Poche Beach between Dana Point and San Clemente. In 2001, the City of Laguna Niguel in Orange County, California installed a temporary UV treatment system at a storm drain outfall to treat bacteria during dry weather. Monitoring data showed this unit to be effective while it was operational, however it was replaced in 2003 by a network of constructed wetlands designed to treat dry weather flows and urban runoff from small storms. Runoff from larger storms bypasses most of the wetlands.

- Ozone treatment—An ozone treatment system for removing bacteria from urban runoff is being constructed by another southern California Pacific beach community—the City of Dana Point. At $4.6 million, this system is more expensive than the UV systems installed in nearby communities, but it will handle flows that have diminished water clarity and will be capable of treating up to 1000 gallons per minute (2.2 cfs). In this case, the catchment includes baseflow with naturally high concentrations of manganese and iron.

- Infiltration BMPs—Infiltration BMPs can include trenches, sand filters, porous pavement, permeable pavers, filter strips, and rain gardens. Just as properly sited, designed, and maintained septic systems that rely on infiltration have proven effective at controlling bacteria and other pollutants from wastewater, other types of infiltration facilities can be effective at controlling bacteria and other pollutants from stormwater. As long as adequate separation distances are maintained, bacteria are not likely to contaminate groundwater resources. In the case of sand filters, where infiltrated waters are returned to surface drainage, five of six studies catalogued in the second edition of the National Pollutant Removal Performance Database for Stormwater Treatment Practices (National Database) showed that these systems were effective at removing 36 percent to 83 percent of the bacteria. However, one study of a sand filter in Austin, Texas showed a net increase in bacteria.

- BMP ponds—In general, lakes have significantly lower bacteria levels than the streams and rivers that feed into them, but the data are more variable for small ponds. Given that bacteria levels increase with turbidity and that bacteria tend to cling to sediments, bacteria may be removed from the water as these sediments have a chance to settle out. To the extent that BMP ponds promote settling (and inhibit resuspension during high flow events), they will likely remove significant amounts of bacteria. In general, larger, deeper ponds with forebays are likely to do a better job of removing bacteria than smaller ponds without forebays, as re-suspension becomes less of an issue. The National Database documents bacteria removal efficiencies from ten studies that show that properly designed and maintained wet ponds can remove significant amounts of bacteria (46 percent to 99 percent for 9 of 10 studies). Unmown vegetative buffers around ponds are useful for many reasons, including their value for discouraging geese and other bacteria-contributing waterfowl that otherwise flock to easy-grazing fields of grass mown up to the water's edge (typical of golf courses and many BMP ponds). See www.novaregion.org/pdf/NViron13-1.pdf for more discussion on geese and BMP ponds.

- Constructed wetlands—While bacteria reduction results from constructed wetland studies are more varied than results from wet ponds, constructed wetlands have been demonstrated to be very effective in certain applications. For example, the preliminary data from Laguna Niguel (see "UV disinfection" section above) suggests that the three-cell wetlands network will be capable of reducing fecal coliform bacteria by more than 90 percent for baseflow periods and small storms. An Australian study published in 2000 by Cheryl Davies and John Bavor showed that a constructed wetland outperformed a BMP wet pond at removing bacteria from runoff and attributed it to settling and bacterial predation. The use of constructed wetlands in wastewater treatment for removal of bacteria and other pollutants is well documented.

Removing Bacteria from Runoff: An Overview of Strategies (continued)

- Floc agents—According to research published last year, polyacrylamide (PAM) is effective at intercepting bacteria, nutrients, and suspended sediments when added to irrigation water. The research was conducted by James Entry and Robert Sojka with the USDA's Agricultural Research Service and demonstrated that when PAM alone was added to irrigation water, populations of bacteria from cow and pig leachate were reduced by about 90 percent. Wh PAM was used in combination with either aluminum sulfate or calcium oxide, bacteria counts were reduced from farm runoff by about 99 percent. This research is described in more detail in the July 2002 issue of the USDA's *Agricultural Research Journal*, available on the Internet at www.ars.usda.gov/is/AR/archive/jul02/pam0702.pdf. According to the USDA, PAM is a relatively environmentally safe flocculent agent available in many varieties that can be categorized into three basic types: anionic, which has no known aquatic toxicity and is recommended for outdoor use; cationic, which is recommended for use by wastewater treatment plants and certain other industrial applications; and non-ionic, used more rarely for specific mining applications. It is the safest form that is typically used for irrigation water and for erosion and sediment control. Floc logs embedded with PAM are designed to release this polymer into streams at slow, controlled rates, and are becoming increasingly popular for removing suspended sediments contributed by stormwater runoff. Because of the affinity that fecal coliform bacteria have for suspended sediments, floc logs also hold promise for pulling bacteria out of the water column, although more research is needed to verify this. Another floc agent is chitosan, a biopolymer typically obtained from chitin in crab shells. Chitosan has been shown to be effective at coagulating clay-sized particles suspended in runoff, which causes them to settle out of the water column. It may be that chitosan also has application as a bacteria-reduction agent in streams with high levels of sediment and bacteria, since bacteria behave similarly to clay particles in the water column.

- Alum injection—When injected into storm drains at the right dosages, alum has been used to coagulate the bacteria and suspended sediments through ionic bonding and settle them out of the water column. Alum injection has been used successfully in parts of Florida to substantially reduce nutrients, turbidity, and bacteria. However, alum injection might be a option of last resort because of toxicity concerns when pH levels cannot be maintained between 6 and 7, relatively high capital and operating costs, and potential aesthetic impacts. More information on alum injection for bacteria control is available online at www.stormwater-resources.com/Library/077PBactiRemoval.doc.

- Catchbasin insert with antibacterial coating—A proprietary, patented catchbasin insert with a special antimicrobial coating, AbTech's Smart Sponge Plus, is being investigated by municipalities and a state agency for its effectiveness at reducing bacteria from runoff entering storm sewers. The Smart Sponge is a product designed to trap oil and other hydrocarbons as they enter the urban storm drain system. The Smart Sponge Plus adds an antimicrobial coating to the basic Smart Sponge polymer. This coating is an organosilane that is bonded to the Smart Sponge polymer. The coating acts as an electrically charged "sword" to attract negatively charged microbes such as fecal coliform bacteria, puncturing their cell membranes and killing them upon contact. More information on the antimicrobial agent is available on the Aegis Environment web site at www.microbeshield.com; Aegis Environment is AbTech's partner for the Smart Sponge Plus. The New Hampshire Department of Environmental Services is currently field-testing the performance of this product, and a final report is expected later this summer. Several Pacific Coast municipalities in southern California, including Newport Beach, Long Beach, and Manhattan Beach, have recently installed the antimicrobial version of the Smart Sponge in storm drain catchbasins and are conducting their own field monitoring, as well. Preliminary field results from New Hampshire and southern California have been mixed, but this technology may continue to evolve.

As a final note, some researchers have pointed out that in pristine watersheds, not only are bacteria source loadings lower than they are in urban watersheds by several orders of magnitude, natural stream systems with intact headwaters have balances of predator-prey microbial communities. In the microbial realm, relatively larger microbes like heterotrophic nanoflagellates, paramecia, rotifers, and others, prey on the smaller fecal coliform bacteria to help keep their populations in check. These larger predatory microbes are known collectively as bacterivores. With regard to heavily degraded urban and agricultural stream systems, Virginia Tech biologist and bacteria DNA fingerprinting pioneer Dr. George Simmons notes that a stream with consistently high bacteria levels "indicates a microbial community that is out of balance." He believes that certain types of bacteria, such as *E. coli*, may be considerably more adaptable than their natural predators to highly impacted streams. To solve this problem, he advocates restoring natural conditions and functions into degraded streams to encourage greater bacteria predation.

[For more information, contact Don Waye, U.S. Environmental Protection Agency, 4503T, 1200 Pennsylvania Avenue, NW, Washington, DC 20460. Phone: 202-566-1170; e-mail: waye.don@epa.gov.]

Software Spotlight

CommunityViz: Planning Made Transparent

In an era when both planning professionals and citizens have access to various demographic and natural resource data over the Web, there is a marked need for tools that can integrate the data in ways that generate meaningful information for growth planning, and more importantly, citizen inputs into these processes.

A GIS-based tool called CommunityViz appears to be exciting the planning community, especially those working in smaller municipalities and rural areas, by filling the need for data integration. Sponsored to the tune of $10 million in research and development by the Orton Family Foundation (www.orton.org) based in Vermont, the software grew as a response to a need that founder Vyman Orton himself felt during his experiences working in small town planning boards in Vermont. The software has the potential to empower the citizen participant in the planning process by visually presenting potential impacts of different proposed development scenarios. It allows planners and citizens who are involved in the review and comment process to understand the benefits as well as compromises of a given development plan, and therefore, consider a growth scenario more meaningfully.

Alongside the increasingly popular GIS capability of analyzing viewsheds in 3-D from different vantage points, users can also analyze and quantify a proposed development's impact on a host of environmental and economic variables: in effect, evaluate the impact that proposed growth will

Example of 3D viewshed impact.

have on issues of interest, including utility infrastructure cost, open space, post-development runoff quantities, and projected impacts on water quality. These additional capabilities are typically not available to planning boards and citizen stakeholders. Using the software, however, allows incomplete or speculative information on the future to be converted to a rational, modeled report. A post-development scenario may be accompanied with: (1) projected costs (e.g., the cost to run utility lines to houses in one layout configuration, as opposed to another, costs of extending sewer lines versus septic systems), (2) expected revenues from new tax bases, and (3) environmental indicators (e.g., total land required for utility easements, and new roads, expected total impervious surface after development). Such information is usually available only piecemeal, in individual analyses from sources such as the private developer, the municipality, the utility companies.

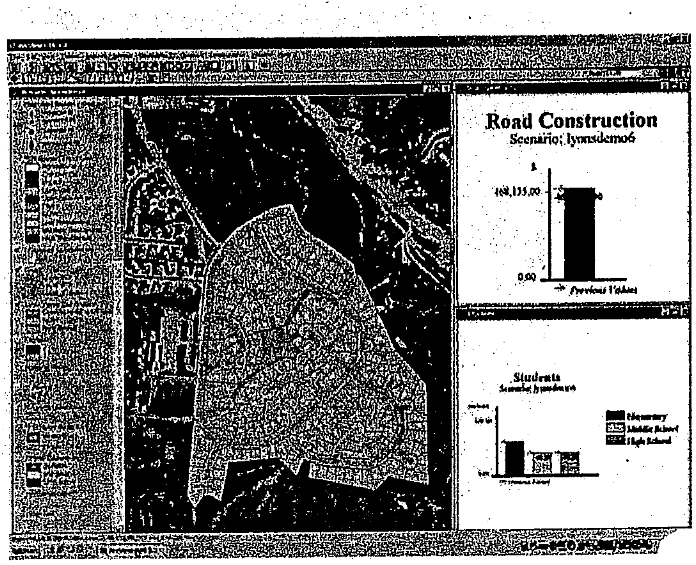
"The software doesn't provide the answers," says Doug Walker, managing director of Boulder, Colorado-based CommunityViz. "It is just a tool to reveal information that can be well utilized in any growth planning process." The software allows users to set the parameters for growth before the design stage and then evaluate the design against those parameters. For example, the user can define community goals such as environmental and economic goals (e.g., preserve 'x' amount of open space within this boundary, retain existing wetlands in location 'y', allow 'n' new commercial zones). It allows users to define limitations and caps (e.g., cost ceilings for new sewer lines in the proposed development, current regulations, zoning limitations, etc.). The software can generate a spatial and numerical analysis of a proposed development design as evaluated against these goals.

Because the software is fairly complex to use, a review in GeoWorld magazine (October 2002) suggests that for maximum effectiveness, a GIS specialist is required to navigate the software, and to format and enter data, in combination with a planning committee or a group of informed citizens. This is similar to requirements for any GIS-analysis system, which requires technical and information systems skills. A workshop on land use impact assessment tools hosted by the Wisconsin Department of Natural Resources for public officials, watershed groups, town planners, and other interested parties was another test of the software's usability. The general consensus was that CommunityViz was useful in planning applications and that it would raise the public's level of discussion regarding land use decisions. However it was tempered with concern about the cost and training required to use the tool effectively. (Proceedings of Changing Landscapes: Anticipating the Effects of Local Land Use Decisions, March 31 and April 1, 2003, Madison, WI)

Watershed Applications

There are several watershed based applications of the software. "I've used CommunityViz to do a runoff-sensitivity analysis for a watershed", said Lex Ivey, consultant to CommunityViz. He used soil, slope and landcover data, embedded the Universal Soil Loss Equation (USLE) into the software, and then evaluated the impact of a ground disturbance by adding a building footprint. He placed the building at different sites in the watershed and was able to compare the different sites in terms of vulnerability to runoff.

"The flexibility of the software is that it provides the framework for a variety of variables that can be defined for a local site," says Ivey. A classic example of the software's use is in optimizing the cost of mitigating nutrient pollution by using BMPs at different sites in a watershed. "Using costs that we define for the local area, we were able to define a target budget for



Example of proposed subdivision design.

CommunityViz: Planning Made Transparent (continued)

mitigation practices for a watershed. We also defined the appropriate BMP for a particular type of landcover. We then evaluated different sites in the watershed for BMPs, and the rest was just crunching out the numbers; we got a spatially referenced cost-spreadsheet that we could fine-tune and optimize for our budget and nutrient removal effectiveness." Because of the software's visual interface, Ivey says a programmer is not needed to add variables nor to manipulate them. For example, a slider bar may be used to increase the quantity or size of a BMP, such as adding more mulch to the ground. The runoff analysis can be re-run with different quantities of the BMP.

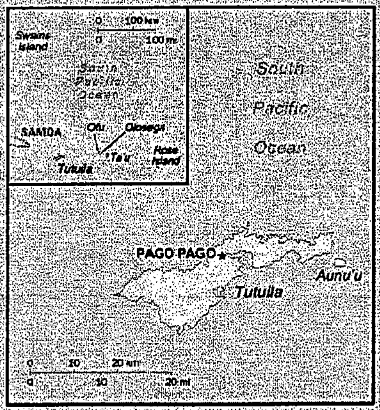
Data that the software is designed to utilize includes digital aerial photography, existing municipal geographically referenced data, such as zones, roads, land use, buildable land, etc. More advanced policy simulations require demographic and business information, sales and income tax information, wages and consumption information. The model library that comes with SiteBuilder 3-D offers a library of over 2500 residential and building models that can be used in the visualization.

[For more information, contact Lex Ivey, Consultant, CommunityViz, 1035 Pearl Street, Boulder, CO 80302. Phone: 303-442-8800; e-mail: Iveylivey@communityviz.com; Web: www.communityviz.com.]

Notes on Education

Preaching Environmental Stewardship in American Samoa

One of the biggest challenges for public awareness campaigns is reaching the target audience with the intended message. Coastal resource managers in American Samoa have found that a good way to do this is to put the message in the context of a community's cultural understanding. "Our culture is very important to us," says Tali Tuinei, assistant public awareness coordinator with the American Samoa Coastal Management Program. "In Samoan society, there is no separation of society and religion. Our motto is 'Put God First.'"



Map of American Samoa

American Samoa is a group of five volcanic islands and two coral atolls in the South Pacific, located fourteen degrees below the equator, about half way between Hawaii and New Zealand. American Samoa became a U.S. territory in 1900.

Because Christianity plays such a major role in the lives of the American Samoan people, Tuinei says, the coastal program staff created a Religious Consciousness Project to help spread the word about the islands' environmental problems. "We saw this as a vehicle to expand our existing outreach program," she says. "Our hardest audience is adults. It's easy to go into schools and get kids to accept our message, but it's harder to get that message to adults."

In 1999 they created a task force of 12 representatives from the various religious denominations on the islands. Tuinei explains that they also contracted with a reverend at a correctional facility to serve as a liaison between the government agency and the churches. At the taskforce's suggestion, the coastal program held a series of workshops with the Sunday school teachers, ministers, and other representatives of the territory's various denominations. "We presented to them the environmental issues we have facing us now and what needs to be done to save the natural resources. We divided each workshop into groups and asked them to provide an action plan by the end of the workshop and give us suggestions on the best way to implement the plan," Tuinei says.

Ideas that came out of the workshops included encouraging ministers to put the environmental message into their sermons; putting the message into the local televised religious service, which rotates weekly between the different denominations; and incorporating the message into summer and Christmas programs. The idea that has had the most impact, says Tuinei, is having the churches hold a special meeting and invite the coastal program managers to present information on issues such as water quality, population growth, wetlands preservation, and nonpoint source pollution.

Having the church's reverend moderate the meeting usually encourages the congregation to be more open to the environmental message. "You might be quick to insult someone you don't kno but you would never insult your own pastor," she says. "Most of the people . . . listen and ask questions and by the end want to know more about how they can help."

Other benefits of the project include new contact lists that have expanded the coastal program's outreach into the villages. Tuinei explains, "For years we've tried to get the village mayors to help us, and that was unsuccessful. As a result of this project, we've had a village mayor workshop that has helped us start a water quality project." They hope to build on these contacts, she says, "so that we can reach the individual chiefs in the villages and then into the village councils."

Tuinei notes that the project hasn't always been easy, pointing out that the staff person conducting the process left and it languished until the position could be filled, and that every time they tried to evaluate the taskforce's progress, the group would assume its job was over. "We had many problems along the way," she says. "The message we want to send out is that it was a good idea. The project was not perfect, but we learned from our mistakes."

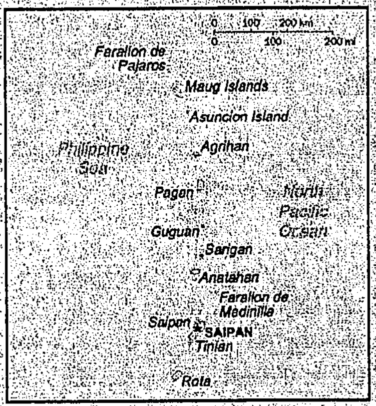
[For more information on the American Samoa Religious Consciousness Project, contact Tali Tuinei at 684-633-5155 or by e-mail at TTUINEI@doc.asg.as. This article was reprinted in part with permission from the November/December 2002 issue of Coastal Services, a National Oceanographic and Atmospheric Administration publication found at www.csc.noaa.gov/magazine/.]

Project Contributes to Success

American Samoa's coastal nonpoint program under Section 6217 of the 1990 Coastal Zone Act Reauthorization Amendments (CZARA) was recently approved in part because of the Religiousness Consciousness Project. American Samoa faces problems with pollution-rich runoff from numerous poorly managed, small-scale piggeries. Runoff on the mountainous islands is amplified by heavy tropical rainfalls, steep slopes, and thin soils, and leads to excessive erosion. According to the EPA Office of Water, American Samoa's religious consciousness project uses a localized, cultural-based approach to public education that helps address these nonpoint issues. For more information about CZARA and American Samoa's coastal nonpoint program, see http://coastalmanagement.noaa.gov/czm/6217.

The Northern Marianas' Drive to Protect the Beach

The cultural tradition of families picnicking on the beach in the Commonwealth of the Northern Mariana Islands is clashing with the environment. As the number of vehicles on the islands has increased over the past decade, the illegal but accepted practice of driving off-road to a favorite picnic spot is now destroying vegetation and sea turtle habitat, and is contributing to nonpoint source pollution. The off-road traffic accelerates beach erosion and can leak petroleum products. A collaborative education campaign has been put into gear by the islands' natural resource managers to begin the challenging process of changing the behavior of beachgoers.



Map of the Northern Mariana Islands

The Mariana Islands archipelago is located about three-quarters of the way from Hawaii to the Philippines in the western Pacific Ocean. The archipelago consists of the 14 islands of U.S. Commonwealth of the Northern Mariana Islands (CNMI), plus the southernmost island of the U.S. Territory of Guam. The CNMI is a self-governing Commonwealth of the United States. Islanders are not allowed to vote in federal U.S. elections, but they enjoy all of the other benefits of U.S. citizenship. The Northern Mariana Islands are about 2.5 times the size of Washington, DC and have a population of approximately 80,000.

"This was never a great concern until about 10 years ago when th number of cars on island drastic

The Northern Marianas' Drive to Protect the Beach (continued)

increased," says Kathy Yuknavage, environmental health specialist with the Northern Marianas College Cooperative Research, Extension, and Education Service. "Most people are unaware that there is a law making it illegal to drive on the beach," explains Erica Cochrane, Northern Marianas Coastal Resource Management Office coral reef coordinator. "We needed an educational campaign because most of the island residents aren't aware of the impacts."

Yuknavage notes that while driving on the beach is illegal, authorities believe it to be a minor infraction, and with a limited workforce, citations are rarely written. The islands' law enforcement agency, however, participated in the education campaign.

The "Walk it, don't drive it" campaign includes slide public service announcements (PSAs) shown before each movie at the only movie theater on the islands, multiagency presentations at schools, student field trips, and the involvement of the islands' elders, or Man am'ko.

Driving on the beach compacts sand, which increases run-off and destroys nesting sites for turtles and other egg laying creatures.

It is illegal for unauthorized vehicles to drive on the beach.
9 CMC Section 5807 (b)
This message is brought to you by the Northern Marianas College-Cooperative Research, Extension & Education Service.

Two of six PSA slides shown at the islands' movie theater.

The program began in 2002 when Yuknavage, who calls beach driving one of her pet peeves, surveyed drivers at gas stations. She also took aerial photos of the beach and completed a beach count to determine the pervasiveness of the problem. Of the 700 people surveyed, 68 percent said they were unaware of the law prohibiting off-road driving. Of the 32 percent that knew about the law, only four percent admitted driving on the beach, but 15 percent responded affirmatively when asked if they had ever gotten stuck in the sand. A count of cars at a popular beach showed that 70 percent of beachgoers drive on the beach.

Yuknavage says the survey shows that many people didn't consider driving to their favorite spot to drop off a picnic basket actually driving on the beach. "Our biggest problem was that we needed to get our message across about the law and why it was written."

Yuknavage turned to the local theater to get her message across. She worked with artists from Northern Marianas College and their Cooperative Research, Extension and Education Service to create six slide PSAs that run in rotation before each movie. The slides feature striking images, such as an exaggerated photo of a truck running over a sea turtle, with tag lines about why driving on the beach is harmful or unwise. The islands' Man am'ko are featured in one slide because they are so culturally respected and remember when few cars were on the beaches.

Yuknavage worked with Cochrane and staff at other natural resource agencies to create PowerPoint presentations on the topic, which they presented to students, along with business-size cards with information on the environmental impacts for the children to pass out to friends and family. Two college students took the presentation to local high school classes. With the help of the tourism association, 50 students went on field trips to beaches for hands-on observation of driving impacts. These students were then given thank you cards to distribute to law abiding beachgoers.

In February 2003, after almost a year of outreach, the team conducted follow-up written surveys of drivers (randomly selected at local schools), as well as a car count at the beach. The surveys showed that 58 percent of drivers were aware of the law prohibiting off-road driving, compared to 32 percent in 2002. Survey respondents indicated that they had learned about the law primarily from local television news (45 percent), followed by newspapers (38 percent), PSAs (17 percent), thank you cards from children (five percent), and from their child who learned it in school (two

The Northern Marianas' Drive to Protect the Beach (continued)

percent). The car count revealed a corresponding decrease in beach traffic: only 40 unauthorized cars were noted driving onto the beach, a 27 percent decrease from the year before.

While awareness of the law appears to have increased, both Cochrane and Yuknavage agree that change will come slowly to the islands. "It's a great approach that we'd like to duplicate many times over," Cochrane emphasizes. "Just because it's slow doesn't mean we shouldn't do it."

[For more information on the "Walk it, don't drive it" campaign, contact Kathy Yuknavage at 670-664-8311, or via e-mail at kathy.yuknavage@crm.gov.mp. This article was reprinted in part with permission from the March/April 2003 issue of Coastal Services, *a National Oceanographic and Atmospheric Administration publication found at www.csc.noaa.gov/magazine/.]*

Reviews and Announcements

Adopt-a-Stream Educator Guide Newly Revised

After a year of editing, the Georgia Adopt-a-Stream Educator Guide is finally available. Designed for grades K-12 and for youth groups, the guide takes key stream-related messages and outlines them in fun and interactive lesson plans. Lesson plans have been correlated to the Georgia Quality Core Curriculum standards, which can be reviewed on the Adopt-a-Stream Web site at riversalive.org/aas.html, and by selecting "Teacher's Corner." Although designed for Georgia, the guide contains useful information and ideas for educators in all regions. To receive a copy of this educator guide, please call Georgia Adopt-a-Stream at 404-675-1636 or e-mail kimberly_morris-zarneke@mail.dnr.state.ga.us.

Freshwater Invertebrates Guide Helps Backyard Nature Enthusiasts

Popular interest in the observation and study of freshwater invertebrates for use as indicators of water quality is increasing. *A Guide to Common Freshwater Invertebrates of North America* serves as a wonderful tool to help people identify and learn about the freshwater invertebrates present in the local waterways. Section I of the book provides background on the biology and ecology of freshwater environments and explains why and how this group of organisms can be studied, simply and without complex equipment, in the field and the laboratory. Section II describes nearly 100 of the most common groups of invertebrates and provides a whole-body color illustration, along with brief text pointing out the most important features to use to identify group members. Section III contains expanded descriptions of the life history, behavior, and ecology of the various invertebrate groups, and identifies their important ecological contributions and relationships to humans. The book was written by J. Reese Voshell, Jr., illustrated by Amy Bartlett Wright, and published in Spring 2002 by McDonald & Woodward Publishing Company. Soft cover copies costs $29.95 and may be ordered by phone by calling 800-233-8787 or on the Internet at www.mwpubco.com/inverts.htm.

Guidance for Streambank and Lakeshore Stabilization Available

A Soil Bioengineering Guide for Streambank and Lakeshore Stabilization provides information on how to successfully plan and implement a soil bioengineering project, including the application of soil bioengineering techniques. Readers learn the basic principles and background information on ecology and the stream dynamics that are needed before attempting a restoration project. This guide is applicable to those who plan restoration projects and for those engaged in the day-to-day construction and maintenance of water-related recreation facilities, including dispersed areas, forest roads, and trails. It is also appropriate for persons interested in learning more about soil bioengineering stabilization techniques and how to apply them.

The guide was published in October 2002 by the U.S. Department of Agriculture, Forest Service, San Dimas Technology and Development Center. A copy is available for download at www.fs.fed.us/publications/soil-bio-guide.

New Video Documents Tribes Protecting Water Resources

EPA recently released a video that documents the successful protection of water quality on Native American reservations. "Our Water Our Future: Saving Our Tribal Life Force Together" shows the efforts of the Pueblo of Acoma in New Mexico and the Confederated Tribes of the Chehalis Reservation in Washington in developing water quality standards. Tribal elders and leaders and the directors and staffs of tribal environmental departments recount their experiences. The tribes took positive steps to protect present and future generations by adopting water quality standards for their reservations. EPA approved the Pueblo of Acoma's water quality standards in 2001 and those of the Confederated Tribes of the Chehalis Reservation in 1997. Segments of the video can be viewed online at www.epa.gov/waterscience/tribes/videoreal.htm. Tribal-adopted and EPA-approved water quality standards for these two tribes (and for other authorized tribes) are available online at www.epa.gov/waterscience/standards/wqslibrary/tribes.html. EPA is distributing copies of the video to all federally recognized Indian tribes. Copies are also available by contacting Eleanor Jackson by phone at 202-566-0052 or via e-mail at jackson.eleanor@epa.gov. For more information, contact John Millet at 202-564-7842 or via e-mail at millett.john@epa.gov.

Receive Free Watershed Academy Web CDs

Watershed Academy is now offering a free CD version of its popular online watershed training program, *Watershed Academy Web*. Since its beginnings in 1996 *Watershed Academy Web* has provided a broad overview of the fundamentals of watershed protection and management through the Web site www.epa.gov/watertrain. All the peer-reviewed modules are interactive, rich in visuals, and written in a style to optimize understanding of technical materials by general audiences. The Certificate Program, which requires the completion of 15 modules and passing their interactive tests, now has over 500 graduates in 47 states and 16 countries. A number of professors use *Watershed Academy Web* modules as a framework for their college courses. To request free CDs go to www.epa.gov/watertrain/getCD.html. Orders for up to 50 CDs require no special approval, and can be obtained by requesting "Watershed Academy Web on CD" publication no. EPA 841-C-03-001 via one of the following: e-mail: ncepimal@one.net; phone: 800-490-9198 (toll-free); 513-489-8190 (local); mail: U.S. Environmental Protection Agency, EPA Publications Clearinghouse, P. O. Box 42419, Cincinnati, Ohio 45242.

Riparian Buffers All the Rage

Is your locality considering adopting a buffer ordinance? Are you a homeowner thinking of converting your streamside lawn to a buffer? South Carolina is now offering riparian and vegetated buffer publications that can help you. The Department of Health and Environmental Control's Ocean, and Coastal Resources Management (OCRM) Planning Division staff recently reviewed and compiled current literature on vegetated buffers. The review resulted in two easy-to-read informative booklets: one for both local government officials and citizens of South Carolina, entitled *Vegetated Riparian Buffers and Buffer Ordinances* (www.scdhec.net/ocrm/pubs/buffers.pdf), and a second for homeowners, entitled *Backyard Buffers for the South Carolina Lowcountry* (www.scdhec.net/ocrm/pubs/backyard.pdf).

Although written for South Carolina, these documents present information applicable to a wider audience. To further assist local government officials and the public, OCRM also offers *A Model Riparian Buffer Ordinance* (www.scdhec.net/ocrm/pubs/model.pdf), which lists suggested components of a buffer ordinance. For more information, or to request hard copies of these publications, please contact Ward Reynolds, SC DHEC OCRM, 1362 McMillan Avenue, Suite 400, Charleston, SC 29405; Phone: 843-744-5838 ext.141; e-mail: reynoldsww@dhec.sc.gov.

Study Shows Link Between Forest Protection and Drinking Water Quality

A new study, conducted by The World Bank/World Wildlife Fund Forest Alliance, shows that protecting forest areas can provide a cost-effective means of supplying many of the world's bigger cities with high quality drinking water, providing significant health and economic benefits to urban populations. The team's report, titled "Running Pure: the Importance of Forest Protected Areas to Drinking Water," shows that more than a third of the world's 105 biggest cities—including New York, Jakarta, Tokyo, Los Angeles, Barcelona, Nairobi, and Melbourne—rely on fully or partly protected forests in catchment areas for much of their drinking water. Well-managed natural forests minimize the risk of landslides, erosion and sedimentation. They substantially improve water purity by filtering pollutants, such as pesticides, and in some cases capture and store water. According to the report, adopting a forest protection strategy can result in massive savings. For more information, and to download a copy of the report, see www.forest-alliance.org.

Urban Subwatershed Restoration Manual Series Available

Under a cooperative agreement from EPA's Office of Wastewater Management and Office of Wetlands, Oceans, and Watersheds, the Center for Watershed Protection (CWP) has just published three manuals of what will be a series of 11 manuals, known collectively as the "Urban Subwatershed Restoration Manual Series." This series is being developed by CWP to organize the enormous amount of information needed to restore small urban watersheds into a format that can be easily accessed by watershed groups, municipal staff, environmental consultants and other users. Together, the USRM manuals introduce an integrated framework for urban watershed restoration, outline effective techniques for assessing urban watersheds, and provide a comprehensive review of watershed restoration techniques. Each manual is packed with color photos, graphics, and data, including detailed field methods, practice specifications, costs, applicability and tips on implementation. The manuals are approximately 100 pages long each; some also include a CD with software to facilitate data collection and storage.

The eleven manuals are:

1. An Integrated Framework to Restore Small Urban Watersheds
2. Methods to Develop Restoration Plans for Small Urban Watersheds
3. Storm Water Retrofit Practices
4. Stream Repair and Restoration Practices
5. Riparian Management Practices
6. Discharge Prevention Practices
7. Previous Area Management Practices
8. Pollution Source Control Practices
9. Municipal Practices and Programs
10. The Unified Stream Assessment: A User's Manual
11. The Unified Subwatershed and Site Reconnaissance: A User's Manual

Thanks to an EPA grant, you can download the first three manuals in this series (#1, #10, and #11) in PDF format FREE through October 2004. To download, simply visit the Center's Web site: www.cwp.org. Color hard copies are also available from the Center for a nominal charge. Five additional manuals are scheduled for release before the end of 2004, and the remaining three some time after that. For more information, contact the Center for Watershed Protection, 8390 Main Street, 2nd Fl. Ellicott City, MD 21043. Phone: 410-461-8323; e-mail: center@cwp.org.

Web Sites Worth a Bookmark

Agriculture Ecosystems Research Group

www.uwex.edu/ces/forage/ageco.htm
This group, based out of the University of Wisconsin-Madison, brings together researchers and farmers from across Wisconsin to collaborate on research projects. The group focuses on identifying crops and agricultural practices that will economically benefit farmers while protecting environmental resources. Their Web site offers description of their ongoing research projects, and provides links to collaborators' Web sites.

Ramsar Video for World Wetlands Day

www.ramsar.org/wwd2004_index.htm#offer
Download materials including a leaflet, logos, poster, and video created to highlight the values and benefits of wetlands. The materials were developed as part of World Wetlands Day 2004 by the secretariat of the Ramsar convention, based in Switzerland. The 30-minute video highlights wetlands-related restoration projects around the world. E-mail ramsar@ramsar.org to request copies of materials.

Robocow

www.agr.gc.ca/pfra/flash/robocow/en/robocow_e.htm
This Web-based flash animation has made the rounds in various e-mail and electronic list-serve circles because of its attention-grabbing animation, and is well worth a mention here. Put together by the Prairie Farm Rehabilitation Administration of the Canadian Government's Agriculture and Agri-Food Ministry, these animations feature a new superhero, Robocow. Watch as Robocow flies over agricultural horizons, rescuing us from ill-advised practices that endanger the quality of surface waters. Conceived to make students from grades 6 to 10 aware of best farm management practices, Robocow has also been receiving rave reviews as a creative and informative outreach tool for the entire farming community.

Tools of Change

www.toolsofchange.com
"Tools of Change" is a Canada-based, bilingual Web site for those who plan and carry out programs to promote healthier or more environmentally sustainable actions and habits. Users have free access to case studies, planning guides, and worksheets to help them learn from collective experiences and create healthier, more sustainable communities. The site also offers links to resources on partners' Web sites. The site's primary sponsors include Health Canada, Environment Canada, Natural Resources Canada, and the Federation of Canadian Municipalities.

Smart Communities Network: Water Efficiency—Pollution Prevention

www.sustainable.doe.gov/efficiency/wpinfo.shtml
As part of the U.S. Department of Energy's Smart Communities Network, this site presents resources aimed at preventing water pollution and improving water efficiency. It includes a descriptive list of links to many on-line NPS pollution resources. This site also provides links to other water efficiency information, including success stories, example ordinances, educational materials, and publications.

Tribes Water Quality Standards and Criteria

www.epa.gov/waterscience/tribes
This EPA site serves as the central location for disseminating all tribe-related water quality standards and criteria information. EPA designed the site to help carry out the Office of Water objectives to meet the goal of clean and safe water in Indian country.

Datebook

Meetings and Events

August 2004

5	*"After the Storm"* polluted runoff education video available for free distribution to cable and other television stations (in high quality Beta SP format). Co-produced by the EPA and The Weather Channel. For more information, see www.epa.gov/weatherchannel.
16–20	*World Water Week*, Stockholm, Sweden. For more information, visit the Web site: www.siwi.org/waterweek/.

September 2004

1	*Public Meeting of the Mississippi River/Northern Gulf of Mexico Watershed Nutrient Task Force*, St. Paul, MN. More information is available at: www.epa.gov/msbasin.
12–15	*Second National Conference on Coastal and Estuarine Habitat Restoration*, Seattle, WA. For more information, e-mail nmaylett@estuaries.org or visit the Web site: www.estuaries.org/2ndnationalconference.php.
12–15	*Self-Sustaining Solutions for Streams, Wetlands, and Watersheds*, St. Paul, MN. For more information, visit the Web site: www.asae.org/meetings/streams2004.
12–17	*Watershed Restoration Institute 2004.* Seattle, Washington. Hosted by the Center for Watershed Protection in partnership with the University of Washington and River Network. For further details, see www.cwp.org.
14–16	*11th Annual Conference, Workshop and Trade Exposition*, Mid-Atlantic Chapter of the International Erosion Control Association. The theme of the conference: "NPDES: From Problems to Solutions." Martinsburg, WV. For more details, see www.macieca.org.
17	*Conference on Watershed Conservation 2004: Water Resources, Ecosystems, and People.* University of Massachusetts Amherst, MA. For more information, see http://madras.fnr.umass.edu/conference04/.
20–22	*8th International Wild Trout Symposium.* Yellowstone Park, MT. For more information, visit the Web site: www.fedflyfishers.org/wildtrout8.
21-23	*Putting the LID on Stormwater Management*, College Park, MD. Through a grant from the U.S. EPA, the Metropolitan Washington Council of Governments, Prince George's County, and the Anacostia Watershed Toxics Alliance are hosting the first-ever national low impact development (LID) conference. For more information, see www.mwcog.org/environment/LIDconference/.
20–24	*Monitoring Science and Technology Symposium.* Denver, CO. For more information, visit the Web site: www.monitoringsymposium.com.
26–30	*9th International Conference on Wetland Systems for Water Pollution Control.* Avignon, France. For more information, visit the Web site: http://iwa-ws.lyon.cemagref.fr/index.php?p_section=overview&p_lang=en.
26–30	*12th National Nonpoint Source Monitoring Workshop: Managing Nutrient Inputs and Exports in the Rural Landscape*. Ocean City, MD. For more information, visit the Web site: www.ctic.purdue.edu/NPSWorkshop/NPSWorkshop.html.

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EUROPEAN APPROACHES AGAINST DIFFUSE WATER POLLUTION CAUSED BY URBAN DRAINAGE

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ABSTRACT

Broader political approaches (legislative, economic, co-operative and participatory instruments) as well as detailed technical measures are investigated for integrated reduction of diffuse water pollution caused by urban drainage. Cost-effectiveness-analysis is used for priority setting and selection of final recommendations among the different measures. In this step solutions in the main fields of agriculture and morphology of waters are also considered in an integrated view. In relation with the water framework directive (WFD) of the European Union the results will be helpful to establish cost-effective action plans in river basin management. Most promising solution is the storm water infiltration as main element of the sustainable urban drainage system.

KEYWORDS : **Water protection, sustainability, quality objectives of waters, urban drainage, emission, storm water treatment, cost-effectiveness**

INTRODUCTION

Agriculture as well as urban drainage are recognised as important sources of diffuse water pollution with regard to nutrients and pollutants. According to the scientific definition of diffuse pollution (all sources which are directly associated with rainfall-runoff processes) the main urban diffuse inputs are:

- storm water effluents from urban areas drained by separate sewerage systems,
- combined sewer overflows (CSO) from urban areas drained by combined sewerage systems,
- effluents from road drains,
- wastewater effluents, which are not connected to a wastewater treatment plant (WWTP).

Böhm et al. (2000) carried out pollutant input balances for waters in Germany and the reference year 1997. The data for diffuse emissions are based on Behrendt et al. (1999) which are overall confirmed by estimations of other authors. The main nutrient input originates more and more from the diffuse sources while the input load from point sources decreases due to the achieved effect of sewage treatment. It was determined that about 67 % of the total phosphorus load (25 kt P/a) is caused by diffuse inputs. The main pathways of this input are erosion of agricultural soils (33 % of diffuse sources), wash out via groundwater (23 %) and urban areas (4 kt P/a, 16 %). About 72 % of the total nitrogen load (586 kt N/a) comes from diffuse sources. The main pathways of this input are wash out via groundwater (2/3 of diffuse sources), agricultural drainage (21 %) and urban areas (34 kt P/a, 5 %). So in total the urban areas provide 11 % of the nutrients diffuse pollution load.

The share of the total load of all heavy metals for diffuse sources is around 77 % in Germany (Böhm et al., 2000). Within the diffuse input pathways, the most important ones are the erosion of agricultural soils (30 % of diffuse sources) and the urban areas (32 %). The inputs by the effluents from separate sewers and CSO during heavy rainfalls are playing the main role. 15-44 % of the diffuse heavy metal load comes from roofs and roads in the cities during heavy rainfalls. After Hullmann and Kraft (2002) the proportional part of heavy metal load in the river Rhine shows for copper 1.3 % and for zinc 5.2 % originating from metal roofs.

A joint working team is commissioned by the German Federal Environment Agency to evaluate political approaches and investigate technical measures for the reduction of diffuse water pollution on both agricultural and urban pathways. The results for the agricultural sector are presented in three papers at this conference (Lange, Möller et al., Schultheiß et al.). The urban storm drainage pathway will be presented in this paper. Following an earlier presentation at the 6th Conference on Diffuse Pollution which focused on recent technical measures and methods in Germany (Ristenpart and Prigge, 2002) this contribution analyses the approaches throughout Europe in a broader sense and gives recommendations for integrated water protection management.

INSTRUMENTS

The basic instruments for realisation of diffuse water pollution reduction were compiled in a joint paper by the Working group of the federal states of Germany on water problems and the German Federal Environment Agency (LAWA and UBA, 2001):

1. ***state authority principle***
   Appropriate further development of the authority of the state (a proven instrument of prevention and precaution in the past) as the guarantor of high environmental standards.

2. ***market principle***
   Use of targeted economic / market incentives to reduce water pollution (pass on environmental costs in prices) and assessing the efficiency of water protection measures in environmental and economic terms
3. ***co-operation principle***
   Build on co-operative approaches, demand responsible action from those whose activities can impact on water quality (achieve sustainable development at a minimum cost and with a maximum of creativity).
4. ***public participation, rising public awareness, environmental education***
   Information and training or education as an instrument for modifying the behaviour of individuals, social groups and business

APPROACHES

The concrete approaches which are described in this section can all be related to the above basic catalogue of instruments which is used here as structure. On the other hand it is most effective to promote single measures like e.g. storm water management with several of the approaches and instruments.

Legal Regulations

Federal and state standards for wet weather urban drainage discharges.

In a project funded by the German Federal Environment Agency new emission requirements for storm water discharges are set up for their later implementation in a law or ordinance. The discharge into receiving waters is to be limited by quantity as well as by solids load. Groundwaters have to be protected according to the soil conservation act (Grottker, 2003). On the federal states level for separate storm systems requirements only exist in a few German states although its effluents pollution load is comparable (or even higher) to those of the overflows in combined systems. Discharge of polluted storm water should be permitted only after its treatment. Advanced requirements has to be defined according to the state of surface waters quality (see section '*Guidelines ...*').

Requirements for storm water management in state acts.

In some German states (e.g. North Rhine-Westphalia, Baden-Württemberg) storm water infiltration as an important source control measure in new built properties has to be preferred in comparison to conventional drainage systems. In Switzerland also the infiltration is obligatory. In North Rhine-Westphalia even in permitted drainage master plans for existing urban areas storm water infiltration has to be taken into account belatedly.

State ordinances for self surveillance of sewerage systems.

In nine German states such ordinances are already realised (N.N., 1998). The municipalities which are responsible for the operation have to self-supervise their sewerage system and have to report on this to the water authorities. Main aspects of surveillance are the structural state of sewers (e.g. leakage) and accurate operation of overflow structures.

Guidelines for wet weather urban drainage discharges.

The philosophy of the WFD is based on a combined approach of quality standards for waters with supplemental consideration of limit values for emissions. Two recently enacted German guidelines are following this approach. The guideline BWK M 3 (BWK, 2001) was developed for the State of North Rhine-Westphalia for "Derivation of state of waters-orientated requirements to combined sewage and storm water discharge under consideration of local conditions". It enables assessments of the state of receiving waters with adequate efforts. It determines limit values for hydraulic stress and pollution and it additionally defines sections of waters which must be totally kept clear from urban drainage effluents. The guideline ATV-DVWK M 153 (ATV-DVWK, 2000) formulates the objective to minimise the hydraulic and pollution impact of storm water from separate drainage systems. Field of application is the storm water treatment in the context of storm water management. Discharges into surface waters on the one hand and storm water infiltration into groundwaters on the other hand are considered.

Design guidelines for storm water treatment structures

For constructed wetlands (technical references see below) as presently strongly favoured type of treatment structures new design guidelines were developed by some German states (e.g. North Rhine-Westphalia) or are just in preparation by technical associations (ATV-DVWK) respectively.

Economic instruments

Funding.

For some technical measures funding programmes were set up in Germany. For instance storm water management measures (e.g. infiltration structures) are funded by some German states (e.g. in Hesse and North Rhine-Westphalia), municipalities or water associations (e.g. Emschergenossenschaft). Funding rates for the property owners are ranging from 5 to 30 € per square meter runoff producing area disconnected from the sewer system. Some storm water treatment structures like constructed wetlands are also funded by German states to a significant amount (e.g. in North Rhine-Westphalia).

The state funding policies have to be optimised in terms of their efficiency to deliver the greatest possible relief for water bodies. The different fund receiving sectors (agriculture, industry, urban drainage, etc.) have to be evaluated in an integrated approach by cost-benefit analysis. Only those sectors should be further funded where the most effective relief is to be expected.

Wastewater charges.

According to the German wastewater charges act direct sewage effluents into receiving waters are charged in relation to their quantity and pollutant concentrations. Different pollutants are taken into account by specific pollution units. For polluted storm water discharges only special lump regulations are valid. By increasing the pollution units for storm water a charging equivalent to the point source effluents has to be reached. The increased revenues should be used for better funding of storm water management (Böhm et al., 1999).

For the indirect storm water runoff discharges from urban areas into the sewer systems the property users (private, industrial and municipal) have to pay a wastewater fee. This fee has to depend on the quantity of the discharges. Therefore the introduction of split sewage rates is necessary. The foul flow fee is calculated with the help of the amount of fresh water consumed. The storm water fee is depending on the paved area connected to the sewer system. By this means an incentive to disconnect runoff producing areas is given.

In Norway, Switzerland and Germany (as mentioned) the wastewater fee must cover the calculated costs as required by the WFD - the polluter pays principle. In Austria and Portugal exists a subsidy-system, in the first case the costs are covered by the community budget and in the second case other fees within the water sector cover them. Only in Austria, Switzerland and Germany (44 % of the municipalities) a separate storm water fees exist.

Co-operative instruments

EU water framework directive.

The WFD aims at achieving a good ecological and chemical status of all water bodies. This implies an integrated approach considering all the different sources of pollution (agriculture, urban drainage, industry, river development, etc.). An effective pollution control without serious efforts of the agricultural sector will be unsuccessful. In the sense of the above mentioned combined approach the state of waters-orientated requirements have also to lead to strengthened efforts of ecologically developing rivers and streams instead of expensive technical treatment structures. Cost-benefit analysis (see economic instruments) will help to support this integrated approach.

Voluntary self commitments in industry and business

In terms of a more sustainable source control approach and integrated environmental protection commitments of the industry to reduce emissions should be proposed. The companies are asked to voluntarily abandon the use of toxic substances and to substitute hazardous constituents with ones less hazardous to water (e.g. heavy metals in construction industry).

Public participation

Urban water planning

Integrated municipal water plans including optimised pollution control strategies are more effective in the implementation and operation phase when public participation is guaranteed. This information and involvement of the public is required at an early stage in an 'open' planning process. Geldorf (2003) furthermore reported about a 'parallel' planning 'approach where goals, measures and support emerge together out of a process with a lot of interactions between the actors and where planning and implementation are not strictly separated in time'.

Storm water experience.

An important principle of decentralised storm water management (see below) is to make the storm water visible for the public. Attractively designed structures like infiltration swales, open channels, cascades, ponds and waterworks bring back the storm water within the peoples experience. By this means a better understanding of the water system is gained and it is much easier for the public to take responsibility also for water pollution control.

TECHNICAL MEASURES

After the above review of the broader approaches this section closer describes the single technical measures for reduction of diffuse water pollution.

Storm water management

Storm water management concepts are combining unsealing of paved areas, infiltration of runoff from disconnected areas, storm water re-use, distributed retention, delayed transport and treatment (the latter to be described in the following sub-section). The pressure to rethink conventional drainage systems and realise such modern concepts is due to mainly water quantity problems (insufficient hydraulic capacity of sewer systems as well as of streams and rivers) but also quality requirements. In the sense of sustainable development, ecological criteria are taken into account in these drainage concepts which are potentially much closer to nature than the traditional approach has been. The decentralised solutions (e.g. infiltration structures as main element) are used as best management practices (BMP) and are recently named 'sustainable urban drainage system' (SUDS). Practical planning experience shows the necessity to involve drainage planners into town and traffic planning at an early stage because boundary conditions are fixed then which are very important for feasibility and efficiency of the local storm water management concept.

SUDS are a very popular topic in urban drainage in Germany. Beginning with first exemplary projects in the late 1980s which already include investigations of impacts on groundwater quality SUDS are now widely used in drainage planning. The approach is also beginning to be used more extensively in other European countries, e.g. in the UK, France and Switzerland as well as in the US and in Australia.

The first mentioned two elements of SUDS (unsealing and infiltration) as source control measures have a reduction effect on the runoff volume, the others an attenuation effect on the peak flows. Both effects are reducing the hydraulic stress for the receiving waters (disturbance of benthic fauna). Infiltration closes the natural water cycle by increasing the ground water feeding. Böhm et al. (1999) stated an efficient decrease of emissions of hazardous substances into receiving waters (especially heavy metals, nutrients only to a minor extent), but partly these loads are transferred to soils and wastes. Therefore measures at source are necessary in parallel (see sub-section 'Replacement of hazardous substances'). Additionally it is expected that the elimination efficiency of the existing treatment structures improves by 10-15 % in terms of pollutant load emissions due to the reduced inflow rates.

Urban storm water treatment

Storm water treatment is one of the elements of the above described urban storm water management concepts. First aim is to treat only that part of storm water which is really polluted. Therefore a consistent separation of storm water fluxes with regard to their pollution degree is a pre-condition which has already to be guaranteed in the storm water management concept (e.g. infiltration of roof runoff, further treatment of road runoff with heavier traffic load). Infiltration structures itself also show a good treatment efficiency (for less polluted runoff) due to the treatment processes occurring in the top soil layer.

Basins for storm water treatment do exist in Germany only to a small extent. Böhm et al. (1999) therefore expected a significant load reduction by increased construction of efficient settling basins. Due to the controversial efficiency of the basins constructed wetlands (called 'soil filters') are at present strongly favoured in Germany for (advanced) treatment of storm water discharge from combined and separate drainage systems and from roads (Ristenpart and Prigge, 2002). Recent research work showed that the different types of constructed wetlands fulfil their purpose of elimination of noxious substances from sewerage with high performance as well as their water retention function. The suitability of other technical measures for limiting pollutant pressure on waters is evaluated by BWK (2001) and Geiger et al. (2001) and summarised in tables by Ristenpart and Prigge (2002). Böhm et al. (1999) additionally mentioned that in 30-50 % of the cases treatment is due to the poor state of the receiving waters. Efforts to ecologically develop rivers and streams for reducing their pollution sensitivity is an alternative to expensive technical treatment.

Combined sewage treatment has to be improved in Germany by consistent overall realisation of states requirements in terms of construction of retention and settling basins. Böhm et al. (1999) expected an overflow load reduction by around 50 % for SS, PAH and some heavy metals. Reduction rates for pollutants which have a higher soluble share will be significantly lower (e.g. by 20-30 % for COD). These load reduction expectations are based on relatively high controversial cleaning efficiencies.

The treatment of CSO is quite different in Europe. In Germany (as mentioned) and Switzerland a lot of treatment measures for the discharged wastewater are used like storm water sedimentation tanks, retention tanks, screens and brushes. In Austria and Portugal special treatment structures for spilled combined sewage do not exist, only a few storm water retention tanks and sand filtration structure are known in Portugal. In Norway some large cities have retention tanks and screens at exposed places.

Road runoff treatment

Car traffic is a diffuse source of pollution of water, soil and atmosphere. Road runoff is polluted by heavy metals and oils due to abrasion of tyres, brakes and road surfaces, leakage of lubricants and corrosion of crash barriers. This occurs from narrow village streets, city roads and highways with no strict correlation to traffic intensity. According to a Dutch general policy guideline on traffic emissions (Berbee et al., 2002) highways are generally made of porous asphalt. It consists of an upper layer of 5 cm of porous asphalt on impervious asphalt. The runoff contains far lower concentrations of pollutants which is probably a result of solids filtration in the top layer. These solids are transported to the unused hard shoulders by a typ of pumping effect by the tyres. To avoid plugging, the shoulders have to be cleaned periodically. But porous asphalt has a few disadvantages: its lifetime is less than traditional asphalt and it requires more salt for de-icing in winter. Runoff then mostly infiltrates in the verges. Infiltration is controlled by periodical inspection of chemical quality of soil and groundwater. Only in sensitive areas there is an option to route the runoff outside by a sewage system.

In France, Germany and the UK settling basins are more or less used for treating pollutants. But efficiency of removing heavy metals was disappointingly low at 20-40 % and costs are more than a factor ten higher compared to wastewater treatment (Berbee et al., 2002). Investigations at German highways by Lange et al. (2003) confirm the low efficiencies of concrete settling basins but determined much better ones for earth basins planted with reed (67-84 % for SS, COD and metals, 96 % for PAH).

Sewer system inspection and renovation

By sewer inspections leakage leading to sewage exfiltration into groundwater and groundwater infiltration into sewers is detected and has to be rehabilitated. Avoiding exfiltration reduces raw sewage emissions into groundwater. Reduction of infiltrating water allows to use a higher capacity of the continuation flow for the foul flow to the WWTP which reduces overflows into surface waters. Böhm et al. (1999) estimated a reduction of overflow volume by 10 % in case the extraneous water decreases by 50 %. Additionally an increase of the treatment efficiency at the WWTP is to be expected due to reduced dilution of raw sewage.

The performance of CSO structures has to be hydraulically checked. The throttle devices have to prove the accurate limitation of the continuation flow to the WWTP. This assures that the CSO are performing like they are designed and that the amount of overflow into surface water is restricted to the permitted values.

Alternative integrated urban water concepts

In contrast to traditional flushing sewer systems the main principles of alternative sustainable drainage concepts are the consistent separation of wastewater fluxes and their subsequent split flow treatment with adapted technologies. Pilot projects are realised in some countries for new housing development sites (e.g. Germany, Austria, Sweden), but there are also approaches for existing urban areas. The water and material fluxes are as follows:

- Storm water is re-used for toilet flushing, washing-machines and garden irrigation. Surplus storm water is infiltrated into the ground by swales, trenches etc..
- Grey water (from washing, bathing, cooking) is treated in sand filters or constructed wetlands and afterwards re-used like storm water as far as possible.
- Faeces and urine are treated in an anaerobic reactor together with the biodegradable waste. The treated sludge is re-used as agricultural fertiliser. In further advanced concepts the separated urine is directly used as fertiliser substitute without pre-treatment.

Hillenbrand and Böhm (2001) analysed the pollutant fluxes and showed an efficient decrease of emissions into receiving waters (by 60-90% for nutrients, by 45 % for copper and AOX), but partly these loads are transferred to agricultural soils. Additionally the water consumption decreases significantly.

Replacement of hazardous substances

As mentioned earlier measures at source to abandon the use of hazardous substances and to substitute their noxious constituents are needed because they prevent emissions prior to their emerging. This most sustainable approach has to receive unanimous support. In this sense real no-emission substitutes have to have priority over only slightly changed conventional substances with still low emissions. As an example the reduction of heavy metals in construction industry is described in the following. For other pollutants like herbicides (urban weed control strategies) and phtalates (replacement of PVC) similar strategies are known. In general all measures against air pollution take effect at source and reduce rainfall pollution and thus indirectly runoff emissions also.

Runoff from building roofs is a main source of zinc (and copper) emissions due to corrosion and abrasion of roof surfaces and gutters. In 2001 the Dutch government and the zinc industry have agreed that if product innovation and the actual application of the new materials (supported by a promotion campaign) is successful the government will not take action to reduce zinc applications. However, the Dutch government acknowledges the local government's responsibility for solving their local environmental problems and for executing the environmental regulations (Gouman, 2002). To improve zinc as a building material another alloy of zinc which causes less emissions and the possibilities for coating are investigated. The covering of gutters (and other construction elements) with an impermeable EPDM rubber foil reduces emissions by 90 %. To reduce zinc loads on the local scale in Amsterdam for instance zinc roofs on new and renovated buildings are not permitted. Runoff from roofs of existing buildings is allowed to contain a maximum zinc concentration of 200 µg/l. In Germany and Switzerland substitution of zinc by aluminium or stainless steel for roof and façade covering is promoted but worse corrosion behaviour has to be taken into account (Böhm et al., 1999).

For a substantial part the copper load to surface waters is due to the wash out from copper drinking water tubes. The Dutch industry has developed a special copper alloy which reduces copper losses by 30-70 %. Further development is necessary to improve price, safety of production and workability (van Tilborg et al., 2002). In Germany substitution of copper by polyethylene (PEX), polypropylene (PP) and stainless steel is promoted (Böhm et al., 1999).

Dutch environmental policy promotes the substitution of primary building materials (e.g. sand, gravel) by secondary building materials (e.g. bulky wastes like mine stone, steel and phosphorus slag, demolition waste). The latter materials contain various harmful substances (heavy metals), which may leach into ground and surface water. Leuven and Willems (2002) determined the contribution of secondary building materials in river engineering to total heavy metals pollution of Dutch surface waters to be relatively low (<< 1 %). Nevertheless the authors recommended the application of these materials in constructions that are not or to a lesser extent exposed to water flows.

PRIORITIES

Böhm et al. (2002) have examined in Germany costs of measures in the three fields of urban drainage, agriculture and morphology of waters and assessed their effectiveness on water pollution. They are considered in an integrated way to find the most cost-effective combinations of measures. The cost-effectiveness-analysis is then used for priority setting among the different measures. The most important results in the field of urban drainage are:

The cost-effectiveness of measures is showing a wide spread but per pollution unit avoided the costs of the single measures differ significantly over orders of magnitude. This is the case especially for the urban drainage measures storm water infiltration, unsealing of paved areas and reduction of extraneous water. The wide spread of the results is very much influenced by a similar spread of the boundary conditions of each measure but also by the uncertainty related to the effects of the measures. Böhm et al. (2002) therefore proposed more detailed investigations which has to be supported. The assumptions for the favourable conditions of storm water infiltration and unsealing seems to be too optimistic, especially the cost savings due to saved sewer system upgrading. Thus the priority of measures mentioned below has to be carefully interpreted and the results cannot be simply transferred to single cases without going deeper into local details.

In general the cost-effectiveness of measures with low priority under favourable conditions is better than that of the best measures under only mean boundary conditions. Over all storm water infiltration shows under favourable conditions the best cost-effectiveness due to cost savings for the drainage system. However under unfavourable conditions reduction of emissions is very expensive, but on the other hand important effects like reduction of hydraulic stress and solids load of surface waters and groundwater recharge has not been taken into account here. With regard to nitrogen reduction agricultural measures are more cost-effective than further advanced wastewater treatment. With regard to phosphorous reduction storm water infiltration and small wastewater treatment plants are the most effective measures under favourable conditions. A significantly worse cost-effectiveness showed the P-elimination on large WWTP and even agricultural measures. With regard to heavy metals reduction again storm water infiltration is the most effective measure under.

CONCLUSIONS

In general a reduction plan will consist of multiple single measures which have to be balanced and co-ordinated. Cost-effectiveness-analysis is an essential element of setting the priority of effective measures, but there are still large uncertainties in quantifying and comparing costs, effects and benefits. To reach significant emission reductions and to shift to sustainable water resources management different areas of society and policy have to be taken into account (households, municipalities, industry, agriculture, traffic, landscape planning). It is necessary to realise an integrated view of sewer systems, treatment plants, surface and ground waters, agriculture and the morphology of waters. Source control measures are to be preferred because theyprevent emissions prior to their emerging. The chosen approaches will have to cover the whole set of legislative, economic, co-operative and participatory instruments. Most of the measures are of a mid term character. Realisation will not be a task to solve in the near future, but needs to be a continually operated, strategically directed political process for many years.

A main approach which has to be supported in the future are the SUDS. Storm water management with respect to quantity and quality like decentralised infiltration structures and constructed wetlands for biological treatment and retention are favoured measures not only for new building areas. But for existing drainage systems realisation will be a middle to long term task. So in the short term only minor reductions of emissions are expected from this measure.

REFERENCES

ATV-DVWK (2000). Handlungsempfehlungen zum Umgang mit Regenwasser. Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall (ATV-DVWK) Merkblatt M 153, Hennef.

Berbee, R., Vermij, P., van de Laak, W.J. (2002). Policy development for the reduction of pollution caused by traffic - experiences from the Netherlands. Proceedings 6th Int. Conf. on Diffuse Pollution, Amsterdam.

Behrendt, H., Huber, P., Opitz, D., Schmoll, O., Scholz, G., Uebe, R. (1999). Nährstoffbilanzierung der Flussgebiete Deutschlands. UBA-Texte, 75/99.

Böhm, E., Hillenbrand, T., Liebert, J., Schleich, J., Walz, R. (2002). Kosten-Wirksamkeitsanalyse von nachhaltigen Maßnahmen im Gewässerschutz. UBA-Texte, 12/02.

Böhm, E., Hillenbrand, T., Marscheider-Weidemann, F., Schempp, C., Fuchs, S., Scherer, U., Lüttgert, M. (2000). Emissionsinventar Wasser für die Bundesrepublik Deutschland. UBA-Texte, 53/00.

Böhm, E., Hillenbrand, T., Walz, R., Borchardt, D., Henke, S. (1999). Maßnahmenplan Wasserwirtschaft. UBA-Texte, 25/99.

BWK (2001). Ableitung von immissionsorientierten Anforderungen an Misch- und Niederschlagswassereinleitungen unter Berücksichtigung örtlicher Verhältnisse. Bund der Ingenieure für Wasserwirtschaft, Abfallwirtschaft und Küstenschutz (BWK), Merkblatt M 3, Düsseldorf.

Geiger W.F., Kutzner R., Nafo I., Fach S. (2001). Bemessung und Gestaltung von Anlagen zur Niederschlagswasserbehandlung. Forschungsbericht IV B 6-042 210 0010, Universität Essen, Siedlungswasserwirtschaft.

Geldorf, G.D. (2002). The Nijmegen water plan and diffuse pollution – integrated water management from theory to practice. Proceedings 6th Int. Conf. on Diffuse Pollution, Amsterdam.

Gouman, E. (2002). Reduction of zinc emissions from buildings; the policy of Amsterdam. Proceedings 6th Int. Conf. on Diffuse Pollution, Amsterdam.

Grottker, M. (2003). Personal communication.

Hillenbrand, T., Böhm, E. (2001). Neue Entwässerungskonzepte – Warum? Neue Wege in der Siedlungsentwässerung, Universität Karlsruhe, Institut für Siedlungswasserwirtschaft, 43-68

Hullmann, H., Kraft, U. (2002). Kupfer- und Zinkabschwemmungen von Metalldächern. Wasser, Luft und Boden, 10, 26-31.

Lange, G., Grotehusmann, D., Kasting, U., Schütte, M., Dieterich, M., Sondermann, W. (2003). Wirksamkeit von Entwässerungsbecken im Bereich von Bundesfernstraßen. Forschung Straßenbau und Straßenverkehrstechnik, 861, Bonn.

LAWA, UBA (2001). Water pollution from diffuse sources: analysis, prevention and reduction. German discussion paper by Working group of the federal states of Germany on water problems (LAWA) and German federal environment agency (UBA), presented at 6th Technical EA/LAWA Workshop on WFD, Belfast, June 2001.

Leuven, R.S.E.W., Willems, F.H.G. (2002). Cumulative metal leaching from utilisation of secondary building materials in river engineering. Proceedings 6th Int. Conf. on Diffuse Pollution, Amsterdam.

N.N. (1998). Eigenkontrollverordnungen der Länder für die Selbstüberwachung von Kanalisationsanlagen. KA-Wasserwirtschaft-Abwasser-Abfall, 45, 7, 1343-1344

Ristenpart, E., Prigge, A. (2002). Measures and methods against diffuse water pollution caused by urban drainage. Proceedings 6th Int. Conf. on Diffuse Pollution, Amsterdam.

van Tilborg, W.J.M., Frankena, R.B., van den Bosch, J. (2002). Views related to ongoing developments around zinc, copper and lead in the building and construction industry. Proceedings 6th Int. Conf. on Diffuse Pollution, Amsterdam.

DRY WEATHER WATER QUALITY LOADINGS IN ARID, URBAN WATERSHEDS OF THE LOS ANGELES BASIN, CALIFORNIA, USA.

Running Head: Dry Weather Water Quality

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Manuscript Submitted to *Journal of the American Water Resources Association*
Submitted March 25, 2005
Revised manuscript submitted January 10, 2006 and May 6, 2006 - in press

ABSTRACT

Dry-weather runoff in arid, urban watersheds may consist entirely of treated wastewater effluent and/or urban non-point source runoff, which can be a source of bacteria, nutrients, and metals to receiving waters. Most studies of urban runoff focus on storm water, and few have evaluated the relative contribution and sources of dry weather pollutant loading for a range of constituents across multiple watersheds. This study assessed dry weather loading of nutrients, metals, and bacteria in six urban watersheds in the Los Angeles region of southern California to estimate relative sources of each constituent class and the proportion of total annual load that can be attributed to dry weather discharge. In each watershed, flow and water quality were sampled from storm drain and treated wastewater inputs, as well as from in-stream locations during at least two time periods. Data was used to calculate mean concentrations and loads for various sources. Dry weather loads were compared to modeled wet weather loads under a range of annual rainfall volumes to estimate the relative contribution of dry weather load. Mean storm drain flows were comparable between all watersheds, and in all cases approximately 20% of the flowing storm drains accounted for 80% of the daily volume. Wastewater reclamation plants (WRP) were the main source of nutrients, storm drains accounted for almost all the bacteria, and metals sources varied by constituent. In-stream concentrations reflected major sources, for example nutrient concentrations were highest downstream of WRP discharges, while in-stream metals concentrations were highest downstream of the storm drains with high metals loads. Comparison of wet vs. dry weather loading indicates that dry weather loading can be a significant source of metals, ranging from less than 20% during wet years to greater than 50% during dry years.

Key Terms: dry weather water quality, urban runoff, non-point source pollution, pollutant loads, urban watersheds

INTRODUCTION

Increased urbanization often results in increased runoff and pollutant loading to receiving waters (USEPA, 1995; Schueler and Holland, 2000; Davis et al., 2001; Paul and Meyer, 2001). Runoff from highly impervious urban landscapes occurs at amplified magnitude and frequency during both wet and dry weather conditions (Roesner and Bledsoe, 2003). Increased urban runoff contributes to higher loadings of a broad range of constituents, including nutrients and metals, primarily from discharge of treated wastewater effluent and non-point source (i.e. storm drain) runoff (Paul and Meyer, 2001). Many of those pollutants, such as heavy and trace metals, can accumulate and result in downstream bioaccumulation and toxicity (Schueler, 2000). Similarly, bacterial loading to streams in urban areas has been well documented as one of the most common pollutants affecting aquatic systems (Porcella and Sorenson, 1980; Simpson et al., 2002).

Over the past ten years, management of urban runoff has focused primarily on evaluation and control of storm water. However, dry weather pollutant discharge may also constitute a significant impact to water quality both in terms of concentration and load (Piechota and Bowland, 2001; McPherson et al., 2002; Ackerman et al., 2003; Stein and Tiefenthaler, 2005). This is especially true for urban watersheds in arid environments where stream flow may be comprised entirely of urban runoff and treated effluent for the majority of the year. Furthermore, during dry weather, streams have lower flow and a lower assimilative capacity than during wet weather, resulting in water column concentrations that may exceed levels that pose a toxicity risk to aquatic organisms (Duke et al., 1999; Bay et al., 2003).

Previous studies have shown that concentrations of many water quality constituents in dry weather flow are generally lower than in wet weather; nevertheless, concentrations may be high enough to be of concern with regard to aquatic life use (Mizell and French, 1995; Duke et al., 1999). Duke et al. (1999) and Mizell and French (1995) reported dry weather copper and zinc concentrations of 5- 51 ug/L and 10-60 ug/L, in California and Nevada, respectively. Mizell and French (1995) also reported total ammonia levels in the Flamingo Wash in Las Vegas, NV ranging from less than 1 to 9.9 mg/L. Few studies have investigated the contribution of dry weather loading to overall annual load, and those that have found that the proportion of total annual load discharged during the dry weather can vary dramatically based on flow conditions and rainfall patterns. For example, McPherson et al. (2002) characterized long-term wet and dry weather flow and loading from the Ballona Creek watershed and determined that between 8 and 42% of the total annual trace metals load occurs during dry weather. This translates to between 100 and 500 kg/yr of dry season loading for most metals.

Previous investigations of dry weather water quality have focused on relative comparisons of constituent concentrations during wet vs. dry conditions. Substantially less attention has been devoted to the assessment of dry weather constituent load in several streams of a similar setting. More importantly, no studies have investigated relative sources of dry season loading in arid, urban watersheds and related them to responses in in-stream concentrations. Such information is necessary to allow decision makers to draw general conclusions about expected concentrations and loads during dry conditions and potential sources where management measures may be considered.

The goal of this study was to demonstrate the potential importance of dry weather constituent loading in arid, urban watersheds. This was accomplished by quantifying the relative contribution of dry weather nutrient, metals, and bacteria loading in six urban watersheds in southern California that receive runoff from wastewater effluent, storm drain discharge, or a combination of the two. The predominant sources of the various constituents were also investigated in order to assess the relevance of this research to other arid, urban watersheds, and to provide insight for decisions regarding management of dry weather pollutant loading.

METHODS

Study Areas

The six study watersheds drain the highly urbanized greater Los Angeles area in southern California and represent a range of typical conditions for arid, urban streams (Figure 1, Table 1). The watersheds range in size from the 73 km^2 lower San Gabriel watershed to the 2,160 km^2 Los Angeles River watershed. The proportion of developed land use ranges from 49% to 94% of total watershed area. The Ballona Creek watershed drains much of Los Angeles and flows through Marina del Rey to the Pacific Ocean. The Los Angeles River (LAR) extends 90 km, starting from its headwaters in the San Fernando Valley, flowing past downtown Los Angeles, and eventually draining to San Pedro Bay near Long Beach. The remaining four watersheds, lower San Gabriel River, Coyote Creek, San Jose Creek, and Walnut Creek, are catchments in the greater San Gabriel River watershed. During dry weather, flow control structures isolate each of these four watersheds. In addition the upper (undeveloped) portion of the greater 1,866 km^2 San Gabriel watershed is completely isolated from the lower watershed during non-storm periods by a series of dams and diversions; consequently, this area is not addressed by this study.

Sampling

Flow and water quality data were collected from inputs and in-stream locations in each watershed between 2000 and 2004 to characterize sources and effects of dry weather loading. Potential sources that were sampled include point-source discharges from water reclamation plants (WRPs) and untreated non-point source discharges from storm drains. Industrial discharges, when present, typically occur either directly into the storm drain system or only during the wet season; therefore, they were not considered in this study. Data were collected synoptically in each watershed to provide a "snapshot" of conditions at the time of each sampling event. Each watershed was sampled two or three times (typically over a multiple year period) to help asses temporal variability in the data.

Storm drains were selected for sampling based on the presence of consistent dry season flow (Table 2). Storm drains along the mainstem creek in each of the six study watersheds were visually surveyed 2-3 times during the month prior to each sampling event. Drains that were flowing during all pre-surveys were included, and drains that were not flowing during at least one of the surveys were excluded. At each storm drain sampled, flow was measured using a timed-volumetric or depth-velocity method (whichever was more appropriate for the conditions at a given location). Storm drain flow was estimated based on the mean of three replicate measurements at each drain. WRP effluent flow data was obtained from the Los Angeles County Sanitation Districts (LACSD) and in-stream flow information was acquired from existing flow gages maintained by the Los Angeles County Department of Public Works (LADPW).

Storm drains samples were collected by directly filling a single bottle by holding it under the discharge from each drain until the bottle was full. At the in-stream locations, three composite samples were collected at 20-min intervals. Each composite consisted of three grab samples collected at approximately equal intervals across the channel cross-section. A fill bottle was dipped into the stream just below the surface and the collected water was then transferred to a pre-cleaned sample bottle. Upon collection, water quality samples were immediately placed on ice for subsequent analysis. The WRP effluent was collected by LACSD as a 4-h composite sample and analyzed for the parameters listed in Table 3.

Water samples were analyzed for constituents for which the specific water body was listed as impaired by EPA's under Section 303(d) of the Clean Water Act (Table 3). In all cases except Ballona Creek, this included metals, bacteria, and some form of nutrient impairment (e.g. nutrients, algae, total ammonia toxicity). Ballona Creek is listed as impaired for only metals and bacteria; consequently, no nutrient analysis was conducted. Analyses were conducted following protocols provided by Standard Methods for the Examination of Water and Wastewater (Greenberg et al., 2000) and EPA Chemical Methods for the Examination of Water and Wastes (USEPA, 1983). Metals were analyzed using inductively coupled plasma (ICP) mass spectroscopy and bacteria were analyzed using the Idexx QuantiTray® chromogenic substrate method. Nitrate and nitrite were analyzed using the cadmium reduction method, total total ammonia was analyzed using distillation followed by the automated phenate colorimetric method, and Total Kjeldahl Nitrogen (TKN) was analyzed using the semi-micro-Kjeldahl digestion/distillation method. Standard quality assurance (QA) measures, including laboratory blanks, matrix spikes, and duplicate samples were analyzed along with every batch of samples. If the data quality objectives were not met for a given batch of samples, the data were either qualified or rejected, depending on the source of the error. Detection limits for all constituents analyzed are shown in Table 3. In all cases, non-detects were assigned a value of zero.

All sampling occurred between June and September during the period when surface flow in the streams originates exclusively from urban runoff. No measurable rain fell within two weeks of any sampling period and all sampling was conducted in the morning to minimize potential effects of diurnal variability.

Data Analysis

Means and ranges of flow and water quality concentrations and loads were calculated and analyzed for spatial and temporal patterns. Constituent loads for storm drain and in-stream sites were calculated by multiplying flow and concentration for each sample:

$$Load = \sum F_i C_i \qquad (1)$$

where F_i was the flow at sampling location i averaged over the period when each water sample was collected and C_i was the constituent concentration at location i resulting from the composite grab sampling described above. Where replicate samples were collected, results of the replicates were averaged. In all cases, non-detectable results were assigned a value of zero. For bacteria, results that were greater than the maximum quantifiable levels were assigned the maximum value for that test.

For one selected watershed, additional calculations were done to estimate annual loadings for both dry and wet weather conditions. Ballona Creek was selected for this analysis because it is representative of highly urbanized watersheds in southern California. Furthermore, there are no WRP discharges into Ballona Creek making it easier to directly compare dry and wet weather urban storm drain runoff (as opposed to treated effluent). Dry weather loads were calculated using the mean downstream concentrations measured during the 2003 sampling events. Average dry weather flows were derived by multiplying the watershed area by a scaling factor from an analysis (Ackerman and Stein, in review) that showed average dry weather runoff in the watershed was 180 $m^3 km^{-2} d^{-1}$. Volume and concentration were then multiplied to get an annual load.

A GIS-based stormwater runoff model was used to estimate wet weather pollutant load based on land use, rainfall, and local water quality information. Ackerman and Schiff (2003) developed a model that established a relationship between rainfall and total storm runoff volume for six land use categories with an associated water quality concentration:

$$\mathit{Load} = A * i * c * Conc * k \tag{2}$$

where:

A = Drainage area (km^2)
i = Rainfall (mm)
c = Runoff coefficient (unitless)
Conc = Water quality concentration (mg/L)
K = Constant (unit conversion factor)

Fifty-two years of rainfall data from the Los Angeles International Airport was used to determine the 10th, 25th, median, 75th, and 90th rainfall volumes. These volumes were scaled using the 30-year orographic average rainfall information (Daly and Taylor, 1998) for each modeled watershed. Annual land use runoff volumes were multiplied by average storm water concentration from each land use (Ackerman and Schiff, 2003) to estimate annual wet weather loads.

Statistics

Mean storm drain concentrations for nutrients and metals are reported as arithmetic means ± 1 standard error of the mean (SEM). Bacteria levels are reported as geometric means ± 1 SEM. Storm drain concentration data between surveys and across watersheds were log-transformed and compared using a one-way analysis of variance (ANOVA), with a significance of $p<0.05$. In cases where the ANOVA revealed significant differences in the data set as a whole, a Tukey's means-separation technique was used to identify specific differences between pairwise comparisons (Sokal and Rohlf, 1969). Results were back-transformed for presentation in summary tables to allow easier comparison with other studies.

RESULTS

Flow

Dry weather stream flows were much higher in streams that receive treated WRP effluent than those that receive only storm drain discharge (Table 4). For example, average daily flow during our surveys in the San Gabriel and Los Angeles Rivers was 2.9 and 5.5 m^3 sec^{-1}, respectively, much of which was from WRP effluent. In contrast, Ballona Creek and Walnut Creek, which lack WRP discharge and receive flow mainly from storm drain inputs, had average daily flows of 0.3 and 0.2 m^3 sec^{-1}, respectively. The proportion of total volume in each watershed attributed to WRP discharge varied from 34% in the Los Angles River to 98% in the San Gabriel River. The variability in relative contribution from WRPs was primarily a function of differences in storm drain discharge. In general, the WRP discharge rate was consistently between 1.7 and 3.3 m^3 sec^{-1}. However, mean storm drain discharge varied from 4.6 - 5.0 x 10^{-3} m^3 s^{-1} in San Gabriel River to 39.3 - 40.2 x 10^{-3} m^3 s^{-1} in the Los Angeles River (Table 5).

The distribution of storm drain flows was comparable among the study watersheds (Figure 2). For every watershed sampled, a few large storm drains dominate the overall daily storm drain volume, with 20% of the flowing storm drains typically accounting for approximately 80% of total storm drain flow. This pattern was the same, despite differences in the size and shape of the six watersheds, and the magnitude of storm drain flows. This suggests that regardless of watershed size or shape, management of dry season storm drain discharge could be focused on relatively few drains.

Water Quality

Estimated daily dry weather loads for representative bacteria, nutrients, and metals, by source, are summarized in Table 6. Constituent loading exhibited some consistent patterns between watersheds; however, measured concentrations and estimated loads varied considerably within a watershed, between sampling events. For example, estimated metals loading varied by 16% to 357% between successive sampling years, with the mean annual difference being 48% ± 37%. In Ballona Creek, storm drain *E. coli* concentrations varied by 18% to 270% between successive sampling events, with the mean difference being 121% ± 76%.

The majority of nutrients discharged during dry weather were associated with treated WRP effluent. Total ammonia and nitrate+nitrite loads were substantially higher in streams that receive WRP discharge. For example, 247.2 - 534.7 kg/d and 3,337.2 - 8.061.6 kg/d of total ammonia were discharged to the San Gabriel and Los Angeles rivers, respectively. In contrast, Walnut Creek, which does not receive any WRP discharge had a total ammonia load of 0.1 - 0.2 kg/d. The higher total ammonia loads in Los Angeles River are due to a combination of higher storm drain contributions and higher concentrations and volumes from the WRPs. Ammonia concentrations from WRPs discharging to the Los Angeles River are, on average 66% higher than those that discharge to the San Gabriel River. In addition, average daily WRP discharge volumes are 61 - 116% higher in the Los Angeles River (e.g. 3.8×10^5 m^3/d *vs*. 8.2×10^5 m^3/d).

Metals loadings were generally higher from storm drains than from WRPs, but there were some differences based on individual metals. With the exception of copper in the Los Angeles River, storm drains accounted for the majority of daily copper and lead load, and the daily loads were comparable between watersheds. In contrast, WRPs contributed 47 - 91% of the daily zinc load, which was 1 - 2 orders of magnitude higher than that of copper or lead. If the contribution of WRPs is removed, daily storm drain loads of zinc are still one order of magnitude greater than those of copper and lead. For example, in Ballona Creek daily copper and lead loads were 421.4 - 571.3 g/d and 137.2 - 323.6 g/d, whereas daily zinc loads were 1,701.9 - 1,947.6 g/d. It is interesting to note that storm drains discharged appreciable lead loads, despite the fact that many of the major sources of lead have been restricted by regulations over the last several decades, suggesting that legacy sources of lead persist in these developed watersheds.

Storm drains were the primary source of bacteria in every study watershed. Daily loads of bacteria were comparable between watersheds, with the exception of the Los Angeles River, which had significantly higher loads for all constituents sampled, most probably associated with higher discharge volumes from both WRPs and storm drains (we assumed that the fecal coliform analyzed in 2002 was equivalent to *E. coli*). For all study watersheds *E. coli* loads were in the range of 10^{12} organisms/day.

Mean storm drain concentrations were generally comparable within and between watersheds for each of the constituents sampled (Table 7). Total ammonia concentrations ranged from 0.1 mg/L in Coyote and Walnut Creeks to 1 mg/L in the Los Angeles River. Total phosphate concentrations ranged from 0.3 mg/L in Walnut Creek to 0.8 mg/L in the San Gabriel River. Storm drain concentration of lead was in the 1 - 3 ug/L range, copper was in 5 - 25 ug/L range, and zinc was in the 50 - 200 ug/L range. For the three bacteria indicators sampled, *E. coli* concentrations were in the 10^2 - 10^3 MPN/100 ml range, Enterococcus were in the 10^4 MPN/100 ml range, and total coliform were in the 10^4 - 10^5 MPN/100 ml range. Storm drain constituent concentrations in the Los Angeles River were generally comparable (or slightly lower) than those in the other five watersheds. This is in contrast to the higher estimates of loading in the Los Angeles River, once again suggesting that higher loads are due mainly to higher discharge volumes.

The distribution of storm drains with various concentration ranges varied by constituent (Figure 3). For metals and nutrients, less than 20% of the storm drains had appreciable constituent concentrations. From a cumulative mass loading perspective, approximately 90% of the daily storm drain load for most metals was accounted for by 10% of the storm drains (Figure 4). In contrast, almost all storm drains sampled had high bacteria concentrations, i.e., greater than the state standard of 10^2 MPN/100mL for *E. coli*. Therefore, unlike metals and nutrients, sources of bacteria appear to be relatively evenly distributed across the study watersheds.

Comparison of total and dissolved metals concentrations in the Ballona Creek watershed for both storm drains and in-stream sites showed that, unlike storm water, dry-season metals occur predominantly in the dissolved phase, ranging from 60% dissolved for iron to 95% dissolved for nickel, with all metal except iron being at least 75% dissolved phase (Figure 5).

The spatial distribution of pollutants in the receiving waters generally reflected the influence of major sources. For example, in-stream total ammonia levels in San Jose Creek and the San Gabriel River were markedly higher downstream of the WRPs (Figure 6). Where storm drains were the only inputs; i.e., upper Coyote Creek and Walnut Creek, nutrient concentrations were consistently low. In Ballona Creek, the highest mean in-stream concentrations and loads of copper, lead, and zinc were observed immediately downstream of two large storm drains (Figure 7). Bacteria concentrations were generally high throughout all stream reaches in the study watersheds, with no apparent spatial pattern, corresponding to the uniformly high bacteria concentrations observed in most storm drains sampled.

Wet vs. Dry Weather Volume and Loadings

For most metals, a substantial portion of the total annual load during years with low rainfall can be attributed to dry weather loading. The relative contribution of dry weather loading to overall annual load for Ballona Creek was estimated by modeling annual storm water loading under a range of total annual rainfall amounts. Modeled output for storm water loading was compared to extrapolated dry weather loads based on the empirical instream water quality data collected in this study and volumetric loading from Ackerman and Stein (in review; Table 8). During dry years (i.e. years in the 10th percentile of rainfall), dry weather discharge may account for up to 57% of the total annual volume. Similarly dry weather loading may account for between 30 and 50% of the total annual load of many metals. For example, when rainfall totals are 45% of the annual average, dry weather loading accounts for 46, 31, and 36 percent of the total annual load of copper, lead, and zinc, respectively. In median years 37% of total annual volume and between 15% and 30% of total annual metals load may occur during the dry season. During wet years (i.e. years in the 90th percentile of rainfall, or with 176% of the average annual rain), storm water becomes the dominant pollutant source. Nevertheless, dry weather discharge may still comprise 25% of the total annual volume and dry weather metals loading may still comprise between 9% and 19% of the total annual load. The majority of *E. coli* loading occurs during wet weather in all years. However, concentrations are high during both wet and dry conditions.

DISCUSSION

The results of this study yielded three important conclusions regarding dry weather water quality in watersheds where the non-storm flow is dominated by urban runoff and other effluent. Estimates of dry weather loading are inherently variable; therefore, repeated measurement will be necessary in order to bound the uncertainty associated with these estimates. Despite this uncertainty, this study indicates that constituent loading during the dry weather period can comprise a substantial portion of the total annual load in semi-arid urban watersheds, such as those investigated in this study. Finally, comprehensive measurement of dry weather discharges can provide insight into specific sources of constituents.

Variability in Loading Estimates

Dry weather constituent concentrations were highly variable, resulting in uncertainty in the loading estimates. This study presents data collected at several points in time that provide a "snapshot" of conditions. The main sources of uncertainty are the inherent (and unpredictable) variability in both flow and concentration that may occur at time scales from hours to months (Hatje et al, 2001). These fluctuations are due to a variety of sources, such as illicit discharges, permitted periodic discharges of industrial or construction-related effluent, diurnal patterns, and random variability in storm drain concentration and flow. For example, copper concentrations in Ballona Creek varied by 137% between the May and July sampling. On an inter-annual basis, copper concentrations varied by up to five-fold: Mean copper concentrations were 29 ug/L in 1999 (McPherson et al., 2002), "not-detected" in 2002 (City of Los Angeles, unpublished monitoring data - http://www.lacity.org/SAN/wpd/index1.htm), and 6 ug/L in 2003 (this study). Others have reported similar variability in metals concentrations. For example, Nimick et al. (2003) reported that metals concentrations in streams vary by 100 - 500% over the course of a day, and Hatje et al. (2001) reported fluctuations in metals concentrations of 100 - 200% on a month-to-month basis, with variability increasing with increasing anthropogenic input.

Bacterial counts typically vary by up to five orders of magnitude on daily, seasonal, and inter-annual scales. Furthermore, between 5% and 22% of storm drain samples exceed the maximum detectable bacterial counts (depending on the specific indicator). Therefore, mean concentrations reported from storm drains likely underestimate the actual bacteria levels being discharged to urban streams. The greater variability observed in bacteria *vs.* metals data (i.e., several orders of magnitude *vs.* several fold) is expected. As living organisms, many processes that do not influence metals, such as growth, die-off, and random fluctuations in population size, may affect bacterial counts. In addition, the analytic method used to quantify bacteria is based on colorimetric estimation of bacterial density, which is inherently less precise than the approach used to quantify metals (mass spectroscopy). It is important to note that variability in estimations of bacteria density is not solely a function of the method chosen. All three methods typically used, membrane filtration (MF), multiple tube fermentation (MTF), and chromogenic substrate (CS, the method used by this study) are based upon measuring products of bacterial growth. This approach can result in errors associated with growth of bacteria in the lab and in interpretation of the growth results by laboratory technicians. Noble et al. (2003) compared results from 22 laboratories using MF, MTF, and CS using laboratory fabricated samples and found the three methods to be comparable. More recently, Griffith et al. (2006) compared results from 26 laboratories using ambient water samples in a variety of matrices and also found the three methods to be comparable.

In addition to variability in concentration, flow may also vary at multiple time scales. Review of daily flow data from the Los Angeles County Department of Public Works shows that non-storm flows in Ballona Creek and the Los Angeles River can vary by up to 5-fold over the course of a year. For example dry weather flow in Ballona Creek may range from 0.2 m^3/s to 1.4 m^3/s. In a system such as the San Gabriel River (Figure 9) or Coyote Creek, that is affected by WRPs that discharge intermittently, dry weather flow may vary by up to 40-fold over the course of a year (i.e. Coyote Creek flows ranged from 0.2 – 8.3 m^3/s). In addition, Ackerman and Stein (in review) observed that dry weather flow in arid, urban watersheds varied in a predictable manner by up to 40% over the course of a single day.

The manner in which samples with non-detectable levels of a particular constituent are treated may also affect overall estimates of load and introduce additional uncertainty into conclusions regarding the relative magnitude of sources of dry weather loading. Non-detectable values could be assigned a value ranging from zero to the detection limit. The degree to which this choice influences general conclusions about loading depends on the frequency of non-detectable values. For the metals focused on in this study, only storm drain lead samples had a substantial fraction of non-detectable values (60%). If we had assumed that non-detectable values were equal to the detection limit, our estimate of storm drain load would have increased by 100%. Similarly, the manner in which samples with non-detectable levels of a particular metal were treated may affect conclusions regarding distribution of load among sources. Due to the large volumetric input by the WRPs, small differences in these estimates can have a dramatic effect on the overall distribution of trace metal sources. For example, assuming that non-detectable samples for nickel were equal to a concentration of zero led to estimation that storm drains account for 100% of the nickel loading. If this assumption were changed to a concentration equal to one-half the detection limit, the WRPs would become the dominant source for nickel as well as five of the six other metals analyzed. (Figure 8). As previously stated, we chose a conservative strategy by assigning a value of zero to all non-detectable results so as to not artificially assume a load associated with a particular source.

Uncertainty in loading estimates can be reduced by compiling data representing numerous observations over time. This is typically accomplished by either repeated field measures or by long-term simulation models. For dry weather loading estimates, we believe simulation models are not as useful as they are for bounding the uncertainty associated with storm water loading. Variability in storm water loading (within a given watershed) is largely a function of differences in rainfall-runoff patterns, which conform to fairly well established physical principles. In contrast, variability in dry weather loading is largely a function of unpredictable and somewhat random events (e.g. discharges from industrial sites, construction sites, or illicit sources). Consequently, estimates of dry weather loading should be based on repeated measures of concentration and flow over time that can be used to bound the expected range of variability.

Contribution of Dry Weather Loading

Data from the six watersheds sampled in this study showed similar patterns, allowing us to conclude that dry weather loading can be an appreciable source of total annual constituent load for the watersheds in the greater Los Angeles area, in recognition of the inherent variability associated with dry weather water quality.

In arid systems, water quality loading is of particular interest because the majority of dry weather stream flow is derived from urban runoff and effluent discharge for approximately 85% of the year. Although concentrations may be appreciably lower during dry weather conditions, as noted by Mizell and French (1995) and Duke et al. (1999), this study showed that in arid, urban watersheds, dry weather loading could contribute between 20% and 50% of the total annual metals load. This analysis was based on modeling for Ballona Creek, which lacks WRP discharge, thereby allowing a direct comparison of loading from dry and wet weather urban runoff. In watersheds where WRPs are an appreciable source, dry weather loading would comprise a larger proportion of the total annual load than estimated for Ballona Creek for certain constituents, such as zinc and ammonia.

The emphasis on load vs. concentration is important from a management perspective for several reasons. First, many urban streams are subject to Total Maximum Daily Load (TMDL) requirements, that limit mass loadings to ensure that water quality standards are met and require managers to ensure that both dry and wet weather loads meet regulatory requirements. Second, many urban streams drain to lentic or semi-lentic waterbodies, such as lakes or estuaries, where accumulation of toxic compounds in sediment and subsequent bioaccumulation may be of concern. In this case, dry weather loading is important not only in terms of its contribution to the total annual load, but because the lower velocities associated with dry weather flow (vs. storm flow) may facilitate deposition of metals and other toxic compounds in downstream water bodies. Furthermore, dry weather loads occur predominantly in the dissolved form (Figure 5), which is more bioavailable to organisms than the particle-bound constituents that are predominant in storm water (SCCWRP, unpublished data). The exception to this is iron, which has a relatively higher particulate phase than other metals. This is likely due to a combination of the fact that iron occurs in much higher concentrations than other metals and transforms to its reduced (soluble) form at a much lower redox potential. Consequently, reductive dissolution is less effective at transforming particulate iron. Third, management strategies for dry and wet weather loading are typically different. Storm water management typically focuses on retention or detention of flows, whereas dry weather runoff control focus on treatment, diversion, infiltration, and source control.

For bacteria, concentration (or counts) is a more appropriate management endpoint because unlike metals and other toxic compounds, bacteria do not typically accumulate in receiving water sediments. Dry weather counts of *E. coli* are typically around 10^3 MPN/100ml. This level is several orders of magnitude lower than the 10^4–10^6 MPN/100ml typically observed in urban storm water (City of Los Angeles, unpublished monitoring data - http://www.lacity.org/SAN/wpd/index1.htm); however it is still consistently above the state freshwater standard of 400 MPN/100ml.

CONCLUSIONS

This study has demonstrated that in semi-arid, urban watersheds, dry weather loadings can comprise a substantial proportion of the total annual load for a range of constituents, especially during years with low rainfall. Consequently, water quality management strategies should focus on dry weather runoff in addition to storm water loadings, which are typically the focus of most management efforts.

Source identification can be particularly problematic in urban watersheds where flows and constituent concentrations vary in somewhat unpredictable ways. Investigation of all potential sources of dry weather loading over multiple time periods can help reduce the uncertainty and allow managers to begin identifying patterns that can be use to focus management efforts. Using this approach, several consistent patterns were observed in the six watersheds analyzed in this study: The WRPs consistently contributed the majority of nutrients to the receiving waters, while storm drains contributed the majority of bacteria. In the case of trace metals, the dominant source varied by specific metal. Analysis of storm drain loading from the six study watersheds revealed that relatively few storm drains (i.e. < 20%) had high concentrations and contributed relatively large metal loads, whereas most drains (i.e. > 90%) had high concentrations of bacteria. The consistently high bacteria concentrations throughout the system make establishing linkages between sources and receiving water concentrations difficult. In addition, potential in-stream sources of bacteria (e.g., birds or regrowth) were not evaluated in this study. Therefore, from a management perspective, nutrients and metals could be managed by targeting specific sources; whereas, management of bacteria loading would require a more coordinated systematic approach.

ACKNOWLEDGMENTS

This study was funded by the Los Angeles Regional Water Quality Control Board, the Los Angeles County Sanitation Districts, the Los Angeles County Department of Public Works, the City of Los Angeles and the Southern California Coastal Water Research Project (SCCWRP). The authors would like to acknowledge the assistance of the Los Angeles/San Gabriel Rivers Watershed Council, Friends of the San Gabriel River, Santa Monica Baykeeper, and U.S. EPA

Region IX in collecting and analyzing samples. We are indebted to the many volunteers who assisted in sample collection and Dario Diehl in the organization of those sampling efforts. We also are grateful to Andrea Steinberger and Liesl Tiefenthaler for assistance in data analysis. Collected data can be downloaded from http://www.sccwrp.org.

REFERENCES

Ackerman, D. and E.D. Stein, in review. Temporal Patterns of Dry Weather Runoff in Arid Urban Watersheds. Journal of Environmental Engineering

Ackerman, D. and K. Schiff, 2003. Modeling Stormwater Mass Emissions To The Southern California Bight. Journal of Environmental Engineering 129:308-317.

Ackerman, D., K.C. Schiff, H. Trimm, and M. Mullin, 2003. Characterization of Water Quality in the Los Angeles River. Bulletin of the Southern California Academy of Sciences 102:17-25.

Bay, S., B.H. Jones, K. Schiff, and L. Washburn. 2003. Water Quality Impacts of Stormwater Discharges to Santa Monica Bay. Marine Environmental Research 56:205-223.

Daly, C. and G. Taylor, 1998. California Average Monthly or Annual Precipitation, 1961-90. *Available at*: http://www.ftw.nrcs.usda.gov/prism/prism.html.

Davis, A.P., M. Shokouhian, and S. Ni, 2001. Loading Estimates of Lead, Copper, Cadmium, and Zinc in Urban Runoff From Specific Sources. Chemosphere 44:997-1009.

Duke, L.D., T.S. Lo, and M.W. Turner, 1999. Chemical Constituents in Storm Flow vs. Dry Weather Discharges in California Storm Water Conveyances. Journal of American Water Resource Association 35:821-836.

Greenberg, A.E., L.S. Clesceri, and A.D. Eaton. 2000. Standard Methods for the Examination of Water and Wastewater, 20th Edition. American Public Health Association, Washington, DC.

Griffith, J.G., L.A. Aumand, I.M. Lee, C.D. McGee, L.L. Othman, K.J. Ritter, K.O. Walker, and S.B. Weisberg. 2006. Comparison and Verification of Bacterial Water Quality Indicator Measurement Methods Using Ambient Coastal Water Samples. Environmental Monitoring and Assessment (in press).

Hatje, V., K. Rae, and G.F. Birch. 2001. Trace Metal and Suspended Solid Concentrations in Freshwater: The Importance of Small-Scale Temporal Variation. Journal of Environmental Monitoring 3:251-256.

Los Angeles County Department of Public Works (LADPW) 2004. Imported and Reclaimed Water Data 2002-2003 Final. *Available at* http://www.ladpw.org/wrd/spreadingground/watercon, April 29, 2004.

McPherson, T.N., S.J. Burian, H.J. Turin, M.K. Stenstrom, and I.H. Suffet, 2002. Comparison of the Pollutant Loads in Dry and Wet Weather Runoff in a Southern California Watershed. Water Science and Technology 45:255-261.

Mizell, S.A. and R.H. French, 1995. Beneficial Use Potential of Dry Weather Flow in The Las Vegas Valley, Nevada. Water Resources Bulletin 31:447-461.

Nimick, D., C.H.Gammons, T.E. Cleasby, J.P. Madison, D. Skaar, and C.M. Brick, 2003. Diel Cycles in Dissolved Metal Concentrations in Streams: Occurrence and Possible Causes. Water Resources Research 39:1247.

Noble, R.T., S.B. Weisberg, M.K. Leecaster, C.D. McGee, K. Ritter, K.O. Walker, and P.M. Vainik. 2003. Comparison of Beach Bacterial Water Quality Indicator Measurement Methods. Environmental Monitoring and Assessment 81:301-312.

Paul, M.J. and J.L. Meyer, 2001. Streams in the Urban Landscape. Annual Review of Ecological Systems 32:333-365.

Piechota, T.C. and L. Bowland, 2001. Characterization of Wet and Dry Weather Flows From Urban Runoff in An Arid Region. *In:* Proceedings of the Specialty Symposium Held in Conjunction with The World Water and Environmental Resources Congress, May 20-24, 2001, Orlando, Florida, B.K. Panigrahi (Editor). American Society of Civil Engineers, Reston, VA: 195-203.

Porcella, D. B., and D. L. Sorenson, 1980, Characteristics of Nonpoint Source Urban Runoff and its Effects on Stream Ecosystems, *EPA-600/3-80-032*. United States Environmental Protection Agency, Corvallis, OR., pp. 99.

Roesner, L.A. and B.P. Bledsoe, 2003. Physical Effects of Wet Weather Flows on Aquatic Habitats: Present Knowledge and Research Needs. Water Environment Research Foundation Technical Report # 00-WSM-4. Alexandria, VA., pp. 197.

Schueler, T.R. 2000, The importance of imperviousness. *In*: The Practice of Watershed Protection, Watershed Protection Techniques, T.R. Schueler and H.K. Holland (Editors). Center for Watershed Protection, Ellicott City, MD pp. 100-111.

Simpson, J. M., J. W. S. Domingo, and D. J. Reasoner, 2002. Microbial Source Tracking: State of the Science. Environmental Science and Technology 36:5279-5288.

Sokal, R.R. and F.J. Rohlf, 1969. Biometry: The Principles And Practice Of Statistics In Biological Research, W.H. Freeman and Company, San Francisco, CA., 776 pp.

Stein, E.D. and L.L. Tiefenthaler. 2005. Dry-Weather Metals and Bacteria Loading in an Arid, Urban Watershed: Ballona Creek, California. Water, Air, and Soil Pollution 164:367-382.

U.S. EPA, 1983. Chemical Methods for the Examination of Water and Wastes. EPA-600/4-79-020, Cincinnati, OH.

U.S. EPA, 1995. National Water Quality Inventory; 1994 Report to Congress. EPA/841/R-95/005, Washington, D.C.

Table 1. Size And Land Use Distribution of Sampled Watersheds.

Watershed	Area (km^2)	Percent Land Use in Watershed					
		Commercial	High Density Residential	Industrial	Low Density Residential	Open Space	Other
Los Angeles	2,160	8 %	7 %	10 %	30 %	43 %	2%
Coyote	487	13 %	7 %	14 %	41 %	24 %	1%
San Gabriel	73	19 %	7 %	13 %	52 %	6 %	3%
San Jose	194	11 %	4 %	15 %	41 %	25 %	4%
Walnut	205	8 %	4 %	5 %	31 %	51 %	1%
Ballona	338	16 %	22 %	7 %	36 %	18 %	1%

Source: Southern California Association of Governments 2000 land use data. Available at http://www.scag.ca.gov/landuse/

Table 2. Number of Storm Drains, Water Reclamation Plants (WRPs) and Instream Locations Sampled During the Dry Weather Surveys.

Watershed	Year	Number of storm drains	Number of WRPs	Number of instream sites
Los Angeles River	Sept 2000	52	3	19
	July 2001	95	3	24
Coyote	Sept 2002	19	1	3
	Sept 2003	20	1	5
San Gabriel	Sept 2002	19	1	4
	Sept 2003	9	1	4
San Jose	Sept 2002	33	1	5
	Sept 2003	34	1	8
Walnut	Sept 2002	10	0	2
	Sept 2003	14	0	3
Ballona Creek	May 2003	35	0	12
	July 2003	37	0	12
	Sept 2003	47	0	12

Table 3. Sampled Water Quality Constituents and Their Detection Limits.

Constituent	Detection Limit	Units
Nutrients		
Total ammonia-N	0.02	mg/L
Nitrate-N	0.03	mg/L
Nitrite-N	0.01	mg/L
Nitrite - Nitrate	0.05	mg/L
Total Kjeldhal Nitrogen	0.1	mg/L
Dissolved Phosphorous	0.01	mg/L
Total Phosphorous	0.01	mg/L
Metals (total and dissolved)		
Arsenic	0.4	ug/L
Cadmium	0.08	ug/L
Chromium	0.7	ug/L
Copper	1.5	ug/L
Iron	24	ug/L
Lead	3.0	ug/L
Nickel	0.24	ug/L
Zinc	2.0	ug/L
General		
Hardness	2	mg/L
TSS	1	mg/L
Bacteria		
Total Coliforms	20	MPN/100 mL
E. coli	10	MPN/100 mL
Enterococcus	10	MPN/100 mL
Fecal Coliform*	10	MPN/100 mL

* San Gabriel River watersheds 2002

Table 4. Measured Flows ($m^3 s^{-1}$) in the Sampled Watersheds and Their Relative Contribution to the Total Volumetric Output from the Watershed. "Flow from upstream of the study area" is primarily from storm drains that discharge upstream of the area we sampled, but may also include some groundwater discharge from both natural and anthropogenic sources. There were no WRP discharges upstream of the study area in any of the six watersheds. WRP = Water reclamation plant. NA = not analyzed because of lack of flow from the specific source.

		Flow ($m^3 s^{-1}$)		Percent of Total Volume		
		WRP	Storm Drain	WRP	Storm Drain	Flow from Upstream of Study Area
Los Angeles	2000	3.3	2.0	62 %	38 %	
	2001	2.0	3.8	34 %	66 %	
Coyote	2002	0.0	0.5	0 %	87 %	13%
	2003	0.5	0.6	41 %	42 %	17%
San Gabriel	2002	2.8	0.1	97 %	3 %	
	2003	3.0	0.1	98 %	2 %	
San Jose	2002	1.7	0.4	73 %	19 %	8%
	2003	2.5	0.6	78 %	18 %	4%
Walnut	2002	NA	0.2	-	100 %	
	2003	NA	0.2	-	100 %	
Ballona	2003	NA	0.3	-	100 %	

Table 5. Average Storm Drain Flow (10^{-3} m^3 s^{-1}) in the Six Monitored Watersheds. Mean ± SEM for flowing storm drains. Flow was measured using a timed-volumetric or depth-velocity method (whichever was more appropriate for the conditions at a given location). Storm drain flow was estimated based on the mean of three replicate measurements at each drain.

		Average Flow (10^{-3} m^3 s^{-1})	SEM (10^{-3} m^3 s^{-1})	Number of drains sampled
Los Angeles River	2000	39.3	5.5	52
	2001	40.2	4.1	95
Coyote Creek	2002	28.2	6.5	19
	2003	27.3	6.1	20
San Gabriel River	2002	4.6	1.1	19
	2003	5.0	1.7	9
San Jose Creek	2002	13.1	2.3	33
	2003	16.8	2.9	34
Walnut Creek	2002	20.4	6.5	10
	2003	11.4	3.1	14
Ballona Creek	May 2003	24.2	10.1	25
	July 2003	10.4	6.2	28
	Sept 2003	21.4	8.8	30

Table 6. Pollutant Loading by Source and Watershed. Ballona loads were calculated using the most downstream flow and water quality concentrations. Boundary is the load entering the stream from upstream boundary of the study area. WRP = Water reclamation plant. NS = not sampled.

			Mass Emissions	Units	Percent Contribution					Mass Emissions	Units	Percent Contribution		
					Storm Drains	WRPs	Boundary					Storm Drains	WRPs	Boundary
E. coli	Los Angeles River	2000	12.022.4	10^9/d	100%	0%	-	Copper	2000	3.706.0	g/d	15%	85%	-
		2001	20,534.6	10^9/d	96%	4%	-		2001	12,296.4	g/d	51%	49%	-
	Coyote Creek	2002	14,156.7	10^9/d	100%	0%	0%		2002	167.6	g/d	88%	0%	12%
		2003	3,244.6	10^9/d	88%	0%	12%		2003	195.9	g/d	100%	0%	0%
	San Gabriel River	2002	4,646.4	10^9/d	100%	0%	0%		2002	84.0	g/d	100%	0%	0%
		2003	9.7	10^9/d	100%	0%	0%		2003	7.3	g/d	97%	3%	0%
	San Jose Creek	2002	3,255.0	10^9/d	72%	0%	28%		2002	291.1	g/d	55%	0%	45%
		2003	2,318.1	10^9/d	91%	0%	9%		2003	384.5	g/d	25%	0%	75%
	Walnut Creek	2002	1,638.3	10^9/d	100%	0%	0%		2002	312.8	g/d	100%	0%	0%
		2003	2,680.3	10^9/d	100%	0%	0%		2003	69.2	g/d	100%	0%	0%
	Ballona Creek	2003a	NS	10^9/d					2003a	NS	g/d			
		2003b	299.1	10^9/d	100%				2003b	571.3	g/d	100%		
		2003c	5,436.1	10^9/d	100%				2003c	421.4	g/d	100%		
Total ammonia	Los Angeles River	2000	3,357.2	kg/d	0%	100%	-	Lead	2000	533.2	g/d	100%	0%	-
		2001	8,061.6	kg/d	32%	68%	-		2001	0.0	g/d	-	-	-
	Coyote Creek	2002	0.8	kg/d	32%	68%	0%		2002	131.3	g/d	84%	0%	16%
		2003	64.1	kg/d	0%	100%	0%		2003	52.2	g/d	51%	0%	49%
	San Gabriel River	2002	534.7	kg/d	0%	100%	0%		2002	27.4	g/d	100%	0%	0%
		2003	247.2	kg/d	0%	100%	0%		2003	1.1	g/d	97%	3%	0%
	San Jose Creek	2002	946.8	kg/d	2%	98%	0%		2002	82.0	g/d	29%	0%	71%
		2003	174.9	kg/d	2%	98%	0%		2003	55.7	g/d	100%	0%	0%
	Walnut Creek	2002	0.1	kg/d	100%	0%	0%		2002	47.1	g/d	100%	0%	0%
		2003	0.2	kg/d	100%	0%	0%		2003	71.0	g/d	100%	0%	0%
	Ballona Creek	2003a	NS	kg/d	NS				2003a	NS	g/d			
		2003b	NS	kg/d	NS				2003b	323.6	g/d	100%		
		2003c	NS	kg/d	NS				2003c	137.2	g/d	100%		
Nitrate + Nitrite	Los Angeles River (Nitrate-N)	2000	363.0	kg/d	63%	37%	-	Zinc	2000	11,217.0	g/d	9%	91%	-
		2001	2,529.5	kg/d	31%	69%	-		2001	45,977.7	g/d	41%	59%	-
	Coyote Creek	2002	60.4	kg/d	60%	0%	40%		2002	1,733.6	g/d	89%	0%	11%
		2003	240.6	kg/d	38%	34%	28%		2003	7,937.7	g/d	43%	47%	10%
	San Gabriel River	2002	805.2	kg/d	1%	99%	0%		2002	5,363.1	g/d	20%	80%	0%
		2003	479.0	kg/d	0%	100%	0%		2003	7,965.4	g/d	4%	96%	0%
	San Jose Creek	2002	663.4	kg/d	7%	69%	24%		2002	7,678.4	g/d	15%	76%	9%
		2003	674.0	kg/d	11%	75%	14%		2003	16,626.8	g/d	19%	77%	4%
	Walnut Creek	2002	4.0	kg/d	100%	0%	0%		2002	495.3	g/d	100%	0%	0%
		2003	8.8	kg/d	100%	0%	0%		2003	1,070.7	g/d	100%	0%	0%
	Ballona Creek	2003a	NS	kg/d	NS				2003a	NS	g/d			
		2003b	NS	kg/d	NS				2003b	1,941.6	g/d	100%		
		2003c	NS	kg/d	NS				2003c	1,701.9	g/d	100%		

Table 7. Mean Storm Drain Water Quality Concentration by Watershed. Bacteria data are geometric means ± SEM, All other constituents are arithmetic means ± SEM. NS = not sampled.

		LA River		Coyote Creek		San Gabriel River		San Jose Creek		Walnut Creek		Ballona	
		Average	SEM	Average	SEM	Average	SEM	Average	SEM	Average	SEM	Average	SEM
Enterococcus	MPN/100 mL	2,177	897	21,321	7,882	22,225	6,563	12,130	3,337	13,373	3,735	775	204
E. Coli	MPN/100 mL	644	141	1,152	374	1,041	210	754	134	1,767	459	359	77
Total Coliform	MPN/100 mL	48,148	17,522	140,637	56,498	149,700	26,688	56,464	10,077	65,209	13,527	25,518	5,698
TSS	mg/L	208	187	13.	6	13	5	34	20	17	4	22	6
Hardness	mg/L	NS		323	21	319	19	415	25	289	31	457	55
Chromium	ug/L	3	2	0.3	0.3	0.4	0.4	0.7	0.7	0	0	2	0.2
Copper	ug/L	25	8	5.8	1	26	9	8	2	13	3	19	3
Iron	ug/L	288	75	469	259	571	301	1,911	1,373	558	105	515	105
Lead	ug/L	2	0.8	2	0.3	3	1	2	0.7	3	0.9	4	1
Nickel	ug/L	3	2	1.	0.9	9	4	5	3	1	1	5	0.4
Zinc	ug/L	122	63	57	7	213	85	117	31	73	7	79	22
Total ammonia-N	mg/L	1	0.2	0.1	0.1	0.6	0.2	0.7	0.3	0.1	0.04	NS	NS
Nitrate-Nitrite	mg/L	1*	0.1*	4	1	3	2	3	0.4	1	0.2	NS	NS
TKN	mg/L	6	3	2	0.3	4	1	2	0.5	2	0.3	NS	NS
Total Phosphate-P	mg/L	0.6	0.6	0.4	0.4	0.8	0.5	0.4	0.5	0.3	0.2	NS	NS

* LA River data is nitrate-N

Table 8. Fraction of Total Annual Load of Various Constituents Accounted for by Dry-Weather Loading, for Varying Annual Precipitation Conditions in Ballona Creek. Dry weather loads were calculated using the mean downstream concentrations measured during the 2003 sampling events multiplied by the annual non-storm discharge volume. Wet weather loads were estimated using a validated watershed model based on land use, rainfall, and local water quality information. Fifty-two years of rainfall data from the Los Angeles International Airport was used to determine the 10th, 25th, median, 75th, and 90th rainfall volumes. These volumes were scaled using the 30-year orographic average rainfall information.

Percent of average annual rain	45	64	100	132	176
Rain percentile rank	10	25	50	75	90
	Dry Load as a Percent of Total Annual Load				
Volume	57	48	37	31	25
Fecal Coliform	3	2	2	1	1
Total Coliform	25	19	13	10	8
TSS	19	14	9	7	6
Cadmium	29	22	15	12	9
Chromium	29	22	15	12	9
Copper	46	38	28	23	18
Lead	31	24	17	13	10
Nickel	47	39	29	23	19
Zinc	36	29	21	16	13

Figure Legends

Figure 1. Location of the Six Monitored Watersheds.

Figure 2. Cumulative Distribution of Measured Storm Drain Flows in the Sampled Watersheds.

Figure 3. Cumulative Distribution of Storm Drain Water Quality Concentrations For Total Ammonia, Copper and *E. coli*.

Figure 4. Cumulative Distribution of Storm Drain Mass Loading for *E. coli* and copper.

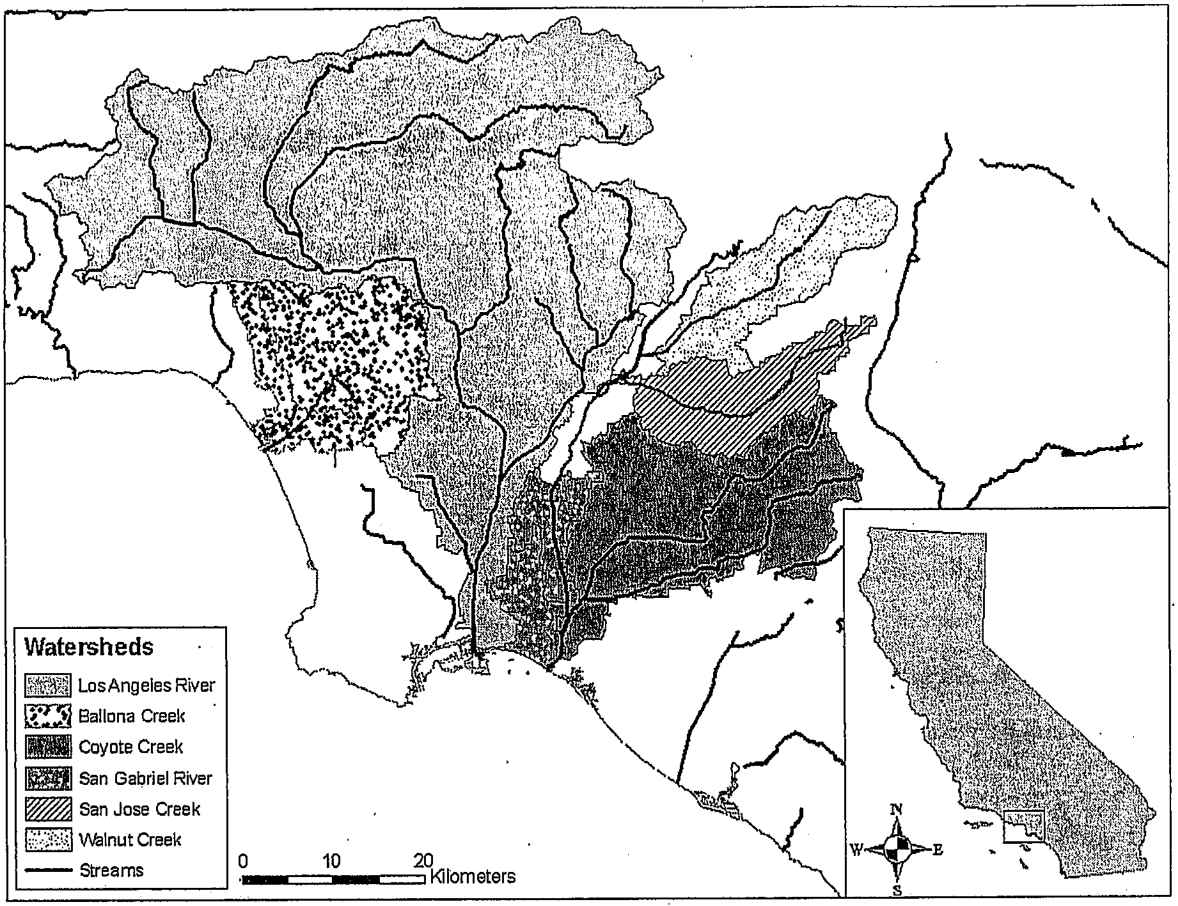
Figure 5. Comparison of Percent Dissolved Metals. Percent of total metals as dissolved fraction in samples collected from storm drains and in-stream sites in the Ballona Creek watershed.

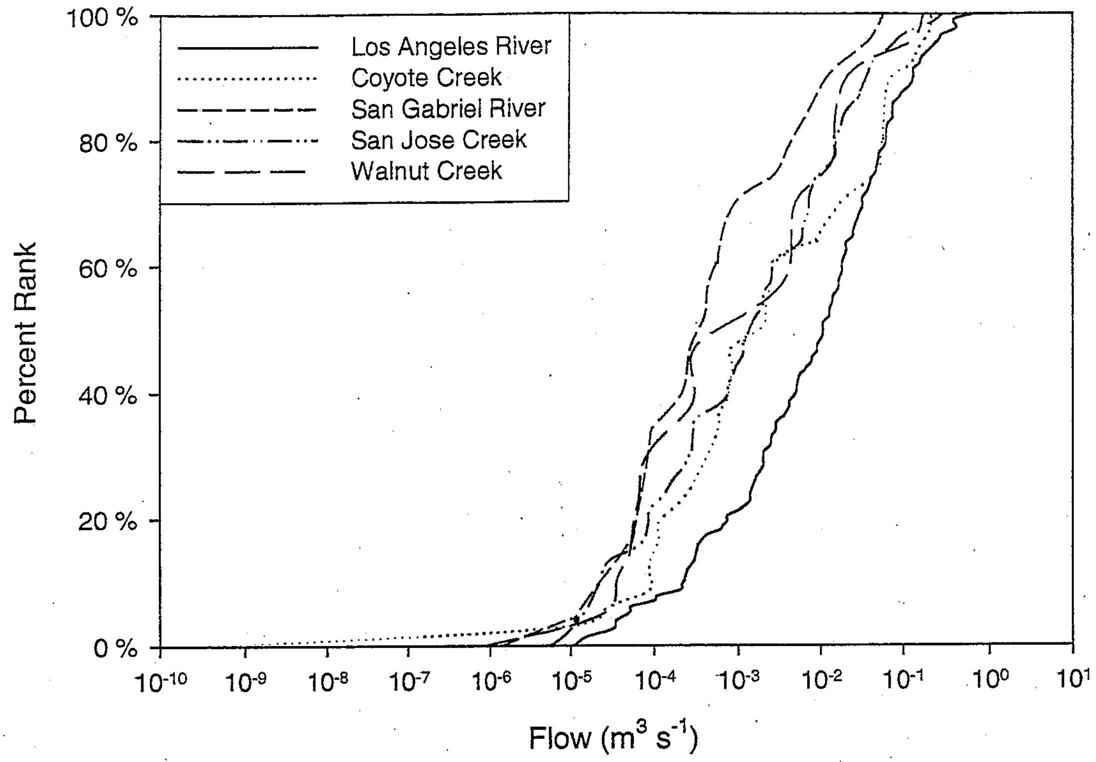
Figure 6. In-Stream Total Ammonia Concentrations by Stream and Year. Vertical arrows show locations of wastewater reclamation plants (WRPs).

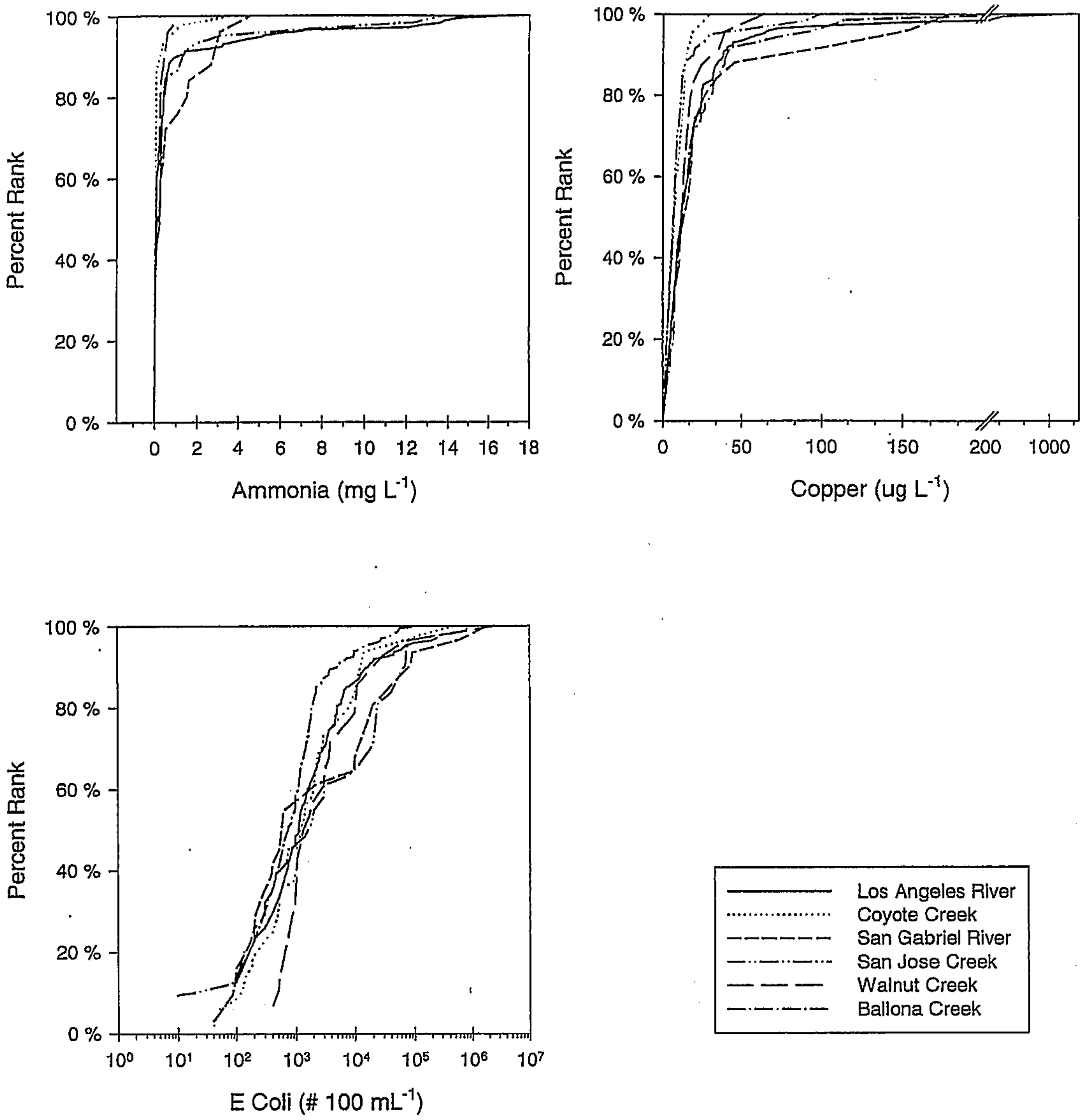
Figure 7. Change in Mean In-stream Metals Loads. Graph shows the change in mean in-stream load (± standard deviation) between successive sampling locations in Ballona Creek for (a) total copper, (b) total lead, (c) total zinc (right y-axis). Left y-axis shows mean storm drain load (± standard deviation) by position along Ballona Creek.

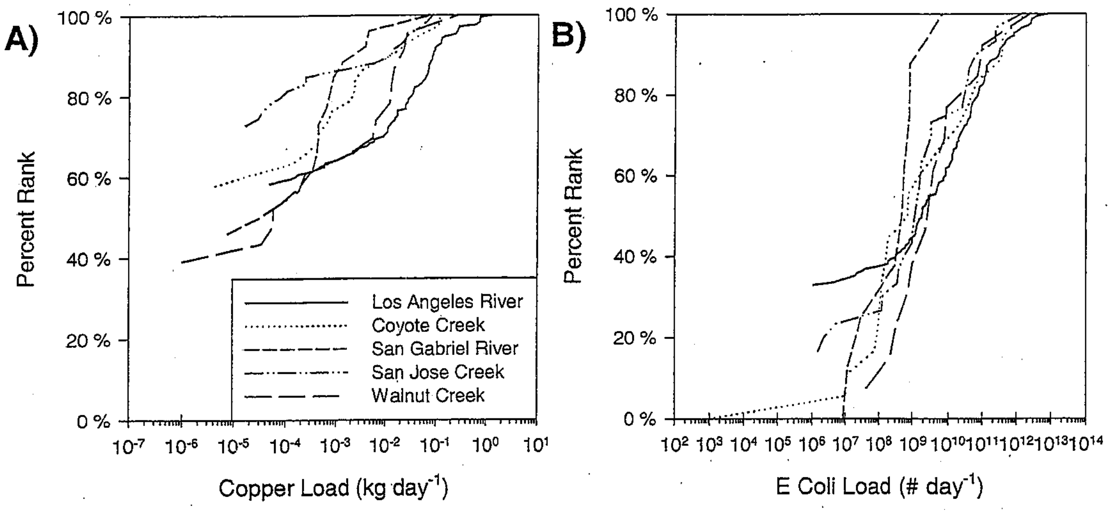
Figure 8. Effects of Non-Detected Constituents on Mass Loadings of Metals in the Greater San Gabriel River Watershed. Graphs show how the estimated relative distribution of load varies based on the values assigned to "non-detect" sample results. WRP = water reclamation plant.

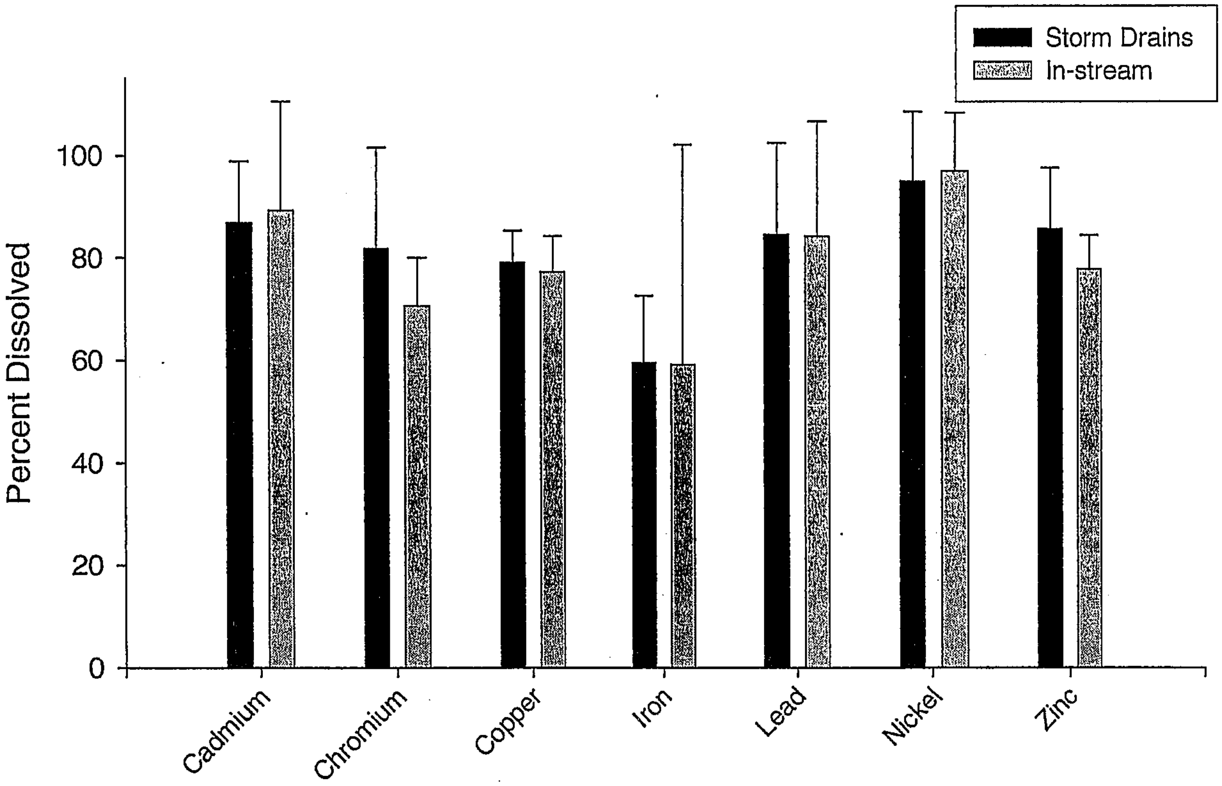
Figure 9. San Gabriel River Flow Variability During the 2002 Sampling Event.

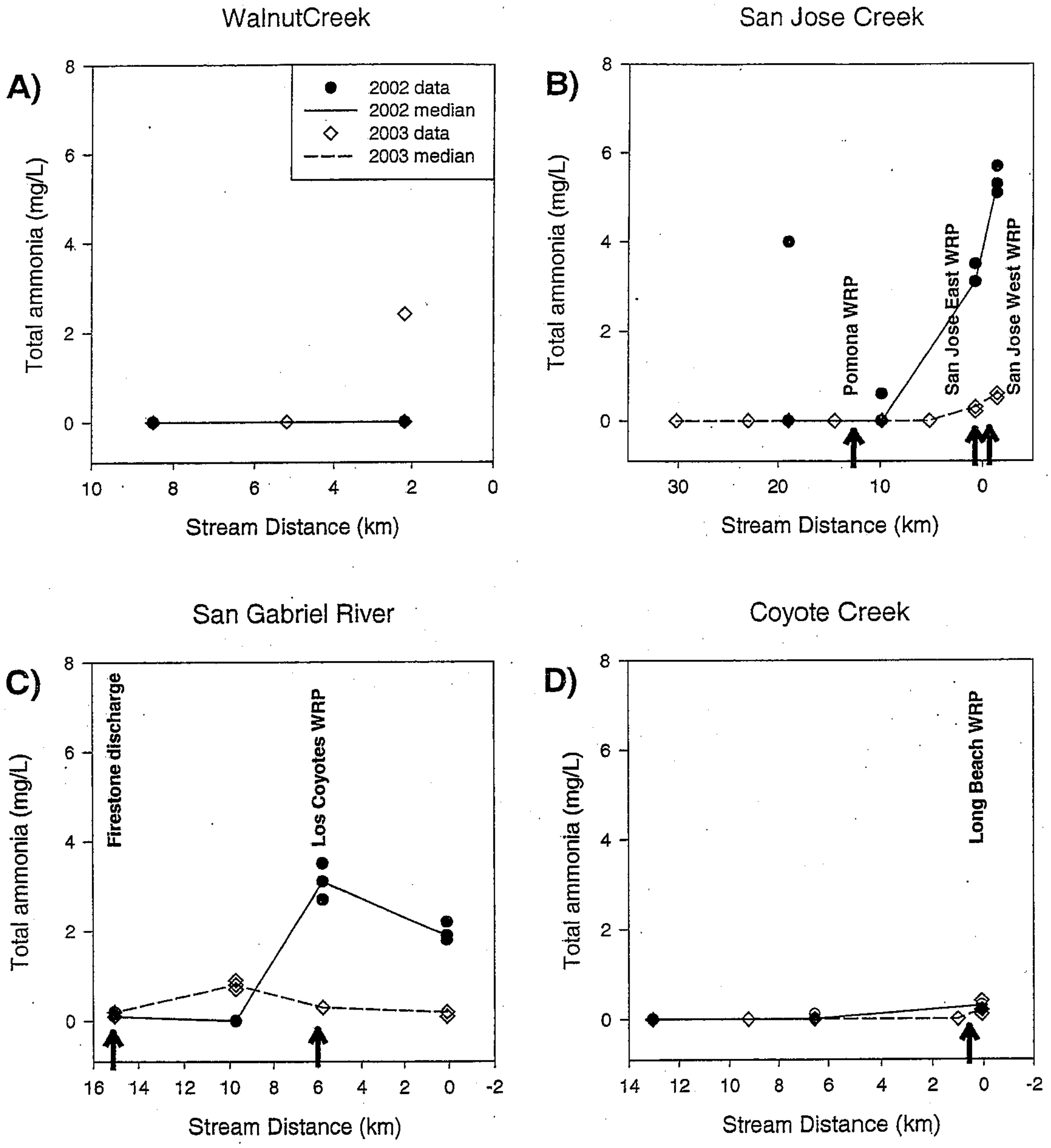

Watersheds
Los Angeles River
Ballona Creek
Coyote Creek
San Gabriel River
San Jose Creek
Walnut Creek
Streams
0
10
20
Kilometers
N
W
E
S

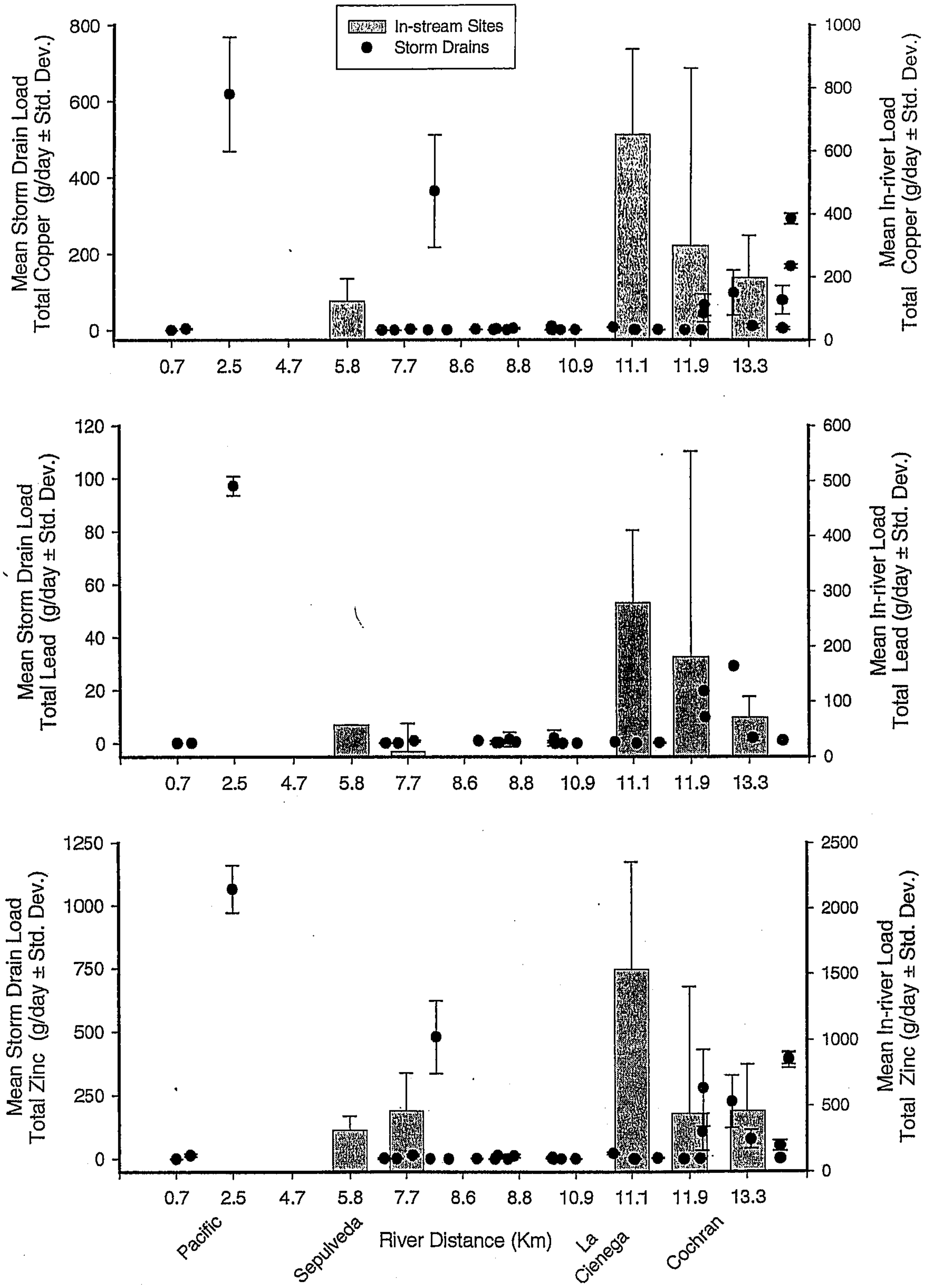

Los Angeles River
Coyote Creek
San Gabriel River
San Jose Creek
Walnut Creek
Percent Rank
100 %
80 %
60 %
40 %
20 %
0 %
10^{-10}
10^{-9}
10^{-8}
10^{-7}
10^{-6}
10^{-5}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
10^{0}
10^{1}
Flow ($m^3 s^{-1}$)

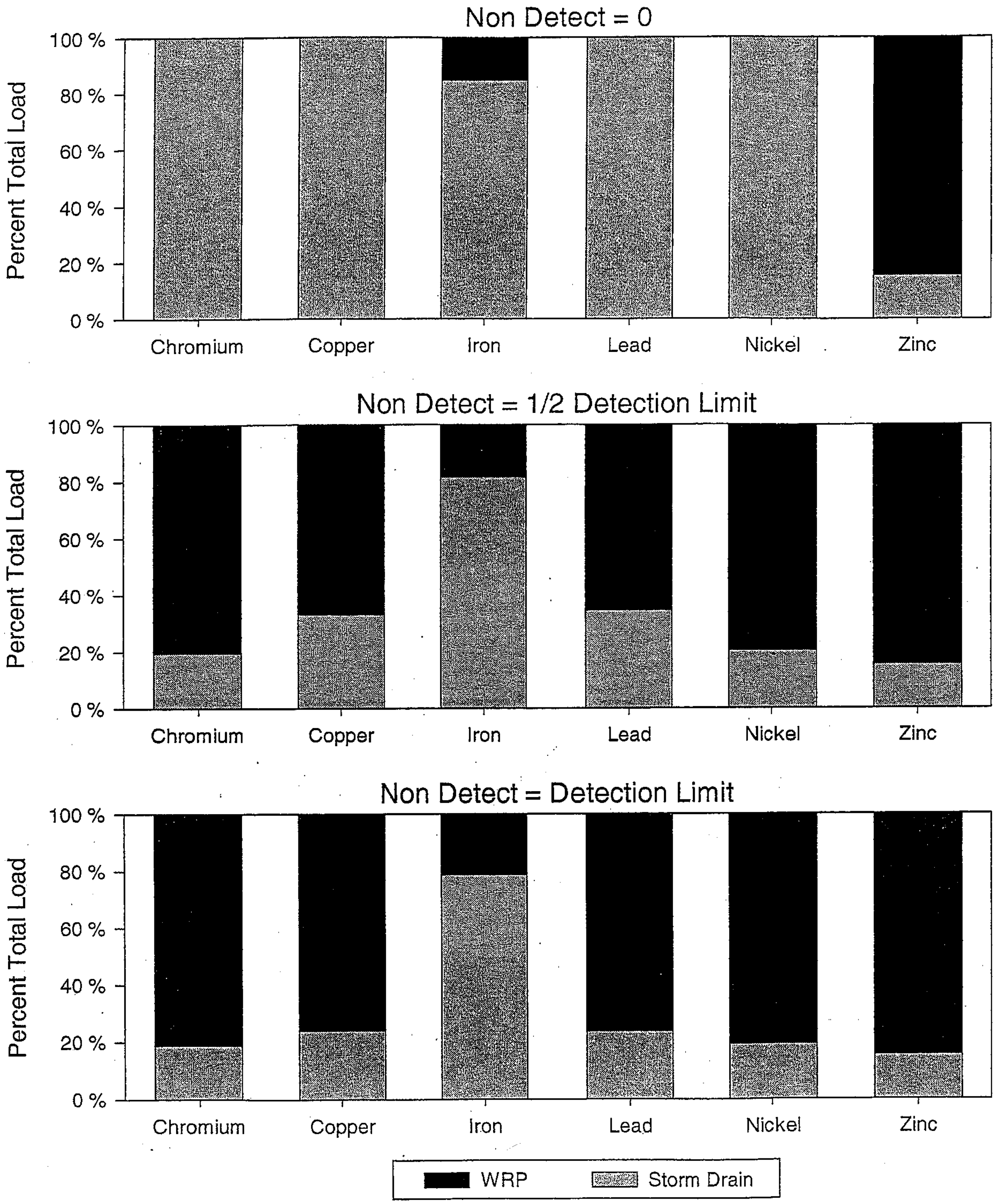

Percent Rank
100 %
80 %
60 %
40 %
20 %
0 %
0
2
4
6
8
10
12
14
16
18
Ammonia (mg L^{-1})
Percent Rank
100 %
80 %
60 %
40 %
20 %
0 %
0
50
100
150
200
1000
Copper (ug L^{-1})
Percent Rank
100 %
80 %
60 %
40 %
20 %
0 %
10^0
10^1
10^2
10^3
10^4
10^5
10^6
10^7
E Coli (# 100 mL^{-1})
Los Angeles River
Coyote Creek
San Gabriel River
San Jose Creek
Walnut Creek
Ballona Creek


A)
Percent Rank
100 %
80 %
60 %
40 %
20 %
0 %
10-7 10-6 10-5 10-4 10-3 10-2 10-1 10^0 10^1
Copper Load (kg day-1)
Los Angeles River
Coyote Creek
San Gabriel River
San Jose Creek
Walnut Creek
B)
Percent Rank
100 %
80 %
60 %
40 %
20 %
0 %
10^2 10^3 10^4 10^5 10^6 10^7 10^8 10^9 10^10 10^11 10^12 10^13 10^14
E Coli Load (# day-1)


Storm Drains
In-stream
Percent Dissolved
0
20
40
60
80
100
Cadmium
Chromium
Copper
Iron
Lead
Nickel
Zinc

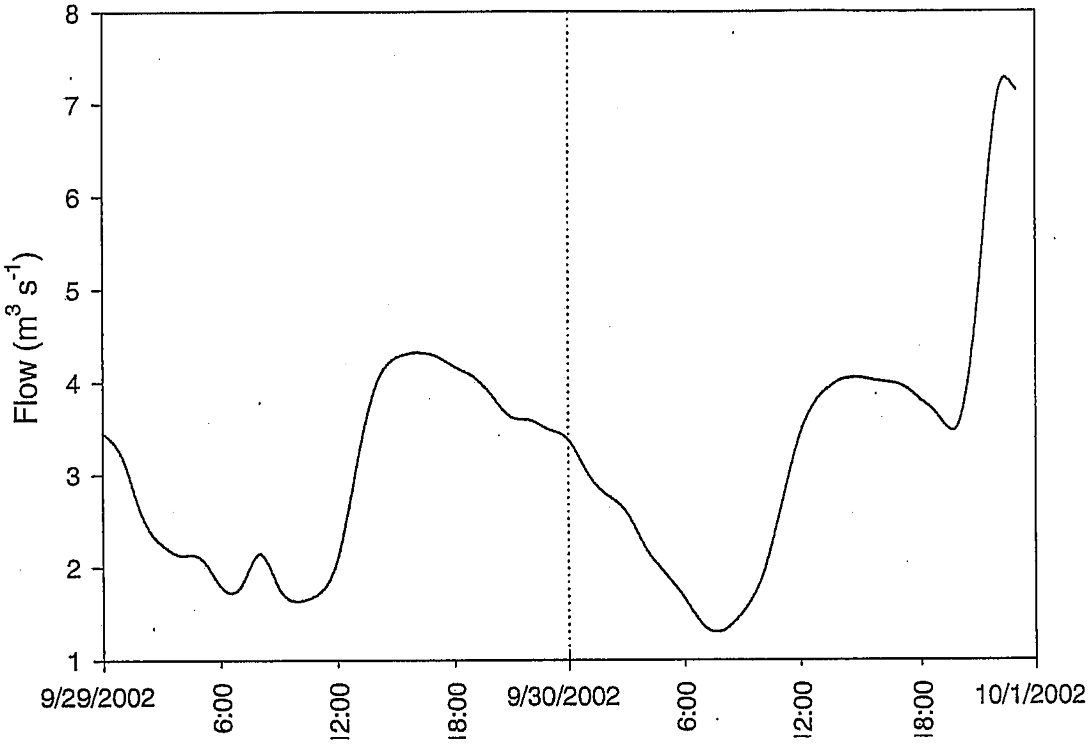

WalnutCreek
A)
Total ammonia (mg/L)
8
6
4
2
0
10
8
6
4
2
0
Stream Distance (km)
● 2002 data
2002 median
◇ 2003 data
2003 median
San Jose Creek
B)
Total ammonia (mg/L)
Pomona WRP
San Jose East WRP
San Jose West WRP
30
20
10
0
Stream Distance (km)
San Gabriel River
C)
Total ammonia (mg/L)
Firestone discharge
Los Coyotes WRP
16
14
12
10
8
6
4
2
0
-2
Stream Distance (km)
Coyote Creek
D)
Total ammonia (mg/L)
Long Beach WRP
14
12
10
8
6
4
2
0
-2
Stream Distance (km)


In-stream Sites
Storm Drains
Mean Storm Drain Load Total Copper (g/day ± Std. Dev.)
Mean In-river Load Total Copper (g/day ± Std. Dev.)
800
600
400
200
0
1000
800
600
400
200
0
Mean Storm Drain Load Total Lead (g/day ± Std. Dev.)
Mean In-river Load Total Lead (g/day ± Std. Dev.)
120
100
80
60
40
20
0
600
500
400
300
200
100
0
Mean Storm Drain Load Total Zinc (g/day ± Std. Dev.)
Mean In-river Load Total Zinc (g/day ± Std. Dev.)
1250
1000
750
500
250
0
2500
2000
1500
1000
500
0
0.7
2.5
4.7
5.8
7.7
8.6
8.8
10.9
11.1
11.9
13.3
Pacific
Sepulveda
River Distance (Km)
La Cienega
Cochran


Non Detect = 0
Percent Total Load
100 %
80 %
60 %
40 %
20 %
0 %
Chromium
Copper
Iron
Lead
Nickel
Zinc
Non Detect = 1/2 Detection Limit
Percent Total Load
100 %
80 %
60 %
40 %
20 %
0 %
Chromium
Copper
Iron
Lead
Nickel
Zinc
Non Detect = Detection Limit
Percent Total Load
100 %
80 %
60 %
40 %
20 %
0 %
Chromium
Copper
Iron
Lead
Nickel
Zinc
WRP
Storm Drain

45°

San Gabriel River above Spring St



Environmental Toxicology and Chemistry, Vol. 25, No. 2, pp. 373–385, 2006
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Printed in the USA
0730-7268/06 $12.00 + .00

WATERSHED-BASED SOURCES OF POLYCYCLIC AROMATIC HYDROCARBONS IN URBAN STORM WATER

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(*Received* 22 *April* 2005; *Accepted* 19 *August* 2005)

Abstract—Polycyclic aromatic hydrocarbons (PAHs) are carcinogenic and mutagenic compounds, ubiquitous in the air and water of urban environments, and have been shown to accumulate in coastal estuarine and marine sediments. Although previous studies have documented concentrations and loads of PAHs in urban runoff, little is known about the sources and temporal patterns of PAH loading from storm water. This study characterized the sources and temporal patterns of PAHs in urban storm water by analyzing PAH concentrations and loads from a range of homogeneous land use sites and in-river mass emission sites throughout the greater Los Angeles, California, USA, region. Samples were collected at 30- to 60-min intervals over the course of a storm during multiple storm events over a four-year period in order to investigate PAH sources and inter- and intrastorm patterns in loading. Polycyclic aromatic hydrocarbon storm fluxes ranged from 1.3 g/km^2 for the largely undeveloped Arroyo Sequit watershed to 223.7 g/km^2 for the highly urbanized Verdugo Wash watershed, with average storm fluxes being 46 times higher in developed versus undeveloped watersheds. Early-season storms repeatedly produced substantially higher loads than comparably sized late-season storms. Within individual storms, PAHs exhibited a moderate first flush with between 30 and 60% of the total PAH load being discharged in the first 20% of the storm volume. The relative distribution of individual PAHs demonstrated a consistent predominance of high-molecular-weight compounds indicative of pyrogenic sources.

Keywords—Polycyclic aromatic hydrocarbons Storm water First flush Source identification

INTRODUCTION

Polycyclic aromatic hydrocarbons (PAHs) are associated with carcinogenic and mutagenic effects in humans and biota [1–4]. These compounds are ubiquitous in the air and water of urban environments and have been shown to accumulate in coastal estuarine and marine sediments [5–9]. Although some PAHs are naturally occurring, the majority are anthropogenic and enter the environment through release of petroleum products (petrogenic sources) or by combustion of organic matter (pyrogenic sources) [10–12]. Recent studies have shown that pyrogenic sources predominate in urban settings and that the profile of PAHs in urban storm water resembles that of atmospheric deposition [8,11,13–15].

The discharge of PAHs from urban watersheds is exacerbated in arid regions. Arid urban watersheds have a tremendous number of sources. For example, the average daily traffic in the Los Angeles, California, USA, region exceeds 81 million vehicle miles traveled per day ([16]; http://mobility.tamu.edu/mmp). These mobile sources lead to exceedingly high PAH levels in the atmosphere [17–19]. Moreover, the long antecedent periods without rain in arid regions potentially enhance the dry deposition of PAHs to urban landscapes from these atmospheric sources. When rainfall does occur, the precipitation is often short but intense. Storms flows in urban watersheds from the Los Angeles region can range from <0.5 cubic meters per second (cms) to $>1,000$ cms in less than 1 h [20]. Runoff from these largely impervious urban surfaces efficiently mobilizes deposited material, including PAHs, in the resulting surface runoff.

Although previous studies have documented concentrations and loads of PAHs in urban storm-water runoff [3,8,11,21], little is known about the sources and temporal patterns in PAH loading from storm water. Studies on other pollutants, such as pesticides [22] and metals [23], have shown that concentrations can vary dramatically between individual storms as well as over the course of a single storm. However, this information has not been documented for PAHs. Because these temporal patterns can influence the ultimate fate of a pollutant, this knowledge is important for developing predictive models and management strategies for storm-water pollutants.

The objective of this study was to characterize temporal patterns and sources of PAH concentrations and loads in storm water. The goal was to answer the following four questions. First, how does the concentration and flux of total PAH differ between urban and arid watersheds? Second, how does the concentration of total PAH vary within a storm season? Third, how does the concentration and load of total PAH vary within storm events? Finally, what are the potential sources of PAH in storm-water runoff from urban watersheds? The first question was addressed by sampling at the mouth of various watersheds with differing levels of development. The second question was addressed by sampling multiple storm events with varying size, duration, intensity, and antecedent dry periods at the same watershed. The third question was addressed by measuring PAH concentrations over the course of entire storm events to construct time-versus-concentration plots. The fourth question was addressed in two fashions. First, concentrations and flux were compared among a variety of small, homogeneous land use types. Second, the relative distribution of individual PAHs were examined for source signatures indicative of pyrogenic versus petrogenic origin.

MATERIALS AND METHODS

Sampling locations

The highly urbanized greater Los Angeles metropolitan area in southern California has a population of approximately 15

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million residents (U.S. Census Bureau 2000, http://factfinder.census.gov/home/saff/main.html?_lang=en). Winter storms generally occur between December and March, with about 30 cm of total precipitation being distributed over 3 to 5 large and 8 to 10 small storms [20]. Runoff from a range of residential, commercial, industrial, and other land uses drain to engineered flood control channels (highly modified rivers) and ultimately discharge to the Pacific Ocean. These flood control channels integrate runoff from all the land use types in their contributing watersheds and are termed mass emission (ME) sites. Eight different ME sites representing six developed and two undeveloped watersheds and ranging in size from 31 to 2,161 km² were sampled during the 2000–2001 through 2003–2004 storm seasons (Table 1 and Fig. 1). In addition, 15 homogeneous land use sites, representing seven land use types, were sampled (Fig. 1). Land use categories included high-density residential, low-density residential, commercial, industrial, agricultural, recreational, and transportation.

Sampling and analysis

A total of 10 discrete storms were sampled, with each site being sampled between one and four individual storms. Rainfall amounts ranged from 0.28 to 9.17 cm and antecedent conditions from 2 to 142 d without measurable rain. Rainfall was measured using a standard tipping bucket at each site that recorded at 0.025-cm increments. Antecedent dry conditions were determined as the number of days since the cessation of measurable rain. Water quality sampling was initiated when flows were greater than base flows by 20%, continued through peak flows, and ended when flows subsided to less than 20% of base flow. Since watersheds in southern California have highly variable flows that may increase orders of magnitude during storm events, these criteria are considered conservative. Flow at ME sites was estimated at 15-min intervals using existing, county-maintained flow gauges or stage recorders in conjunction with historically derived and calibrated stage-discharge relationships. At ungauged ME sites and previously unmonitored land use sites, stream discharge was measured as the product of the channel cross-sectional area and the flow velocity. Velocity was measured using an acoustic Doppler velocity (AV) meter. The AV meter was mounted to the invert of the stream channel, and velocity, stage, and instantaneous flow data were transmitted to a data logger/controller on query commands found in the data logger software.

Between 10 and 15 discrete grab samples were collected per storm at approximately 30 to 60 min intervals for each site-event based on optimal sampling frequencies in southern California described by Leecaster et al. [24]. Samples were collected more frequently when flow rates were high or rapidly changing and less frequently during lower-flow periods. All water samples were collected by one of three methods: by peristaltic pumps with Teflon® tubing and stainless-steel intakes that were fixed at the bottom of the channel or pipe pointed in the upstream direction in an area of undisturbed flow, by direct filling of the sample bottle either by hand or affixed to a pole, or by indirect filling using an intermediate bottle for securing large volumes. After collection, the samples were stored in precleaned amber glass bottles on ice with Teflon-lined caps until they were shipped to the laboratory for analysis. Twenty-six specific PAHs were extracted, separated, and quantified by capillary gas chromatography coupled to mass spectrometry according to U.S. Environmental Protection Agency (U.S. EPA) method 625 [25].

Data analysis

Total PAH (ΣPAH) was computed as the sum of the 26 individual PAH compounds quantified (Table 2). The individual PAHs were divided into low-molecular-weight (LMW) PAH compounds (<230, two to three rings) and high-molecular-weight (HMW) PAH compounds (>230, four to six rings) for source analysis.

Four basic analyses were used to characterize temporal patterns and determine sources of PAH in storm water. First, event flow-weighted mean (FWM) concentrations, loading, and flux rates among undeveloped and developed ME sites were compared to determine if significant differences existed among watershed types. Using only those samples for a single storm, the event FWM was calculated according to Equation 1:

$$\mathrm{FWM} = \frac{\sum_{i=1}^{n} C_i \cdot F_i}{\sum_{i=1}^{n} F_i} \qquad (1)$$

where FWM = flow-weighted mean for a particular storm, C_i = individual runoff sample concentration of *i*th sample, F_i = instantaneous flow at the time of *i*th sample, and n = number of samples per event. Mass loading was calculated as the product of the FWM and the storm volume during the sampling period. Flux estimates facilitated loading comparisons among watersheds of varying sizes. Flux was calculated as the ratio of the mass loading per storm and watershed area. Differences in concentration or flux between ME sites were investigated using a one-way analysis of variance, with a $p < 0.05$ significance level [26]. In all cases, nondetectable results were assigned a value of zero.

The second analysis compared seasonal patterns of total PAH concentration and load by plotting FWM concentration, load, and flux as a function of cumulative rainfall before the date of the storm being sampled. For this analysis, all ME sites were analyzed as a group to look for differences between early- and late-season storms across the sampling region. Annual total PAH loads per year (kg/year) for each site were calculated by summing mean daily flow data for all days with storm flow for the corresponding watershed water years to get an annual storm volume. The annual storm volume was multiplied by the storm-event mean concentration to produce an estimated annual load.

The third analysis compared flows and total PAH concentration within storm events. This comparison was evaluated by examining the time-concentration series relative to the hydrograph using a plot we term a pollutograph. A first flush in concentration from individual ME storm events was defined as when the peak in concentration preceded the peak in flow. This was quantified using cumulative discharge plots whereby cumulative mass emission was plotted against cumulative discharge volume during a single storm event [27]. When these curves are close to unity, mass emission is a function of flow discharge. A strong first flush was defined when ≥80% of the mass was discharged in the first 20% of runoff volume. A moderate first flush was defined when ≥30% and ≤80% of the mass was discharged in the first 20% of runoff volume. No first flush was assumed when ≤30% of the mass was discharged in the first 20% of runoff volume.

The fourth analysis examined sources of PAHs. First, the FWM concentrations from the homogeneous land use sites were compared. Differences between land use sites were in-

Table 1. Storm-water polycyclic aromatic hydrocarbon mass emissions from in-river sampling locations in the Los Angeles, California, USA, region. Annual loads are based on water year, as indicated in the footnotes (cms = cubic meters per second; SD = standard deviation; PAH = polycyclic aromatic hydrocarbons; EMC = event mean concentration)

							Total PAHs					
							EMC			Mass emissions		
	Watershed size (km²)	Date of storm event	Rainfall (cm)	Antecedent dry days	Mean flow (cms)	Peak flow (cms)	ng/L	SD	Flux (kg/km²)	kg	SD	Annual total PAH load (kg/year)
Mass emission sites												
Los Angeles River above Arroyo Seco	1,460	11/12–11/13/2001	1.73	127	62.6	262.5	3,256.8	846.7	0.0049	7.16	0.35	3.74[a]
Los Angeles River at Wardlow	2,161	5/2–5/3/2003	3.56	4	209.9	756.7	470.7	453.2	0.0023	4.90	0.32	34.9[b]
		2/2/2004	1.14	29	90.4	375.6	3,559.9	1,185.5	0.0064	13.93	0.99	150.6[c]
										Mean load:		92.8 ± 81.8
Verdugo Wash	65	11/12–11/13/2001	1.83	11	68.5	368.2	4,283.7	2,043.2	0.2236	14.54	0.83	NA[d]
		10/31–11/1/2003	1.74	30	56.5	155.0	4,992.3	1,093.3	0.1529	9.94	0.46	NA
Arroyo Seco	130	2/9–2/11/2001	3.56	12	2.9	13.5	788.8	177.8	0.0009	0.11	0.01	2.79[e]
		4/6–4/7/2001	1.78	30	7.8	21.8	816.5	258.5	0.0016	0.20	0.01	
Ballona Creek	338	4/6–4/7/2001	1.24	31	32.6	100.9	948.7	379.9	0.0054	1.81	0.13	20.5[e]
		11/24–11/25/2001	1.52	11	53.1	396.2	3,118.9	1,104.8	0.0246	8.30	1.78	17.3[a]
		5/2–5/3/2003	2.03	4	52.8	134.4	981.7	583.0	0.0032	1.08	0.12	20.0[b]
		10/31–11/1/2003	2.03	30	62.0	148.1	5,821.2	1,814.9	0.0233	7.87	0.54	72.9[c]
										Mean load:		32.7 ± 26.8
Dominguez Channel	187	3/17–3/18/2002	0.28	10	4.8	14.0	3,293.4	791.8	0.0013	0.24	0.01	NA
		2/21–2/22/2004	1.52	18	14.7	35.5	2,182.1	745.2	0.0123	2.31	0.09	NA
Santa Monica Canyon	41	4/6–4/7/2001	3.05	50	0.6	3.0	766.8	247.2	0.0002	0.01	0.00	NA
Open Space Arroyo Sequit	31	2/25–2/26/2004	9.17	2	3.4	21.9	137.6	0.0	0.0013	0.04	0.00	NA

[a] Water year 2002 = October 2001–September 2002.
[b] Water year 2003 = October 2002–September 2003.
[c] Water year 2004 = October 2003–September 2004.
[d] NA = annual storm volumes not available; consequently, annual loads could not be estimated.
[e] Water year 2001 = October 2000–September 2001.

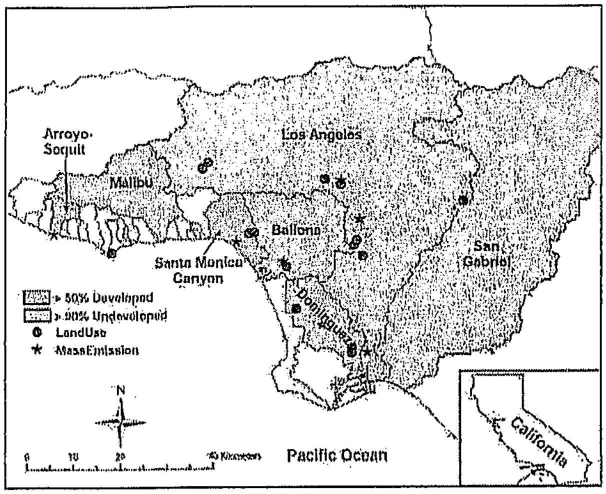

Fig. 1. Map of in-river mass emission sampling sites and watersheds within the greater Los Angeles region, California, USA. Watersheds indicated in gray contained land use sites that drain catchments that are >90% undeveloped.

vestigated using a one-way analysis of variance, with a $p < 0.05$ significance level [26]. Next, the ratio of fluoranthene (F) to pyrene (P) (F/P) and the ratio of phenanthrene (P) to anthracene (A) (P/A) were used to determine pyrogenic versus petrogenic sources of PAH. Pyrogenic sources predominate when F/P ratios approach 0.9 [28]. Pyrogenic sources predominate when P/A ratios ranged from 3 to 26 [29,30].

RESULTS

Developed versus undeveloped watersheds

In-river total PAH loads, concentrations, and fluxes were higher for developed versus undeveloped watersheds. For the 14 storm events measured, mean PAH load from developed watersheds was 5.6 ± 5.1 kg/storm, while mean load from undeveloped watersheds was 0.03 ± 0.02 kg/storm. Similarly, mean total PAH concentration from developed watersheds exceeded that from undeveloped watersheds (2,655.0 ± 1,768.1 ng/L vs 452.2 ± 444.9 ng/L; Tables 1 and 3). Flux of PAHs from developed watersheds was 46 times greater than that from undeveloped watersheds (Table 1). Mean PAH flux from the developed watersheds was 35.6 ± 69.8 g/km^2 compared to 0.75 ± 0.77 g/km^2 for the undeveloped watersheds. When the anomalously high fluxes from the Dominguez watershed are removed, flux from the developed watersheds was 7.8 ± 8.6 g/km^2, which is still greater than 10 times that of the undeveloped watersheds. Furthermore, the higher fluxes from developed watersheds were generated by substantially less rainfall than the lower fluxes from the undeveloped watersheds (1.85 ± 0.97 cm for storms in developed watersheds vs 6.11 ± 4.32 cm for storms in undeveloped watersheds).

The annual output rate of total PAHs in the Los Angeles River watershed during the 2002–2003 water year was approximately 34.9 kg/year (Table 1). During this same period, Ballona Creek had an annual output rate of approximately 20.0 kg/year into Santa Monica Bay. The following water year (2003–2004), the storm-water runoff discharge rate from Ballona Creek increased by a factor of four (72.9 kg/year). For comparative purposes, during the same time period, the Los Angeles River watershed discharged an estimated 150.6 kg/year of total PAHs into Santa Monica Bay. Annual output rates for undeveloped watersheds could not be estimated because those sites are not gauged, and consequently annual storm volumes are not available for estimation of annual PAH loads.

Effect of rainfall patterns

Antecedent dry period (expressed as cumulative rainfall) was strongly correlated with total PAH concentration, load, and flux in an exponentially nonlinear manner ($r^2 = 0.54$–0.81; Fig. 2). Early-season storms have significantly higher PAH loads than late-season storms both within and between watersheds, even when rainfall quantity is similar. For example, the two early-season storms from Ballona Creek in water years 2002 and 2003 had total PAH loadings that were approximately four times larger (ranging from 7.9–8.3 kg) than the two storms that occurred at the end of the rainy season (1.1–1.8 kg), despite the early- and late-season storms resulting from comparable rainfall. When all watersheds are analyzed together, PAH concentration and load decrease with increasing cumulative rainfall until approximately 10 cm (average annual rainfall is 33 cm), beyond which the effect is markedly less dramatic (Fig. 2).

PAH variability within storms

The greatest total PAH concentrations occurred during the rising limb of the storm hydrograph for nearly every storm

Table 2. List of the 26 individual polycyclic aromatic hydrocarbon compounds measured during the study. Compounds were divided into low-molecular-weight (LMW) compounds (<230, two to three rings) and high-molecular-weight (HMW) compounds (>230, four to six rings) for source analysis

LMW compounds	Weight	No. rings	HMW compounds	Weight	No. rings
1-Methylnaphthalene	156 + 170	2	Benz[*a*]anthracene	228	4
1-Methylphenanthrene	192 + 206	3	Benzo[*a*]pyrene	252	5
2,3,5-Trimethylnaphthalene	155 + 170	2	Benzo[*b*]fluoranthene	252	5
2,6-Dimethylnaphthalene	156 + 170	2	Benzo[*e*]pyrene	252	5
2-Methylnaphthalene	156 + 170	2	Benzo[*ghi*]perylene	276	6
2-Methylphenanthrene	192 + 206	3	Benzo[*k*]fluoranthene	252	5
Acenaphthene	154	2	Chrysene	228	5
Acenaphthylene	152	3	Dibenz[*a,h*]anthracene	278	5
Anthracene	178	3	Fluoranthene	202	4
Biphenyl	154	2	Indeno[1,2,4-*cd*]pyrene	276	6
Fluorene	166	3	Methylanthracene	222	5
Naphthalene	128	2	Perylene	252	5
Phenanthrene	178	3	Pyrene	202	4

Table 3. Total polycyclic aromatic hydrocarbons (PAHs) and selected polycyclic aromatic hydrocarbon ratios for the the watersheds in the Los Angeles, California coastal region, USA. EMC = event mean concentration; HMW = high-molecular-weight compounds

	Date of storm event	EMC ΣPAHs (ng/L)	EMC pyrene (ng/L)	Pyrene/ ΣPAHs (%)	Fluoranthene/ pyrene ratio	Phenanthrene/ anthracene ratio	EMC Phenanthrene (ng/L)	Phenanthrene/ ΣPAHs (%)	HMW (%)	Dominant sources of origin
Mass emission sites										
Los Angeles River above Arroyo Seco	11/12–11/13/2001	3,256.8	427.9	13.1	1.1	8.0	291.3	8.9	76.4	Pyrogenic
Los Angeles River at Wardlow	5/2–5/3/2003	470.7	133.5	28.4	1.1	20.9	97.3	20.7	69.7	Pyrogenic
	2/2/2004	3,559.3	401.0	11.3	1.0	7.5	278.1	7.8	71.8	Pyrogenic
Verdugo Wash	11/12–11/13/2001	4,283.7	593.8	13.9	1.1	7.8	373.0	8.7	83.5	Pyrogenic
	10/31–11/1/2003	4,992.3	677.9	13.6	0.9	11.6	341.8	6.8	82.0	Pyrogenic
Arroyo Seco	2/9–2/11/2001	788.8	131.9	16.7	1.0	8.6	101.2	12.8	81.7	Pyrogenic
	4/6–4/7/2001	816.5	135.0	16.5	1.1	7.2	101.9	12.5	84.6	Pyrogenic
Ballona Creek	4/6–4/7/2001	948.7	177.9	18.8	0.9	4.9	89.6	9.4	88.7	Pyrogenic
	11/24–11/25/2001	3,118.9	428.8	13.8	1.0	8.1	302.9	9.7	71.8	Pyrogenic
	5/2–5/3/2003	981.7	237.4	24.2	1.0	4.3	122.3	12.4	74.6	Pyrogenic
	10/31–11/1/2003	5,821.2	786.2	13.5	1.1	10.2	473.0	8.1	82.7	Pyrogenic
Dominguez Channel	3/17–3/18/2002	3,293.4	534.6	16.2	0.9	74.9	508.2	15.4	77.5	Petrogenic
	2/21–2/22/2004	2,182.1	308.8	14.2	1.1	6.4	210.5	9.6	69.7	Pyrogenic
Santa Monica Canyon	4/6–4/7/2001	766.8	134.9	17.6	1.0	4.1	73.8	9.6	86.5	Pyrogenic
Open Space Arroyo Sequit	2/25–2/26/2004	137.6	14.3	10.4	1.2	10.2	17.2	12.6	61.0	Pyrogenic
Mean ΣPAHs (ng/L)		2,300								

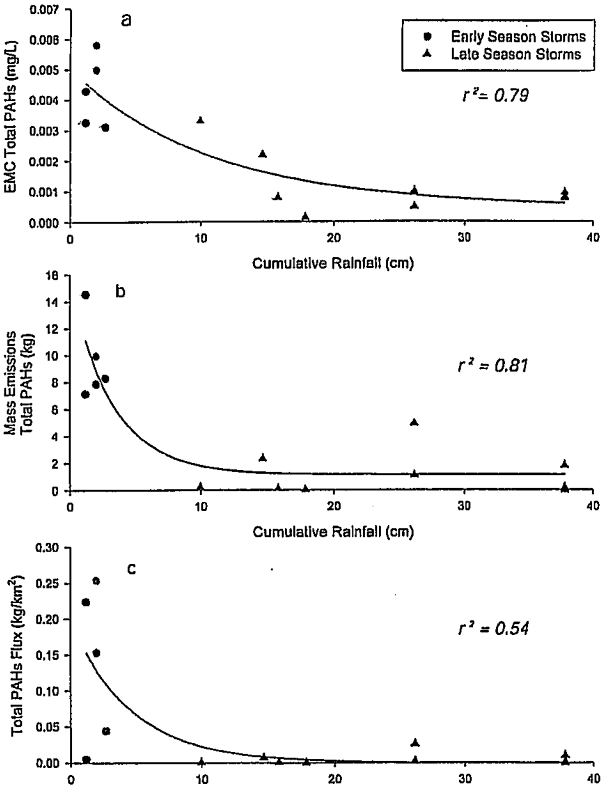

Fig. 2. Cumulative annual rainfall versus polycyclic aromatic hydrocarbon (PAH) event mean concentration (EMC) (a), load (b), and flux (c). Plots show data for mass emission sites only.

sampled. For example, peak concentrations (2,761 and 2,276 ng/L, respectively) occurred before the peak in flow (757 and 101 cms) in both the Los Angeles River and Ballona Creek (Fig. 3). In the Los Angeles River example, peak total PAH concentrations occurred almost 8 h before the peak in storm flow. In the Ballona Creek example, a second peak in flow (75 cms) was also preceded by a second peak in total PAH concentration (1,015 ng/L).

Despite a strong and consistent pattern of first flush in concentration, cumulative mass loading plots exhibited only a moderate first flush of PAHs. Between 30 and 60% of the total PAH load was discharged in the first 20% of storm volume for the storms examined in this study. The mass loading plots for Ballona Creek (Fig. 4) illustrate a consistent pattern of higher mass loading in the early portions of the storm, with a slightly stronger first flush in late-season storms.

Potential sources of PAHs

Sources of PAHs were investigated by comparing concentrations and loads in runoff from homogeneous land uses sites. For all land use sites samples, mean PAH flux was between 0.33 and 140 g/km², while FWM concentration was between 4.6E + 02 and 4.4E + 03 ng/L (Table 4). Despite some apparent differences between land uses (e.g., high-density residential having higher concentrations and industrial having higher flux), no significant differences were observed in either concentration or flux among land use category (p = 0.94 and 0.60, analysis of covariance, with rainfall as a covariate).

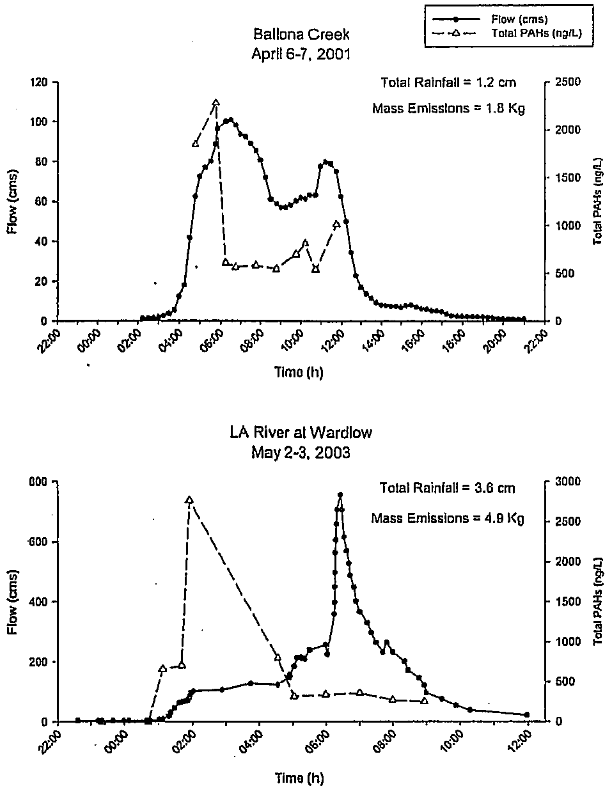

Fig. 3. Variation in polycyclic aromatic hydrocarbon (PAH) concentrations with time for storm events in Ballona Creek (top) and Los Angeles River (bottom), California, USA.

The relative proportion of individual PAH compounds can also be used to determine the source of PAHs in storm water. The HMW PAHs dominated LMW PAHs in runoff from all storms analyzed, suggesting a pyrogenic source. During the

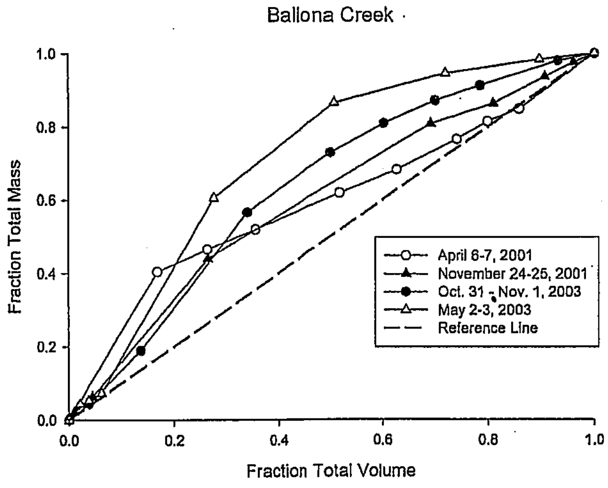

Fig. 4. Cumulative polycyclic aromatic hydrocarbon mass loading for four storms in Ballona Creek, California, USA. Plots show percent of mass washed off for a given fraction of the total runoff. Reference line indicates a 1:1 relationship between volume and mass loading. Portions of the curve above the line indicate proportionately higher mass loading per unit volume (i.e., first flush). Portions below the line (if any) indicate the reverse pattern.

Table 4. Event mean concentration (EMC) and mass loading of polycyclic aromatic hydrocarbons (PAHs) from land use sites in the Los Angeles, California, USA, region. Site numbers indicate different sites within a given land use category. SD = standard deviation; NA = watershed size not available

								Total PAHs		
									EMC	
	Watershed size (km²)	Date of storm event	Rainfall (cm)	Dry days	Sampling duration (h)	Mean flow (cms)	Peak flow (cms)	Flux (kg/km²)	ng/L	SD
High-density residential 1	0.02	2/17/2002	0.89	21	3	0.001	0.006	1.8E − 03	1.92E + 03	7.03E + 02
High-density residential 1	0.02	2/2/2004	1.19	2	5	0.004	0.0251	2.0E − 02	3.31E + 03	1.00E + 03
High-density residential 2	0.52	3/17–3/18/2002	0.20	27	1	0.000	0.003	1.1E − 05	7.84E + 03	5.99E + 03
Mean high-density residential								7.2E − 03	4.4E + 03	2.6E + 03
Low-density residential 1	0.98	3/4–3/5/2001	2.67	3	31	0.017	0.071	7.2E − 05	1.55E + 02	5.54E + 01
Low-density residential 1	0.98	2/2/2004	2.26	2	5	0.030	0.143	3.3E − 03	3.3E + 03	1.6E + 03
Low-density residential 2	0.18	3/17–3/18/2002	2.13	9	3	0.008	0.116	1.7E − 03	8.86E + 02	1.82E + 02
Mean low-density residential								1.7E − 03	1.4E + 03	6.0E + 02
Commercial 1	NA	2/17/2002	0.89	20	4	0.002	0.008	NA	2.27E + 02	1.63E + 02
Commercial 2	2.45	2/17/2002	0.74	20	3	0.337	1.340	7.7E − 03	4.43E + 03	2.05E + 03
Commercial 3	0.06	4/6–4/7/2001	2.03	31	6	0.008	0.018	8.2E − 05	3.00E + 01	1.95E + 01
Commercial 3	0.06	3/17–3/18/2002	0.12	9	1	0.000	0.001	2.9E − 06	2.08E + 02	6.93E + 01
Mean commercial								2.6E − 03	1.2E + 03	5.8E + 02
Industrial 1	0.004	4/6–4/7/2001	2.06	31	6	0.008	0.017	5.7E − 03	1.36E + 02	6.85E + 01
Industrial 2	0.001	2/17/2002	0.74	20	3	0.000	0.002	2.9E − 03	6.31E + 02	3.42E + 02
Industrial 3	2.77	3/17–3/18/2002	0.25	9	1	0.000	0.003	6.6E − 06	4.41E + 03	2.29E + 03
Industrial 4	0.01	3/15/2003	4.50	9	10	0.117	0.375	5.6E − 01	8.89E + 02	7.55E + 02
Mean industrial								1.4E − 01	1.5E + 03	8.6E + 02
Agricultural 1	0.98	3/4–3/5/2001	2.74	3	32	0.021	0.053	4.3E − 04	6.83E + 02	7.77E + 02
		3/17–3/18/2002	0.23	10	1	0.012	0.031	2.0E − 05	4.55E + 02	1.72E + 02
		2/2/2004	1.17	2	5	0.023	0.128	5.3E − 04	1.43E + 03	2.09E + 02
Mean agricultural								3.3E − 04	8.6E + 02	1.0E + 03
Recreational 1	0.03	3/4–3/5/2001	1.42	3	32	0.003	0.014	1.8E − 03	4.58E + 02	2.97E + 02
Mean recreational								1.8E − 03	4.6E + 02	3.0E + 02
Transportation 1	0.01	4/6–4/7/2001	3.05	31	5	0.022	0.057	1.4E − 02	3.63E + 02	2.54E + 02
Transportation 2	0.002	2/17/2002	0.89	47	3	0.001	0.006	3.7E − 03	5.95E + 02	3.16E + 02
Mean transportation								8.9E − 03	4.8E + 02	2.8E + 02

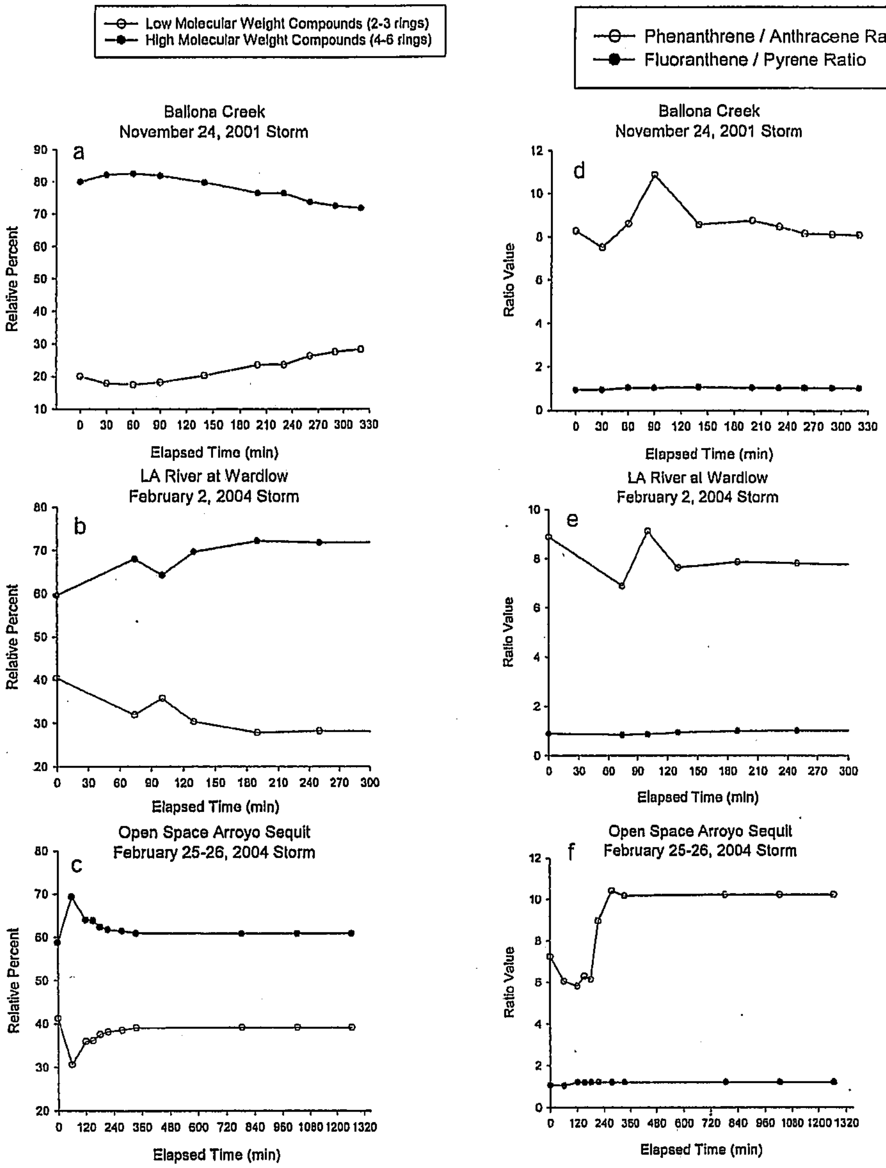

Fig. 5. Distribution of polycyclic aromatic hydrocarbons (PAHs) within storms for mass emission sites located in the Los Angeles region, California, USA. Plots on the left (**a–c**) show distribution of high- versus low-molecular-weight PAHs throughout individual storms. Plots on the right (**d–f**) show phenanthrene/anthracene (P/A) and fluoranthene/pyrene (F/P) ratios throughout individual storms. Peaks in the P/A ratio correspond to peak storm flows.

May 2–3, 2003, storm, HMW PAHs in runoff from the Los Angeles River and Ballona Creek accounted for 72% of the total PAH concentrations from these watersheds (Fig. 5 and Table 3). Similarly, HMW PAHs in runoff from the Dominguez channel watershed in Los Angeles County, California, USA, accounted for 74% of the total PAH concentrations from its watershed. Even in the undeveloped Arroyo Sequit watershed, HMW PAHs accounted for 63% of the total PAH concentrations. In all storms and at all sites, the HMW compounds fluoranthene and pyrene were the dominant HMW PAHs. Analysis of the distribution of PAHs within each storm event shows that HMW PAHs are predominant uniformly throughout each storm regardless of land use (Fig. 6). The exceptions were the industrial oil refinery and the agricultural sites, where the proportions of HMW and LMW PAHs were comparable throughout the storm. In all cases (except the oil refinery and agricultural sites), the relative contribution of LMW PAH compounds averaged 14 to 30% of the total PAH mass. Phenanthrene was the most dominant LMW PAH, comprising 7 to 21% of the total PAH contribution (Table 3).

The F/P ratio was between 0.9 and 1.2 for all storms in this study, indicating a strong predominance of pyrogenic PAH sources (Table 3). Furthermore, the P/A ratio was nearly always less than 21, once again indicating a strong predominance of pyrogenic PAH sources (Table 3) [28–30]. Only one storm, March 17–18, 2002, at the Dominguez channel site, had a potential petrogenic source; the F/P ratio was 0.9, but the P/A ratio was >74. This result is consistent with the data from the land use sites, as the Dominguez watershed contains four major oil refineries. As with the distribution of HMW versus

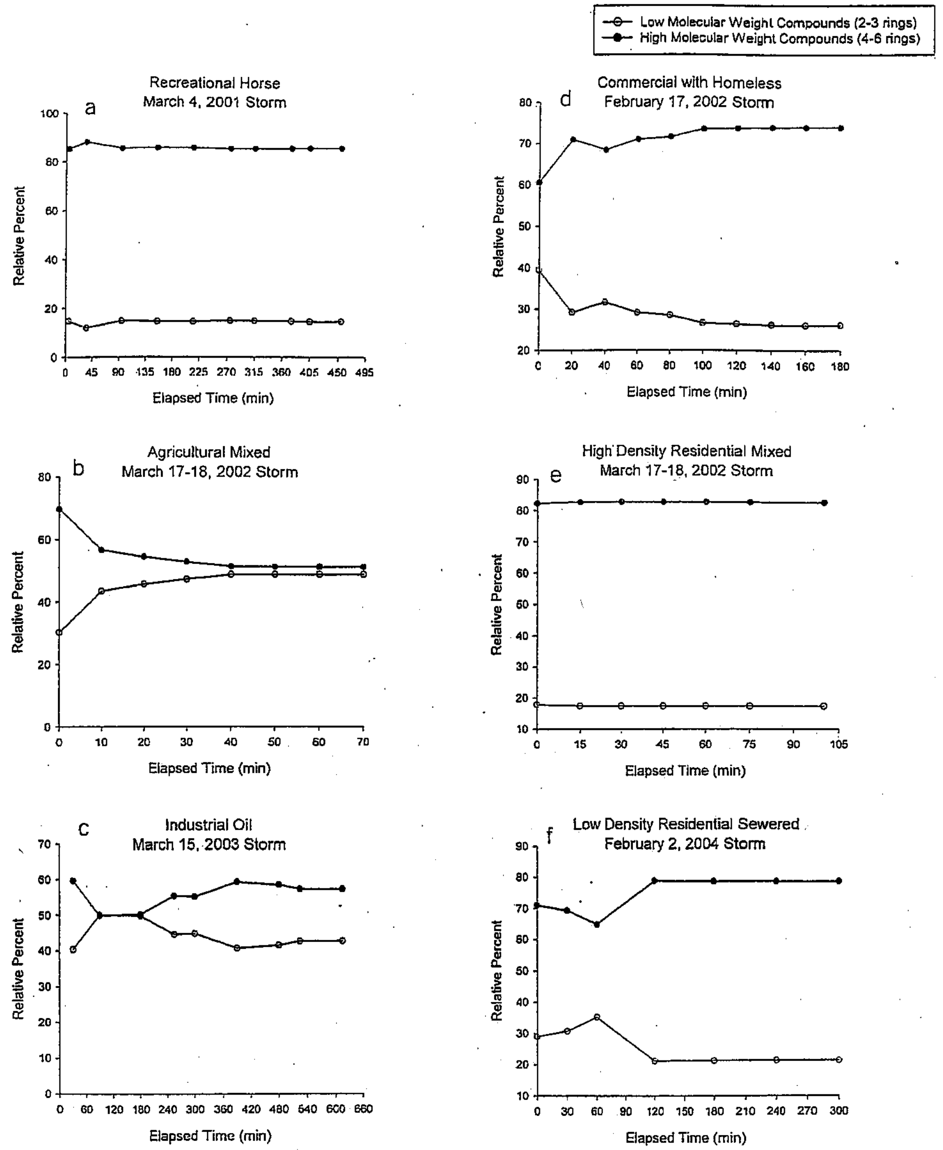

Fig. 6. Distribution of polycyclic aromatic hydrocarbons (PAHs) within storms for representative land use sites (a–f). Plots show distribution of high- versus low-molecular-weight PAHs throughout individual storms. Data are shown for six sites that represent the results observed for the 15 land use sites where data were collected.

LMW PAHs, the F/P and P/A ratios indicate a consistent pyrogenic source for all lands use and mass emission sites regardless of the point within the storm (Fig. 7). Again, the exception was at the industrial oil refinery, where the P/A ratio is low until the peak runoff occurs, at which time it rises to between 17 and 20. For both Ballona Creek and the Los Angeles River, a moderate, transient increase in the P/A ratio occurs coincident with the time of peak flow (Fig. 5).

DISCUSSION

Anthropogenic sources of total PAHS in storm-water runoff from urbanized coastal watersheds appears to be a significant source of PAHs to the southern California Bight. Estimates from this study based on FWM concentrations and gauged annual discharge volume indicate that approximately 92.8 and 32.7 kg/year of total PAH are discharged annually from the Los Angeles River and Ballona Creek watersheds, respectively. Over the same time period, the combined treated wastewater discharge from the city and county of Los Angeles (~2.8 × 10^6 m^3/d) discharged an estimated 740 kg of PAHs to the southern California Bight [31]. The main difference between the two types of discharges is the delivery of the load to the coastal oceans; the treated wastewater discharge occurs in small, steady doses that occur daily, while storm-water loading occurs over the 10 to 12 precipitation events that this region averages annually.

The impact of the total PAHs in storm water discharged from urbanized watersheds is also reflected in receiving waterbody impacts. Regional monitoring of the southern California Bight revealed that the highest concentrations of PAHs were associated within bay and harbor areas that receive inputs from urbanized coastal watersheds ([32]; http://www.sccwrp.org).

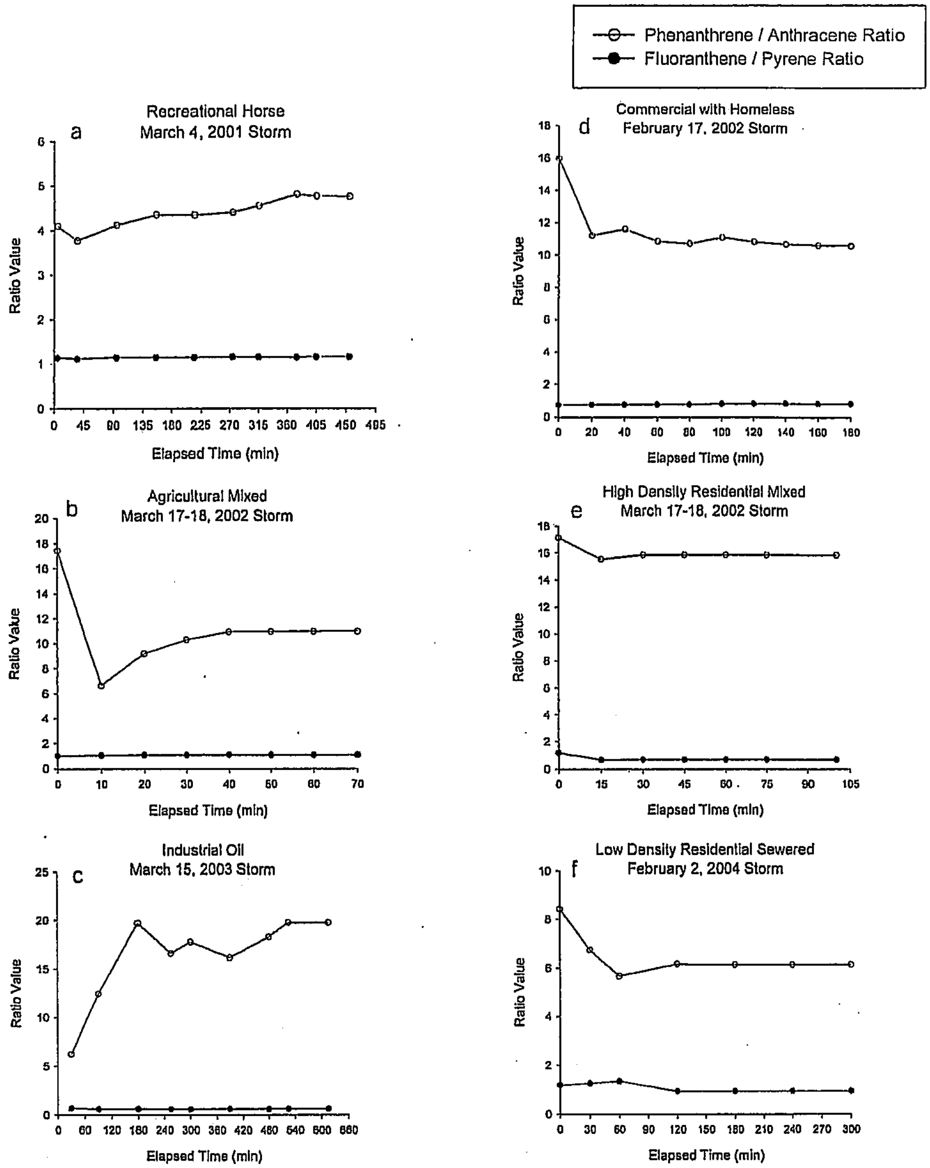

Fig. 7. Distribution of polycyclic aromatic hydrocarbons within storms for representative land use sites. Plots (a–f) show phenanthrene/anthracene (P/A) and fluoranthene/pyrene (F/P) ratios throughout individual storms. Data are shown for six sites that represent the results observed for the 15 land use sites where data were collected.

Bays and harbors only accounted for 5% of the total area of soft-bottom habitat but contained approximately 40% of the total PAH mass residing in southern California Bight surficial sediments. A second concern is the cost of remediating PAH in dredged materials. Total PAH is one of the most commonly occurring contaminants in dredged materials from San Pedro Bay [33]. While some of these contaminants likely arise from port and industrial activities, they are colocated at the mouths of the Los Angeles River and Dominguez Channel watersheds, which is likely a contributing source.

The impact of PAH contributions on receiving waters from urbanized watersheds are not constrained to the southern California Bight. The National Status and Trends Program, which samples sediments and tissues in estuaries and coastal areas nationwide, repeatedly finds elevated PAHs near urban centers [7]. San Pedro Bay (CA, USA) ranked third nationwide in total PAH concentration in mussel tissue during 2002. The top two locations are Elliott Bay (WA, USA) and Puget Sound (WA, USA), both located near urban centers. On the East Coast, Long Island Sound (NY, USA) adjacent to New York City was ranked fourth.

The annual watershed loadings of PAHs estimated from this study are lower than those estimated from two studies in the eastern United States. Hoffman et al. [11] estimated 680 kg/year of PAH loading from the 4,081 km^2 Narragansett Bay watershed in Rhode Island, USA. Similarly, Menzie et al. [8] estimated 640 kg/year of PAH loading from the 758 km^2 Massachusetts Bay, USA, watershed. This difference may be explained by several factors. First, PAH loading relies on wash-off of aerially deposited materials. Watersheds in the western United States typically experience less than one-third rainfall and runoff volumes than comparably sized watersheds in the eastern United States. The lower volumes of annual runoff likely translate to lower loads. Second, PAH in the eastern United States are predominantly from concentrated point sources, such as coal-fired power plants. Southern California does not have coal-fired power plants; rather, PAHs are predominantly from mobile sources (cars, trucks, and trains), which discharge more diffusely across the region.

Concentrations in runoff from land use sites in this study were between 0.03 and 7.84 μg/L; these values are similar to those observed in previous studies by others. For example, Mahler et al. [21] reported PAH concentrations between 5.1 and 8.6 μg/L in parking lot runoff, and Menzie et al. [8] reported concentrations between 1 and 14 μg/L from a broad range of land uses.

In contrast to the results of this study, storm-water monitoring by local municipalities in southern California consistently report no detectable PAHs in storm water. This discrepancy is likely attributable to two factors. First, the practical PAH detection limit used by local municipalities is typically between 1 and 5 μg/L, which is acceptable by U.S. EPA regulatory guidelines. However, the FWM mean concentrations in storm water during this study were often lower than this level. The second factor is the sampling design used for regulatory-based monitoring. Most local municipalities are mandated to collect a storm composite sample that do not emphasize (and may completely miss) the first flush of total PAH that was observed. We almost always observed the greatest peaks in total PAH concentrations during initial storm flows, up to 8 h before peak flow. This pronounced first flush suggests that in highly urbanized watersheds, particle-bound PAHs may be rapidly mobilized from impervious land surfaces during the early portions of storms. Similar first-flush patterns in PAH concentrations during storms were observed by Hoffman et al. [11] and Smith et al. [34]. Furthermore, Buffleben et al. (University of California, Los Angeles, Los Angeles, CA, USA, unpublished data) also observed that peak PAH concentrations in Ballona Creek occur up to 14 h before peak flow.

Seasonal flushing at mass emissions sites was one phenomenon not previously reported by others. Seasonal flushing occurred when early-season storms consistently discharged higher PAH loads than storms of a similar size or larger later in the season. This seasonal effect was correlated with the length of antecedent dry condition but not with rainfall quantity. The lack of a meaningful relationship between rainfall quantity and PAH loading has been reported in several other studies [10,11]. Hoffman et al. [11] suggested that the lack of a clear relationship was due to the complex spatial and temporal dynamics associated with rain patterns, which may affect runoff patterns more than the total amount of rainfall during a given storm. In addition, differential particle wash-off from land surfaces may mask any differences associated with total rainfall. The strong relationship between PAH flux and antecedent dry period suggests that storm-event PAH loads are a function primarily of the amount of time available for PAHs to build up on the land surfaces between subsequent rain events. The PAH loads from land surfaces during later-season storms (i.e., after ~10 cm of accumulated rainfall) may reflect contributions from wet deposition or from localized accumulation; however, we currently lack the data to answer this question definitively. Analysis of PAH concentration in wet deposition would help improve our understanding of the sources of PAHs during the latter part of the storm season. Environmental managers can use this knowledge of temporal patterns of PAH loading to focus efforts on storm capture or treatment during the early portions of storms and during the earliest storms of the year.

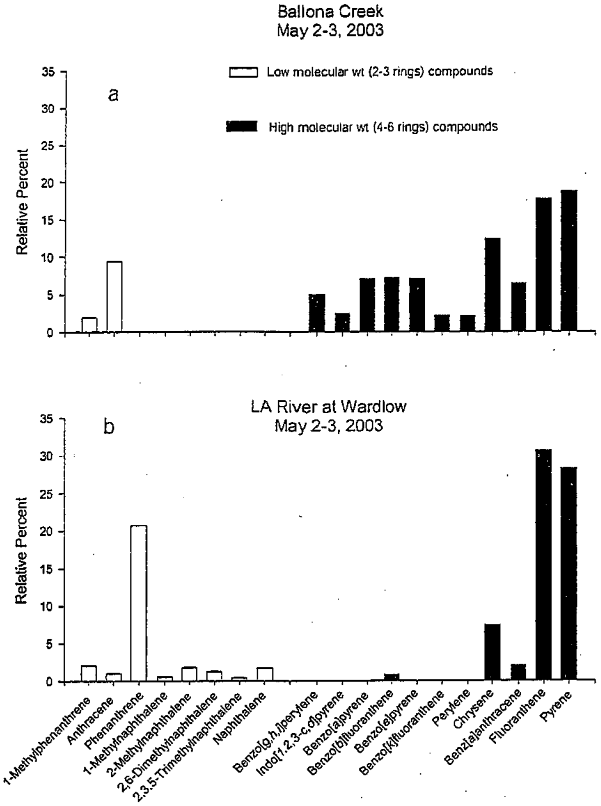

Fig. 8. Relative distribution of individual polycyclic aromatic hydrocarbon compounds for Ballona Creek (**a**) and Los Angeles River (**b**), California, USA, on May 2–3, 2003.

Sources of PAH in storm water

Several lines of evidence implicate aerial deposition and subsequent wash-off of combustion by-products as the main source of PAH loading in storm water. First, the flux of total PAHs among large developed watersheds were similar throughout the urbanized region of Los Angeles, suggesting a similar regional source of PAHs. If urban land use distribution strongly influenced PAH loadings, then flux would have differed by watershed based on differential urban land use practices. In fact, no difference was observed in PAH concentrations in runoff between various urban land uses, which differs from the findings of previous studies from the eastern United States [35]. Menzie et al. [8] concluded that residential and commercial land uses generated higher PAH concentrations than other land use types because of secondary petrogenic sources that enhanced the regional pyrogenic source of PAHs. Hoffman et al. [11] found that runoff from industrial and highway sites had higher PAH concentrations than residential runoff but accounted for these differences in runoff dynamics as opposed to unique sources.

Second, the relative abundance of individual PAHs in runoff indicates a strong pyrogenic source indicative of combusted fossil fuels. The typical distribution of PAHs observed from mass emission sites (Fig. 8) was similar to the distribution of PAHs observed in dry deposition collected in Los Angeles by

Table 5. Selected polycyclic aromatic hydrocarbon ratios and their source signature ranges

Indicator	Pyrogenic	Petrogenic	Reference
Fluoranthene/pyrene ratio (F/P)	0.9 to ≤1	>1	[21]
Phenanthrene/anthracene ratio (P/A)	3–26	>26	[29–30]
Methylphenanthrene/phenanthrene (M/P)	<1.0	2–6	[42]

Sabin and Schiff [17]. Furthermore, in this study, HMW PAH consistently comprised approximately 73% of the total PAH concentration regardless of land use. Hoffman et al. [11] reported comparable results in their study of urban runoff in Rhode Island's Narragansett Bay watershed, where HMW PAHs accounted for 71% of the total inputs to Narragansett Bay. A more recent study by Menzie et al. [8] of PAHs in storm-water runoff in coastal Massachusetts identified similar HMW PAH compounds as observed in this study (chrysene, fluoranthene, phenanthrene, and pyrene) as the primary PAH compounds in storm water. Similarly, Socolo et al. [12] found that high PAH loads associated with storm-water runoff to the Cotonou Lagoon in Benin were characterized by HMW PAHs that appear to be derived from atmospheric deposition. The consistent predominance of HMW PAHs throughout all storms, even during the period of first flush, further indicates a consistent regional source, such as aerial deposition. If specific land uses were generating secondary petrogenic wash-off as suggested by Menzie et al. [8], the distribution of PAHs would have changed during the storm; however, we did not observe any differences within storms. The exception to this pattern was for the industrial oil refinery site, where the signature of petrogenic PAHs was more pronounced. This makes sense given the obvious petrogenic source associated with this land use type. Nevertheless, the pyrogenic signature was still prevalent at this land use, especially during the latter portions of the storm.

The PAH sources can also be inferred by examining ratios of particular PAHs in runoff samples. We used both the fluoranthene/pyrene (F/P) and phenanthrene/anthracene (P/A) ratios. Small F/P ratios close to 0.9 suggest that individual PAHs are associated with combustion products [28]; in contrast, large F/P ratios suggest petrogenic sources of PAHs [36] (Table 5). Both the F/P and the P/A ratios observed in this study indicate that aerial deposition of combustion by-products is likely the dominant source of PAHs in the watersheds that drain to the greater Los Angeles coastal region, and this source is consistent during all portions of storm-water runoff. Several additional ratios have been used to assess the different sources of PAHs. Takada et al. [37] used methylated/parent PAH ratios as indicators of PAH sources. Results showed that PAHs in runoff from residential streets had a more significant contribution from atmospheric fallout of other combustion products. Zakaria et al. [38] explained their low ratios of methylphenanthrene to phenanthrene (MP/P) (<0.6) to mean that combustion-derived PAHs are transported atmospherically for a long distance and serve as background contamination. The ratios of methylphenanthrene to phenanthrene in our study (0–0.2) also suggest a strong contribution of aged urban aerosols to overall PAH loads [39,40,41]. Watersheds in the greater Los Angeles area are heavily urbanized; therefore, ample opportunity exists for combustion-derived aerosols that generate particulate matter to be deposited on land surfaces. The petrogenic signature seen in the Dominguez Channel can be explained by the presence of slightly different sources in this watershed. The Dominguez watershed contains a high density of oil refineries and other industrial land uses that drain directly to the Ports of Los Angeles and Long Beach. The presence of multiple oil refineries discharging to a single stream explains the concentration of petrogenic PAHs in this area.

Conclusions based on ratios of specific PAH compounds should be used with some caution, especially because a relatively limited set of PAHs were analyzed in this study. Furthermore, if reference (or source) samples were not analyzed, it is always a good idea to use these ratios on a relative basis. Nevertheless, the preponderance of evidence from this study, combined with the well-documented fact that atmospheric deposition (both wet and dry) is the major source of contamination in arid and semiarid climates, such as that existing in southern California [17,42], supports the conclusions of this study: The predominant source of PAHs in urban storm water in the greater Los Angeles area is from aerial deposition and subsequent wash-off of PAHs associated with combustion byproducts.

Acknowledgement—The authors would like to thank Jay Shrake, Sean Porter, Richard Rusnik, and the rest of the MacTec Engineering field crews for their assistance and dedication in collecting storm-water samples. Funding for this study was provided by the Los Angeles Regional Water Quality Control Board, Western States Petroleum Association, Los Angeles Contaminated Sediments Task Force, City of Los Angeles, Los Angeles Department of Water and Power, Los Angeles County Sanitation Districts, City of Carson, and the Southern California Coastal Water Research Project.

REFERENCES

1. Lehr RE, Jerina DM. 1977. Metabolic activation of polycyclic aromatic hydrocarbons. *Arch Toxicol* 39:1–6.
2. Bjorseth A, Ramhal T, eds. 1985. *Handbook of Polycyclic Aromatic Hydrocarbons-Emission Sources and Recent Progress in Analytical Chemistry,* Vol 2. Marcel Dekker, New York, NY, USA.
3. Crunkilton RL, DeVita WM. 1997. Determination of aqueous concentrations of polycyclic aromatic hydrocarbons (PAHs) in an urban stream. *Chemosphere* 35:1447–1463.
4. Karahalil B, Burgaz S, Fisek G, Karakaya AE. 1998. Biological monitoring of young workers exposed to polycyclic aromatic hydrocarbons in engine repair workshops. *Mutation Research—Genetic Toxicology and Environmental Mutagenesis* 412:261–269.
5. Zeng EY, Vista CL. 1997. Organic pollutants in the coastal environment off San Diego, California. 1. Source identification and assessment by compositional indices of polycyclic aromatic hydrocarbons. *Environ Toxicol Chem* 16:179–188.
6. Su MC, Christensen ER, Karls JF. 1998. Determination of PAH sources in dated sediments from Green Bay, Wisconsin by a chemical mass balance model. *Environ Pollut* 99:411–419.
7. Daskalakis KD, O'Connor TP. 1995. Distribution of chemical concentrations in U.S. coastal and estuarine sediment. *Mar Environ Res* 40:381–398.
8. Menzie CA, Hoeppner SS, Cura JJ, Freshman JS, LaFrey EN. 2002. Urban and suburban storm water runoff as a source of polycyclic aromatic hydrocarbons (PAHs) to Massachusetts estuarine and coastal environments. *Estuaries* 25:165–176.
9. Mai B, Qi S, Zeng E, Yang Q, Zhang G, Fu J, Sheng G, Peng P, Wang Z. 2003. Distribution of polycyclic aromatic hydrocarbons in the coastal region off Macao, China: Assessment of input sourc-

es and transport pathways using compositional analysis. *Environ Sci Technol* 37:4855–4863.

10. Eaganhouse RP, Simoneit BRT, Kaplan IR. 1981. Extractable organic matter in urban stormwater runoff. 2. Molecular characterization. *Environ Sci Technol* 15:315–326.
11. Hoffman EJ, Mills GL, Latimer JS, Quinn JG. 1984. Urban runoff as a source of polycyclic aromatic hydrocarbons to coastal waters. *Environ Sci Technol* 18:580–587.
12. Soclo HH, Affokpon A, Sagbo A, Thomson S, Budzinski H, Garrigues P, Matsuzawa S, Rababah A. 2002. Urban runoff contribution to surface sediment accumulation for polycyclic aromatic hydrocarbons in the Cotonou Lagoon, Benin. *Polycyclic Aromatic Compounds* 22:111–128.
13. Burns WA, Mankiewicz PJ, Bence AE, Page DS, Parker KR. 1997. A principal-component and least-squares method for allocating polycyclic aromatic hydrocarbons in sediments to multiple sources. *Environ Toxicol Chem* 16:1119–1131.
14. Gigliotti CL, Dachs J, Nelson ED, Brunciak PA, Eisenreich SJ. 2000. Polycyclic aromatic hydrocarbons in the New Jersey coastal atmosphere. *Environ Sci Technol* 34:3547–3554.
15. Larsen RK, Baker JE. 2003. Source apportionment of polycyclic aromatic hydrocarbons in the urban atmosphere: A comparison of three methods. *Environ Sci Technol* 37:1873–1881.
16. Mobility Monitoring Program. 2003. Annual report on freeway mobility and reliability. Office of Operations, Federal Highway Administration and the Texas Transportation Institute, College Station, TX, USA.
17. Sabin L, Schiff K. 2004. Atmospheric concentrations of PAH, pesticides and other semi-volatile organic compounds in the Los Angeles coastal region. In Hallock D, Weisberg SB, eds, *Southern California Coastal Water Research Project Annual Report 2003–04*. Westminster, CA, USA, pp 61–72.
18. Naumova YY, Eisenreich SJ, Turpin BJ, Weisel CP, Morandi MT, Colome SD, Totten LA, Stock TH, Winer AM, Alimokhtari S, Kwon J, Shendell D, Jones J, Maberti S, Wall SJ. 2002. Polycyclic aromatic hydrocarbons in the indoor and outdoor air of three cities in the U.S. *Environ Sci Technol* 36:2552.
19. Park J-S, Wade TL, Sweet ST. 2002. Atmospheric deposition of PAHs, PCBs, and organochlorine pesticides to Corpus Christi Bay, Texas. *Atmos Environ* 36:1707.
20. Ackerman D, Weisberg SB. 2003. Relationship between rainfall and beach bacterial concentrations on Santa Monica Bay beaches. *Journal of Water and Health* 1:85–89.
21. Mahler BJ, Van Metre PC, Wilson JT. 2004. Concentrations of polycyclic aromatic hydrocarbons (PAHS) and major trace elements in simulated rainfall runoff from parking lots, Austin, Texas, 2003. U.S. Geologic Survey Open File Report 2004-1208. Final Report. Austin, TX.
22. Schiff K, Sutula M. 2004. Organophosphate pesticides in stormwater runoff from southern California (USA). *Environ Toxicol Chem* 23:1845–1821.
23. Characklis GW, Wiesner MR. 1997. Particles, metals, and water quality in runoff from large urban watersheds. *Journal of Environmental Engineering* 123:753–759.
24. Leecaster M, Schiff K, Tiefenthaler L. 2001. Assessment of efficient sampling designs for urban stormwater monitoring. *Water Res* 36:1556–1564.
25. U.S. Environmental Protection Agency. 1991. Methods for the determination of PAHs in environmental samples. EPA/600/4-91/010. Office of Research and Development, Washington, DC.
26. Sokal RR, Rohlf FJ. 1969. *Biometry*. W.H. Freeman, San Francisco, CA, USA.
27. Bertrand-Krajewski J, Chebbo G, Saget A. 1998. Distribution of pollutant mass versus volume in stormwater discharges and the first flush phenomenon. *Water Res* 32:2341–2356.
28. Maher WA, Aislabie J. 1992. Polycyclic aromatic hydrocarbons in nearshore sediments of Australia. *Sci Total Environ* 112:143–164.
29. Lake JL, Norwood C, Dimock C, Bowen R. 1979. Origins of polycyclic aromatic hydrocarbons in estuarine sediments. *Geochim Cosmochim Acta* 43:1847–1854.
30. Gschwend PM, Hites RA. 1981. Fluxes of polycyclic aromatic hydrocarbons to marine and lacustrine sediments in the northeastern United States. *Geochim Cosmochim Acta* 45:2359–2367.
31. Steinberger A, Schiff KC. 2003. Characteristics of effluents from large municipal wastewater treatment facilities between 1998 and 2000. In Hallock D, ed, *Southern California Coastal Water Research Project Annual Report 2001–02*. Southern California Coastal Water Research Project, Westminster, CA, USA, pp 2–12.
32. Noblet JA, Zeng EY, Baird R, Gossett RW, Ozretich RJ, Phillips CR. 2003. *Southern California Bight 1998 Regional Monitoring Program: VI. Sediment Chemistry*. Southern California Coastal Water Research Project, Westminster, CA, USA.
33. Steinberber A, Stein ED, Schiff KC. 2003. Characteristics of dredged material disposal to the southern California bight between 1991 and 1997. In Hallock D, ed, *Southern California Coastal Water Research Project Annual Report 2001–02*. Southern California Coastal Water Research Project, Westminster, CA, USA, pp 47–57.
34. Smith JA, Seivers M, Huang S, Yu SL. 2000. Occurrence and phase distribution of polycyclic aromatic hydrocarbons in urban storm-water runoff. *Water Sci Technol* 42:383–388.
35. Ngabe B, Bidleman TF, Scott GL. 2000. Polycyclic aromatic hydrocarbons in storm runoff from urban and coastal South Carolina. *Sci Total Environ* 255:1–9.
36. Colombo JC, Pelletier E, Brochu C, Khalil M. 1989. Determination of hydrocarbon sources using n-alkane and polyaromatic hydrocarbon distribution indexes. Case study: Rio de La Plata Estuary, Argentina. *Environ Sci Technol* 23:888–894.
37. Takada H, Onda T, Oguru N. 1990. Determination of polycyclic aromatic hydrocarbons in urban street dusts and their source materials by capillary gas chromatography. *Environ Sci Technol* 24:1179–1186.
38. Zakaria MP, Takada H, Tsutsumi S, Ohno K, Yamada J, Kouno E, Kumata H. 2002. Distribution of polycyclic aromatic hydrocarbons (PAHs) in rivers and estuaries in Malaysia: A widespread input of petrogenic PAHs. *Environ Sci Technol* 36:1907–1918.
39. Nielsen T. 1996. Traffic contribution of polycyclic aromatic hydrocarbons in the center of a large city. *Atmos Environ* 30:3481–3490.
40. Simo R, Grimalt JO, Albaiges J. 1997. Loss of unburned-fuel hydrocarbons from combustion aerosols during atmospheric transport. *Environ Sci Technol* 31:2697–2700.
41. Hwang H, Wade TL, Sericano JL. 2003. Concentrations and source characterization of polycyclic aromatic hydrocarbons in pine needles from Korea, Mexico, and United States. *Atmos Environ* 37:2259–2267.
42. Gunther AJ, Davis JA, Phillips DJH. 1987. An assessment of the loading of toxic contaminants to the San Francisco Bay Delta. Technical Report. San Francisco Estuary Institute, Richmond, CA, USA.

Contribution of trace metals from atmospheric deposition to stormwater runoff in a small impervious urban catchment

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ABSTRACT

The contribution of atmospheric deposition to emissions of trace metals in stormwater runoff was investigated by quantifying wet and dry deposition fluxes and stormwater discharges within a small, highly impervious urban catchment in Los Angeles. At the beginning of the dry season in spring 2003, dry deposition measurements of chromium, copper, lead, nickel, and zinc were made monthly for one year. Stormwater runoff and wet deposition samples also were collected, and loading estimates of total annual deposition (wet + dry) were compared with annual stormwater loads. Wet deposition contributed 1% to 10% of the total deposition inside the catchment, indicating the dominance of dry deposition in semi-arid regions such as Los Angeles. Based on the ratio of total deposition to stormwater, atmospheric deposition potentially accounted for as much as 57% to 100% of the total trace metal loads in stormwater within the study area. Despite potential bias attributable to processes that were not quantified in this study (e.g., resuspension out of the catchment or sequestration within the catchment), these results demonstrate atmospheric deposition represents an important source of trace metals in stormwater to waterbodies near urban centers.

INTRODUCTION

Urban stormwater runoff can be highly contaminated with heavy metals and other toxic compounds, representing a significant non-point source of pollution to waterbodies within and adjacent to urban centers (Sansalone and Buchberger 1997, Smullen *et al.* 1999, Buffleben *et al.* 2002). In Southern California, mass emissions from urban stormwater runoff can be higher than from point sources, e.g., wastewater treatment plants and industrial discharges (Schiff *et al.* 2000). Furthermore, urban stormwater runoff can be toxic to aquatic organisms, and trace metals may be one of the constituents responsible for this toxicity (Marsalek *et al.* 1999, Schiff *et al.* 2002, Greenstein *et al.* 2004).

While future water quality improvements in urban areas may depend on contaminant reduction from stormwater, many of the trace metal sources to urban stormwater have not been well characterized. In semi-arid regions such as Southern California, pollutants may build-up on impervious surfaces during the extended dry season, and subsequently wash-off into nearby waterbodies once the wet season begins. Atmospheric deposition may be especially important as a source of pollutants to stormwater in these regions because significant quantities of trace metals and other pollutants are emitted into the atmosphere daily (SCAQMD 2003), and the ultimate fate of the trace metals in particular is unknown.

Yet despite this potential, there are relatively few studies specifically targeting the pollutant contribution of atmospheric deposition to urban stormwater runoff in Los Angeles. The majority of atmospheric deposition research has focused on areas such as the Great Lakes and Chesapeake Bay regions (Lin *et al.* 1993, Baker *et al.* 1997, Paode *et al.* 1998). These areas have different atmospheric emissions and climatic parameters, and greater precipitation than Southern California, which may increase the importance of wet vs. dry deposition. Studies specific to urban atmospheric deposition have been limited even though urban areas have been shown to have higher deposition rates for a number of pollutants, including trace metals (Galloway *et al.* 1982, Yi *et al.* 2001). The present research was designed to quantify the contribution of atmospheric deposition of trace metals to stormwater loadings in a small urban catchment in Los Angeles.

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METHODS

Los Angeles has a semi-arid climate, with an average annual rainfall of 33 cm. Typically, the bulk of this precipitation occurs from December to March. Starting with the beginning of the dry season in May 2003 and continuing for one year, dry deposition and atmospheric concentrations of chromium, copper, nickel, lead and zinc were measured for 48-hours once a month, on days without rain within a defined catchment in Los Angeles. Concentrations of trace metals in rain and stormwater within the catchment were measured from December 2003 to March 2004. The data were used to estimate the contribution of atmospheric deposition to stormwater loadings within the catchment. The site was selected to minimize sources of trace metals to stormwater within the catchment other than urban background atmospheric deposition.

Site description

The catchment was located in the San Fernando Valley of Los Angeles, California, within the grounds of a water reclamation plant. This site was suitable for this study as (1) the land surface was relatively flat; (2) the plant was surrounded by an earthen berm, preventing surface runoff from surrounding areas from entering the catchment; (3) sources of metals inside the plant were limited because of restricted access and lack of major industrial activities within the plant. Virtually all of the surface flow from the catchment was routed through a single catch basin, which was the site of runoff collection. The estimated drainage area to the catch basin was 5 ha based upon facility storm drain plans, discussions with the Plant Engineer, visual inspection, and on site measurements. The drainage area consisted primarily of impervious surfaces including asphalt roads, concrete sidewalks, and concrete structures with monolithic poured foam roofs. Unpaved dirt and vegetated areas covered <20% of the drainage area. A runoff coefficient of 1.0 was assumed because pervious areas were not subject to substantial infiltration. Evaluation of this assumption led to minimal bias and any overestimation of the runoff volume would result in conservative estimates of stormwater discharges. Traffic inside the plant was limited to ~50 vehicles per day, and streets were cleaned weekly.

Instrumentation

Dry deposition measurements were made using a modification of surrogate surfaces used by Paode *et al.* (1998) and Lin *et al.* (1993). Surrogate surfaces for this study were comprised of a circular PVC deposition plate, 33 cm in diameter, with a sharp edge (<10 degree angle), covered with a Mylar® sheet coated with Apezion L grease. The grease was liquefied by heating and then painted onto the Mylar® film to obtain a thin, uniform 10 mm layer. During sampling, the plate was mounted onto a tripod at a height of 2 m. Atmospheric concentrations of trace metals on total suspended particulate (TSP) were collected using a filter based sampling system attached to a vacuum pump. The open-faced inlet was loaded with a 37 mm, 2.0 μm pore Teflon® filter, and sampling was done at a flow rate of 10 l/min. The open-faced inlet was expected to reduce large particle losses to the walls and inlets typical of conventional impactor samplers. Wind speed and direction, temperature, and relative humidity were measured using a portable meteorological station (PortLog, Rain Wise, Inc., Bar Harbor, Maine).

Event-based wet deposition samples were collected using an automated rainwater collector developed by the National Atmospheric Deposition Program (NADP; 1997). The cover opened during periods of precipitation and closed when precipitation ended, eliminating evaporation from the sampler and preventing contamination of the sample. A precleaned container was used for each event.

Flow-weighted composite stormwater samples were collected during each storm in 500 ml plastic bottles using an ISCO 6700 automated stormwater sampler, which also logged flow to determine runoff quantity.

Sample preparation and analysis

For the deposition plates, Mylar® sheets were cut into 30 cm diameter circles, wiped with methanol and soaked in 10% nitric acid followed by methanol for 5 min each, then rinsed with distilled water, and allowed to air dry. Each sheet was coated with a thin layer of grease, mounted on a deposition plate, and stored in clean, airtight containers for transport to the field. After sampling, the Mylar® sheets were removed, folded (greased side inward), and placed inside a clean glass jar. In the laboratory, Mylar® sheets were cut into ten smaller pieces and rinsed three successive times with 15 ml of n-hexane. The rinses were combined into a 50 ml centrifuge tube. The Mylar pieces were then rinsed with 5% Optima Grade nitric acid and the acid and hexane rinses were combined. The hexane was evaporated in a

50°C water bath and the sample was acid-digested at 65°C under sonication for a minimum of 24 hours.

Prior to sampling, a clean Teflon® filter was loaded into the TSP sample holder, and the sample holder was stored in a clean plastic bag for transport to the field. After sampling, the filter was stored in a clean petri dish prior to analysis. In the laboratory, Teflon® filters were placed into clean 15 ml plastic centrifuge tubes and 10 ml of 5% Optima Grade nitric acid was added and the tubes capped tightly. The samples were acid-digested at 65°C under sonication for a minimum of 24 hours.

For wet deposition and stormwater analyses, collection vessels were cleaned with soap and water, soaked in 10% nitric acid and rinsed with distilled water. All stormwater samples from a given storm were acidified to pH 2 with ultra-pure nitric acid and stored at 4°C. A representative composite from each storm was digested by acidification to pH <2 using HNO_3 for a minimum of 16 hours.

All acid-digested samples were transferred to a centrifuge tube and analyzed for metals per EPA Method 200.8 using inductively coupled plasma-mass spectroscopy. Method detection limits (MDL) ranged from 0.5 - 1.0 ng corresponding to $<0.01 \mu g/m^2$/day for flux and <0.03 ng/m^3 for concentration based on the sampling times and air volumes collected. The MDL for metals in precipitation and stormwater was <0.1 μ/L for all metals. A five-point external calibration curve, laboratory blank, matrix spike, and matrix spike duplicate were measured with each batch of fifteen or less samples to ensure quality. Matrix spike recoveries were within 99-107% for all metals. Matrix spike duplicates were within 10% of the original spike for all metals (relative percent difference or RPD). All laboratory blanks were nondetectable. Field blanks (greased Mylar® sheets mounted on a deposition plate, Teflon® filters loaded into a TSP sampling cartridge, stormwater sample bottles filled with distilled water) were prepared, taken to the field, and analyzed along with the samples. All field blanks contained detectable levels of trace metals, and all samples were corrected for their respective field blank. Field blank corrections were typically <20% of the sample mass for copper, lead and zinc, but up to 100% of sample mass for chromium and nickel. Field duplicates indicated the precision of the deposition plates for each of the five metals, on average, was 31% (chromium), 25% (copper), 24% (lead), 87% (nickel) and 47% (zinc) RPD. This was an acceptable level of precision for field duplicates because differences of less than a factor of two between fluxes measured during different sampling events were not considered significant.

Mass loading calculations

Annual dry deposition mass loadings were calculated for each metal by multiplying the mean daily flux from each sampling event by the number of dry days between that sampling event and the next. These loadings were then summed to obtain the total annual load inside the catchment. It was assumed no dry deposition occurred during periods of rain. Any errors introduced by this assumption would be small because of the limited number of days with precipitation that occurred during the year.

The annual event mean concentration (EMC) was calculated for both rainwater and stormwater using Equation 1:

$$C_m = \frac{\sum_{i=1}^{n}(C_i V_i)}{\sum_{i=1}^{n} V_i} \qquad (1)$$

Where: C_m = Annual EMC for population j; C_i = Concentration during storm event i; V_i = Weighting factor - total volume sampled for event i; and n = Number of storm events sampled.

For wet deposition, the total mass loading for each metal was then calculated by multiplying the rainwater annual EMC by the area of the catchment and the total volume of rainfall during the year, which was obtained from published precipitation data from the Sepulveda Dam Rain Gauge (NOAA 2003, 2004), located less than 1.5 km from the catchment.

The individual wet deposition flux for each storm was calculated by multiplying the rainwater EMC by the catchment area and the volume of rainfall from a single storm. The mean storm flux provided a better comparison to the mean daily dry deposition flux because it more closely approximated a daily wet deposition value than the annual flux.

The mass loadings of trace metals in stormwater were calculated by multiplying the stormwater annual EMC (Equation 1) by the total volume of runoff during the storm season. To obtain stormwater volumes, standard hydrologic equations were used based on water level, slope, and roughness of the storm drain pipe from which samples were collected. Water level was measured using a bubbler. Pipe slope and roughness were provided by the facility manager. Flow estimates were calibrated using the relationship between rainfall, measured runoff volumes, and catchment area (Figure 1) to account for uncertainties in the inputs and assumptions used in the flow calculations (e.g., estimated slope, assumption of uniform flow, etc.). The relationship between rainfall and runoff was significant (R2 >0.99) and this regression was used to estimate runoff volume for storms that were not sampled, providing a good approximation of the total runoff volume inside the catchment for the entire year. From the y-intercept of the regression equation, when rainfall was <0.15 cm, runoff volume was zero. This was supported by observations at the site.

RESULTS

Dry atmospheric deposition fluxes and atmospheric concentrations

The TSP detection frequency was 100% for all trace metals except chromium, which was 92%. Atmospheric concentrations of trace metals on TSP were relatively stable over time (Figure 2a). The ranges of chromium, copper, lead, and zinc concentrations were all within factors of two during the year-long survey, while nickel concentrations were the most variable, but still within a factor of four.

Deposition plate detection frequencies were 100% for all metals except nickel, which was only detected in ~50% of the samples. With the exception of a single event, discussed below, dry deposition fluxes were normally distributed and not highly variable over time during the course of this study (Figure 2b). Dry deposition fluxes of all metals ranged within factors of 2 to 5 from their mean values. For all five metals, deposition fluxes were not significantly correlated with meteorological parameters including mean daily wind speed, temperature and relative humidity, maximum 10-minute wind speed, and antecedent rainfall days (p>0.05).

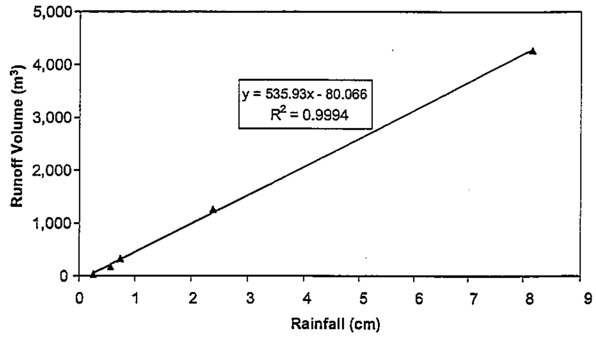

Figure 1. Linear Regression of rainfall vs. runoff measured in an urban Los Angeles catchment.

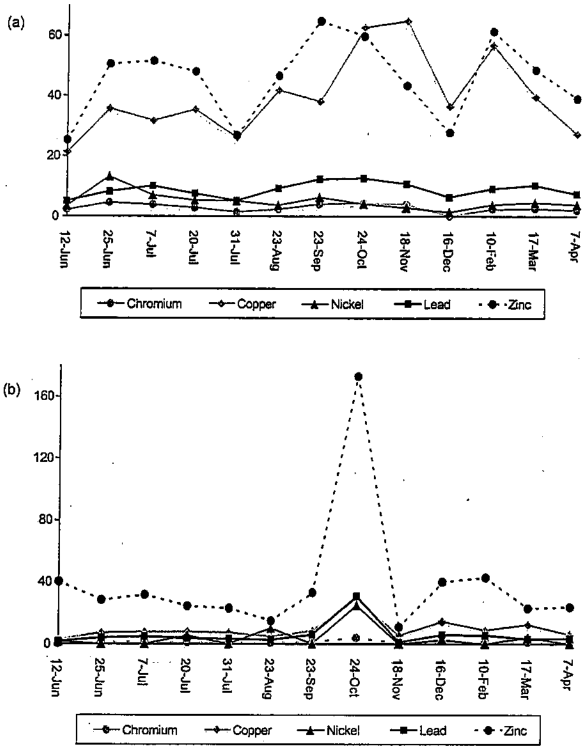

Figure 2. Time series of atmospheric concentrations (a) and dry deposition fluxes (b).

Forest fires in nearby mountains and offshore (i.e., Santa Ana) wind conditions occurred during a single sampling event in October. The highest fluxes for all metals were measured during this unique event. While the sample size limited the application of statistical tests of significance, it is interesting to note the fluxes measured during these unusual conditions of forest fires were factors of four (chromium and copper), six (zinc), eight (lead), and thirteen (nickel) times greater than the mean fluxes for all other sampling events.

Storm events

There were twenty-one rainfall events inside the catchment during the period from October 2003 through April 2004 (Figure 3). The total amount of rainfall from these events was 20 cm, with ~75% of the total rainfall for the season produced by only three storms. Samples of rainwater were collected from seven events, comprising ~70% of the total rainfall for the season. Ten rainfall events had sufficient volume to generate runoff within the catch-

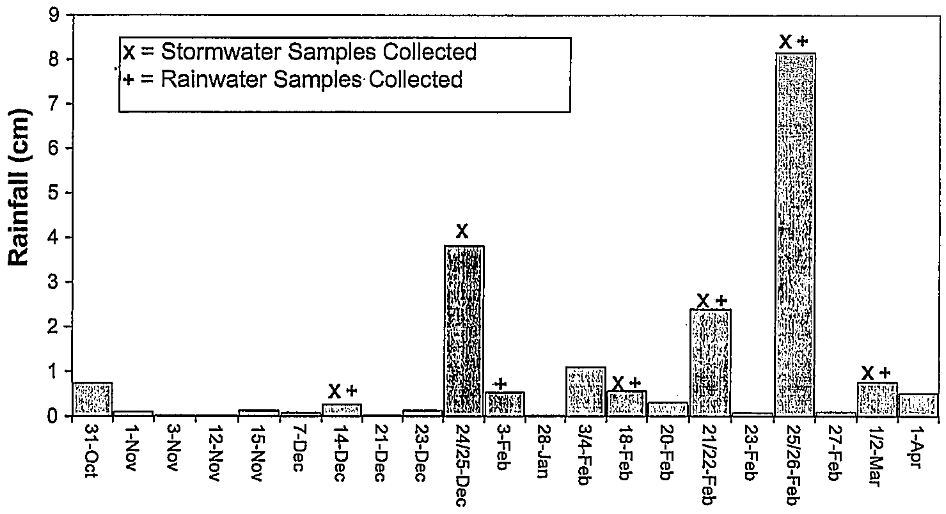

Figure 3. Rainfall in the catchment during the 2003-2004 storm season.

ment. Stormwater runoff samples were collected from six of these events, comprising ~50% of the total stormwater runoff inside the catchment during the season.

Detection frequencies in rainwater were low for most metals (Table 1). The highest concentrations for all metals were from the December 14, 2003 storm. The rainwater annual EMCs for each of the five metals were an order of magnitude lower than the rainwater concentrations from the December 14th storm. The relative proportions of metals in rainwater and on atmospheric TSP at the site were similar, indicating particle scavenging from the atmosphere was the likely source of these metals in precipitation (Figure 4).

Chromium, copper, nickel, lead, and zinc were detected in 100% of the stormwater runoff samples (Table 1). The highest concentrations of chromium and zinc were observed during the first sampled storm of the season (December 14, 2003), while the highest concentrations of copper, lead, and nickel were observed during the largest storm of the season (February 25, 2004). No relationship was evident between stormwater concentrations and parameters such as storm intensity, mean or peak flow rates, or antecedent rainfall days using regression models ($p>0.05$). Thus, the annual EMCs were used to estimate the loads of trace metals in stormwater runoff within the catchment.

Table 1. Concentrations of metals in precipitation and stormwater inside the catchment.

	Detection Frequency	Range (μg/l)	Annual Event Mean Concentration ± standard error (μg/l)
Precipitation			
Chromium	14%	b.d.- 2.2	0.09 ± 0.06
Copper	86%	b.d.-14	1.0 ± 0.6
Lead	29%	b.d.-5.0	0.15 ± .09
Nickel	71%	b.d.-3.2	0.19 ± 0.12
Zinc	43%	b.d.-210	7.8 ± 4.9
Stormwater			
Chromium	100%	2.1-20	3.1 ± 1.6
Copper	100%	5.9-37	27 ± 24
Lead	100%	1.2-16	12 ± 10
Nickel	100%	2.1-8.5	6.6 ± 5.2
Zinc	100%	32-320	160 ± 130

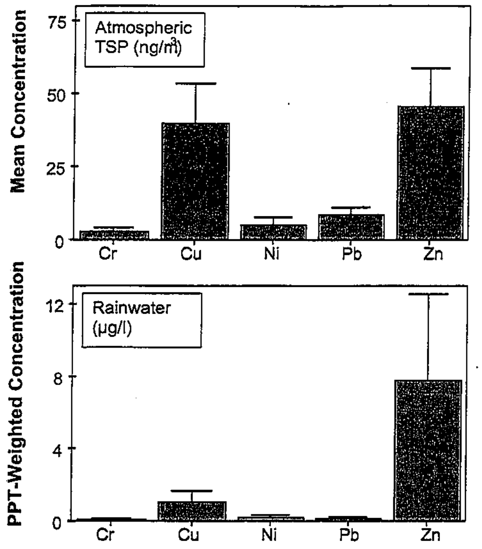

Figure 4. Mean trace metal concentrations on atmospheric TSP (a) and in precipitation measured in the catchment (b). Error bars represent the standard error of the mean.

Wet vs. dry deposition flux compared to stormwater loading estimates

Based on the total annual flux, dry deposition fluxes were substantially greater than wet deposition fluxes (Table 2). Wet deposition comprised 1% to 10% of the total annual deposition (wet+dry) inside the catchment. For all five metals, the mean wet deposition fluxes per storm (which typically lasted <1 day) were the same order of magnitude as the daily dry deposition fluxes (Table 2); the differences between individual storm wet fluxes and daily dry fluxes ranged from a factor of one to four for all metals. Only zinc had a higher mean wet deposition flux per storm compared with the daily dry deposition flux.

For each metal, the estimated mass of cumulative wet and dry atmospheric deposition to the catchment was similar to the estimated mass of trace metals discharged from the catchment through stormwater runoff (Table 3). Annual wet and dry deposition mass ranged from 57% (for zinc) to approximately 100% (for nickel and lead) of the

Table 2. Comparison between wet and dry deposition fluxes; ranges indicated in parenthesis.

	Wet Deposition Fluxes				Dry Deposition Fluxes			
	Annual Flux[a] (µg/m^2/yr)		Average Flux Per Storm (µg/m^2/storm)		Annual Flux[b] (µg/m^2/yr)		Average Daily Flux (µg/m^2/day)	
Metal								
Chromium	18	(0-45)	0.84	(0.07-1.6)	440	(250-620)	1.3	(0.7-1.8)
Copper	200	(0-520)	9.6	(0.9-18)	3,211	(1,800-4,600)	9.4	(5.3-14)
Lead	29	(0-74)	1.4	(0.1-2.6)	2,000	(390-3,600)	5.8	(1.1-10)
Nickel	38	(0-96)	1.8	(0.2-3.4)	1,300	(0-2,700)	3.7	(0-8.0)
Zinc	1,500	(0-3,900)	73	(6-140)	13,000	(4,900-22,000)	39	(14-64)

[a] October 2003 - April 2004 storm season
[b] May 2000 - April 2004 dry days

Table 3. Comparison of metal loadings from atmospheric deposition and stormwater runoff form may 2003 - April 2004 (g/year).

	Chromium	Copper	Nickel	Lead	Zinc
Wet Deposition	1	10	2	1	77
Dry Deposition	22	160	63	99	670
Stormwater Runoff	32	230	59	93	1300
Wet Deposition/Stormwater	0.03	0.04	0.03	0.01	0.06
Dry Deposition/Stormwater	0.69	0.70	1.07	1.06	0.52
Total Deposition(Wet+Dry)/Stormwater	0.72	0.74	1.10	1.08	0.57

Table 4. Comparison of measured air concentrations and fluxes of trace metals.

		Year	Chromium	Copper	Lead	Nickel	Zinc
Air Concentration (ng/m³)							
This Study		2003-2004	2.8	40	9	4.9	46
Los Angeles[a]		2002-2003	4.9	52	14	9.2	84
Los Angeles[b]		1998-1999	4.9	39	25	8.7	106
Total Deposition Flux: wet+dry (mg/m²/year)							
This Study		2003-2004	0.46	3.4	2.0	1.3	14.5
Lake Michigan[c]		1993-1994	0.20	1.9	1.6	0.6	6.0
Lake Superior[c]		1993-1994	0.21	3.1	1.5	0.8	8.8
Lake Erie (urban influenced)[c]		1993-1994	1.06	4.2	1.8	0.7	16.5
Chesapeake Bay Atmsopheric Deposition Study (non-urban)[d]	*Wye*	1990-1992	0.35	0.60	1.2	0.93	3.7
	Elms	1990-1992	0.25	0.67	1.1	0.71	3.5
	Haven Beach	1990-1992	0.20	0.85	1.2	1.1	7.1

[a] Lim *et al.* In press
[b] SCAQMD 2000.
[c] Sweet *et al.* 1998
[d] Baker *et al.* 1997

annual stormwater load. Annual dry deposition had the greatest potential for influencing stormwater mass emissions. Between 52% (for zinc) and approximately 100% (for nickel and lead) could be attributed to dry deposition alone. Moreover, rainwater concentrations were typically more than an order of magnitude lower than concentrations in stormwater runoff (Table 1).

DISCUSSION

Deposition fluxes

Atmospheric deposition of trace metals in semi-arid urban areas has unique characteristics not observed in previous studies (Table 4). The magnitude of the total deposition fluxes measured in urban Los Angeles in the present study was significantly higher than the fluxes measured at non-urban sites. This demonstrates the importance of anthropogenic sources in urban areas to higher deposition rates. Also, annual wet deposition fluxes were significantly lower than dry deposition fluxes, indicating the dominance of dry deposition in arid regions compared with other areas of the country. For example, wet deposition comprised only 1% to 10% of the total deposition flux in the present study, while measurements near Chesapeake Bay, where annual rainfall is typically three times that of Los Angeles, indicated wet deposition accounted for 20% to 50% of the total flux (Baker *et al.* 1997). Thus, dry deposition appears to be the dominant mechanism for transfer of atmospheric pollutants to watershed surfaces because of the low rainfall quantity in semi-arid regions like Los Angeles.

Temporal variability of dry deposition fluxes was low, in agreement with the findings of Sabin *et al.* (2004) for urban Los Angeles. The exception was the sampling event during Santa Ana winds and forest fires, which produced high fluxes for all metals, suggesting these anomalous conditions contributed to high fluxes. Other seasonal or meteorological variables were not correlated with fluxes due, in part, to the limited range of meteorological data resulting from the mild climate in Southern California. These results suggest daily, chronic conditions are primarily responsible for the majority of the dry deposition mass of trace metals in Southern California, as demonstrated by computer modeling developed by Lu *et al.* (2003).

While direct measurements of trace metal deposition fluxes have not been made extensively in Southern California, other data for Los Angeles indicate atmospheric TSP concentrations of trace metals at the study site were approximately half the concentrations measured at other urban sites in Los Angeles (Table 4). This result was not unexpected, since the site in the present study was located in a relatively suburban area of the city, and predominantly upwind of significant point and mobile sources. Because dry deposition is directly proportional to atmospheric concentrations near the surface (Hicks *et al.* 1984), higher deposition fluxes, and subsequently higher loadings from deposition, would be expected in heavily urbanized areas which have higher atmospheric concentrations.

Contribution to stormwater loading

The data from the present study indicate atmospheric deposition is an important contributor to stormwater runoff in urban catchments. Assuming the total quantity deposited onto the catchment was available for removal in stormwater runoff, atmospheric deposition potentially accounted for as much as 57% to 100% of the total trace metal loads in annual stormwater discharges. The finding that atmospheric deposition and stormwater loadings were approximately the same order of magnitude is in agreement with previous studies in this region (Lu *et al.* 2003, Sabin *et al.* 2004), and further demonstrates atmospheric deposition should not be ignored when assessing sources of trace metal pollution to contaminated waterbodies near urban centers.

There are several limitations to these findings. First, not all of the trace metal loads estimated from the average daily deposition measurements may be effectively available for immediate washoff. Some fraction of the deposited material may be removed from surfaces by means other than stormwater runoff due to processes we have not quantified, including resuspension out of the catchment or sequestration within the catchment through uptake by vegetation, accretion, adsorption, and other means (James and Shivalingaiah 1985, Novotny *et al.* 1985). Second, material remaining on the surface may not be completely washed off during storm events (Vaze and Chiew 2002). The amount of material mobilized during surface flows depends on a number of factors, such as surface type (e.g., impervious vs. natural surfaces), street cleaning practices, and rainfall intensity and duration (Novotny *et. al.* 1985, Vaze and Chiew 2002). This material may then be available for removal at a later time, and thus some portion of the runoff load may be due to materials that were deposited earlier than the period of measurement.

LITERATURE CITED

Baker, J.E., D.L Poster, C.A. Clark, T.M. Church, J.R. Scudlark, J.M. Ondov, R.M. Dickgut and G. Cutter. 1997. Loadings of atmospheric trace elements and organic contaminants to the Chesapeake Bay. pp. 171-194 *in*: J.E. Baker (ed.), Atmospheric Deposition of Contaminants to the Great Lakes and Coastal Waters. SETAC Press. Pensacola, FL.

Buffleben, M.S., K. Zayeed, D. Kimbrough, M.K. Stenstrom and I.H. Suffet. 2002. Evaluation of urban non-point source runoff of hazardous metals entering Santa Monica Bay, California. *Water Science and Technology* 45:263-268.

Galloway, J.N., J.D. Thornton, S.A. Norton, H.L. Volchok and R.A.N. Mclean. 1982. Trace metals in atmospheric deposition: a review and assessment. *Atmospheric Environment* 16:1677-1700.

Greenstein, D., L. Tiefenthaler and S. Bay. 2004. Toxicity of parking lot runoff after application of simulated rainfall. *Archives of Environment Contamination and Toxicology* 47:199-206.

Hicks, B., D. Lenschow and V. Mohnen. 1984. Wet and dry removal processes. pp. 88-93 *in*: Global Tropospheric Chemistry – A plan for Action. National Academy Press. Washington D.C.

James, W. and B. Shivalingaiah. 1985. Storm water pollution modeling: buildup of dust and dirt on surfaces subject to runoff. *Canadian Journal of Civil Engineering* 12:906-915.

Lim, J.H., L.D. Sabin, K.D. Stolzenbach and K.C. Schiff. In press. Mass size distributions and dry deposition fluxes of trace metals measured in the Los Angeles air basin.

Lin, J.-M., G.-C. Fang, T.M. Holsen and K.E. Noll. 1993. A comparison of dry deposition modeled from size distribution data and measured with a smooth surface for total particle mass, lead and calcium in Chicago. *Atmospheric Environment* 27:1131-1138.

Lu, R., R.P. Turco, K.D. Stolzenbach, S.K. Freidlander, C. Xiong, K. Schiff, L.L. Tiefenthaler and G. Wang. 2003. Dry deposition of airborne trace metals on the Los Angeles Basin and adjacent coastal waters. *Journal of Geophysical Research 108:4074.*

Marsalek, J., Q. Rochfort, B. Brownlee, T. Mayer and M. Servos. 1999. An exploratory study of urban runoff toxicity. *Water Science and Technology* 39, 33-39.

National Atmospheric Deposition Program (NADP). 1997. National Atmospheric Deposition Program/National Trends Network wet deposition in the United States 1996. Illinois State Water Survey. Champaign, IL.

National Oceanic and Atmospheric Administration (NOAA). 2004. Hourly precipitation data. ISSN 0364-6092. 54:1-4.

National Oceanic and Atmospheric Administration (NOAA). 2003. Hourly precipitation data. ISSN 0364-6092. 53:5-12.

Novotny, V., S.-M. Sung, R. Bannerman and K. Baum. 1985. Estimating nonpoint pollution from small urban watersheds. *Journal of the Water Pollution Control Federation* 57:339-348.

Paode, R.D., S.C. Sofuoglu, J. Sivadechathep, K.E. Noll and T.M. Holsen. 1998. Dry deposition fluxes and mass size distribution of Pb, Cu and Zn measured in Southern Lake Michigan during AEOLOS. *Environmental Science and Technology* 32, 1629-1635.

Sabin, L.D., K.C. Schiff, J.H. Lim and K.D. Stolzenbach. 2003 Atmospheric dry deposition of trace metals in the Los Angeles coastal region. pp. 50-60 *in*: D. Elmore and S.B. Weisberg (eds.), Southern California Coastal Water Research Project Biennial Report 2003-2004. Southern California Coastal Water Research Project. Westminster, CA.

Sansalone, J.J. and S.G. Buchberger, S.G. 1997. Partitioning and first flush of metals in urban roadway storm water. *Journal of Environmental Engineering* 123:134-143.

Schiff, K., M.J. Allen, E.Y. Zeng and S.M. Bay. 2000. Southern California. *Marine Pollution Bulletin* 41:76-93.

Schiff, K., S. Bay and C. Stransky. 2002. Characterization of stormwater toxicants from an urban watershed to freshwater and marine organisms. *Urban Water* 4:215-227.

Smullen, J.T., A.L. Shallcross and K.A. Cave. 1999. Updating the U.S. nationwide urban runoff quality database. *Water Science and Technology* 39:9-16.

South Coast Air Quality Management District (SCAQMD). 2000. Multiple air toxics exposure study in the South Coast Air Basin: MATES-II. Final report. SCAQMD. Diamond Bar, CA.

South Coast Air Quality Management District (SCAQMD). 2003 Air Quality Management Plan. http://www.aqmd.gov/aqmp/AQMD03AQMP.htm

Sweet, C.W., A. Weiss and S.J. Vermette. 1998. Atmospheric deposition of trace metals at three sites near the Great Lakes. *Water, Air, and Soil Pollution* 103:423-439.

Vaze, J. and F.H.S. Chiew. 2002. Experimental study of pollutant accumulation on an urban road surface. *Urban Water* 4:379-389.

Yi, S-M., U. Shahin, J. Sivadechathep, S.C. Sofuoglu and T.M. Holsen. 2001. Overall elemental dry deposition velocities measured around Lake Michigan. *Atmospheric Environment* 35:1133-1140.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the cooperation of Clayton Yoshida of the Los Angeles Bureau of Sanitation and of the staff of the Tillman Water Reclamation Plant (especially Dariush Vosooghi, Rick Sabath, and Rameswari Korand, who provided access to the facility; and Ed Lozon, who provided technical support). We acknowledge technical assistance from Dario Diehl of Southern California Coastal Water Research Project, and the laboratory analysis provided by CRG Laboratories, Inc. This project was funded in part by the Los Angeles County Department of Public Works, the City of Los Angeles, the Santa Monica Bay Restoration Project, the Regional Water Quality Control Board, the State Water Resources Control Board, and the U.S. Environmental Protection Agency Great Waters Program.

Dry deposition and resuspension of particle-associated metals near a freeway in Los Angeles

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ABSTRACT

Dry atmospheric deposition represents a potentially large source of pollutant metal contamination in urban stormwater runoff, yet there is a limited amount of research on the relationship between atmospheric emissions and water quality problems in urban areas. In Los Angeles, significant quantities of toxic materials are released into the atmosphere every day and paved road dust represents the largest source of particle-associated metal emissions to the atmosphere. In order to better understand the role of roadways as a source of localized metal deposition, we characterized the horizontal dry deposition patterns of chromium, copper, lead, nickel and zinc upwind and at increasing distances downwind of the I-405 Freeway in coastal Los Angeles. Dry deposition fluxes and atmospheric concentrations of these metals were highest at the site closest to the freeway, and reduced to approximately urban background concentrations between 10 and 150 m downwind of the freeway. Compared with urban background, atmospheric particle size distributions indicated the freeway was a significant source of these metals on large particles >6 µm in diameter, which deposit close to their source and account for the increased dry deposition flux rates observed near the freeway. The spatial pattern of measured deposition flux was well predicted by a relatively simple line-source Gaussian plume model modified to include particle deposition and resuspension. The model results indicated dilution by vertical dispersion of the plume was the most important mechanism regulating downwind concentrations and deposition.

INTRODUCTION

Dry atmospheric deposition near urban centers, especially in semi-arid regions such as southern California, represents a potentially important non-point source of particle-associated metals to waterbodies (Baker *et al.* 1997, Lu *et al.* 2003). Atmospheric particulate matter may be directly deposited onto the surface of a waterbody or may reach the waterbody indirectly through deposition onto the land surface during dry periods, followed by subsequent wash-off during storm events. Atmospheric deposition may be particularly important in the Los Angeles Air Basin, since air quality in this region, with a population greater than 17 million, ranks among the worst in the United States (SCAQMD 2000). Emission inventories of the basin indicate significant quantities of toxic materials are regularly released into the atmosphere (SCAQMD, 2003), and the ultimate fate of the heavy metals in particular is unknown.

In urban areas, emissions from paved roadways are a major source of atmospheric particulate matter (Dunbar 1976; Cowherd *et al.* 1977; Reider 1983; Cowherd and Englehart 1984, 1985). Investigation of the most recent emission inventories for the Los Angeles region by Stolzenbach *et al.* (2003) found resuspended dust represents the largest source of particle-bound pollutant metals in the Los Angeles region, with paved road dust representing the most significant fraction. Paved road dust originates from pavement wear and decomposition, dustfall, litter, mud and dirt carryout, spills, biological debris, and erosion from adjacent areas (Cowherd and Englehart 1984, Chow *et al.* 1990, Chow and Watson 1992). In an urban setting, vehicle exhaust, as well as particulate from vehicle brake and tire wear, is a source of zinc and copper in paved road dust (Watson and Chow 2000, Councell *et al.* 2004).

In response to human health concerns, air quality standards have been set for particles less than 10 µm in diameter; consequently, most research on road dust emissions has focused on particles in this size fraction (Cowherd and Englehart 1984, Kantamaneni *et al.* 1996, Venkatram and Fitz 1998, Fitz 2001). However, the results from a number of studies indi-

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cate that nearly 50% of road dust total suspended particulate matter (TSP) is due to particles larger than 10 µm (Ahuja *et al.* 1989; Houck *et al.* 1989, 1990). Moreover, particles greater than 10 µm in diameter are largely responsible for metal deposition (Lin *et al.* 1993, 1994; Paode *et al.* 1998; Zufall *et al.* 1998). Because coarse particles settle faster due to their greater inertia and gravitational settling, deposition of these particles is likely to occur relatively close to the source (Sehmel 1973). Previous studies have documented a pattern of locally high atmospheric concentrations of particulate matter near roadways using tracers and downwind direct measurements of air and ground surface concentrations (Claiborn *et al.* 1995; Hitchins *et al.* 2000; Zhu *et al.* 2002a, b); however, few studies have focused on particle deposition gradients near roadways, especially for particles larger than 10 µm.

In addition to deposition as a source of metal loading into water bodies, re-entrainment of suspended atmospheric particles contributes to pollutant dispersion and impacts the subsequent mass loading into water bodies. The size of particles that can be easily resuspended ranges from 1 µm to 50 µm in diameter. Resuspended particles are estimated to travel globally; for example, Asian dust has been identified in Hawaii (Parrington *et al.*, 1983) and Sahara dust in the central United States (Perry *et al.* 1997). According to Sternbeck *et al.* (2002), measured metal concentrations in air are generally similar to the chemical profiles of crustal elements. This result indicates resuspension may control particle abundance and chemical composition.

The re-entrainment and suspension of particles in the atmosphere may occur through several natural and anthropogenic processes. Meteorological conditions during and after deposition (e.g., wind speed and rain intensity) and surface characteristics, such as surface roughness and surface moisture, are important influences on natural resuspension (Nicholson 1988). Anthropogenic activities such as vehicular activities, agricultural activities and various cleaning operations induce resuspension (Kashparov *et al.* 1994, Garger *et al.* 1998).

Because of the difficulty of measuring concentrations under different atmospheric stability and roadway configurations, predictions of concentration and particulate dispersion near roadways have been made using line-source Gaussian plume models (Chock 1978, Horst 1978, Sistla *et al.* 1979). The most widely used versions of these models are the modified HIWAY (Zimmerman and Thompson 1975), HIWAY-2 (Petersen 1980), GM (Chock 1978), and CALINE-3 (Benson 1979). However, these models have been used primarily to estimate vapor phase concentrations of constituents such as carbon monoxide, and do not include deposition or resuspension.

This study was designed to gain a better understanding of the role of major roadways, such as a freeway, as a significant source of localized metal deposition to urban surfaces and to understand the role of resuspension in the net deposition and dispersion of particulate matter near roadways. To accomplish this goal, the following objectives were defined: 1) to characterize the horizontal dry deposition gradient and atmospheric concentrations of five pollutant metals (chromium, copper, lead, nickel, and zinc) near a major freeway in Los Angeles; 2) to compare atmospheric particle size distributions of these metals near a freeway with urban background values; and 3) to compare measured horizontal deposition fluxes with the predictions of a Gaussian line-source dispersion model modified to include deposition and resuspension.

METHODS

Sampling

The freeway site selected for this study was the I-405 freeway between Wilshire and Sunset Boulevards in West Los Angeles (Figure 1). This site was selected because: 1) this stretch of freeway runs perpendicular to the on-shore, southwest winds that dominate coastal Los Angeles during daytime in the spring; and 2) the I-405 freeway experiences heavy traffic volume, with an annual average daily traffic count of approximately 300,000 (CADOT, 2004). All sampling equipment was located along Constitution Boulevard, which runs perpendicular to the freeway.

Dry deposition flux of metals was measured simultaneously at 10 m (DW1), 150 m (DW2) and 450 m (DW3) downwind, and 150 m upwind (UP) of the I-405 Freeway over a three-week period in April and May, 2003. All deposition measurements were collected during daytime, high traffic hours (~8 a.m. to 5 p.m.) over a period of three to four days for a single sample, in order to obtain sufficient mass. Atmospheric concentrations of TSP were simultaneously collected at 2 downwind locations (DW1 and DW3) and analyzed for both particle mass and metal concentrations. Atmospheric concentrations of metals on four coarse particle size fractions were also measured at the downwind site

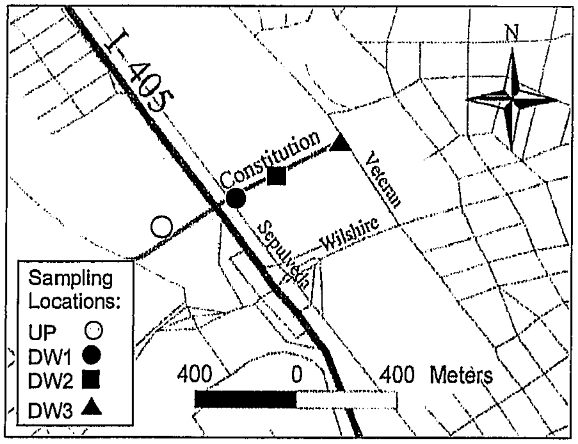

Figure 1. Map of the freeway site and sampling locations.

closest to the freeway (DW1) one day each week. All sampling took place during typical meteorological conditions for spring in Los Angeles during periods with no precipitation. Local wind data were utilized during sampling to confirm the upwind and downwind status of the sampling locations.

Four pieces of sampling equipment were used during this study. First, dry deposition flux measurements were made using a 33-cm diameter circular polyvinyl chloride (PCV) plate with a sharp edge (<10 degree angle), covered with a Mylar® sheet coated with a uniform 10-μm layer of Apiezon L grease. This surrogate surface has been used previously and is described in more detail elsewhere (Lim *et al.* 2006). The second piece of equipment was a filter-based sampling system attached to a vacuum pump used to collect TSP for measurement of atmospheric concentrations of metals. The open-faced inlet was loaded with a 37-mm, 2.0-μm pore Teflon® filter (Pall Life Science), and sampling was done at a flow rate of 10 L minute^{-1}. The third piece of sampling equipment was a portable meteorological station (PortLog, Rain Wise, Inc.), used to measure wind speed and direction, temperature, relative humidity and barometric pressure at the DW2 site. The fourth piece of sampling equipment was a Noll Rotary Impactor (NRI), used to collect size distributions of particulate matter for measurement of atmospheric metals concentrations. This instrument has been used previously to measure air concentrations on coarse particle size fractions and is described in detail in other studies (Mamane and Noll 1985, Noll *et al.* 1985, Lin *et al.* 1994). The NRI operates by simultaneously rotating four rectangular collector stages through the air at high velocity to collect particles directly from ambient air by impaction. Each collector stage is a different width to collect a different particle size fraction. The collector stages were mounted with Mylar strips, sized according to the width of the collector stage, which were coated with Apiezon L grease in the same manner as the Mylar for the deposition plates. The instrument was operated at 320 rpm, producing cut diameters of 6, 11, 20 and 29 μm for the four collector stages. To prevent overloading, the smallest collector stage (stage A) was changed every 2 hours, while the next largest collector stage (stage B) was changed every 4 hours. The two largest collector stages (stages C and D) were not changed during the ~8-hour collection period. The metal concentration of the particle size fraction smaller than 6 μm was obtained by subtracting the metal mass concentration collected on the NRI Stage with the cut diameter of 6 μm from the TSP metal mass concentration.

Prior to sampling, the Mylar was cut to the desired size, rigorously cleaned, prepared for deployment, and stored in airtight containers for transport to the field. After sampling, the Mylar was placed into clean plastic centrifuge tubes, rinsed three successive times with 15 ml of n-hexane to dissolve the Apiezon grease, and a final rinse of 5% Optima Grade nitric acid. The acid and hexane rinses were combined, the hexane was evaporated in a 50° C water bath, and the remaining acidified sample was then heated to 65° C under sonication for a minimum of 24 hours. TSP filters returned from the field did not require hexane rinses, but were directly digested using 5% Optima Grade nitric acid.

All acid-digested samples were analyzed for 26 metals per EPA Method 200.8 using inductively coupled plasma-mass spectroscopy (ICP-MS). Results reported in this study are for chromium, copper, lead, nickel and zinc, because these are the primary metals associated with water quality issues in southern California. Method detection limits were 0.5 ng for lead and 1 ng for all other metals, corresponding to a minimum detectable air concentration of 0.02 ng m^{-3} and a minimum detectable deposition flux of 0.004 mg m^{-2} day^{-1} for lead and 0.01 mg m^{-2} day^{-1} for all other metals. Laboratory blanks, analyzed with each batch of 15 samples, were consistently nondetectable. Field blanks were collected and analyzed along with each sampling event. Field blanks contained detectable levels of metals and all samples were corrected for their respective field blank. Field duplicates indicated the relative percent difference (RPD) between side-by-side deposition plates, on average, was 31% chromium, 25% copper, 87% nickel, 24% lead, and 47% zinc. These were acceptable levels of precision for field duplicates because differences of less than a factor of two between fluxes measured during different sampling events were not considered significant.

Image analysis

An image processing program was used to count particles and to obtain the particle size and mass distributions of the particles deposited on the NRI stage A (d_p >6μm) from photographs of the Mylar strips taken with an optical microscope (LW Scientific) set at a magnification of 100x. For each image the distribution of the aerodynamic particle diameter d_p was determined using

$$d_p = \frac{1}{\overline{S}_v}\left(\frac{\rho_p}{\rho_o S_D}\right)^{\frac{1}{2}} d_{PA} \qquad (1)$$

Where d_{PA} is the equivalent projected area diameter measured by the image analysis, S_D is a dynamic shape factor set equal to 1.41 (Davies, 1979), ρ_p is the particle density assumed to be 1800 kg m^{-3}, ρ_0 is a unit particle density of 1000 kg m^{-3}, and $\overline{S}_v$ is the volume averaged shape factor set equal to 1.61 for urban sites (Lin *et al.* 1994, Tai *et al.* 1999). The aerodynamic diameter (d_p) and assumed particle density (ρ_p) were then used to calculate total particle volume and mass. The atmospheric concentration was obtained using the known NRI rotation speed and empirically determined collection efficiencies (Noll *et al.* 1985).

Modeling

The model used in this study was based on the ground-level line-source Gaussian plume model, formulated to consider metal deposition and resuspension (Horst 1978). Assumptions for the model were constant emission rate, constant wind speed both in time and space, neutral stability (stability D), and a flat and unobstructed ground surface (Masters 1998). The emissions from the freeway were assumed to form a single, continuously emitting, infinite line source with metal mass flow per unit length q_o (mg m^{-1} second^{-1}).

With these assumptions, the metal concentration in the air down wind at distance x and elevation z from the line source can be described by the following:

$$C(x,z) = \frac{1}{u\sqrt{\pi/2}}\left\{\frac{q_o}{\sigma_z(x)}\exp\left(\frac{-z^2}{2\sigma_z^2(x)}\right) + \int_0^x \frac{m(x)}{\sigma_z(x-\xi)}\exp\left(\frac{-z^2}{2\sigma_z^2(x-\xi)}\right)d\xi\right\} \qquad (2)$$

where u is the wind speed; $m(x)$ is the net metal mass flow per unit ground surface area (mg m^{-2} second^{-1}) at a distance x resulting from deposition and resuspension; $\sigma_z(x) = c(x)^d + f$ is the vertical standard deviation of the plume at a distance x from the plume source, where c, d, and f are constants that are a function of the stability classification (Masters 1998).

The net metal mass flow to the atmosphere per unit ground surface area resulting from deposition and resuspension is computed by:

$$m(x) = \Lambda G(x) - V_d C(x,0) \qquad (3)$$

where $G(x)$ mg m^{-2} is the surface metal mass per unit area, Λ second^{-1} is a specified resuspension rate, $C(x, 0)$ is the ground level metal concentration in the air, and V_d is a specified deposition velocity. The change in surface contamination with time is then given by:

$$\frac{dG(x)}{dt} = -m(x) = V_d C(x,0) - \Lambda G(x) \quad G(x) = 0 \text{ at } t = 0 \quad (4)$$

The build-up of $G(x)$ is the only time dependent process in the model, although changes in $G(x)$ drive changes in all other variables. A steady state condition where $m(x) = 0$ and $\Lambda G(x) \approx V_d C(x,0)$ is reached in a time of about 1/Λ. The steady state atmospheric metal concentration is given by the first term in equation 2 and is independent of the deposition velocity V_d. and the resuspension rate Λ, but the deposition flux is $V_d C(x,0)$.

Model calculations used a wind speed u = 2 m second^{-1}, which was the average value during the observation period, and a deposition velocity V_d = 0.01 m second^{-1}, which was the mean of the flux-averaged deposition velocities calculated for each metal by dividing the measured deposition flux by the air concentration measured by the TSP sampler at both DW1 and DW3 (Table 1).

RESULTS

There was little day-to-day variability in the meteorological data measured during the sampling at the freeway site (Table 2), and even hour-to-hour variability during the 8 a.m. to 5 p.m. sampling period within the same day was low. Because meteorological conditions were stable throughout the study period, this

Table 1. Measured flux-averaged deposition velocities for different metals.

Metal	*N*	Deposition Velocity (cm second^{-1})
Chromium	6	0.56 ± 0.1
Copper	6	1.4 ± 2
Lead	6	1.3 ± 0.5
Nickel	6	0.26 ± 0.2
Zinc	6	1.1 ± 0.4

study did not attempt to correlate these data with weekly concentration or deposition flux measurements. Wind direction remained predominately from the southwest on all sampling days, as expected for springtime in Los Angeles, maintaining the desired upwind and downwind locations of the sampling sites.

The highest measured deposition fluxes of all five metals were observed at the downwind site closest to the freeway (DW1; Table 3). For copper, lead and zinc, ANOVA indicated that variation between sites was significant ($p <0.002$). This variation was due entirely to the higher fluxes observed at DW1, based on the Tukey test for pairwise multiple comparisons ($p <0.003$). Mean fluxes at DW1 were higher than UP and DW3 by factors of two to five, depending on the metal. Mean fluxes at DW1 were higher than DW2 by factors of two to three for all five metals. In contrast, differences in fluxes measured at UP (considered to represent "urban background"), DW2, and DW3 were not significant for all five metals (ANOVA, $p >0.05$).

TSP metal concentrations were higher at the downwind site closest to the freeway (Figure 2a), although the differences between DW1 and DW3 were only significant for lead and zinc using the paired samples t-test ($p <0.02$). TSP particle mass concentrations were also consistently higher at the downwind site closest to the freeway (DW1) compared with the furthest site (DW3; Figure 2b), however differences between the sites were not statistically significant. Again, the sample size ($n = 3$) may have limited this study's ability to detect small differences between locations.

The mean particle size distribution differed between the site nearest the freeway and urban background sites located away from major freeways in Los Angeles, as measured by Lim *et al.* (2006; Figure 3). The primary difference was that more metal mass fraction was observed in the particle fraction >6 μm, especially for copper, lead, and zinc, at the freeway site,. At the urban background site, the majority of the mass fraction (approximately 75%) for all metals was observed in the particle size fraction <6 μm.

Image analysis of stage A NRI strips indicated the particle mass in the fraction >29 μm at the freeway site was relatively constant over time (Figure 4). In contrast, the size fraction >29 μm was absent during the morning period (7:00 a.m. to 11:00 a.m.) at the urban background site. The total particle mass concentration associated with particles >6 μm at the freeway site ranged between 23 and 31 μg m^{-3}, compared with 10 to 16 μg m^{-3} at the urban background

Table 2. Summary of mean meteorological data measured during sampling at the freeway site. Ten minute data were recorded. The 8-hour means are presented here, except as noted.

Week	Date	Temperature (°C)	Relative Humidity (%)	Wind Speed (m second^{-1})		Wind Direction From:
				Mean 8-hour	Range of 10-minute Max	
1	13-Apr-04	19 ± 1	63 ± 4	2.1 ± 0.6	0.4 - 7.2	Southwest
	14-Apr-04	19 ± 1	62 ± 4	2.1 ± 0.7	2.2 - 7.2	Southwest
	15-Apr-04	20 ± 1	62 ± 2	2.1 ± 0.7	2.7 - 6.7	Southwest
	16-Apr-04	18 ± 1	61 ± 5	2.1 ± 0.6	3.1 - 6.7	Southwest
2	19-Apr-04	18 ± 1	54 ± 4	2.4 ± 0.8	2.7 - 8.0	Southwest
	20-Apr-04	19 ± 1	60 ± 5	2.4 ± 0.7	2.7 - 7.2	Southwest
	21-Apr-04	19 ± 1	64 ± 3	2.4 ± 0.6	3.1 - 7.2	Southwest
3	28-Apr-04	21 ± 2	67 ± 7	2.2 ± 0.5	2.7 - 7.2	Southwest
	29-Apr-04	20 ± 1	55 ± 4	2.4 ± 0.5	3.1 - 7.2	Southwest
	30-Apr-04	19 ± 1	67 ± 5	2.7 ± 0.6	3.1 - 7.2	Southwest
	1-May-04	26 ± 1	38 ± 5	2.5 ± 0.4	4.0 - 6.3	Southwest

Table 3. Mean dry deposition flux ± standard deviation ($\mu g m^{-2} day^{-1}$) of trace metals measured at varying distances from the I-405 Freeway. N = 3 for all metals.

Location	Chromium	Copper	Nickel	Lead	Zinc
10 m Downwind (DW1)	4.3 ± 0.3	48 ± 8	3.1 ± 0.6	24 ± 3	140 ± 33
150 m Downwind (DW2)	2.4 ± 1.9	18 ± 7	1.0 ± 1.3	11 ± 4	45 ± 23
450 m Downwind (DW3)	2.5 ± 1.1	14 ± 3	1.2 ± 1.1	7.3 ± 1.8	38 ± 1
150 m Upwind (UP)	2.2 ± 0.5	11 ± 5	1.5 ± 0.9	7.9 ± 1.3	37 ± 10

site. The time variation of the total particulate mass concentration at the freeway site for particles >6 μm did not demonstrate any significant difference between times (ANOVA $p > 0.5$).

Good agreement between the steady state model calculation and measured deposition fluxes was obtained for chromium, copper, lead, and zinc, particularly within 200 m from the source (Figure 5). The data for nickel diverged from the model results, which was not surprising because of the expected absence of a nickel source at the freeway. Both the model and the measurement data indicated deposition and air concentrations return to background between 10 m and 150 m from the source; a result consistent with the findings of Zhu *et al.* (2002b) for ultra fine particles. Model calculations with $\Lambda = 0$ were nearly identical to the steady state solution, indicating that on the scale of this experiment, atmospheric dispersion was the major mechanism determining the spatial distribution of atmospheric metal concentration and metal deposition flux.

DISCUSSION

The findings of this study indicate that metal deposition rates, especially for copper, lead and zinc, increase in the immediate vicinity of a large freeway and quickly reduce to urban background deposition rates between 10 m and 150 m down-

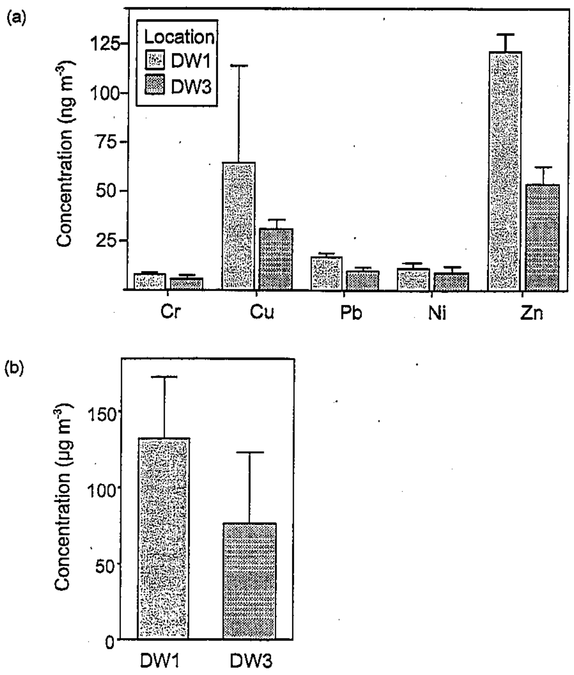

Figure 2. Mean atmospheric TSP concentrations 10 m downwind (DW1) and 450 m downwind (DW3) from the I-405 Freeway for metals (a) and particulate matter mass (b). Error bars represent the standard deviation for the mean.

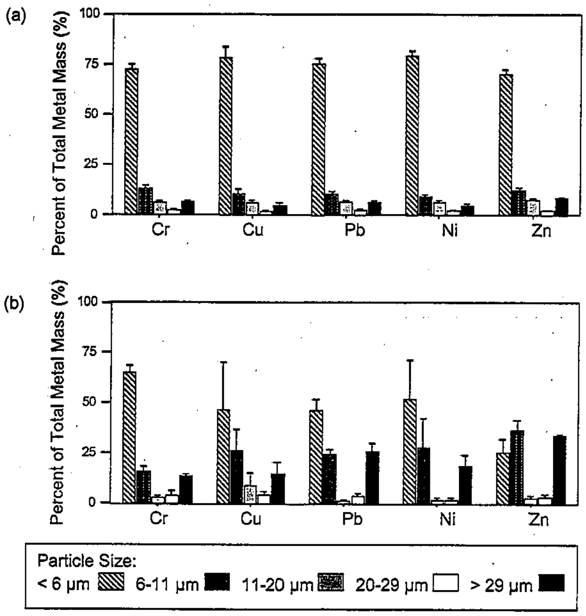

Figure 3. Mean distributions of metal concentrations on five particle size fractions as a percent of the total metal mass measured at urban background sites as measured by Lim et al. 2006 (a) and 10 m downwind of the I-405 Freeway (b). Error bars are the standard error of the mean.

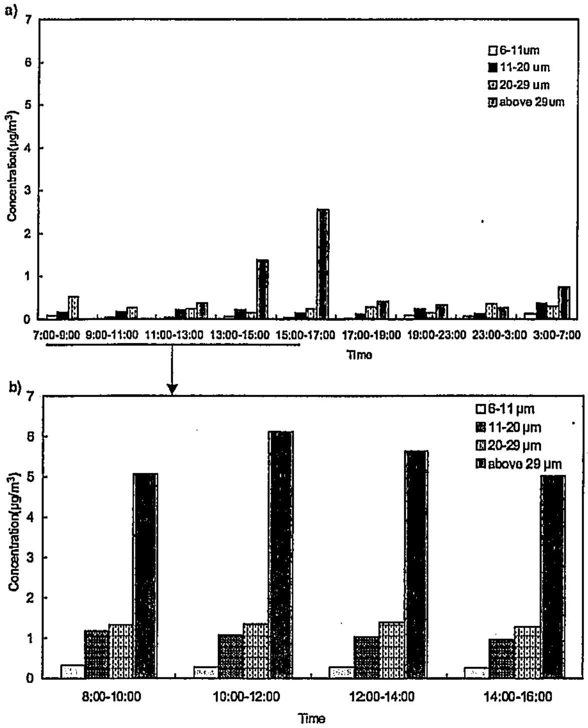

Figure 4. Diurnal pattern of particulate mass concentration measured using image analysis: urban background site as measured by Lim et al. 2006 (a); freeway site, this study (b).

wind of the freeway. These results are similar to the observations of Zhu *et al.* (2002b) for ultra fine particle concentrations (d_p <0.1 µm) measured downwind of the same freeway. In that study, high concentrations near the freeway reduced to urban background within 300 m. This present study's results also suggest that sources of deposited copper, lead, and zinc, which had higher fluxes near the freeway, may be different from chromium and nickel sources, which were not increased near the freeway. The freeway likely represents a source of large particles containing copper, lead and zinc due to resuspension of road dust as vehicles travel on the freeway at high velocities (Sehmel 1973, Nicholson *et al.* 1989) and particulate from vehicular tire and brake wear (Chow *et al.* 1990, Chow and Watson 1992, Councell *et al.* 2004). The small sample size in this study was an important limitation of these data. However, the general trend of decreasing deposition flux with distance from the freeway was consistently observed during the study period.

This study's comparison of trace metal concentrations on different particle size fractions observed near the freeway and at urban background sites indicates that higher concentrations near the freeway are primarily due to increased mass in the particle size fraction >6 µm. One limitation of this study is the absence of simultaneous measurements of the particle size distribution near the freeway and at urban background. However, because both lower TSP metal concentrations at the DW3 site and reduced metal mass fraction due to the largest particles at urban background locations away from the freeway were observed, a hypothesis that the lower metal concentrations were due to removal of the largest particles by deposition near their source was formed. Thus, it was concluded that variance in the particle size distributions of metal mass at the freeway site compared with urban background sites likely resulted from the freeway acting as an emission source for particles >6µm. As coarse particles are more readily removed from the air by deposition close to the source, lower concentrations of these particles and lower percentages of the total mass as distance from the emission source increases were expected. Smaller particles (<6 µm), which are slower to deposit, remain suspended and contribute a higher proportion of the total mass away from local sources. This explains why both atmospheric concentrations of metals on the largest particles and metal deposition fluxes were reduced at sites further removed from a freeway. Corroborating results from this study's deposition plate data indicate that the majority of this removal occurs very near to the source (e.g., between 10 and 150 m), resulting in deposition fluxes and concentrations downwind of the freeway

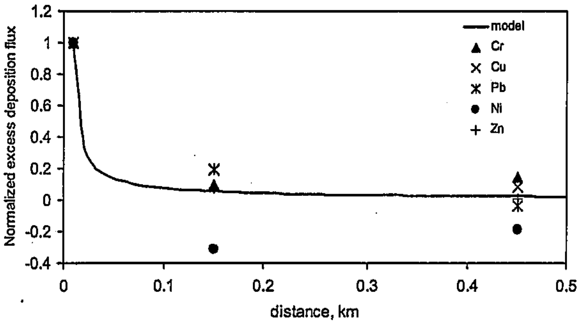

Figure 5. Comparison of computed and measured normalized excess deposition flux where the solid line is the steady state model prediction using a wind speed u = 2 m sec^{-1} and a deposition velocity V_d = 0.01 m sec^{-1}.

comparable to urban background at distances greater than 10 m and within 150 m.

In addition to higher metal fluxes and concentrations near the freeway, this study's image analysis indicated the site nearest the freeway had higher particle mass concentrations throughout the day compared with urban background. In contrast, increased particulate matter concentrations at urban background sites occurred only later in the day, perhaps as a cumulative result of resuspension from adjacent street traffic. The lack of difference between total particulate mass concentrations at the freeway site during different time intervals for particles >6 μm was likely because of the relatively constant traffic flow on this particular freeway over the daytime sampling period.

The modified Gaussian plume model showed relatively good agreement with deposition measurements. In this case, dispersion was the most significant process controlling the spatial variation of concentration and deposition. Resuspension rates Λ reported in the literature for surfaces of all types vary from 10^{-13} second^{-1} to 10^{-6} second^{-1} (Nicholson 1988), and for asphalt surfaces from 5×10^{-9} second^{-1} to 6×10^{-8} second^{-1} (Sehmel 1980). For the present study, values of Λ between 10^{-9} second^{-1} and 10^{-6} second^{-1} reflect the possible range of surface conditions, corresponding to a time to steady state ranging from 10 to 10,000 days, indicating that the surface metal concentration reflects an accumulated average of time-varying conditions. For this reason, the deposition flux measurements were compared with the deposition flux predicted by the steady state model solution. Because the steady state atmospheric concentration distribution reflects a balance between deposition and resuspension, the calculated atmospheric concentration and deposition flux are independent of the assumed resuspension rate. Calculations with $\Lambda = 0$ (i.e., no resuspension, but net loss by deposition) provide an upper bound on the effect of losses by deposition on the atmospheric concentration and associated deposition flux.

LITERATURE CITED

Ahuja, M.S., J.J. Paskind, J.E. Houck and J.C. Chow. 1989. Design of a study for the chemical and size characterization of particulate matter emissions from selected source in California. pp. 145-158 in: J.G. Watson (ed.), Transactions, Receptor Models in Air Resources Management. Air and Waste Management Association. Pittsburgh, PA.

Baker, J.E., D.L. Poster, C.A. Clark, T.M. Church, J.R. Scudlark, J.M. Ondov, R.M. Dickgut and G. Cutter. 1997. Loadings of atmospheric trace elements and organic contaminants to the Chesapeake Bay. pp. 171-194 in: J.E. Baker (ed.), Atmospheric Deposition of Contaminants to the Great Lakes and Coastal Waters. SETAC Press. Pensacola, FL.

Benson, P.E. 1979. CALINE-3, A versatile dispersion model for predicting air pollutant concentrations near roadway. Final Report FHWA/CA/TL-79/23. California Department of Transportation. Sacramento, CA.

California Department of Transportation (CA DOT). 2004. Annual Average Daily Traffic. State of California, Department of Transportation Traffic, Operations Division. http://www.dot.ca.gov.

Chock, D.P. 1978. A simple line source model for dispersion near roadways. *Atmospheric Environment* 12:823-829.

Chow, J.C., J.G. Watson, R.T. Egami, C.A. Frazier, Z. Lu, A. Goodrich and A. Bird. 1990. Evaluation of regenerative-air vacuum street sweeping on geological contributions to PM10. *Journal of the Air and Waste Management Association* 40:1134-1142.

Chow J.C. and J.G. Watson. 1992. Fugitive emissions add to air pollution. *Environmental Protection* 3:26-31.

Claiborn, C., A. Mitra, G. Adams, L. Bamesberger, G. Allwine, R. Kantamaneni, B. Lamb and H. Westberg. 1995. Evaluation of PM10 emission rates from paved and unpaved roads using tracer techniques. *Atmospheric Environment* 29:1075-1089.

Councell, T.B., K.U. Duckenfield, E.R. Landa and E. Callender. 2004. Tire-wear particles as a source of zinc to the environment. *Environmental Science and Technology* 38:4206-4212.

Cowherd, C., Jr., R. Bohn and T. Cuscino, Jr. 1977. Iron and steel plant open dust source fugitive emission evaluation. EPA-600/2-79-103. US Environmental Protection Agency. Research Triangle Park, NC.

Cowherd C., Jr. and P.J. Englehart. 1984. Paved road particulate emissions. EPA-600/7-84-077. US

Environmental Protection Agency. Research Triangle Park, NC.

Cowherd, C., Jr. and P.J. Englehart. 1985. Size specific particulate emission factors for industrial and rural roads. EPA-600/7-88-038. US Environmental Protection Agency. Research Triangle Park, NC.

Davies, C.N. 1979. Particle fluid interaction. *Journal of Aerosol Science* 10:477-513.

Dunbar, D.R. 1976. Resuspension of particulate matter. EPA-450/2-76-031. US Environmental Protection Agency. Research Triangle Park, NC.

Fitz, D.R. 2001. Measurements of PM10 and PM2.5 emission factors from paved roads in California. Final Report Contract No. 98-723. California Air Resources Board, Monitoring and Laboratory Division. Sacramento, CA.

Garger, E.K., H.G. Paretzke and J. Tschiersch. 1998. Measurement of resuspensded aerosol in the Chernobyl area part III. Size distribution and dry deposition velocity of radioactive particles during anthropogenic enhanced resuspension. *Radiation and Environmental Biophysics* 37:201-208.

Hitchins, J., L. Morawskaa, R. Wolff and D. Gilbert. 2000. Concentrations of submicrometre particles from vehicle emissions near a major road. *Atmospheric Environment* 34:51-59.

Horst, T.W. 1978. Estimation of air concentrations due to the suspension of surface contamination. *Atmospheric Environment* 12:797-802.

Houck, J.E., J.C. Chow, J.G. Watson, C.A. Simons, L.C. Pritchett, J.M. Goulet and C.A. Frazier. 1989. Determination of particle size distribution and chemical composition of particulate matter from selected sources in California. Executive summary. Report No. A6-175-35. Prepared for California Air Resources Board, Sacramento, CA. Desert Research Institute. Reno, NV.

Kantamaneni, R., G. Adams, L. Bamesberger, E. Allwine, H. Westberg, B. Lamb and C. Claiborn. 1996. The measurement of roadway PM10 emission rates using atmospheric tracer ratio techniques. *Atmospheric Environment* 24:4209-4223.

Kashparov, V.A., V.P. Protsak, V.I. Yoschenko and J.D. Watterson. 1994. Inhalation of radionuclide during agricultural work in areas contaminated as a result of the Chernobyl reactor accident. *Journal of Aerosol Science* 25:761-766.

Lim, J.-H., L.D. Sabin, K.C. Schiff, and K.D. Stolzenbach. 2006. Concentration, size distribution, and dry deposition rate of particle-associated metals in the Los Angeles Region. *Atmospheric Environment* 40:7528-7538.

Lin, J.-M., G.-C. Fang, T.M. Holsen and K.E. Noll. 1993. A comparison of dry deposition modeled from size distribution data and measured with a smooth surface for total particle mass, lead and calcium in Chicago. *Atmospheric Environment* 27:1131-1138.

Lin, J.J., K.E. Noll and T.M. Holsen. 1994. Dry deposition velocities as a function of particle size in the ambient atmosphere. *Aerosol Science and Technology* 20:239-252.

Lu, R., R.P. Turco, K.D. Stolzenbach, S.K. Freidlander, C. Xiong, K. Schiff, L.L. Tiefenthaler and G. Wang. 2003. Dry deposition of airborne trace metals on the Los Angeles Basin and adjacent coastal waters. *Journal of Geophysical Research* 108:4074-4089.

Mamane, Y. and K.E. Noll. 1985. Characterization of large particles at a rural site in the eastern United States: mass distribution and individual particle analysis. *Atmospheric Environment* 19:611-622.

Masters, G.M. 1998. Introduction to Environmental Engineering and Science, Second Edition. Prentice Hall. Saddle River, NJ.

Nicholson, K.W. 1988. A review of particle resuspension. *Atmospheric Environment* 22:2639-2651.

Nicholson, K.W., J.R. Branson, P. Giess and R.J. Cannell. 1989. The effects of vehicle activity on particle resuspension. *Journal of Aerosol Science* 20:1425-1428.

Noll, K.E., A. Pontius, R. Frey and M. Gould. 1985. Comparison of atmospheric coarse particles at an urban and non-urban site. *Atmospheric Environment* 19:1932-1943.

Paode, R.D., S.C. Sofuoglu, J. Sivadechathep, K.E. Noll and T.M. Holsen. 1998. Dry deposition fluxes and mass size distribution of Pb, Cu and Zn measured in Southern Lake Michigan during AEOLOS. *Environmental Science and Technology* 32:1629-1635.

Parrington, J.R., W.H. Zoller and N.K. Aras. 1983. Asian dust-seasonal transport to the Hawaiian-islands. *Science* 220:195-197.

Perry, K.D., T.A. Cahill, R.A. Eldred, D.D. Dutcher and T.E. Gill. 1997. Long-range transport of North African dust to the eastern United States. *Journal of Geophysical Research-Atmospheres* 102:11225-11238.

Peterson, W.B. 1980. Users guide for highway air pollution model. EPA-60018-80-018. US Environmental Protection Agency. Research Triangle Park, NC.

Reider, J.P. 1983. Size-specific particulate emission factors for uncontrolled industrial and rural roads. EPA Contract 68-02-3158. Midwest Research Institute. Kansas City, MO.

Sehmel, G.A. 1973. Particle resuspension from an asphalt road caused by car and truck traffic. *Atmospheric Environment* 7:291-309.

Sehmel, G.A. 1980. Particle resuspension: a review. *Environment International* 4:107-127.

Sistla, G., P. Samson, M. Keenan and T. Rao. 1979. A study of pollutant dispersion near highways. *Atmospheric Environment* 13:669-685.

South Coast Air Quality Management District (SCAQMD). 2000. Air Quality Report. http://www.aqmd.gov/smog/docs/aq00web.pdf.

South Coast Air Quality Management District (SCAQMD). 2003. Air Quality Management Plan. http://www.aqmd.gov/aqmp/AQMD03AQMP.htm.

Sternbeck, J., A. Sjodin and K. Andreasson. 2002. Metal emissions from road traffic and the influence of resuspension-results from two tunnel studies. *Atmospheric Environment* 36:4735-4744.

Stolzenbach, K.D., R. Lu, R. Turco, J.H. Lim, K. Schiff and L.D. Sabin. 2003. Sources of particulate matter and metal emission to the atmosphere in the Los Angeles Region. Final Report. Los Angeles Regional Water Quality Control Board. Los Angeles, CA.

Tai, H.S., J.J. Lin and K.E. Noll. 1999. Characterization of atmospheric dry deposited particles at urban and non-urban locations. *Journal of Aerosol Science* 30:1057-1068.

Venkatram, A. and D. Fitz. 1998. Measurement and modeling of PM10 and PM2.5 emissions from paved roads in California. Final Report. California Air Resources Board Contract 94-336. Sacramento, CA.

Watson, J.G., J.C. Chow and G.P. Thompson. 2000. Fugitive dust emissions. pp. 117-135 *in*: W.T. Davis (ed.), Air and Waste Management Association Air Pollution Engineering Manual, Second Edition. John Wiley and Sons. New York, NY.

Zhu, Y., W.C. Hinds, S. Kim, S. Shen and C. Sioutas. 2002a. Study of ultrafine particles near a major highway with heavy-duty diesel traffic. *Atmospheric Environment* 36:4323-4335.

Zhu, Y., W.C. Hinds, S. Kim, S. Shen and C. Sioutas. 2002b. Concentration and size distribution of ultrafine particles near a major highway. *Journal of the Air and Waste Management Association* 52:1032-1042.

Zimmerman, J.R. and R.S. Thompson. 1975. User's guide for HIWAY, a highway air pollution model. EPA-960/4-74-008. US Environmental Protection Agency. Research Triangle Park, NC.

Zufall M.J., C.I. Davidson, P.F. Caffrey and J.M. Ondov. 1998. Airborne concentrations and dry deposition fluxes of particulate species to surrogate surfaces deployed in Southern Lake Michigan. *Environmental Science and Technology* 32:1623-1628.

ACKNOWLEDGEMENTS

The authors appreciate the laboratory analysis provided by CRG Laboratories, Inc., and thank Mr. William L. Livingston, Mary E. Jones, and the staff at the Los Angeles National Cemetery for their cooperation.

Water quality indicators and the risk of illness in non-point source impacted recreational waters

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ABSTRACT

Numerous studies have demonstrated relationships between indicator bacteria and human illness at marine beaches impacted by point sources of pollution with known human fecal contributions, but extrapolating current water quality thresholds built upon these relationships at locations where nonhuman sources of fecal pollution is uncertain. A good example is Mission Bay, CA where tremendous resources have been expended eliminating human sources of fecal pollution, yet 20% of ongoing microbiological monitoring samples during dry weather exceed water quality objectives. This study answered two questions: 1) did water contact increase the risk of illness in the two weeks following exposure to water in Mission Bay? and 2) did the risk of illness increase with increasing levels of microbial indicators of water quality? Baseline health at the time of exposure and again two weeks later were measured in a cohort of 8,797 beachgoers during the summer of 2003. Nearly 2,000 water samples were analyzed for bacterial indicators (enterococcus, fecal coliforms, and total coliforms) using both traditional and non-traditional methods (chromogenic substrate or quantitative polymerase chain reaction), novel bacterial indicator (*Bacteroides*), and viruses (somatic and male-specific phage, adenovirus, Norwalk-like virus) and associations between water exposure and water quality indicators with health outcomes were assessed. While the incidence of diarrhea and skin rash were elevated in swimmers compared to non-swimmers, there was no statistically increased risk in 12 other symptoms measured, including highly credible gastrointestinal illness (HCGI). The incidence of illness was not associated with indicators traditionally used to monitor beaches nor with the non-traditional water quality indicators. These results contrast with most other recreational bathing studies, most likely because of the lack of human sources of fecal pollution.

INTRODUCTION

Fecal indicator bacteria are monitored at marine recreational bathing beaches to assess the risk of contracting swimming-related illnesses. In southern California, more than 85,000 samples are collected and over $3 million are spent annually to assess public health risk using bacterial tests as indicators of fecal contamination (Schiff *et al.* 2002). The focus on bacteria as a public health monitoring tool is based on the relationship between the density of fecal indicator bacteria and the occurrence of illnesses among those with water exposure.

Numerous studies have demonstrated the relationship between fecal indicator bacteria at marine beaches and swimming-related illnesses (Pruss 1998, Wade *et al.* 2003). Prominent among these studies were those conducted by Cabelli (1983, Cabelli *et al.* 1979) which reported a relationship between enterococcus and illness at several beaches. Haile *et al.* reported an association between swimming-related illnesses and enterococcus, fecal coliforms, and total coliforms in Santa Monica Bay, California (1999). The Cabelli and Haile studies were the focal point for the establishment of water quality thresholds at marine beaches using fecal indicator bacteria in the United States and the State of California, respectively.

While previous studies successfully demonstrated the value of fecal indicator bacteria, virtually all were conducted at locations where human sewage was the predominant contamination source. Haile *et*

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al. was the only study to have focused on urban runoff as a source, but even this non-point source was known to contain human sources of fecal contamination (1999). Most beach water quality problems in California are attributable to non-point source runoff (Noble *et al.* 2003, Schiff *et al.* 2003), and it is not certain that human health relationships for waterborne bacterial indicators would remain the same when non-human sources predominate (Calderon *et al.* 1991). Because animals can shed bacterial indicators without accompanying human pathogens (NRC 2004), there is uncertainty about the present practice of extrapolating water quality thresholds that are based on the risk of swimming-associated illnesses from human point source to non-point sources dominated by animal-associated fecal contamination. A poor correlation between bacterial indicators and virus concentrations has been found in urban runoff (Jiang *et al.* 2001, Noble and Fuhrman 2001), in contrast to the significant relationships that have been found when examining water bodies influenced by human sources (e.g., septic tanks; Lipp *et al.* 2001).

A cohort study conducted in Mission Bay, California, found state water quality standards to be exceeded more than 20% of the time (Schiff and Kinney 2001). Several million dollars have been expended to remove human contamination by inspecting and repairing the sanitary sewerage system surrounding the bay and diverting larger storm drains away from the bay. Recent source tracking studies suggested that human fecal material constitutes a minor proportion (<10%) of fecal inputs to the Bay (City of San Diego and MEC/Weston 2004). However, California water quality standard exceedences continue (Hanley 2002).

To address the pressing need for faster, more specific water quality measurements to protect swimmers' health, microbiologists are developing new test methods. Chromogenic substrate assays have become increasingly popular because they are faster and easier than traditional methods, while producing comparable results (Griffith *et al.* 2006). Genetic-based techniques are not yet commercially available for fecal indicator bacteria, but researchers are capable of obtaining results in a matter of hours (Noble and Weisberg 2005). Finally, genetic-based techniques are exploring new microbial indicators, such as *Bacteroides*, a group of obligate anaerobes that are abundant intestinal flora (Cabelli *et al.* 1982). These techniques also provide new tools for measuring pathogens directly, including human specific virus (Tsai *et al.* 1993, Noble *et al.* 2003). Regardless of rapidity, specificity, or cost, the efficacy of any new public health monitoring tool can only be evaluated through an epidemiological study that documents relationships to the incidence of swimming-related illness.

The goal of this study was to examine health effects experienced by swimmers and the relationship of these effects to water quality indicators in this system where non-human fecal sources dominate. The study was designed to answer two questions. First, did water contact increase the risk of illness in the two weeks following exposure to water in Mission Bay during the summer of 2003? Second, did the risk of illness increase with increasing levels of traditional microbial indicators of water quality? As a corollary question, the increased risk of illness with increasing levels of new, non-traditional microbial methods or indicators of water quality was also examined.

METHODS

Overview

The study was designed as a prospective cohort (Wade *et al.* 2003, NRC2004). Participants were recruited each sampling day and their current health and degree of exposure to the water were recorded. Water quality was synoptically measured at multiple sites and over multiple time periods. Ten to 14 days later, the participants were contacted by phone and interviewed about symptoms of illness that occurred after their beach visit. Regression models were used to evaluate the association between exposure to indicators of water quality and illness and to compare illnesses between swimmers and non-swimmers.

Sampling sites

Study sites were selected to maximize the number of potential study participants. Beach-goers were recruited at six Mission Bay beaches on weekends and holidays, beginning Memorial Day weekend and continuing through Labor Day 2003. Water quality samples were collected at the same six beaches. Eighteen sampling sites were targeted, with the number of sites per beach ranging from two to five, depending upon beach length and anticipated swimming activity. Data were collected on 29 days.

Water quality data collection and analysis (indicator organisms)

Twelve measures of water quality were collected during the study. Three traditional indicators (enterococcus, total coliforms, fecal coliforms) were measured by traditional methods (membrane filtration; MF) and each was also measured using the chromogenic substrate (CS) method. Enterococcus was also determined by a new genetic method, quantitative polymerase chain reaction (QPCR). The final five measures were new indicators (*Bacteroides*, somatic coliphage, male-specific coliphage, adenovirus, and Norwalk-like virus).

Water samples were collected with varying frequency, depending on the specific indicator. The indicators, sampling frequency, and laboratory analysis methods are shown in Table 1. Additional details regarding laboratory procedures are available in the project technical report (Colford *et al.* 2005).

Human health data collection

All study instruments and protocols were approved by the Committee for the Protection of Human Subjects at the University of California, Berkeley.

Beach recruitment

Interviewers canvassed the study beaches. Eligibility criteria included: 1) no previous participation in the study; 2) at least one family member of the household at the beach was 18 years old or older; 3) home address in the United States, Canada, or Mexico (interviews were conducted in either English or Spanish); and 4) had not swam (face or head under water) in the ocean or in a lake in the previous seven days. If an individual or household was eligible and agreed to participate, the interviewers obtained signed consent from the individual or all participating adult members of the household. Adults gave signed consent for children less than 18 years of age. Interviewers marked the screening form to identify the water sampling site that was closest to the location of the individual or family on the beach. Participants were given an incentive and asked to complete a questionnaire prior to their departure that day. The questionnaire assessed possible exposures at the beach and exposures or illnesses experienced during the 2 - 3 days prior to the beach visit. Participants who failed to complete the survey at the beach were contacted within three days by telephone.

Follow-up interview

Approximately 14 days following their beach visit, participants were telephoned and asked to complete a 10- to 15-minute interview. This interview consisted of the following types of questions: 1) demographic information; 2) swimming and other exposures since the beach day; 3) pre-existing health problems (e.g., chronic diarrhea); and 4) acute

Table 1. Methods, analytical laboratories, and sampling intensity used for water quality measurements during the Mission Bay Epidemiology Study.

Parameter	Method	Analytical Laboratory	Sampling intensity
Enterococcus	EPA 1600	City of San Diego	Beach composite once per day
Enterococcus	96 well Quantitray	City of San Diego	Hourly sample at every site
Enterococcus	Quantitative PCR	EMSL	Two samples per day at each site
Fecal Coliforms	APHA Method 9222D	City of San Diego	Hourly sample at every site
Fecal Coliforms (*E. coli*)	96 well Quantitray	City of San Diego	Beach composite once per day
Total Coliforms	APHA Method 9222B	City of San Diego	Hourly sample at every site
Total Coliforms	96 well Quantitray	City of San Diego	Beach composite once per day
Bacteroides	Quantitative PCR	EMSL	Two samples per day at each site
Somatic Phage	Modified EPA 1601	University of North Carolina	Beach composite once per day
Male-specific Phage	Modified EPA 1601	University of North Carolina	Beach composite once per day
Adenovirus 40 and 41	Quantitative PCR	University of North Carolina	Beach composite once per day
Norwalk-like Virus	Quantitative PCR	University of North Carolina	Beach composite once per day

health conditions experienced since the visit to the beach. As with the previous interviews, the head of household answered questions for children less than 18 years of age.

Health outcomes measured

The health outcomes ascertained through the interview included gastrointestinal illness, respiratory symptoms, dermatologic symptoms, and other non-specific symptoms. Gastrointestinal symptoms included nausea, vomiting, diarrhea, and stomach cramps. In addition, two categories of highly credible gastrointestinal illness (HCGI) were measured. HCGI-1 was defined as either: 1) vomiting; or 2) diarrhea and fever; or 3) cramps and fever. This is consistent with the way GI illness was defined by Haile *et al.* (1999). Respiratory outcomes included cough, cough with phlegm, nasal congestion or runny nose, sore throat, and significant respiratory disease (SRD). Significant respiratory disease was defined as: 1) fever plus nasal congestion; or 2) fever plus sore throat; or 3) cough with phlegm. This definition is also consistent with Haile *et al.* (1999) Dermatologic outcomes included skin rashes and infected cuts or scrapes. Non-specific symptoms included fever, redness or eye irritation, earache, and ear discharge.

Data Analysis

Two principal groups of analyses were conducted. The first was a set of models to evaluate any differences in illness rates between swimmers and non-swimmers. The analyses were repeated for two definitions of swimming. In the first set of analyses, "swimming" was defined as participants answering "yes" when asked if they had any water contact during their day at the beach. The analyses were also repeated using a definition of "swimming" as those who answered "yes" when asked if they had swallowed any water. Non-swimmers were those who answered "no" when asked if they had contact with water during their day at the beach.

The second group of analyses consisted of regression models designed to evaluate the association between the risk of illness in swimmers and water quality (as measured by the indicators). In these models, the main outcome was a binary indicator of illness and a continuous measure of exposure, modeled as the geometric mean for the indicator on the beach and day of the swimmer's exposure. As a secondary analysis, enterococcus was treated as a dichotomous variable using California state water quality thresholds as cutpoints (>35 vs. <35 and >104 vs. <104). In all models involving water quality indicators, a value of zero was used for water quality exposure values below the detection limit of the test.

Multivariate models included potential confounding factors, including age, gender, ethnicity, income, allergies, swimming after the beach interview, collecting shells at the beach, digging in the sand, playing with seaweed or algae, chronic or pre-existing illnesses, contact with other sick people, use of insect repellant at the beach, use of sunblock, showering immediately after swimming, consumption of raw or undercooked eggs or meat, and consumption of food at the beach. All variables, except age, were categorized as 1 or 0. Race was collapsed into two categories, white and non-white.

All analyses were conducted using a nested interaction model that effectively assigned non-swimmers a zero exposure value, while including an indicator of swimming. The model permits comparisons among swimmers with different levels of indicator exposure, as well as comparisons among swimmers versus non-swimmers independent of indicator level and is parameterized as follows:

$$\ln(p/(1-p)) = a + \beta_1 x_1 + \beta_2(x_1 * x_2) + \beta_3 x_3 + \beta_4(x_3 * x_2)$$

where p = probability of illness, x_1 = 1 if any contact with water, 0 otherwise; x_2 is a water quality indicator value (continuous); and x_3 is a 1/0 indicator of other specific water exposure (body contact, head under water, etc.)

In the multivariate analyses, a backwards deletion procedure was used to identify factors that most affected the water quality/illness relationship (Rothman and Greenland 1982).

The risk of illness output from the models was expressed as an odds ratio. For models comparing swimmers and non-swimmers, the odds ratio can be interpreted as the odds of a specific illness in swimmers divided by the odds of illness in non-swimmers. For models assessing the association between water quality indicators among swimmers, the odds ratios can be interpreted as the increase in the odds of illness per defined unit of increase in the water quality measure among swimmers. Odds ratios were calculated by exponentiating the regression coefficient provided by the model output.

Models adjusted for relevant covariates (see above) were used to estimate the percentages of swimmers and non-swimmers ill for any health outcomes with a statistically significant elevated adjusted odds ratio (OR). The adjusted attributable risk estimates were determined by estimating adjusted probabilities of swimmers and non-swimmers from a multivariate logistic model, weighting the covariates as the mean value for each covariate. The adjusted attributable risk was then calculated as the difference between the probability of illness among swimmers with mean levels of covariates and non-swimmers with mean levels of covariates. These results are expressed as the number of excess cases of illness predicted among 1,000 swimmers, along with a 95% confidence interval (CI) of this estimate.

RESULTS

Water quality

A total of 1,897 water samples were collected. All but five of these samples were analyzed successfully in the laboratory. The majority of samples had quantifiable levels of indicator bacteria (Table 2). About 16% of the samples exceeded state water quality thresholds for traditional fecal indicator bacteria, with enterococcus accounting for most of the exceedances and total coliforms the least .

Table 2 also shows the range of concentrations for virus measurements. Pathogenic virus was detected in only one sample. The majority of samples had quantifiable levels of somatic phage, but not for male-specific phage, which is thought to be more strongly associated with fecal material.

Health outcomes

A total of 12,469 individuals and 5,062 households were enrolled in the study. Of these, 8,797 (71%) of the enrolled participants and 3,501 (69%) of the households completed the follow-up telephone interview. Fifty-seven percent (n = 4,971) of those that completed the follow-up interview were swimmers, compared to 3,742 non-swimmers. Table 3 shows the individual and household sociodemographic characteristics of the study group.

Health outcomes for swimmers versus non-swimmers

A significant increase in diarrhea (OR 1.36, 95% CI 1.04 - 1.78) and skin rash (OR 2.25, 95% CI 1.60 - 3.16) was observed among swimmers when swimming was defined as having any water contact (Table 4). When swimming was defined as having swallowed water, there was a significant association between exposure and diarrhea (OR 1.89, 95% CI 1.34 - 2.66), cramps (OR 1.53, 95% CI 1.08 - 2.15), skin rash (OR 2.11, 95% CI 1.37 - 3.24), and eye irritation (OR 1.69, 95% CI 1.23 - 2.3; Table 4). No significant elevations were found in any of the other health outcomes measured, regardless of the

Table 2. Range of concentrations for traditional and non-traditional water quality indicators (number/100 ml) and frequency of exceedance (N = 1,897) of the State of California's water quality threshold.

	Total No. of Samples	No. of Samples Below Detection	Geomean (No. per 100ml)	Max. (No. per 100ml)	No. of Samples Exceeding State Water Quality Threshold	State Water Quality Threshold
Enterococcus-CS	1,897	585	29	57,940	265	>104
Fecal Coliform	1,897	304	25	48,000	99	>400
Total Coliform	1,897	808	102	45,000	5	>10,000
Total:Fecal Ratio	1,897	N/A	N/A	N/A	75	Total:Fecal < 10 When Total > 1,000
Enterococcus-QPCR*	790	46	65	141,053	351	>104
Bacteroides	790	294	102	3,718,815	N/A	N/A
Adenovirus	151	150	-	0.01	N/A	N/A
Norwalk-like Virus	151	151	-	-	N/A	N/A
Male-specific Phage	141	125	0.2	0.8	N/A	N/A
Somatic Phage	141	45	0.6	36.6	N/A	N/A

*Quantitative polymerase chain reaction

Table 3. Individual sociodemographic characteristics collected from study participants at all beaches from Mission Bay.

Characteristic	Surveyed Participants							
	All (N = 8,797)		Swimmers (N = 4,971)		Non-swimmers (N = 3,742)		Missing (N = 84)	
	n	%	n	%	n	%	n	%
Age								
0 - 5	1,214	13.8	870	17.5	326	8.7	18	21.4
5.1 - 12	1,808	20.6	1,461	29.4	332	8.9	15	17.9
12.1 - 30	2,366	26.9	1,215	24.4	1,127	30.1	24	28.6
30.1 - 55	2,928	33.3	1,251	25.2	1,654	44.2	23	27.4
>55	332	3.8	76	1.5	253	6.8	3	3.6
Missing	149	1.7	98	2.0	50	1.3	1	1.2
Gender								
Male	4,761	54.1	2,624	52.8	2,100	56.1	37	44.0
Female	3,948	44.9	2,292	46.1	1,609	43.0	47	56.0
Missing	88	1.0	55	1.1	33	0.9	0	0.0
Race								
White	2,495	28.4	1,181	23.8	1,307	34.9	7	8.3
African American	369	4.2	165	3.3	194	5.2	10	11.9
American Indian/ Alaskan Native	62	0.7	35	0.7	27	0.7	0	0.0
Asian/Pacific Islander	463	5.3	177	3.6	281	7.5	5	6.0
Hispanic/Latino	4,723	53.7	3,052	61.4	1,616	43.2	55	65.5
Mixed Race	407	4.6	241	4.8	163	4.4	3	3.6
Other	227	2.6	96	1.9	128	3.4	3	3.6
Missing	51	0.6	24	0.5	26	0.7	1	1.2

definition of swimming.

We explored the relationship between participant age and health outcomes after water exposure (Table 5). Among participants with any water contact, the strongest and only significant association with diarrhea was among children ages 5 to 12 years (OR 2.80, 95% CI 1.07 - 7.27). The OR increased with increased exposure in the 5 - 12 year old age group (OR 5.30, 95% CI 1.96 - 14.33). Skin rash was significantly associated with several age groups among participants either with any water contact or who reported swallowing water. Significant associations were also found among those who swallowed water and who reported skin rash (ages 0 - 5 years and 5 - 12 years) and eye irritation (ages 5 - 12 years).

Table 6 shows the attributable risk calculations for diarrhea, stratified by age group. The estimated excess of cases among swimmers vs. non-swimmers was greatest in participants age 5 - 12 years with any water contact (27.4 excess cases per 1000 swimmers) and

Table 3. (Continued)

Characteristic	Surveyed Participants (N = 3,501 Households)	
Household size (# of persons)	n	%
1	1,269	36.2
2	649	18.5
3	532	15.2
4	511	14.6
5	290	8.3
6	140	4.0
7	68	1.9
≥8	42	1.2
Missing	0	0.0
Country of Residence (HH)		
United States	3,170	90.5
Mexico	66	1.9
Canada	2	0.1
Missing	263	7.5
Average Annual Income (HH)		
≤ 10,000	284	8.1
10,001 to 20,000	639	18.3
20,001 to 30,000	444	12.7
30,001 to 40,000	360	10.3
40,001 to 50,000	294	8.4
50,001 to 60,000	231	6.6
60,001 to 70,000	181	5.2
70,001 to 80,000	210	6.0
80,001 to 100,000	229	6.5
>100,000	309	8.8
Missing	321	9.2

Table 4. Adjusted odds ratios for health outcomes relative to various types of water exposure. Bolded numbers indicate statistical significance.

Health Outcome	Adjusted OR (95% CI)		
	Any Water Contact	Water on Face	Swallow Water
Gastrointestinal			
Diarrhea	**1.36 (1.04 - 1.78)**	**1.54 (1.16 - 2.06)**	**1.89 (1.34 - 2.66)**
HCGI-1	0.96 (0.68 - 1.37)	1.03 (0.71 - 1.50)	1.01 (0.62 - 1.66)
HCGI-2	0.93 (0.49 - 1.75)	1.10 (0.57 - 2.13)	1.12 (0.51 - 2.45)
Nausea	0.88 (0.64 - 1.23)	1.11 (0.77 - 1.61)	1.41 (0.91 - 2.17)
Cramps	1.07 (0.81 - 1.42)	1.14 (0.86 - 1.51)	**1.53 (1.08 - 2.15)**
Vomiting	0.85 (0.58 - 1.26)	0.92 (0.61 - 1.37)	0.86 (0.49 - 1.52)
Skin Rash	**2.25 (1.60 - 3.16)**	**2.39 (1.72 - 3.31)**	**2.11 (1.37 - 3.24)**
Eye Irritation	1.19 (0.93 - 1.52)	1.29 (0.99 - 1.68)	**1.69 (1.23 - 2.30)**
Ear			
Earache	0.96 (0.65 - 1.44)	1.00 (0.64 - 1.56)	1.10 (0.63 - 1.93)
Ear Discharge	0.40 (0.16 - 1.01)	0.47 (0.19 - 1.13)	0.82 (0.22 - 3.00)
Fever	0.96 (0.70 - 1.32)	1.04 (0.74 - 1.47)	1.15 (0.76 - 1.75)
Respiratory			
SRD	1.08 (0.80 - 1.45)	1.03 (0.75 - 1.43)	0.99 (0.62 - 1.57)
Sore Throat	0.89 (0.69 - 1.16)	0.96 (0.71 - 1.32)	0.87 (0.56 - 1.34)
Cough	0.74 (0.54 - 1.02)	0.77 (0.54 - 1.11)	0.82 (0.47 - 1.41)

among those who had swallowed water (59.0 excess cases per 1000 swimmers).

Relationship between health outcomes and water quality among swimmers

No correlation was observed between the risk of illness and increased levels of traditional water quality indicators for enterococcus, fecal coliform or total coliform. Using diarrhea as an example, odds ratios were not statistically elevated due to increases in enterococcus (Table 7). The lack of relationship resulted despite numerous approaches to assigning water quality exposure (i.e., combining or separating sites at a beach) or calculation of indicator metrics (i.e., daily geomean, daily maxima, or various cutpoints). Of particular note, exposure to indicator measures above the two different California state water quality thresholds did not correlate with a significant increased risk of illness (Table 8).

We found no correlation between increased risk of illness and levels of *Bacteroides*, enterococcus using rapid methods (QPCR), human pathogenic virus (adenovirus and Norwalk-like virus), or somatic phage (data not shown, results available in Colford *et al.* 2005). The relationship with viruses could not be adequately evaluated because no Norwalk-like virus was found and adenovirus was only found in one sample, though the low counts were consistent with the absence of increased health risk for the other health outcomes evaluated.

Significant associations between the levels of male-specific coliphage and HCGI-1, HCGI-2, nausea, cough, and fever were observed (Table 9). However, a low number of participants were exposed to the water at times when male-specific coliphage was detected (Table 10). Therefore, the relationships between male-specific coliphage and various health outcomes should be interpreted cautiously.

DISCUSSION

Swimmers experienced more diarrhea and skin rash than non-swimmers in Mission Bay. The prevalence of these symptoms increased with higher exposure (i.e., reported swallowing water), further suggesting that these symptoms were mediated by water contact. However, increased risk was not observed for more severe symptoms such as fever, vomiting, or multi-symptom categories such as HCGI. These more severe symptoms are the foundation for Federal and State water quality thresholds (Cabelli

Table 5. Health outcomes by age group and water exposure type. Bolded numbers indicate statistical significance.

	Any Water Contact			
Health Outcome	Age Group (years)			
	0 - 5	>5 - 12	>12 - 30	>30
Gastrointestinal				
Diarrhea	0.75 (0.40 - 1.40)	**2.80 (1.07 - 7.27)**	1.71 (0.96 - 3.05)	1.28 (0.85 - 1.93)
HCGI-1	0.86 (0.45 - 1.59)	1.33 (0.56 - 3.14)	0.73 (0.36 - 1.44)	1.37 (0.60 - 3.15)
HCGI-2	0.74 (0.31 - 1.75)	2.26 (0.28 - 18.45)	0.64 (0.15 - 2.74)	2.10 (0.30 - 14.73)
Nausea	1.90 (0.62 - 5.83)	1.40 (0.52 - 3.79)	0.46 (0.26 - 0.83)	1.11 (0.63 - 1.95)
Cramps	1.20 (0.53 - 2.70)	1.61 (0.77 - 3.37)	0.57 (0.34 - 0.94)	1.51 (0.93 - 2.43)
Vomiting	0.58 (0.31 - 1.10)	1.59 (0.54 - 4.68)	0.68 (0.31 - 1.47)	1.45 (0.64 - 3.30)
Skin Rash	**5.86 (1.81 - 19.0)**	**3.26 (1.30 - 8.15)**	1.60 (0.89 - 2.86)	**1.84 (1.04 - 3.25)**
Eye Irritation	0.53 (0.27 - 1.04)	1.84 (0.94 - 3.61)	1.21 (0.81 - 1.82)	1.23 (0.80 - 1.88)
Ear				
Earache	0.86 (0.31 - 2.39)	1.14 (0.37 - 3.49)	0.62 (0.30 - 1.25)	1.47 (0.73 - 2.96)
Ear Discharge	0.12 (0.01 - 1.66)	0.22 (0.03 - 1.59)	0.58 (0.14 - 2.37)	0.63 (0.10 - 3.86)
Fever	0.68 (0.39 - 1.16)	1.67 (0.67 - 4.15)	0.83 (0.44 - 1.56)	1.44 (0.73 - 2.84)
Respiratory				
SRD	0.63 (0.32 - 1.22)	1.23 (0.57 - 2.66)	1.01 (0.58 - 1.75)	1.43 (0.86 - 2.35)
Sore Throat	0.74 (0.33 - 1.69)	1.21 (0.57 - 2.57)	0.82 (0.51 - 1.30)	0.90 (0.61 - 1.35)
Cough	0.52 (0.27 - 1.02)	0.84 (0.38 - 1.87)	0.78 (0.41 - 1.49)	0.84 (0.49 - 1.45)

Table 5. (Continued)

	Swallow Water			
Health Outcome	Age Group (years)			
	0 - 5	>5 - 12	>12 - 30	>30
Gastrointestinal				
Diarrhea	0.97 (0.47 - 2.01)	**5.30 (1.96 - 14.33)**	1.76 (0.79 - 3.91)	1.78 (0.86 - 3.66)
HCGI-1	0.61 (0.25 - 1.49)	1.72 (0.65 - 4.59)	1.34 (0.49 - 3.67)	0.70 (0.08 - 6.29)
HCGI-2	0.74 (0.23 - 2.36)	2.83 (0.32 - 24.83)	0.92 (0.13 - 6.46)	3.15 (0.18 - 54.04)
Nausea	2.27 (0.76 - 6.81)	2.29 (0.84 - 6.23)	0.56 (0.21 - 1.46)	2.08 (0.81 - 5.33)
Cramps	2.05 (0.88 - 4.78)	**2.51 (1.18 - 5.33)**	0.52 (0.23 - 1.18)	1.83 (0.85 - 3.92)
Vomiting	0.41 (0.14 - 1.18)	2.15 (0.57 - 8.13)	1.27 (0.43 - 3.77)	1.13 (0.12 - 10.12)
Skin Rash	**10.42 (2.34 - 46.40)**	**4.10 (1.39 - 12.09)**	1.15 (0.46 - 2.86)	1.32 (0.39 - 4.46)
Eye Irritation	0.89 (0.41 - 1.92)	**2.87 (1.44 - 5.71)**	1.48 (0.82 - 2.67)	1.53 (0.72 - 3.25)
Ear				
Earache	0.25 (0.03 - 2.18)	2.09 (0.65 - 6.78)	0.78 (0.26 - 2.28)	0.89 (0.18 - 4.30)
Ear Discharge	tf*	tf	tf	tf
Fever	0.73 (0.36 - 1.45)	2.36 (0.88 - 6.28)	1.51 (0.64 - 3.55)	1.04 (0.22 - 4.91)
Respiratory				
SRD	0.62 (0.24 - 1.57)	1.18 (0.46 - 3.03)	1.03 (0.41 - 2.55)	0.71 (0.15 - 3.25)
Sore Throat	0.81 (0.26 - 2.50)	1.03 (0.42 - 2.52)	0.90 (0.38 - 2.10)	0.69 (0.25 - 1.86)
Cough	0.44 (0.15 - 1.32)	1.34 (0.48 - 3.70)	1.50 (0.53 - 4.27)	tf

*tf = too few individuals for analysis

Table 6. Frequency (percent ill) reporting diarrhea and calculated attributable risk.

	Adjusted Attributable Risk* (95% CI) per 1000 swimmers	Percent ill - Adjusted	
		Non-swimmers	Swimmers
Any Water Contact			
All Ages (years)	11.1 (0.0 - 22.1)	3.20	4.31
0 - 5	-14.1 (-47.7 - 18.5)	6.01	4.60
>5 - 12	27.4 (-8.9 - 63.7)	1.59	4.33
>12 - 30	14.3 (-7.0 - 35.6)	2.09	3.51
>30	10.0 (-8.6 - 28.6)	3.74	4.75
Swallow Water			
All Ages (years)	27.2 (8.9 - 45.6)	3.25	5.97
0 - 5	-1.6 (-42.5 - 39.4)	6.09	5.93
>5 - 12	59.0 (15.0 - 103.0)	1.48	7.38
>12 - 30	18.5 (-13.6 - 50.6)	2.55	4.40
>30	26.4 (-15.7 - 68.4)	3.63	6.28

*Expressed as excess cases per 1,000 swimmers

1983, Haile *et al.* 1999) and have been the focus of most previous epidemiology studies (Wade *et al.* 2003). Symptoms such as HCGI are considered more relevant because multi-symptom reactions that include fever are typically pathogen mediated, whereas symptoms like rash and diarrhea can result from saltwater irritation.

Unlike most previous marine recreational epidemiology studies, we found no relationship between illness rates and fecal indicator bacteria. Wade *et al.* reviewed 27 marine recreational water epidemiology studies and found increased relative risk with increasing fecal indicator concentrations in most of them (2003), particularly for enterococcus. However, in essentially all of these studies, water quality was impacted by known sources of human fecal contamination. There appears to be little human fecal contamination in Mission Bay as evidenced by a recent source tracking study that found the predominant source of fecal contamination was avian (Gruber *et al.* 2005). While animal sources can also harbor disease-causing agents, they are less likely to serve as vectors for human disease (NRC 2004).

The use of bacterial indicators as predictors of swimming-associated illnesses is based on the presumption that they have survival properties similar to the pathogens they are intended to mirror. This presumption is less likely to remain true when circulation is restricted and residence times increase, which can be days to weeks in Mission Bay (SIO 2003). Increased survival and perhaps even regrowth of fecal indicator bacteria, has been suggested in sediments and wrack lining beaches including Mission Bay (City of San Diego and MEC/Weston 2003, Weiskel *et al.* 1996). Regardless, the lack of relationship of non-human sources of fecal indicator bacteria to health risk suggests that water contact advisories posted at beaches in Mission Bay during the course of this study were not reflective of public health risk.

It is arguable whether viral measures in our study were better indicators of risk and could be used in place of bacterial indicators for health risk assessments in Mission Bay. We found that increasing density of male-specific phage was correlated with increased incidence of several health outcomes, including HCGI-1, HCGI-2, nausea, cough, and fever (Table 10). This is consistent with the success of this measure in freshwater application (Lee *et al.* 1997). However, we interpret these associations cautiously because male-specific coliphage was not detected often and few subjects were exposed to the water at those times (Table 10).

The human-specific viruses we measured in Mission Bay were rarely detected, consistent with our low rates of swimming-associated illnesses. We did not encounter high virus counts that would have allowed us to assess their effectiveness as predictors in the positive direction. Interpretation of viruses as negative predictors is compromised by technology limitations.. We used the most advanced techniques available, but quantifying virus particles in seawater is difficult because DNA and RNA are lost due to complexation and interferences when concentrating and extracting nucleic acid material. Thus, we cannot be

Table 7. Adjusted odds ratio (95% CI) for the association of enterococcus, fecal coliform and total coliform levels (ln of daily geometric mean at the beach level) two weeks after exposure. The unit change in exposure in these models was set to represent a change of geometric mean of 30.

	Enterococcus		Fecal Coliform		Total Coliform	
Health Outcome	Any Water Contact	Swallow Water	Any Water Contact	Swallow Water	Any Water Contact	Swallow Water
Gastrointestinal						
Diarrhea	0.77 (0.33 —1.80)	0.31 (0.06 —1.59)	0.41 (0.18 —0.93)	0.33 (0.07 —1.48)	0.34 (0.15 —0.77)	0.47 (0.09 —2.50)
HCGI-1	0.76 (0.28 —2.04)	1.64 (0.23 —11.77)	0.65 (0.25 —1.67)	1.53 (0.22 —10.63)	0.58 (0.21 —1.59)	0.64 (0.08 —4.92)
HCGI-2	0.97 (0.18 —5.23)	1.65 (0.09 —31.24)	0.59 (0.11 —3.08)	3.49 (0.20 —61.77)	0.48 (0.09 —2.70)	0.43 (0.02 —8.79)
Nausea	0.72 (0.22 —2.38)	0.79 (0.10 —6.35)	0.56 (0.19 —1.68)	1.30 (0.17 —9.71)	0.39 (0.12 —1.25)	0.35 (0.04 —2.85)
Cramps	0.87 (0.38 —2.00)	0.67 (0.14 —3.09)	0.58 (0.26 —1.28)	0.62 (0.14 —2.72)	0.84 (0.34 —2.14)	0.56 (0.12 —2.59)
Vomiting	0.69 (0.22 —2.22)	1.98 (0.18 —21.55)	0.76 (0.23 —2.55)	2.63 (0.26 —26.55)	0.48 (0.14 —1.62)	0.69 (0.06 —8.20)
Skin Rash	0.84 (0.34 —2.04)	0.65 (0.11 —3.85)	0.86 (0.36 —2.06)	0.67 (0.12 —3.68)	1.35 (0.52 —3.51)	3.49 (0.59 —20.64)
Eye Irritation	0.74 (0.34 —1.58)	0.79 (0.17 —3.73)	0.69 (0.33 —1.41)	0.67 (0.15 —2.89)	0.64 (0.29 —1.40)	1.21 (0.24 —6.09)
Ear						
Earache	1.13 (0.34 —3.81)	0.45 (0.04 —5.15)	1.50 (0.51 —4.37)	0.38 (0.04 —3.37)	1.85 (0.53 —6.48)	0.46 (0.04 —4.99)
Ear Discharge	1.45 (0.05 —42.31)	1.09 (0.01 —189.13)	7.13 (0.31 —164.89)	0.79 (0.00 —129.89)	6.31 (0.27 —144.82)*	5.21 (0.02 —1139.85)
Fever	0.98 (0.39 —2.43)	1.09 (0.21 —5.82)	0.57 (0.24 —1.37)	0.72 (0.14 —3.76)	0.79 (0.29 —2.11)	0.40 (0.07 —2.20)
Respiratory						
SRD	1.15 (0.47 —2.79)	1.47 (0.23 —9.33)	0.58 (0.25 —1.33)	1.11 (0.16 —7.77)	0,68 (0.26 —1.75)	0.78 (0.10 —6.12)
Sore Throat	1.27 (0.52 —3.13)	0.34 (0.05 —2.13)	1.42 (0.61 —3.31)	0.25 (0.06 —2.03)	1.50 (0.59 —3.82)	0.40 (0.06 —2.61)
Cough	0.50 (0.14 —1.76)	0.06 (0.01 —0.70)	0.44 (0.14 —1.43)	0.16 (0.02 —1.58)	0.37 (0.10 —1.36)	0.14 (0.01 —1.45)

Table 8. Adjusted odds ratios for health outcomes using two dichotomous measures of exposure to enterococcus. There were no statistically significant results.

Health Outcome	Adjusted OR (95% CI)	
	> 35 vs. ≤ 35	> 104 vs. ≤ 104
Gastrointestinal		
Diarrhea	1.01 (0.73-1.39)	1.22 (0.85-1.76)
HCGI-1	0.74 (0.51-1.06)	1.13 (0.73-1.75)
HCGI-2	0.69 (0.38-1.25)	0.80 (0.37-1.73)
Nausea	0.78 (0.51-1.20)	1.12 (0.65-1.92)
Cramps	0.91(0.66-1.24)	1.36 (0.95-1.95)
Vomiting	0.67 (0.43-1.03)	1.13 (0.67-1.92)
Skin Rash	0.83 (0.61-1.15)	1.00 (0.67 - 1.49)
Eye Irritation	0.97 (0.72-1.32)	0.77 (0.53-1.11)
Ear		
Earache	1.08 (0.68-1.70)	1.18 (0.70-2.00)
Ear Discharge	1.15 (0.30-4.36)	0.94 (0.19-4.62)
Fever	0.92 (0.65-1.31)	0.89 (0.58-1.37)
Respiratory		
SRD	0.96 (0.67-1.37)	1.13 (0.73-1.73)
Sore Throat	1.10 (0.80-1.50)	1.15 (0.77-1.72)
Cough	0.65 (0.40-1.05)	0.51 (0.25-1.03)

certain that the low levels we observed were due to their absence from the system or from difficulties in recovering viruses that were present. Our results do suggest that these non-bacterial measures may have the potential to be more effective than traditional bacterial indicators as predictors of illness when non-human sources are dominant.

While we found that traditional fecal indicators were ineffective predictors of health effects, Mission Bay may be an exception rather than the rule. Mission Bay has been subjected to extensive cleanup activities. Recent source tracking studies have identified that human fecal sources are now only a minor contributor to the overall bacterial load (City of San Diego and MEC/Weston 2004). Our study does suggest the need for further evaluation of traditional fecal indicator bacteria in circumstances where non-point, non-human contributions are the dominant fecal source. We found that non-traditional ways of quantifying fecal contamination, such as QPCR, were unassociated with health effects. This contrasts with a recent study which observed a relationship between enterococcus measured by QPCR and gastrointestinal illness at Great Lakes beaches (Wade *et al.* 2005). Unlike Mission Bay, however, these beaches were impacted by human fecal contamination.

Our findings are unique in this field and do not agree with earlier studies reporting associations between water quality indicators and illness. Like Mission Bay, many other enclosed marine beaches, particularly in California, suffer from impaired water quality due to non-point sources of bacteria and poor circulation. We do not recommend extrapolation to other enclosed beaches at this time, however, because we are uncertain if Mission Bay has unique site characteristics. Further studies to confirm the reduced risk of swimming related illnesses at beaches impacted by non-point sources of fecal pollution appear justified and will be an important element of developing revised water quality thresholds and/or improved indicators of water quality. Finally, our findings from Mission Bay were collected during periods of dry weather with no known sewage spills.

Table 9. Adjusted odds ratios for various health outcomes after two weeks for any water contact (per unit increase) to male-specific coliphage. Statistically significant results are shown in bold face type.

Health Outcome	Adjusted OR (95% CI)
Gastrointestinal	
Diarrhea	1.14 (0.97 - 1.35)
HCGI-1	**1.26 (1.06 - 1.48)**
HCGI-2	**1.43 (1.13 - 1.82)**
Nausea	**1.34 (1.16 - 1.55)**
Cramps	1.04 (0.83 - 1.32)
Vomiting	1.21 (0.96 - 1.53)
Skin Rash	1.00 (0.77 - 1.31)
Eye Irritation	1.14 (0.95 - 1.36)
Ear	
Earache	Too few
Ear Discharge	Too few
Fever	**1.25 (1.09 - 1.44)**
Respiratory	
SRD	1.05 (0.85 - 1.31)
Sore Throat	1.04 (0.83 - 1.30)
Cough	**1.22 (1.02 - 1.48)**

Table 10. Association of male-specific coliphage (defined as >0.10 cfu) with diarrhea.

	Diarrhea Reported	No Diarrhea Reported	Total
Male-specific Phage Present (>0.10 cfu)	8	153	161
Male-specific Phage Absent	195	3,878	4,073
Total	203	4,031	4,234

We would predict an increase in health risks, and likely an association with water quality indicators, if large sources of untreated human fecal material entered the Bay. Health risks to swimmers during wet weather remain unknown.

LITERATURE CITED

Cabelli, V. 1983. Health effects criteria for marine recreational waters. US Environmental Protection Agency. Cincinnati, OH.

Cabelli, V.J., A.P. Dufour, M.A. Levin, L.J. McCabe and P.W. Haberman. 1979. Relationship of microbial indicators to health effects at marine bathing beaches. *American Journal of Public Health* 69:690-6.

Cabelli, V.J., A.P. Dufour, M.A. Levin and L.J. McCabe. 1982. Swimming-associated gastroenteritis and water quality. *American Journal of Epidemiology* 115:606-16.

Calderon, R., E. Mood and A. Dufour. Health effects of swimmers and nonpoint sources of contaminated water. *International Journal of Environmental Health Research* 1991;1:21-31.

City of San Diego and MEC Analytical Systems-Weston Solutions, Inc. (City of San Diego and MEC/Weston). 2004. Mission Bay clean beaches initiative bacterial source identification study. Prepared for the State Water Resources Control Board, Sacramento, CA. City of San Diego and MEC/Weston. San Diego, CA.

Colford, J.M., Jr., T.J. Wade, K.C. Schiff, C. Wright, J.B. Griffith, S.K. Sandhu and S.B. Weisberg. 2005. Recreational Water Contact and Illness in Mission Bay, California. Technical Report 449. Southern California Coastal Water Research Project. Westminster, CA.

Griffith, J.F., L.A. Aumand, I.M. Lee, C.D. McGee, L.L. Othman, K.J. Ritter, K.O. Walker and S.B. Weisberg. 2006. Comparison and verification of bacterial water quality indicator measurement methods using ambient coastal water samples. *Environmental Monitoring and Assessment* 116:335-344.

Gruber, S.J., L.M. Kay, R. Kolb and K. Henry . 2005. Mission Bay bacterial source identification study. *Stormwater* http://www.forester.net/sw_0505_mission.html.

Haile, R.W., J.S. Witte, M. Gold, R. Cressey, C. McGee, R.C. Millikan, A. Glasser, N. Harawa, C. Ervin, P. Harmon, J. Harper, J. Dermand, J. Alamillo, K. Barrett, M. Nides and G. Wang. 1999. The health effects of swimming in ocean water contaminated by storm drain runoff. *Epidemiology* 1999 10:355-63.

Hanley, Y. 2002. 2002. Impact of rainfall on microbiological water quality of Mission Bay, California. Masters Thesis, California State University, San Diego. San Diego, CA.

Jiang, S., R. Noble and W. Chu. 2001. Human adenovirus and coliphages in urban runoff-impacted coastal waters of southern California. *Applied & Environmental Microbiology* 67:179-184.

Lee, J.V., S.R. Dawson, S. Ward, S.B. Surman and K.R. Neal. 1997. Bacteriophages are a better indicator of illness rates than bacteria amongst users of a white water course fed by a lowland river. *Water Science and Technology* 35:165-170.

Lipp, E.K., S.A. Farrah and J.B. Rose. 2001. Assessment and impact of microbial fecal pollution and human enteric pathogens in a coastal community. *Marine Pollution Bulletin* 42:286-293.

National Resource Council (NRC). 2004. Indicators for waterborne pathogens. National Academies Press. Washington, DC.

Noble, R.T. and J.A. Fuhrman. 2001. Enteroviruses detected by reverse transcriptase polymerase chain reaction from the coastal waters of Santa Monica Bay, California: low correlation to bacterial indicator levels. *Hydrobiologia* 460:175-184.

Noble, R.T., S.B. Weisberg, M.K. Leecaster, C.D. McGee, P. Dorsey, P. Vainik, M.V. Orozco-Borbón. 2003. Storm effects on regional beach water quality along the southern California shoreline. *Journal of Water and Health* 1:23-31.

Noble, R.T., S.M. Allen, A.D. Blackwood, W.-P. Chu, S.C. Jiang, G.L. Lovelace, M.D. Sobsey, J.R. Stewart and D.A. Wait. 2003. Use of viral pathogens and indicators to differentiate between human and non-human fecal contamination in a microbial source tracking comparison study. *Journal of Water and Health* 1:195-207.

Noble, R.T. and S.B. Weisberg. 2005. A review of technologies being developed for rapid detection of bacteria in recreational waters. *Journal of Water and Health* 3:381-392.

Pruss A. 1998. Review of epidemiological studies on health effects from exposure to recreational water. *International Journal of Epidemilogy* 27:1-9.

Rothman, K.J. and S. Greenland. 1998. Modern Epidemiology. Second ed. Lippincott-Ravens. Philadelphia, PA.

Schiff, K. and P. Kinney. 2001. Tracking sources of bacterial contamination in stormwater discharges from Mission Bay, California. *Water Environment Research* 73:534-542.

Schiff, K., J. Morton and S. Weisberg. 2003. Retrospective evaluation of shoreline water quality along Santa Monica Bay beaches. *Marine Environmental Research* 56:245-253.

Schiff, K., S. Weisberg and V. Raco-Rands. 2002. Inventory of ocean monitoring in the Southern California Bight. *Environmental Management* 29:871-876.

Scripps Institute of Oceanography (SIO). 2003. Mission Bay contaminant dispersion study. Final Report to the City of San Diego General Services Department (Agreement No. 228099) SIO, University of California San Diego. San Diego, CA.

Tsai, Y., M.D. Sobsey, L.R. Sangermano and C.J. Palmer. 1993. Simple method of concentrating enteroviruses and hepatitis A virus from sewage and ocean water for rapid detection by reverse transcriptase-polymerase chain reaction. *Applied Environmental Microbiology* 59:3488-3491.

Wade, T.J., R.L. Calderon, E. Sams, M.J. Beach, K.P. Brenner, A.H. Williams and A.P. Dufour. 2005. Rapidly measured indicators of recreational water quality are predictive of swimming associated gastrointestinal illness. *Environmental Health Perspectives* doi:10.1289/ehp.8273.

Wade, T.J., N. Pai, J.N. Eisenberg and J.M. Colford, Jr. 2003. Do US Environmental Protection Agency water quality guidelines for recreational waters prevent gastrointestinal illness? A systematic review and meta-analysis. *Environmental Health Perspectives* 111:1102-9.

Weiskel, P.K., B.L. Howes and G.R. Heufelder. 1996. Coliform contamination of a coastal embayment: Sources and transport pathways. *Environmental Science & Technology* 30:1872-1881.

ACKNOWLEDGEMENTS

We thank the many organizations that helped with data collection and sample processing on this project. Ric Amador and Laila Othman (City of San Diego) kindly coordinated fecal indicator bacterial analysis using traditional methodologies. Rich Haugland, Al Dufour and Charles LaCerra coordinated the analyses using quantitative polymerase chain reaction (EMSL Laboratories, Cincinnati, Ohio). Virus and coliphage measurements were coordinated by Mark Sobsey (at University North Carolina, Chapel Hill). The human health data collection was coordinated by Jackie Hayes (University California Berkeley). Data management and analytic support were provided in part by Srikesh Arunajadai and Shannon Carr (University California Berkeley). We also wish to thank Rebecca Calderon, Richard Gersberg, Mark Gold, Charles McGee, Alan Brookhart and John Witte for their advice in study design, data analysis and data interpretation. We thank our funding agency contract managers (from the City of San Diego and the San Diego Regional Water Quality Control Board), Christina Arias, Leslie Dobalian and Ruth Kolb.