SAN BERNARDINO COUNTY STORMWATER PROGRAM

A Consortium of Local Agencies

825 East Third Street, Room 201
San Bernardino, CA 92415-0835
(909) 387-8145 | FAX (909) 387-1841

January 4, 2013

File: 10(SAR)-1.20

Kurt V. Berchtold, Executive Officer
California Regional Water Quality Control Board - Santa Ana Region
3737 Main Street, Suite 500
Riverside, CA 92501-3339

RE: WATERSHED ACTION PLAN REPORT ON PHASE 2 ACTIVITIES, COUNTY OF SAN BERNARDINO AREAWIDE STORMWATER MANAGEMENT PROGRAM, NPDES PERMIT NO. CAS618036, RWQCB ORDER R8-2010-0036

Dear Mr. Berchtold:

The San Bernardino County Flood Control District, on behalf of the Co-Permittees comprising the County of San Bernardino Areawide Stormwater Management Program (Program), is pleased to submit the "Watershed Action Plan Report on Phase 2 Activities," including the appurtenant Hydromodification Management and Monitoring Plans, in compliance with NPDES Permit No. CAS618036 and Santa Ana Regional Water Quality Control Board Order R8-2010-0036 (Permit). This submittal documents activities completed by the Program in compliance with Sections XI.B.(a) and (b) of the Permit.

If you have any questions regarding the content of this submittal please contact Marc Rodabaugh or Gia Kim at (909) 387-8145.

Sincerely,

GERRY NEWCOMBE, Director
San Bernardino County Flood Control District

Enclosure

GN:GK:MR:mp

Cc: G. Kim
M. Rodabaugh

WATERSHED ACTION PLAN
REPORT ON PHASE 2 ACTIVITIES

Prepared and Submitted by:
COUNTY OF SAN BERNARDINO AREAWIDE STORMWATER PROGRAM
ORDER No. R8-2010-0036, NPDES No. CAS618036

Submitted to:
California Regional Water Quality Control Board - Santa Ana Region

JANUARY 4, 2013

Contents

Executive Summary

The Watershed Action Plan (WAP) for the San Bernardino County Flood Control District (District), the County of San Bernardino (County) and 16 cities within the County, collectively known as Co-Permittees, is a requirement of the National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer Permit No. CAS618036 and Santa Ana Regional Water Quality Control Board (SARWQCB) Order R8-2010-0036 (Permit) Section XI.B. It has been developed by the County of San Bernardino Areawide Stormwater Program (Program) through a collaborative process with the Co-Permittees, and other watershed stakeholders. The WAP development involved several WAP Task Force meetings and WAP development workshops where watershed stakeholders provided input on the WAP and watershed development process. The Co-Permittees intend to use the WAP to help improve water quality and to implement an integrated water resources approach in the Santa Ana River Watershed. The WAP should be used by the Co-Permittees, stakeholders and project proponents in parallel with the Water Quality Management Plan, Local Implementation Plans, Basin Plan, and TMDL program.

In order to improve integration of water quality, stream protection, stormwater management, water conservation and re-use, and flood protection concepts with the land use planning and development process, the Watershed Action Plan (WAP) was separated into two phases. WAP Phase I included development of program-specific objectives and a structure that emphasizes coordination of watershed priorities with co-Permittees' Local Implementation Plans, an evaluation of potential causes of identified stream degradation, an evaluation of various existing facilities and potential retrofit sites, and development of an online Watershed Geodatabase. WAP Phase II includes development of Hydromodification Management and Monitoring Plans, conducting various training workshops for effective use of the Geodatabase, providing recommendations for streamlining the review process, and proposing regional treatment control Best Management Practices (BMP).

The WAP Phase I documentation was submitted and approved by Santa Ana Regional Water Quality Control Board on July 6, 2011. WAP Phase II is being submitted as an addendum to the WAP Phase I.

The documentation included herein provides a concise summary of activities performed by the Program in compliance with the following Permit requirements:

- "XI.B.b.i. Contingent upon consensus with Regional Board staff and other resource agencies as described in XI.B.2.3.a.vii, above, specify procedures and a schedule to integrate the use of the Watershed Geodatabase into the implementation of the MSWMP, WQMP, and TMDLs;"
- "XI.B.b.ii. Develop and implement a Hydromodification Monitoring Plan... to evaluate hydromodification impacts for the drainage channels deemed most susceptible to degradation. The HMP will identify sites to be monitored, include an assessment methodology, and required follow-up actions based on monitoring results. Where applicable, monitoring sites may be used to evaluate the effectiveness of BMPs in preventing or reducing impacts from hydromodification."

- "XI.B.b.iii. Develop and implement a Hydromodification Management Plan prioritized based on drainage feature/susceptibility/risk assessments and opportunities for restoration."
- "XI.B.b.iv. Conduct training workshops in the use of the Watershed Geodatabase. Each Permittee must ensure that their planning and engineering staffs attend a workshop."
- "XI.B.b.v. Conduct demonstration workshops for the Watershed Geodatabase to be attended by appropriate upper-level managers and directors from each Permittee."
- "XI.B.b.vi. Develop recommendations for streamlining regulatory agency approval of regional treatment control BMPs. The recommendations should include information needed to be submitted to the Regional Board for approval of regional treatment control BMPs. At a minimum, this information should include BMP location; type and effectiveness in removing pollutants of concern; project tributary to the regional treatment system; engineering design details; funding sources for construction, operation and maintenance and parties responsible for monitoring effectiveness, operation and maintenance. The Permittees are encouraged to collaborate and work with other counties to facilitate and coordinate these recommendations."
- "XI.B.b.vii. Implement applicable retrofit or regional treatment recommendations from the evaluation conducted in Section B.3.a.ix, above."
- "XI.B.b.viii. Submit the Phase 2 components in a report to the Executive Officer. The submitted report shall be deemed acceptable to the Regional Board if the Executive Officer raises no written objections within 30 days of submittal."

WAP Phase II Components

1.0 Geodatabase Integration Procedure and Schedule

The on-line Watershed Geodatabase has been developed and includes multiple layers of information to be used by municipality staff and general public. The following is a list of base and information (data) layers contained within the Geodatabase:

- Topo Map
- Street Map
- Aerial Map
- County Maintained Road within Unincorporated area
- City Limits
- Parcels
- County Owned Parcels
- Flood Control Boundaries
- Thomas Brothers Index
- Drainage Facilities
- 303 d/TMDL locations
- Water Storage Facilities
- Drainage Area Boundaries
- City Storm Drain
- Groundwater Basin Locations
- Groundwater Contamination Plumes (lateral extents)
- Estimated Elevations of "first groundwater"
- Soil Types
- As-built Plans
- Possible Retrofit Opportunities
- Possible Restoration Opportunities
- Hydromodifcation Field Observations
- Sensitive Habitat and/or Species area

Linking all of the important components of the WAP Phases I and II will create an efficient and effective strategy to comply with relevant Permit requirements. With this tool, the project proponents can design their project to benefit the watershed through applying the Permit requirements, including applicable WQMP, TMDL and LID criteria. The approving Planner can then, in turn, review the project more effectively using this tool, knowing that the project proponent followed the same protocol during the development planning process.

In addition, this important organizational tool will enable all of the Permittees to stay informed and updated on completed tasks and planned goals. Integrating these criteria into the WAP and incorporating it into the online Geodatabase will be an essential and beneficial tool, allowing stakeholders to stay informed on the latest activities in the watershed.

2.0 Hydromodification Monitoring and Management Plans

The Hydromodification Monitoring Plan (HMoP) evaluates hydromodification impacts for the drainage channels deemed most susceptible to degradation. The HMoP identifies sites to be monitored, including an assessment methodology, and requires follow-up actions based on monitoring results. The Hydromodification Management Plan (HMP) also includes a procedure for prioritization of waterbodies based on drainage feature/susceptibility/risk assessments and opportunities for restoration.

The HMoP and HMP documentation is included in Appendix A.

3.0 Watershed Geodatabase Workshops

Two workshops have been conducted in the use of the online Watershed Geodatabase. One workshop was conducted for Co-Permittees' municipal stormwater, engineering and planning staff and the second was conducted for the Co-Permittees' upper-level managers. Each workshop presented background information on the Geodatabase, an explanation of individual GIS layers, and an introductory demonstration of all program features and tools. The workshops were also interactive, with computers available for a "live" program experience. The workshops were conducted as follows:

- Staff Workshop: July 18, 2012 and September 12, 2012
- Upper-Level Management Workshop: September 12, 2012

Sign-in sheets are included in Appendix B

4.0 Recommendation for streamlining regulatory process

Streamlining the regulatory process is a function of developing regional acceptance of proposed management criteria with all stakeholders including the regulatory agencies. A key step is to develop recommendations for streamlining regulatory agency approval of regional treatment control BMPs. The recommendations should include information needed to be submitted to the RWQCB, California Department of Fish and Game, US Fish & Wildlife and US Army Corps of Engineers for approval of regional treatment control Best Management Practices (BMP). At a minimum, this information should include BMP location; type and effectiveness in removing pollutants of concern; description and analysis of the hydrologic subareas to be managed by the regional treatment system; engineering design details; funding sources for construction, operation and maintenance, and parties responsible for monitoring effectiveness, operation and maintenance. The Co-Permittees are encouraged to collaborate and work with adjacent jurisdictions to facilitate and coordinate these recommendations. The following steps are recommended:

- Obtain approval on hydromodifcation exemptions
    - Ongoing collaboration with Regional Water Board
- Develop conceptual agreement with Regulatory Agencies
    - Standard environmental criteria: baseline and exemptions
    - Standard engineering criteria: flood control, public safety, water quality
- Develop conceptual typical designs for regional use
- Develop example operations and maintenance criteria
- Develop effectiveness assessment strategies
- Strategize opportunities for funding:
    - Grant funding requirements

Project implementation will begin once the stakeholders have completed the preliminary program development and a budget is determined. It will be imperative for the RWQCB to take the regulatory lead on the overall program regulatory agency collaboration in order to develop practical agreement. Programmatic and project specific scheduling cannot be estimated at this time. The stakeholders and agencies would have to come to preliminary agreement on baseline conditions for scheduling to occur.

APPENDIX A - HYDROMODIFICATION MANAGEMENT AND MONITORING PLAN

HYDROMODIFICATION MANAGEMENT and MONITORING PLAN

for the

SANTA ANA RIVER WATERSHED REGION

WITHIN THE

SAN BERNARDINO COUNTY

DECEMBER 2012

CONTENTS

ACRONYMS

ACCCMP	Alameda Countywide Clean Water Program
BAHM	Bay Area Hydrology Model
BEHI	Bank Erosion Hazard Index
BMI	Benthic Macroinvertebrates Index
BMP	Best Management Practice
CASQA	California Stormwater Quality Association
CCCWP	Contra Costa Clean Water Program
CEM	Channel Evolution Model
CEQA	California Environmental Quality Act
D_{50}	Median grain size diameter
Ep	Erosion potential index
ET	Evapotranspiration
FSURMP	Fairfield-Suisun Urban Runoff Management Program
GIS	Geographical Information System
HEC-HMS	Hydrologic Modeling System; distributed by the US Army Corps of Engineers Hydrologic Engineering Center
HMP	Hydromodification Management Plan
HMoP	Hydromodification Monitoring Plan
HR	Hydraulic Radius
HSPF	Hydrologic Simulation Program FORTRAN, distributed by USEPA
IMP	Integrated Management Practices
LEED	Leadership in Energy and Environmental Design
LID	Low Impact Development
LSPC	Loading Simulation Program in C++
MHHW	Mean Higher High Water
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resource Conservation Service
OCHM	Orange County Hydrology Manual
PDP	Priority Development Project
PLS	Pervious Land Surface
PWA	Philip Williams & Associates
S	Slope in Lane's equation
Q or Qw	Flow
Qcrit - Qc	Critical flow
Qcp	Geomorphically critical flow – 10 percent of the 2-year flow
Qs	Sediment discharge in Lane's equation
RWQCB	Regional Water Quality Control Board
SCCWRP	Southern California Coastal Water Research Project
SCVURPPP	Santa Clara Valley Urban Runoff Pollution Prevention Program
SMCWPPP	San Mateo Countywide Water Pollution Prevention Program
STOPPP	San Mateo County Stormwater Pollution Prevention Program
SSMP	Standard Stormwater Mitigation Plan
SUSMP	Standard Urban Stormwater Mitigation Plan
SWM SWMM	Stanford Watershed Model Stormwater Management Model; distributed by USEPA
SWMP	Stormwater Management Plan
SWWM	Stormwater Management Model
TMDL	Total Maximum Daily Load
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey

1.0 Introduction

Hydromodification refers to changes in the magnitude and frequency of stream flows due to urbanization and the resulting impacts on receiving channels, such as erosion, sedimentation, and potentially degradation of in-stream habitat. The degree to which a channel will erode or aggrade is a function of the increase or decrease in work (shear stress), the resistance of the channel bed and bank materials - including vegetation (critical shear stress), the change in sediment delivery, and the geomorphic condition (soil lithology) of the channel. Critical shear stress is the shear stress threshold above which motion of bed material load is initiated. Not all flows cause significant movement of bed material—only those flows that generate shear stress in excess of the critical shear stress of the bank and bed materials. Urbanization increases the discharge rate, volume and timing of runoff, and associated shear stress exerted on the channel by stream flows, and can trigger erosion in the form of incision (channel downcutting), widening (bank erosion), or both. Depths that generate shear below critical shear stress levels have little or no effect on the channel stability.

Section XI.B.3.b.ii of the National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer (MS4) Permit No. CAS618036 and Santa Ana Regional Water Quality Control Board (SARWQCB) Order R8-2010-0036 (Permit) requires "…the Principal Permittee, in coordination with the Co-permittees, shall… develop and implement a Hydromodification Monitoring Plan… to evaluate hydromodification impacts for the drainage channels deemed most susceptible to degradation. The HMP will identify sites to be monitored, include an assessment methodology, and required follow-up actions based on monitoring results. Where applicable, monitoring sites may be used to evaluate the effectiveness of stormwater Best Management Practices (BMP) in preventing or reducing impacts from hydromodification. Section XI.B.3.b.iii of the Permit requires "…the Principal Permittee, in coordination with the Co-permittees, shall… develop and implement a Hydromodification Management Plan prioritized based on drainage feature/susceptibility/risk assessments and opportunities for restoration." Where receiving stream channels are already unstable, hydromodification monitoring and management can be thought of as a method to avoid accelerating or exacerbating existing problems. Where receiving stream channels are in a state of dynamic equilibrium, hydromodification management may prevent the onset of erosion, sedimentation, lateral bank migration, or impacts to in-stream vegetation.

The philosophy of the Hydromodification Monitoring Plan (HMoP) and Hydromodification Management Plan (HMP) derives from the South Orange County HMP and aims at establish regional consistency in hydromodification requirements. The flow control approach includes a geomorphically-significant flow range that ensures the geomorphic stability within the channel. Supporting analyses must be based on continuous hydrologic simulation modeling. Conversely, the loss of sediment supply due to the development is not considered in this HMP.

The SARWQCB jurisdiction area covers the areas of San Bernardino County within the Santa Ana River Watershed Region. MS4 Co-Permittees or dischargers directly or indirectly discharging runoff into waters of the United States and State of California within the Santa Ana Region include the Cities of Big Bear Lake, Chino, Chino Hills, Colton, Fontana, Grand Terrace, Highland, Loma Linda, Montclair, Ontario, Rancho Cucamonga, Redlands, Rialto, San

Bernardino, Upland, Yucaipa, as well as the County of San Bernardino and the San Bernardino County Flood Control District.

2.0 Program HMP and HMoP Development Process

Although the San Bernardino County Flood Control District (SBCFCD) serves as the lead agency for development of the HMP and HMoP, all 18 Co-Permittees, through the formation of the County of San Bernardino Areawide Stormwater Program (Program), have participated in its development, both financially and through participation in Watershed Action Plan (WAP) development workshops and meetings scheduled over the course of the project, and at times corresponding with key decision points in developing Phase II of the WAP. Participants in Phase II of the WAP created a WAP workgroup to provide input on the development of the HMP.

The Program members will continue to meet to discuss and resolve any issues that may arise during the implementation phase of the documents developed during Phase II of the WAP. The Program WAP workgroup will also assist in refining and reinforcing methodologies, criteria, and standards established in the HMP and the HMoP.

3.0 Literature Review

This section provides the results of a literature review conducted to provide a basis for the development of the Hydromodification Management and Monitoring Plans.

Hydromodification, in the context of this Plan, refers to changes in the magnitude and frequency of stream flows due to urbanization and the resulting impacts on the receiving channels in terms of erosion, sedimentation, and degradation of in-stream habitat. The processes involved in aggradation and degradation are complex, but are caused by an alteration of the hydrologic regime of a watershed due to increases in impervious surfaces, more efficient storm drain networks, and a change in historic sediment supply sources. The study of hydromodification is an evolving field, and regulations to manage the impacts of hydromodification must be grounded in the latest science available.

HMP seek ways to mitigate erosion impacts by establishing requirements for controlling runoff from new and significant re-development. In order to establish appropriate regulations, it is important to understand 1) how land use changes alter stormwater runoff; and 2) how these changes can impact stream channels. These, and other issues central to HMP adopted in California, have been addressed in numerous journal articles, books, and reports. This report builds upon previous literature reviews developed for the South Orange County HMP and the San Diego County HMP, including recent studies or information relevant to Southern California.

3.1 Managing Hydromodification

There are many different approaches to managing hydromodification impacts from urbanization and most HMP provide multiple options for achieving and documenting compliance with National Pollutant Discharge Elimination System (NPDES) permit requirements. In general, hydrograph management approaches focus on managing runoff from a developed area to not increase instability in a channel, and in-stream solutions focus on managing the receiving channel to accept an altered flow regime without becoming unstable. This section briefly summarizes various approaches for HMP compliance.

3.1.i Hydrograph Management Solutions

Facilities that detain or infiltrate runoff to mitigate development impacts are the focus of most HMP implementation guidance. They work by either reducing the volume of runoff (infiltration facilities) or holding water and releasing it below Q_c (detention facilities). These facilities, also referred to as BMP, can range from regional detention basins designed solely for flow control, to bioretention facilities that serve a number of functions. A number of BMP, including swales, bioretention, flow-through planters, and extended detention basins have been developed to manage stormwater quality, and several resources describe the design of stormwater quality BMP (CASQA 2003; Richman et al. 2004). In many cases, these facilities can be designed to also meet hydromodification management requirements.

Many HMP also provide guidance for applying LID approaches to site design and land use planning to preserve the hydrologic cycle of a watershed and mitigate hydromodification impacts. These plans typically include decentralized stormwater management systems and protection of natural drainage features, such as wetlands and stream corridors. Runoff is typically directed toward infiltration-based BMP that slow and treat runoff. The following sections summarize how hydromodification management BMP developed for existing HMP have been designed and implemented.

3.1.ii Sizing Hydromodification BMP

Hydromodification BMP differ slightly from those used to meet water quality objectives in that they focus more on matching undeveloped flow-regimes than on removing potential pollutants, although these two functions can be combined into one facility. Various methods exist for sizing hydromodification BMP.

- **Hydrograph Matching** uses an outflow hydrograph for a particular site that matches closely with the pre-project hydrograph for a design storm. This method is most traditionally used to design flood-detention facilities to mitigate for a particular storm recurrence interval (e.g., the 100-year storm). Although hydrograph matching can be employed for multiple storm recurrence intervals, this method generally does not typically take into account the smaller, more frequent storms where a majority of the erosive work in stream channel is done.
- **Volume Control** matches the pre-project and post-construction runoff volume for a project site. Any increase in runoff volume is either infiltrated on site, or discharged to another location where streams will not be impacted. The magnitude of peak flows and time of concentration is not controlled, so while this method ensures there is no increase in total volume of runoff, it can result in higher erosive forces during storms.
- **Flow Duration Control** matches both the duration and magnitude of a specified range of storms. The entire hydrologic record is taken into account, and pre-project and post-construction runoff magnitudes and volumes are matched as closely as possible. Excess runoff is either infiltrated onsite or discharged below Q_{cp} (Geomorphically critical flow – 10 percent of the 2-year flow).

Several agencies have adopted the flow duration control approach. The Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVUPPP) HMP reviewed each of these methods and concluded that a Flow Duration Control approach was the most effective in controlling erosive flows. Two examples were evaluated using this approach, one on the Thompson Creek subwatershed in Santa Clara Valley and one on the Gobernadora Creek watershed in Orange County. The evaluation approach used continuous simulation modeling to generate flow-duration curves, and then designed a test hydromodification management facility to match pre-project durations and flows.

In addition to the SCVURPP HMP, the flow duration control approach has been applied by the Alameda Countywide Clean Water Program (ACCWP), SMCWPPP, the Fairfield-Suisun Urban Runoff Management Program (FSURMP), Contra Costa Clean Water Program (CCCWP), San Diego County, and South Orange County. Among these agencies, different approaches have emerged on how to demonstrate that proposed BMP meet flow-duration control guidelines. Both methods employ continuous simulation to match flow-durations, but differences exist in how continuous simulation is used (site-specific simulation vs. unit area simulation). Differences also exist in the focus of the two approaches (regional detention facilities vs. on-site LID facilities). Both approaches were evaluated by the different RWQCBs and deemed valid (Butcher 2007).

3.1.iii BAHM Approach

The Bay Area Hydrology Model (BAHM) is a continuous simulation rainfall-runoff hydrology model developed for ACCWP, SMCWPPP, and SCVURPP. It was developed from the Western Washington Hydrology Model, which focuses primarily on meeting hydromodification management requirements using stormwater detention ponds alone or combined with LID facilities (Butcher 2007). The Western Washington Hydrology model is based on the Hydrologic Simulation Program – FORTRAN (HSPF) modeling platform, developed by the United States Environmental Protection Agency (U.S. EPA), and uses HSPF parameters in modeling watersheds.

Project proponents who want to size a hydromodification BMP select the location of their project site from a map of the county and BAHM correlates the project location to the nearest rainfall gauge and applies an adjustment factor to the hourly rainfall for the nearest gauge, to produce a weighted hourly rainfall at the project site. The user then enters parameters for the proposed project site describing soil types, slope, and land uses. BAHM then runs the continuous rainfall-runoff simulation for both the pre-project and the post-construction conditions of the project site. Output is provided in the form of flow-duration curves that compare the magnitude and timing of storms between the pre-project and the post-construction modeling runs.

If an increase in flow durations is predicted, the user can select and size mitigation BMP from a list of modeling elements. An automatic sizing subroutine is available for sizing detention basins and outlet orifices that matches the flow duration curves between the pre-project scenario and a post-construction mitigation scenario. Manual sizing is necessary for other BMP included in the program, such as storage vaults, bioretention areas, and infiltration trenches. The program is designed so that, once a BMP is selected and sized, the modeling run can be transferred to the local agency for approval. The model reviewer at the local agency can launch the program and verify modeling parameters and sizing techniques.

3.1.iv Contra Costa Clean Water Program (CCCWP) Approach

The CCCWP developed a protocol for selecting and sizing hydromodification BMP, which are referred to as Integrated Management Practices (IMPs) in their guidebook. Instead of a project proponent running a site-specific continuous simulation to size hydromodification control facilities, the CCCWP provides sizing factors for designing site level IMPs. Sizing factors are based on the soil type of the project site and are adjusted for Mean Annual Precipitation. Sizing factors are provided for bioretention facilities, flow-through planters, dry wells and a combination cistern and bioretention facility.

Sizing factors were developed through continuous-simulation HSPF modeling runs for a variety of development scenarios. Flow-durations were developed for a range of soil types, vegetation and land use types, and rainfall patterns for development areas in Contra Costa County. Then, based on a unit area (one acre) of impervious surface, flow-durations were modeled using several IMP designs. These IMPs were then sized to achieve flow control for the range of storms required, (from 10 percent of the 2-year storm up to the 10-year storm). These sizing factors were then transferred to a spreadsheet form for use by project proponents.

The primary difference between the CCCWP approach and the BAHM approach is the level of modeling required. The CCCWP approach is simplified for the project proponent in that both hydromodification and water quality mitigation are incorporated into the IMP sizing factors. The BAHM allows for more flexibility in that regional BMP may be used for hydromodification, and if desired, water quality, in addition to site level approaches. The South Orange County NPDES Permit allows for regional mitigation of hydromodification impacts. Therefore, an approach that uses continuous simulation to assess regional or neighborhood level BMP implementation is preferred for this Plan.

3.1.v Sediment Management Solutions

Sediment discharge is one of the fundamental independent variables impacting stream stability. Lane (1955) described alluvial channel stability in the relation:

$$Q_s \times D_{50} \propto Q_w \times S$$

Where:
Q_s = Sediment discharge
D_{50} = Median sediment size
Q_w = Flow
S = Channel Slope

As seen by Lane's relationship, if any of the four variables are altered, one or more of the remaining variables must change. In the case of urbanization, runoff usually is increased, causing a reduction in channel slope (S) through downcutting or increased channel meander. Urbanization may also result in a change in sediment discharge (Q_s). Streambed material is derived from the channel bed and banks. If channels are altered by development in such a way as to reduce or increase sediment discharge, instability may occur.

Only a portion of the total sediment load in a channel is important for stream stability. Total channel sediment load may be classified by size or transport mechanism. The wash load commonly refers to the portion of the total sediment load that remains continuously in suspension (based on particle size). The wash load has a nominal impact on channel stability. Bed material load refers to the material that moves along the channel bed via saltation, and is continuously in contact or exchange with the channel bed. Bed material load is the critical portion of total sediment discharge for channel stability.

Urbanization can reduce the mass of bed material transported through the elimination of alluvial channel sections. This occurs in site development when first order and particularly larger streams are lined or placed into underground conduits.
In-Stream Stabilization Solutions

In-stream solutions focus on managing the stream corridor to provide stability, modifying the stream channel to accept an altered flow regime. In cases where development is proposed in a watershed with an impacted stream it may be beneficial to focus on rehabilitating the stream channel to match the new independent variables of channel cross section, sediment discharge, flow discharge and channel slope rather than retrofitting the watershed or only controlling a percentage of the runoff with on-site controls. This type of approach can restore stream functions, beneficial uses, and values at a much more rapid pace, especially in locations that cannot physically be returned to their natural state due to changes in stream channel alignment and restrictions on the channel cross section due to adjacent development. In addition, in some cases where a master-planned watershed development plan is being implemented it may be more feasible to design a new channel to be stable under the proposed watershed land use rather than to construct distributed on-site facilities.

A stream channel that has devolved far enough down the evolution sequence, exhibiting surpassed planforms or bank height, should be allowed to continue progressing toward a new stable equilibrium condition (SCCWRP, 2012). This is specifically the case for channels with significantly altered flow or sediment discharge. In such cases, SCCWRP recommends determining the appropriate channel form that would provide equilibrium for expected future conditions per Lane's interpretation. Numerous publications have concluded that the natural state of channels in urban areas cannot longer be sustained under changed hydrologic conditions.

In-stream stabilization and restoration solutions are available to streams identified as highly susceptible to hydromodification. Phase I of the WAP identified several opportunities for restoration along susceptible channels. Tiered benefits (benthic communities, morphology) of such in-stream restoration projects must offset the hydrologic and sediment changes induced by upstream urbanization.

3.1.vi Other Methods

A number of methods exist for managing channels to accept altered flow regimes and higher shear forces. These have been covered in detail in a number of sources available to watershed groups and public agencies. (A few helpful sources include Riley 1998, Watson and Annable 2003, and FISRWG 1998.)

3.1.vii Stream Susceptibility - Domain of Analysis

Southern California Coastal Water Research Project (SCCWRP) has developed a series of screening tools that evaluate the susceptibility of a stream to hydromodification impacts (SCCWRP, 2010). These screening tools allow a project proponent to rate the susceptibility of the evaluated stream to erosion for a variety of geomorphic scenarios including alluvial fans, broad valley bottoms, incised headwaters, etc.

The development of HMP in most Southern California counties is correlated to the ultimate findings of SCCWRP studies on hydromodification (SCCWRP, 2008 through 2011). It is generally acknowledged that SCCWRP's formulation of regional standards for hydromodification management may serve as a baseline for development of HMP for specific regions in Southern California.

When evaluating the stream susceptibility though the SCCWRP screening tools, a domain of analysis is defined. This domain of analysis corresponds to the reach lengths upstream and downstream from a project from which hydromodification assessment is required. The domain of analysis determination includes an assessment of the incremental flow accumulations downstream of the site, identification of grade control points in the downstream conveyance system, and quantification of downstream tributary influences. Extensive susceptibility mapping was performed during Phase I of the Watershed Action Plan. The results of the investigations are detailed in Section 3.3.

The effects of hydromodification may propagate for significant distances downstream (and sometimes upstream) from a point of impact such as a stormwater outfall. Accordingly, the domain of analysis serves as a representative buffer domain across which the susceptibility of a stream should be evaluated. This representative domain spans multiple channel types/settings, and is defined as follows in this HMP (SCCWRP, 2010):

- Proceed downstream until reaching the closest of the following:
  - at least one reach downstream of the first grade-control point (but preferably the second downstream grade-control location)
  - tidal backwater/lentic waterbody
  - equal order tributary (Strahler 1952)
  - a 2-fold increase in drainage area

OR demonstrate sufficient flow attenuation through existing hydrologic modeling.

- Proceed upstream to extend the domain:
  - upstream for a distance equal to 20 channel widths OR to grade control in good condition - whichever comes first. Within that reach, identify hard points that could check headward migration, evidence that head cutting is active or could propagate unchecked upstream

Within the analysis domain there may be several reaches that should be assessed independently based on either length or change in physical characteristics. In more urban settings, segments may be logically divided by road crossings (Chin and Gregory

2005), which may offer grade control, cause discontinuities in the conveyance of water or sediment, etc.

3.2 Hydrograph Matching Approach

The San Bernardino HMP adopts a hydrograph matching approach, as required per Permit condition XI.E.5.(ii).(c) for priority development or re-development project proponents. The Permit states that "post-development site hydrology (runoff volume, velocity, duration, time of concentration) must not significantly be different from pre-development hydrology for a 2-year return frequency storm. The selection of the 2-year storm event as a matching event may have been linked to the dominant discharge, as defined by Leopold (1964). Leopold (1964) introduced the concept of effective work, whereby the flow-frequency relationship of a channel is multiplied by sediment transport rate. This gives a mass-frequency relationship for erosion rates in a channel. Flows on the lower end of the relationship (e.g., two-year flows) may transport less material, but occur more frequently than higher flows, thereby having a greater overall effect on the work within the channel. Conversely, higher magnitude events, while transporting more material, occur infrequently so cause less effective work. Leopold found that the maximum point on the effective work curve occurred around the 1-to 2-year frequency range. This maximum point is commonly referred to as the dominant discharge. It corresponds roughly to a bankfull event (a flow that fills the active portion of the channel up to a well-defined break in the bank slope).

3.2.i Previous Studies

Previous hydromodification literature reviews were conducted by Geosyntec Consultants (Mangarella and Palhegyi, 2002) for the Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP) and by the Contra Costa Clean Water Program (CCCWP, 2004). Mangarella and Palhegyi provide a detailed overview of the geomorphic and hydrologic processes involved in hydromodification (see **Section 3.2.iii**) for additional details on the mechanics of stream erosion).

To date, six approved HMP have been published. These include HMP for SCVURPPP (2005), the CCCWP (2005), the Fairfield-Suisun Urban Runoff Management Program FSURMP (2005), the Alameda Countywide Clean Water Program (ACCCMP 2005), the San Mateo Countywide Stormwater Pollution Prevention Program (SMCWPPP [formerly STOPPP] 2005), and the San Diego County Hydromodification Plan (2009). In addition, the South Orange County HMP has been approved upon integration of the San Diego Regional Board comments. In addition, a number of HMP were implemented while agencies developed their final plans. Interim HMP are not detailed in this report because these plans have adopted findings from the above listed HMP.

3.2.ii Hydrograph Modification Processes

The effects of urbanization on channel response have been the focus of many studies (see Paul and Meyer, 2001 for a review), and the widely accepted consensus is that increases in impervious surfaces associated with urbanizing land uses can cause channel degradation. Urbanization generally leads to a change in the volume and timing of runoff in a watershed, which increases erosive forces on channel bank and bed material and can cause large-scale channel enlargement, general scour, stream bank failure, loss of aquatic habitat and degradation of water quality.

Channel erosion, like most physical processes, is a complex system based on a variety of influences. Channel erosion is non-linear (Philips 2003), meaning the response of streams is not directly proportional to changes in land use and flow regimes. Small changes or temporary disturbances in a watershed may lead to unrecoverable channel instability (Kirkby 1995). These disturbances may give rise to feedback systems whereby small instabilities can be propagated into larger and larger instabilities (Thomas 2001).

A number of studies have sought to correlate the amount of urbanization in a watershed and stream instability (Bledsoe 2001; Booth 1990, 1991; Both and Jackson 1997; MacRae 1992; 1993; 1996; Coleman et al. 2005). Evidence from these studies suggests that below a certain threshold of watershed imperviousness, streams maintain stability. This threshold or imperviousness transition zone appears to be around seven to ten percent watershed urbanization for perennial streams (Schueler 1998 and Booth 1997), but may begin at a lower level for intermittent streams such as those found in Southern California. Studies done in Santa Fe, New Mexico (Leopold and Dunne 1978) suggest that changes occur at four percent impervious area of the watershed.
Initial studies by Coleman et al. (2005) suggest that a response in the stream channel may begin to occur at two to three percent watershed imperviousness for intermittent streams in Southern California. It is important to understand that use of impermeable cover alone is a poor predictor of channel erosion due to differences in stormwater detention and infiltration within regions.
In highly urbanized watersheds returning a stream to a natural condition is infeasible due to existing development in the watershed.

Though it is well established that watershed urbanization causes channel degradation, a detailed understanding of how development alters runoff and how this altered runoff in turn causes erosion is still being developed. This section briefly describes these processes and summarizes methods used to quantify hydromodification impacts.

Effective Work

The ability of a stream to transport sediment is proportional to the amount of flow in the stream: as flow increases, the amount of sediment moved within a channel also increases. The ability of a stream channel to transport sediment is termed stream power, which integrated over time is work. As described earlier, Leopold (1964) introduced the concept of effective work, whereby the flow-frequency relationship of a channel is multiplied by sediment transport rate. This gives a mass-frequency relationship for erosion rates in a channel. Flows on the lower end of the relationship (e.g., two-year flows) may transport less material, but occur more frequently than higher flows, thereby having a greater overall effect on the work within the channel. Conversely, higher magnitude events, while transporting more material, occur infrequently so cause less effective work. Leopold found that the maximum point on the effective work curve occurred around the 1-to 2-year frequency range. This maximum point is commonly referred to as the dominant discharge. It corresponds roughly to a bankfull event (a flow that fills the active portion of the channel up to a well-defined break in the bank slope).

Urbanization tends to have the greatest relative impact on flows that are frequent and small, and which tend to generate less-than-bankfull flows. Change is greatest in these events because prior to urbanization, infiltration would have absorbed much or all of the potential runoff, but following urbanization, a high percent of the rainfall runs off. Thus, events that might have generated little or no flow in a non-urbanized watershed can contribute flow in urban settings. These smaller less-than-bankfull events have been found to cause a significant proportion of the work in urban streams (MacRae 1993) due to their high frequency, and can lead to channel instability. Less frequent, larger magnitude flows (e.g., flows greater than Q_{10}) are less strongly affected by urbanization because during such infrequent storm events, the ground rapidly becomes saturated, and acts (for purposes of runoff generation) in a similar manner as impervious surfaces.

Estimating Critical Q_c

Due to the increase in impervious surfaces and fewer opportunities for infiltration of stormwater, urbanization creates a higher runoff rate and more runoff volume than a non-urbanized watershed. Opportunities for infiltration of excess stormwater exist in urbanized areas, but many times are infeasible due to cost, technical barriers or land use constraints. Therefore, some of the excess stormwater must be discharged to a receiving stream. In order to achieve an E_p comparable to a pre-developed condition, excess runoff volume must be discharged at a rate at which insignificant effective stream work is done.

Bed load sediment moves through transmission of shear stress from the flow of water on the channel bed. An increase in the hydraulic radius (measure of channel flow efficiency through a ratio of the channel's cross sectional area of the flow to its wetted perimeter) corresponds to an increase in shear stress. In order to initiate movement of bed material, however, a shear stress threshold must be exceeded. This is commonly referred to as critical shear stress, and is dependent on sediment and channel characteristics. For a given point on a channel where the bed composition and cross-section is known, the critical shear can be related to a stream flow. The flow that corresponds to the critical shear is known as the critical flow, Q_c. For a given cross-section, flows that are below the Q_c value do not initiate bed movement, while flows above this value do initiate bed movement.

SCVURPPP expressed Q_c as a percentage of the two-year flow in order to develop a common metric across watersheds of different size, and allow for easy application of HMP requirements. For the two watersheds studied in detail in the SCVURPPP study, a similar relationship was found where Q_c corresponded to 10 percent of the two-year flow. This became the basis for the lower range of geomorphically significant flows under the SCVURPPP HMP and is referred to as Q_{cp} to indicate that it is a percentage of flow. That program also adopted the 10-year flow as the upper end of the range of flows to control with the justification that increases in stream work above the 10-year flow were small for urbanized areas.

3.2.iii Stream Channel Stability

Numerous stream channel stability assessment methods have been proposed to help distinguish which channels are most at risk from hydrograph modification impacts and/or define where HMP requirements should apply. Assessment strategies range from purely empirical approaches to channel evolution models to energy-based models (see Simon et al., 2007 for a critical evaluation). Stream channel stability assessment methods are useful in assessing the impact of urbanization, or control programs over time. Their value lies in showing trends as changes in a watershed occur, rather than classifying the reach of a discrete channel section at a given point in time.

Stream Classification Systems

A recent study by Bledsoe et al. (2008) for SCCWRP describes nine types of classification and mapping systems with an emphasis on assessing stream channel susceptibility in Southern California. The summary below is taken from that study. Bledsoe also provides a summary of the implications of these classification and mapping systems to the development of hydromodification tools for Southern California. The article provides a detailed breakdown of guidelines for developing hydromodification tools given the advantages and disadvantages of each system previously assessed.

Phase I of WAP included a risk susceptibility analysis of stream channels. This analysis classified non-engineered, hardened, maintained channels into high, medium, and low risk levels based on the Rapid Stream Risk Classification method (WEST, 2010). Those findings are summarized in Section 3.3.

Planform Classifications and Predictors

Alluvial channels form a continuum of channel types whose lateral variability is primarily governed by three factors: flow magnitude, bank erodibility, and relative sediment supply. Though many natural channels conform to a gradual continuum between straight and intermediate, meandering, and braided patterns, abrupt transitions in lateral variability imply the existence of geomorphic thresholds where sudden change can occur. The conceptual framework for geomorphic thresholds has proven integral to the study of the effects of disturbance on river and stream patterns. Many empirical and theoretical thresholds have been proposed relating stream power, sediment supply and channel gradient to the transition between braiding and meandering channels. Accounting for the effects of bed material size has been shown to provide a vital modification to the traditional approach of defining a discharge-slope combination as the threshold between meandering and braided channel patterns. The many braided planforms in Southern California indicate the need to refine and calibrate established thresholds to river networks of interest. However, at this time there is not a well-accepted model to predict how hydromodification affects channel planform.

Energy-Based Classifications

The link between channel degradation and urbanization has been studied; however, impervious area is not the solitary factor influencing channel response. Studies have shown that the ratio between specific stream power and median bed material size D50b, where b is approximately 0.4 to 0.5 for both sand-and gravel-bed channels, can be used as a valuable predictor of channel form. Stream power, which is related to the square root of total discharge, is the most comprehensive descriptor of hydraulic conditions and sedimentation processes in stream channels. Several studies have been performed relating channel stability to a combination of parameters such as discharge, median bed-material size, and bed slope, as an analog for stream power.

General Stability Assessment Procedures

By assessing an array of qualitative and quantitative parameters of stream channels and floodplains, several investigators have developed qualitative assessment systems for stream and river networks. These assessment methods have been incorporated into models used to analyze channel evolution and stability. Many parameters used to establish methodologies such as the Rosgen approach are extendable to a qualitative assessment of channel response in Californian river networks. Field investigations in Southern California have shown that grade control can be the most important factor in assessing the severity of channel response to hydromodification. Qualitative methodologies have proven extendable to many regions, and they use many parameters that may provide valuable information for similar assessments in California.

Sand vs. Gravel Behavior / Threshold vs. Live-Bed Contrasts

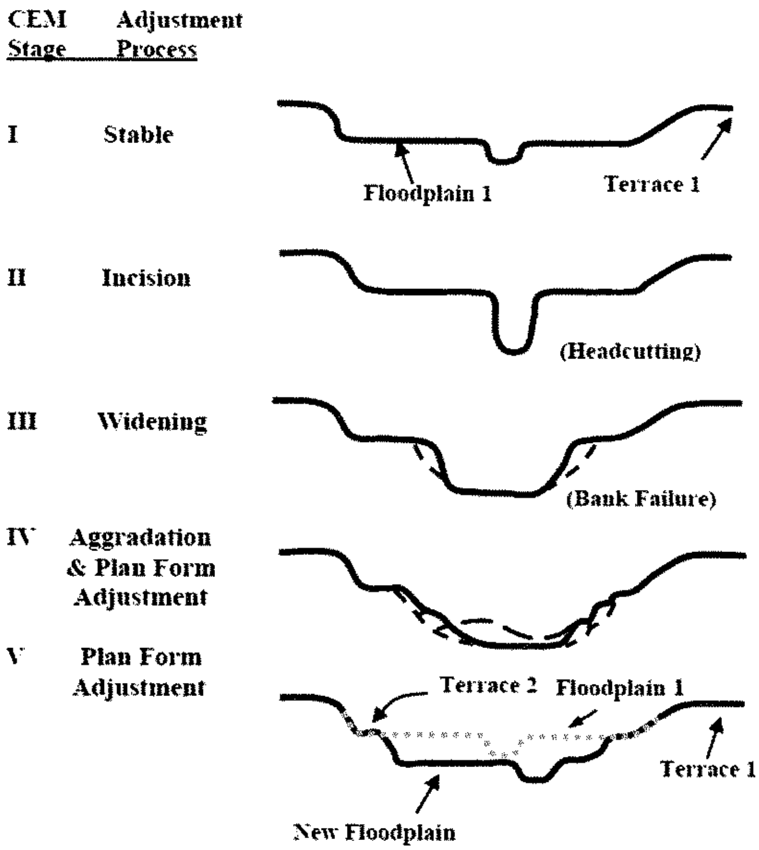
It is well recognized that the fluvial-geomorphic behavior varies greatly between sand and gravel/cobble systems. Live bed channels (of which sand channels are good examples) are systems where sediment moves at low flows, and where sediment is frequently in motion. Threshold channels, such as gravel streams, by contrast, require considerable flow to initiate bedload movement. Live bed channels are more sensitive to increases in flow and decreases in sediment supply than threshold channels. Scientific consensus shows that sand bed streams lacking vertical control show greater sensitivity to changes in flow and sediment transport regimes than do their gravel/cobble counterparts. Factors such as slope and sedimentation regimes are known to have greater impact on sand-bed streams. This can be an important issue for stormwater systems receiving runoff from watersheds composed primarily of streams with sandy substrate. The transition between sand and gravel bed behavior can be rapid, enabling the use of geographic mapping methods to prioritize channel segments according to their susceptibility to the effects of hydromodification.

Channel Evolution Models of Incising Channels

The Channel Evolution Model (CEM) developed by Schumm et al. (1984) posits five stages of incised channel instability organized by increasing degrees of instability severity, followed by a final stage of quasi-equilibrium. Work has been done to quantify channel parameters, such as sediment load and specific stream power, through each phase of the CEM. A dimensionless stability diagram was developed by Watson et al.

(2002) to represent thresholds in hydraulic and bank stability. This conceptual diagram can be useful for engineering planning and design purposes in stream restoration projects requiring an understanding of the potential for shifts in bank stability.

Figure 33-1: Five Stages of the Channel Evolution Model (CEM)



(Schumm et al. 1984)

Channel Evolution Models (CEM) combining Vertical and Lateral Adjustment Trajectories

Originally, CEM focused primarily on incised channels with geotechnically, rather than fluvially, driven bank failure. Several CEM have been proposed that incorporate channel responses to erosion and sediment transport into the original framework for channel instability. In these new systems, an emphasis is placed on geomorphic adjustments and stability phases that consider both fluvial and geomorphic factors. The state of Vermont has developed a system of stability classification that suggests channel susceptibility is primarily a function of the existing Rosgen stream type and the current stream condition referenced to a range of variability. This system places more weight on entrenchment (vertical erosion of a channel that occurs faster than the channel can widen, resulting in a more confined channel) and slope than differentiation between bed types.

Equilibrium Models of Supply vs. Transport-capacity / Qualitative Response

The qualitative response model builds on an understanding of the dynamic relationship between the erosive forces of flow and slope relative to the resistive forces of grain size and sediment supply to describe channel responses to adjustments in these parameters. In this system, qualitative schematics provide predictions for channel response to positive or negative fluctuations in physical channel characteristics and bed material. Refinements to such frameworks have been made to account for channel susceptibility relative to existing capacity and riparian vegetation among other influential characteristics.

Bank Instability Classifications

Early investigations provided the groundwork for bank instability classifications by analyzing shear, beam, and tensile failure mechanisms. The dimensionless stability approach developed by Watson characterized bank stability as a function of hydraulic and geotechnical stability. Rosgen (1996) proposed the widely applied Bank Erosion Hazard Index (BEHI) as a qualitative approach based on the general stability assessment procedures outlined above. Other classification systems, like the CEM, determine bank instability according to channel characteristics that control hydrogeomorphic behavior.

Hierarchical Approaches to Mapping Using Aerial Photographs / GIS

It has become increasingly common practice to characterize stream networks as hierarchical systems. This practice has presented the value in collecting channel and floodplain attributes on a regional scale. Multiple studies have exploited geographical information systems (GIS) to assess hydrogeomorphic behavior at a basin scale. Important valley scale indices such as valley slope, confinement, entrenchment, riparian vegetation influences, and overbank deposits can provide information for river networks in California. Many agencies are developing protocols for geomorphic assessment using GIS and other database associated mapping methodologies. These tools may be useful as they are further developed in a monitoring program, but are not viable at a scale useful for reach-by-reach channel analysis.

The approach taken by this HMP to monitor its effectiveness is embedded in a derivative of the channel classification approach defined by Rosgen (1996). The author distinguishes three different levels of stream classification:

1) Level I that generally describes stream relief, landform, and valley morphology;
2) Level II that describes the morphology of stream and associates the later to a stream type based on channel form and bed composition. Field measurements of entrenchment, width-to-depth ratio, sinuosity, slope, and representative sampling of channel material may be suitable;
3) Level III that assesses stream condition and departure.

A stream that is geomorphically stable per Rosgen's definition is characterized by two elements: a) the dimensions, pattern, and profile of a stream are maintained over time; and b) the transport capacity of a watershed's flows and detritus is maintained over time. As such, physical and biological functions of a geomorphologically stable stream remain in an optimum condition.

3.3 WAP Phase I Findings

3.3.i Exemption Criteria and HCOC Exempt Areas

Phase I of the WAP identified several types of HMP exemptions that are applicable to the Santa Ana River Watershed Region of San Bernardino County. Those exemptions are further investigated in Section 4 per the requirements of the SARWQCB (WAP Phase I approval letter dated July 6, 2011). The rationale for these exemptions is that hydromodification from new or significant redevelopment projects would not result in significant impacts to the downstream watercourse on a watershed-wide basis. The WAP Phase I exemption criteria are: controlled release points, large rivers, areas within Prado Basin, and other factors. Details regarding Hydromodification Exemption Criteria and Areas are included in the Program's 2013 SARWQCB-approved Technical Guidance Document (TGD) for Water Quality Management Plans (WQMP), and also within the Program's on-line WAP GeoDatabase (*http://sbcounty.permitrack.com/wap/*).

3.3.ii Susceptibility and Risk Classification

The existing drainages were delineated and classified based on their susceptibility to hydromodification during Phase I of the WAP. Six classification categories were considered, including:

- EHM - Engineered, Hardened, and Maintained;
- Low Risk - Non-EHM with a low risk for Hydromodification ;
- Medium Risk - Non-EHM with a medium risk for Hydromodification ;
- High Risk - Non-EHM with a High risk for Hydromodification ;
- Default High Risk – Non-EHM that was not evaluated;
- Santa Ana River

Susceptibility risks were determined based on two methods: analysis of the San Bernardino County Flood Control District (SBCFCD) System Index, also known as the Red Book, and conducting Rapid Stream Risk Classifications using the method created by WEST Consultants (2011). The SBCFCD System Index helped identify which channel facilities would be classified as Engineered, Hardened, and Maintained (EHM) or Non-Engineered, Hardened, and Maintained (non-EHM).

The Rapid Stream Risk Classification method was subsequently used to quantify the susceptibility risk of each existing drainage facility based on six criteria:

- Shear Ratio - an indicator of channel's bed shear stress sensitivity to increased discharge;
- Entrainment Ratio - represents the channel erosion potential;
- Geotechnical Stability Number - measures the lateral channel stability;
- Confinement Class – measure of the amount of room that exists for the channel to actively move laterally and is a useful indicator of a channel's vulnerability to erosion;

- Bank Conditions
- Streambed Condition

The resultant spatial classifications of susceptibility risk for the stream channels in the Santa Ana River Watershed Region of San Bernardino County can be found in the Program's on-line WAP GeoDatabase (*http://sbcounty.permitrack.com/wap/*).

3.3.iii Causes of Degradation

Three elements were identified to be responsible for the current level of degradation in the three sub-watersheds (San Antonio, Cucamonga and Live Oak) investigated during the preparation of WAP Phase 1. The three elements include the local erosive geology, the reduced sediment yield from developed land, and constructed basins that cut off upstream sediment supply.

All three sub-watersheds are dominated by Cenozoic Sedimentary Rocks - Alluvium and showing significant signs of degradation. This geology type is a significant factor in channel degradation. This is especially evident in the most downstream portions of the watersheds where the mean grain size of the sediment will be at its smallest, and thus more likely to degrade.

The development of the land, especially in the San Antonio and Cucamonga Watersheds, has increased the potential runoff while at the same time decreasing the sediment produced. This change caused an imbalance and increased the degradation in the downstream reaches of the watersheds.

The last major cause of degradation, the construction of water storage/debris basins, was not part of the original GIS-based analysis, but its effect on the watersheds was very evident. The downstream portions of the watersheds rely on the coarse sediment from the upper reaches to replenish the channel bottoms. Without the upstream sediment supply, the channels have a much higher potential for degradation. Even with the decrease in peak flow rates, an imbalance within the watersheds was created, resulting in downstream erosion. Additionally the attenuation of the storm flows has caused an increased amount of time that the channels could experience degradation.

The investigations were based on a GIS-based methodology for identifying potential causes of degradation. The methodology was developed by the Southern California Coastal Water Research Project (SCCWRP) and is called "Hydromodification Screening Tools: GIS-Based Catchment Analyses of Potential Changes in Runoff and Sediment Discharge" (SCCWRP, 2010). The methodology assesses parameters that were found to exert the greatest influence on the variability of sediment-production rates in a watershed: geology types, land cover, and hillslope gradient. Each watershed was evaluated individually and the detailed findings per watershed may be found in Appendix D of Phase I of the WAP.

3.3.iv Potential Restoration and Rehabilitation Opportunities

Potential stream restoration or rehabilitation locations were identified during Phase I of the WAP. The identification process included a desktop survey based on aerial imagery and a field visit inspection. Channel segments that the SBCFCD or other municipality owned, or had easements for, were the primary targets in this investigation, as implementing retrofit projects in privately owned channels would be less feasible than implementing projects in channels already under public ownership. As for easements, some may contain language restricting channel use solely to flood control purposes, which would preclude retrofit for water quality or other non-flood control related purposes. The factors that were taken into consideration when selecting the restoration sites are:

- The channel was hardened and engineered and/or vulnerable to hydromodification;
- There was sufficient room to widen the channel, either by widening the channel bottom or lowering the bank slopes;
- The overall restoration (including removal of the existing facility) would not have a significantly high cost (example: the removal of an existing regional concrete lined channel);
- The restoration would not adversely affect the primary flood control/drainage function of the facility.
- During the field visit, the channel bank protection and any sign of aggradation/degradation were reported. A basic cross-section was sketched and photographs taken.

Because of high costs and technical challenges associated with the removal of existing channel lining (e.g. m concrete or riprap), only unlined (earthen) channel segments were considered for restoration.

Rehabilitation projects would consider the following concepts:

- Create planted/wetland areas: Channel segments were evaluated for the potential to increase habitat value and receiving water quality by creating a planted/wetland area. Since introducing a vegetated lining on an unlined channel may reduce flood conveyance capacity by loss of channel depth or increased channel roughness, the potential to create a wetland/planted area was limited to those channel segments where there appeared to be sufficient right-of-way to accommodate an increased channel width. In addition, creation of a wetland would typically preclude periodic maintenance of that portion of the flood control system, and further engineering investigations would be required to determine the long-term feasibility of constructing such a project.
- Reduce channel erosion. Earthen channel segments were assessed for the potential to reduce erosion and thus discharges of sediment to receiving waters where observed erosion would potentially threaten nearby infrastructure (e.g., roads, buildings, etc.); and observed erosion would impact habitat resources.
- Potential modifications and stabilization measures for areas include the use of an alternative lining, such as riprap or articulated concrete mat.
- The results of the initial flood control channel restoration assessment are found in Appendix F of Phase I of the WAP.

All the elements and findings gathered during the preparation of WAP Phase I served as the foundation of the HMP and the HMoP. Comments from the HMP, as well as from the SARWQCB, were incorporated into the elements of Phase 2 of the WAP. The HMP is depicted in Section 4. The HMoP is described in Section 5.

4.0 Philosophy of the Hydromodification Management Plan

The philosophy of the HMP lies on the knowledge of hydrograph matching practices and stream rehabilitation. As identified in Section 3, stream rehabilitation and/or flood control facility retrofitting are effective practices to observed hydromodification and geomorphic evolution of a particular stream. Rehabilitation involves modifying the stream channel morphology to match the expected flow and sediment regimes such that the channel will maintain a morphologic equilibrium when subject to geomorphically significant flows. Rehabilitation allows also restoring a prolific environment to a healthy benthic community and improved beneficial uses. Retrofitting of existing facilities involves creation of additional storage, treatment or infilatration capacity to further improve water quality and/or mitigate downstream HCOC. LID requirements, applied to future PDP, will further mitigate downstream HCOC. The HMP provides recommendations as to how restoration, rehabilitation, and retrofit measures may be considered and prioritized by the Program members.

4.1 Project Proponent: Requirements and Standards

Section XI.D.4. of the Permit defines those projects that are considered as PDP and requires the implementation of a Water Quality Management Plan (WQMP). The project WQMP defines LID and hydromodification measures that will ensure that pre-development site hydrology are mimicked through the implementation of onsite hydrologic controls. Projects that have the potential to cause or contribute to Hydrologic Condition of Concerns (HCOC), are required to implement onsite hydrologic control measures and on-site management controls so that post-development runoff volume, velocity, duration, and time of concentration are not significantly different from pre-development hydrology for a 2-year return frequency period.

The Program submitted a draft TGD for WQMP to the SARWQCB in January 2013. The TGD provides direction to project proponents on the design and implementation of LIDs and hydrologic control onsite to ensure compliance with Permit requirements. In addition, the TGD requires project proponents to document potential onsite BMP infeasibility and proposes two alternative mitigation actions: 1) a project proponent constructed off-site regional or sub-regional LID BMP that provides the same level of hydrologic controls as an on-site system; or 2) a financial contribution to an in-lieu project fund.

4.1.i HMP Criteria

Projects that have the potential to cause or contribute to HCOC are required to implement onsite hydrologic control measures and on-site management controls so that post-project runoff volume, velocity, duration, and time of concentration are not significantly different from pre-development hydrology for a 2-year return frequency period.

4.1.ii HMP Applicability Requirements

To determine if a proposed project must implement hydromodification controls, refer to the HMP Decision Matrix in **Figure 4-1.**

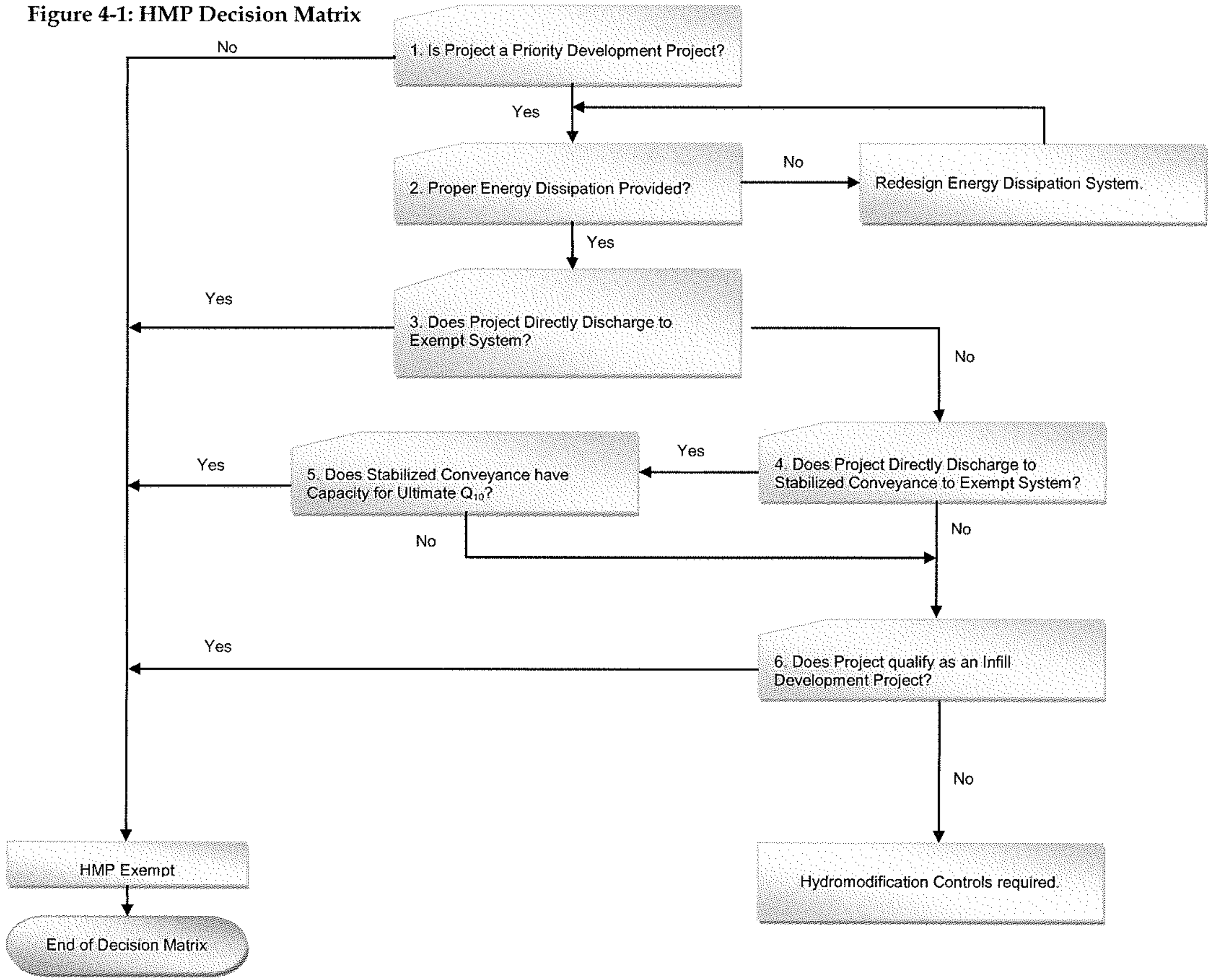
The HMP Decision Matrix can be used for all projects. It should be noted that all Priority Development or re-development Projects (PDP) are subject to the Permit's LID and water quality treatment requirements, even if hydromodification flow controls are not required.

As noted in **Figure 4-1**, projects may be exempt from HMP criteria under the following conditions (these exemptions from HCOC requirements are further detailed in the Program's 2013 TGD for WQMP):

- If the project is an in-stream flood control or restoration project (See **Section 4.3)**.
- If the project is not a PDP. Hydromodification mitigation measures are required only if the proposed project is a PDP, as defined Section XI.D.4. of the Permit (Figure 4-1, Node 1);
- If the project discharges stormwater runoff directly to an exempt receiving water; a controlled release point, or an in-stream flood control restoration project (Figure 4-1, Node 3);
- If the project discharges stormwater runoff directly to an EHM conveyance system that extends to an exempt receiving water or a controlled release point. Such engineered systems could include existing storm drain systems, existing hardened conveyance channels, or stable engineered unlined conveyance channels that are part of the MS4 but that are not receiving waters. To qualify for this exemption, the existing hardened or rehabilitated conveyance system must continue uninterrupted to the exempt system. The engineered conveyance system cannot discharge to an unlined, non-engineered channel segment prior to discharge to the exempt system. Additionally, the project proponent must demonstrate that the engineered conveyance system has the capacity to convey the 10-year ultimate condition flow through the conveyance system. The 10-year flow should be calculated based upon single-event hydrologic criteria as detailed in the San Bernardino County Hydrology Manual (Figure 4-1, Nodes 4 & 5);
- If the project is classified as an infill development project (Figure 4-1, Node 6).

Properly designed energy dissipation systems are required for all project outfalls to unlined channels. Such systems should be designed in accordance with the San Bernardino County Drainage Manual to ensure downstream channel protection from concentrated outfalls.

Figure 4-1: HMP Decision Matrix



4.1.iii Infeasibility and Alternative Compliance Plan

For some PDP, implementation of onsite hydromodification controls consistent with the TGD for WQMP may not be feasible due to site constraints. These projects require alternatives to on-site hydromodification controls. The LID requirements of the Permit require the implementation of LID techniques that effectively result in hydrologic processes that mimic the desired natural watershed conditions. There are two alternative compliance options for PDP that cannot implement onsite hydromodification controls. One option is for a PDP proponent to identify and construct regional or sub-regional mitigation systems to offset the inability to meet the HCOC criteria on-site. The other option is for the PDP proponent to contribute financially into an in-lieu fund, if available to the project proponent.

The technical study documenting the BMP infeasibility will be documented in the PDP WQMP. The study will identify why on-site hydromodification controls cannot be incorporated into the project. The study must include the project constraints and provide detailed technical justification as to why the project constraints prevent implementation of on-site controls. The study will be submitted to the jurisdiction of the location of the PDP for review as part of the Preliminary WQMP.

Regional or sub-regional mitigation opportunities should only be sought within the same watershed as the PDP. The off-site mitigation project must be sized to mitigate the equivalent runoff volume as compared to implementing onsite hydromodification controls for the PDP. The PDP will evaluate and identify potential sites in the same hydrologic unit for implementation of an off-site hydromodification project that has the capacity to mitigate the PDP hydromodification requirements. The project proponent may also investigate the potential for implementation of an in-stream restoration project for the receiving water of the project. It must be determined that the receiving water for the project has hydromodification impacts. The in-stream restoration project must be located in the receiving water of the PDP.

Once the project conceptual plans have been approved by the PDP's jurisdiction, the project proponent must submit the appropriate permit applications to the appropriate regulatory agencies (e.g., Regional Board, California Department of Fish and Game, U.S. Army Corps of Engineers) for review and approval.

The Program will investigate the option to develop an in-lieu fund along with funds specifically allocated to restoration or rehabilitation projects. The in-lieu fund will develop regional HMP mitigation projects where the PDP can buy HMP mitigation credits if it is determined that implementing on-site hydromodification controls is infeasible. The development and operation of an HMP mitigation bank will include the identification of potential regional HMP mitigation projects; the environmental clearance (CEQA), planning, design, permitting, construction, and maintenance of regional HMP mitigation projects; the development of a fee structure for PDP participating in the in-lieu fund; and managing the HMP in-lieu fund. Regional HMP mitigation projects may also be approved for use for off-site LID implementation if site conditions do not allow for implementation of LID-type projects.

4.1.iv Summarized HCOC Requirements

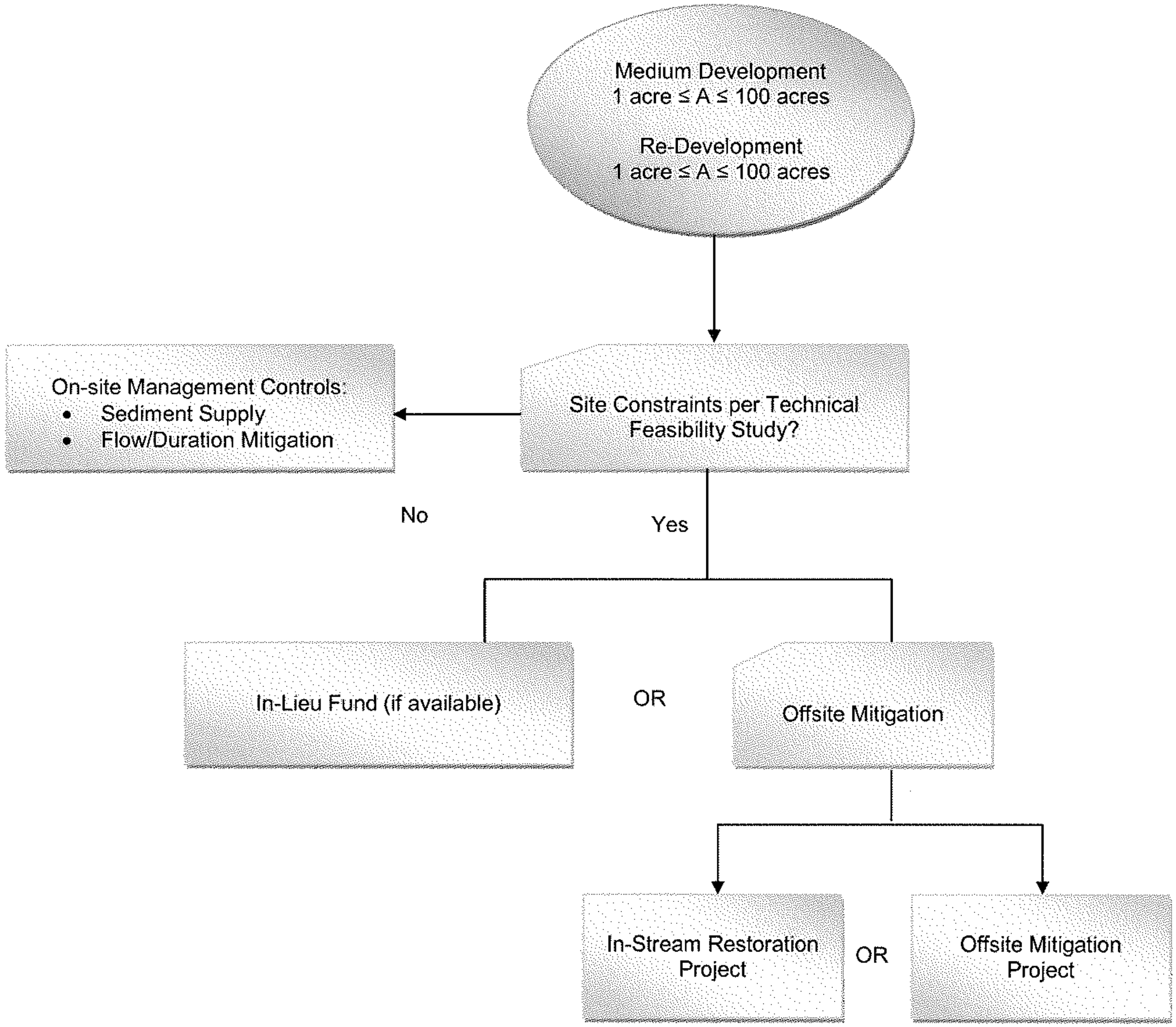
A proposed PDP that does not meet exemption criteria must meet the full HCOC requirements defined in the TGD for WQMP. In addition, the project proponent shall verify the eligibility to exemption criteria as defined in Section 4.1.ii.

Hydrologic control measures and on-site management controls to ensure compliance with the HMP criteria are described in Section 4.1. Using this approach, mitigation of both flow and duration is achieved through on-site hydrologic control measures, and sediment loss is addressed through on-site management controls.

Alternatively, if on-site hydrologic control measures and management controls are not technically feasible due to site constraints, a technical study will be developed to demonstrate the infeasibility per Section 4.1.iii. The second step involves implementation of either an off-site mitigation project in the same hydrologic unit as the PDP, or implementation of an in-stream restoration project in the receiving water that the PDP discharges to. PDPs can pursue the in-lieu fund contribution option, if available.

A flow chart indicating which hydromodification criteria should be pursued and implemented for PDPs is shown in **Figure 4-2**.

Figure 4-2: Priority Development or Re-Development Project HCOC Requirements- Decision Matrix



4.2 Summary of Transportation Project Feasibility Requirements

Municipal and public roadway projects constitute a standalone category based on their unique characteristics. Roadway projects are linear development or re-development projects to be completed within a limited right-of-way.

Routine roadway maintenance projects that maintain the original line and grade, hydraulic capacity, original purpose of the facility, or emergency roadway maintenance activities that are required to protect public health and safety are exempt from HCOC requirements. Roadway projects should implement, to the extent possible, a green street approach to meet compliance with the HMP, as described in Appendix A "Road Guidance" of the TGD for WQMP. The opportunity to develop a green street project will depend upon several factors, including but not limited to the ownership of the land adjacent to the right-of-way, the location of existing utilities, the course of the existing storm drain, and potential access opportunities. If it is determined that due to site constraints implementation of a "green streets" approach for the municipal roadway project is infeasible, the PDP will complete a feasibility study identifying the constraints of why a "green streets" approach cannot be implemented. If a "green streets" approach is infeasible for the municipal roadway project.

4.3 Selection of Potential Rehabilitation and Restoration Projects

Program members are investigating the prioritization of potential rehabilitation and restoration projects that were identified during Phase I of the WAP (Appendix F). Rehabilitation projects are used for streams that require a modified morphology along with restored beneficial uses; and restoration projects are used for streams that are in geomorphic equilibrium and will not observe any altered flow and/or sediment regimes. Higher priority projects will be considered first for individual HCOC mitigation projects (to be constructed by PDP proponents) or Program stream restoration and/or rehabilitation projects. As detailed in Section 4.1.iii., individual HCOC mitigation projects may only be sought by PDP proponents who have demonstrated infeasibility for onsite LID. In addition, individual HCOC projects shall receive permitting approval from the SARWQCB, California Department of Fish and Wildlife, and U.S. Army Corps of Engineers prior to implementation.

The in-lieu Fund and the applicable mitigation fees have not been established by the Permittee, as of the date of this document. Should an in-lieu fund be established, the following criteria shall be considered:

- The HMP shall extend the availability of the mitigation fund to those projects not able to comply with HCOC requirements.
- The Program or Program members may allocate part or a majority of these funds to in-stream restoration projects. Stream restoration projects restore the beneficial uses of a stream and provide a healthy environment for biotic populations.
- A net benefit should be demonstrated through a quantitative cost-to-benefit analysis for all projects.
- Projects shall offset, in terms of beneficial uses and environmental benefits, the hypothetical onsite mitigation of the 2-year return frequency event;

- The stream classification system shall be used to assist in the prioritization of projects as follows: Non-EHM sections are more susceptible to hydromodification than EHM sections. Engineered, hardened, and maintained channels are by definition operated and maintained by the SBCFCD. These channels are designed to convey, at a minimum, the 10-year event. In addition, maintenance corrects any changes in stream morphology after out-of-range events (rarer than 10-year event). Within the Non-EHM sections, priority for projects should be gradually given to those segments identified as having high, medium, and low susceptibility risks. Susceptibility risks were evaluated in Appendix C of Phase I of the WAP.
- The absence of CRPs, non-CRPs, or any type of retarding or sedimentation basin upstream of the project should be considered. As identified in Section 3, upstream basins modify the stresses on channel morphology of downstream waterbodies, most of which are still converging towards a morphologic equilibrium under modified sediment and flow regimes. Unless a combined geomorphic and hydrologic analysis demonstrate that the stream section has reached quasi-equilibrium, projects should not be considered in such cases. Projects without upstream basins will provide the most cost-effective and durable benefits.
- An assessment of expected future developments in the drainage area tributary to the project will provide direction as to whether potential PDP proponents would be able to participate financially into these restoration projects. PDP proponents are directed to contribute to projects in the same watershed, thus offsetting the hydromodification created by the PDP. The second benefit of assessing expected future development is to understand the future sediment and flow regimes under which the stream section will be subject.

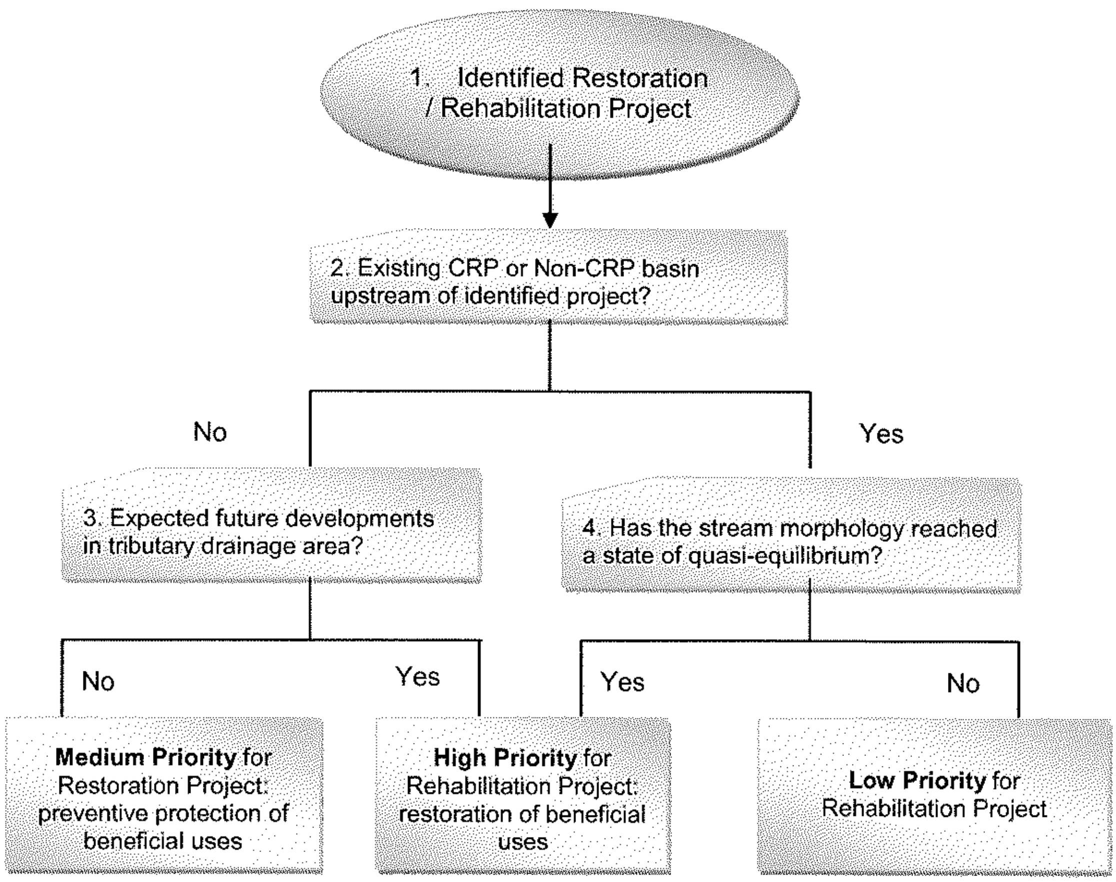
In addition to spatial and technical priorities that are presented above, local jurisdictions should consider the temporal priority associated with each project as part of the in-lieu fund. The temporal priority at the time of consideration of one restoration or rehabilitation project should be determined based on Figure 4-3. Implementation, if required, should focus on those projects demonstrating combined high temporal, technical, and spatial priorities. Figure 4-3 presents a preliminary decision matrix to assist in the process of prioritizing in-lieu projects.

- Figure 4-3, Node 1 – Evaluation of an identified restoration/rehabilitation project, identified in Appendix F of WAP Phase I;
- Figure 4-3, Node 2 – Identify if a flood control retarding basin or sedimentation basin is located upstream of the identified project. During Phase I of the WAP, all CRPs and non-CRPs were identified;
- Figure 4-3, Node 3 – If there are no retarding basin upstream of the potential restoration project, the existence of future developments in the tributary drainage area should be investigated;
- Figure 4-3, Node 4 – If there are identified upstream basins altering sediment and flow regimes in the stream, a combined geomorphic and hydrologic analysis should determine if the stream channel has reached a state of quasi-equilibrium at the location considered for restoration;
- Figure 4-3, Priority Action Nodes – Two types of actions are considered: rehabilitation for streams that require a modified morphology along with restored beneficial uses and

restoration for streams that are in geomorphic equilibrium and will not observe any altered flow and/or sediment regimes.

If an in-lieu fund is established, the Program will re-evaluate the above criteria

Figure 4-3: Prioritization Matrix for Restoration and Rehabilitation Projects



5.0 Hydromodification Monitoring Plan (HMoP)

The following section defines the technical concepts, monitoring approach and the assessment protocol that will be implemented to monitor and verify the effectiveness of the HMP. Section XI.B.3.b.ii. of the Permit requires the identification of sites to be monitored, the inclusion of an assessment methodology, and required follow-up actions based on monitoring results. Monitoring sites should help evaluate the effectiveness of BMP in preventing and/or reducing impacts from hydromodification. Selection of monitoring sites and iterations of the monitoring plan shall focus on those reaches not located in areas meeting HCOC exemption criteria.

This section presents first the technical concepts that form the scientific foundation of the monitoring plan.

The defined assessment methodology addresses the requirements of Permit Section XI.B.3.b.ii., including a description of inspections and maintenance of hydrologic controls, as well as a follow-up protocol to address potential hydromodification impacts.

5.1 Technical Concepts

5.1.i Hydromodification Monitoring Measures

Stream Benthic Community

A stream benthic community is a metric for assessing the condition of a stream. Biological communities represent the health of a portion of the benthic stream community. This is explained by the fact that biological organisms, especially benthic macroinvertebrate and periphyton communities, integrate exposure over time and respond to cumulative stressors (SCCWRP, 2011). The IBI integrates several populations of organisms, and as such the combination of organisms offers a differential sensitivity to stressors, allowing for early detection of potential degradation (SCCWRP, 2011). Bioassessment may only be conducted from May to July and only if water is present; however, samples that are collected late spring may provide the most representative results, as vegetation cover and flow conditions are usually optimal. This is particularly true for non-perennial streams of the San Juan Hydrologic Unit. Seasonal variability in benthic communities is typical for non-perennial streams; however, the current IBI has almost exclusively been calibrated for perennial streams (SCCWRP, 2011). SCCWRP is in the process of developing a Benthic Macroinvertebrate Index (BMI) that would account for the typical seasonal variability of non-perennial streams.

Channel incision and widening

The most obvious way to assess changes due to scour or deposition is to physically measure the pre-project and post-project cross sections, and determine if the channel is incising and/or widening over time. This is accomplished by conducting geomorphic assessments and channel surveys downstream of a planned development before and after construction. In addition to physical measurements, comparison of current and historical photos, aerial photography, and site inspection for signs of channel degradation can provide important supporting evidence.

5.1.ii Temporal and Spatial Variability of Monitoring Locations

Temporal variability

The single most important factor affecting the temporal variability inherent to measuring stream degradation is variable inter-annual rainfall frequency and intensity. Droughts in California can last years, with little to no rainfall occurring in Southern California. During El Niño years, anomalously high storm frequencies and intensities can result in sudden geomorphic changes. Rainfall intensity also varies intra-annually. Accordingly, the value of the monitoring program will be derived only over the long-term. Significant trends will likely require many years to identify. The abundance and composition of benthic communities and the reproductive success for fish may be correlating variables to the frequency of substrate disturbance (SCCWRP, 2012). Geomorphic changes in streams may hence be correlated to the health of benthic macro invertebrates.

Spatial variability

Sampling a representative set of streams is important to capture the range of watershed conditions present in the Permit coverage area. Other important factors that affect stream responses to hydromodification include channel grade, watershed area, vegetated cover, and stream sinuosity of the lower reaches. In addition to channel and watershed features, location within the watershed is an important consideration. Monitoring stations should be located in the watershed headwaters just downstream of a development project of sufficient size, so that hydromodification effects from the proposed development can be isolated for comparison purposes to the maximum extent practicable. Upper watershed sites provide more definitive measures of HMP effectiveness because they can more directly correlate effects to specific development projects.

In San Bernardino County, numerous controlled release points and sedimentation basins that are located at the toe of steep mountain slopes have significantly reduced the sediment supply to downstream waterbodies, resulting ultimately in channel instability. Therefore, monitoring a set of upstream reaches that are not influenced by CRPs would represent the ideal situation.

Middle watershed and lower watershed sites would be influenced by confounding variables (such as mass wasting and impacts from natural tributary confluences and other existing development projects), including phased developments over many years, in the watershed. Therefore, middle and lower watershed monitoring sites would require much more time to assess overall program effectiveness, if achievable.

The concept of providing hydromodification effectiveness measurements in the watershed headwaters is supported by SCCWRP. Research by SCCWRP has shown that hydromodification effects of a development project become muted with increasing distance from the development site (defined by SCCWRP as the Domain of Effect). To the extent practicable, monitoring locations detailed in this plan will be distributed throughout the Santa Ana Region of San Bernardino County to provide for geographic and climatic variability.

5.2 Approaches Selected to Measure the effectiveness of the HMP

A period of five years will be required to fully implement the HMP/HMoP and account for spatial and temporal variability of the conditions in the Santa Ana River Watershed Region of San Bernardino County.

Considering the constraints and technical approach detailed above, the following approaches are proposed for hydromodification monitoring.

Complete a stream channel survey at each of the selected channel sections or monitoring locations on an annual basis.

Only channels that were characterized as non-engineered, hardened, and maintained during Phase I of the WAP will be assessed. The stream channel survey consists of collecting topographic and bathymetric measurements along each cross-section to characterize morphology and longitudinal slope of the stream segment. The collected measures will include those necessary to the computation of a Rapid Stream Risk Classification, including the following six criteria:

- Shear Ratio - An indicator of channel's bed shear stress sensitivity to increased discharge;
- Entrainment Ratio - Represents the channel erosion potential;
- Geotechnical Stability Number - measures the lateral channel stability;
- Confinement Class – Measure of the amount of room that exists for the channel to actively move laterally and is a useful indicator of a channel's vulnerability to erosion;
- Bank Conditions
- Streambed Condition

In addition, the following parameters will also be surveyed: the floodprone width, the bankfull width, the bankfull depth, and the longitudinal slope. Each surveyed stream segment will be subsequently classified per the simplified Rosgen system of channel classification (Rosgen, 1996). **Figure 5-1** shows the different types of channels per Rosgen channel classification (Rosgen, 1996).

Figure 5-1: Simplified Rosgen Channel Classification

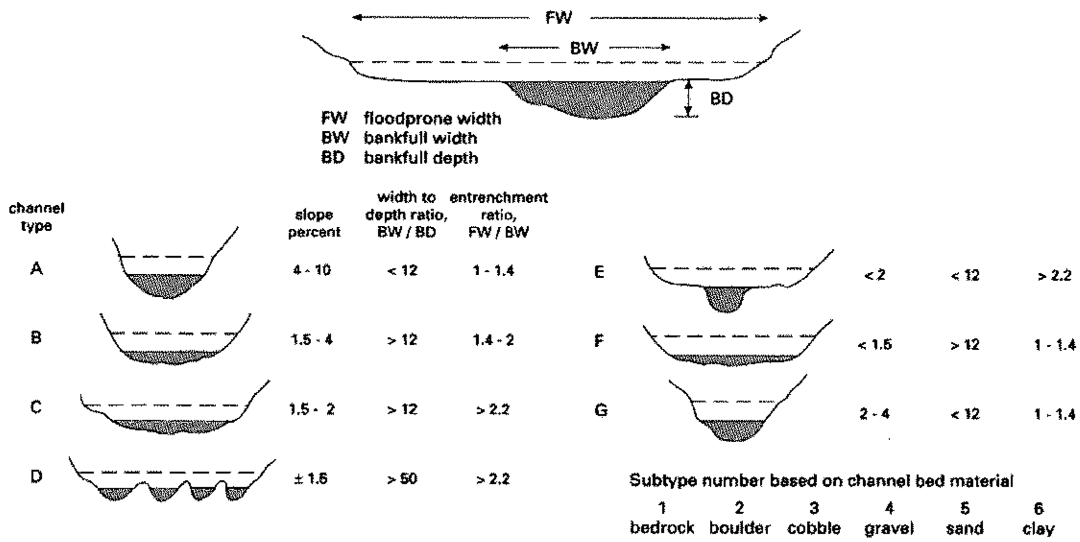
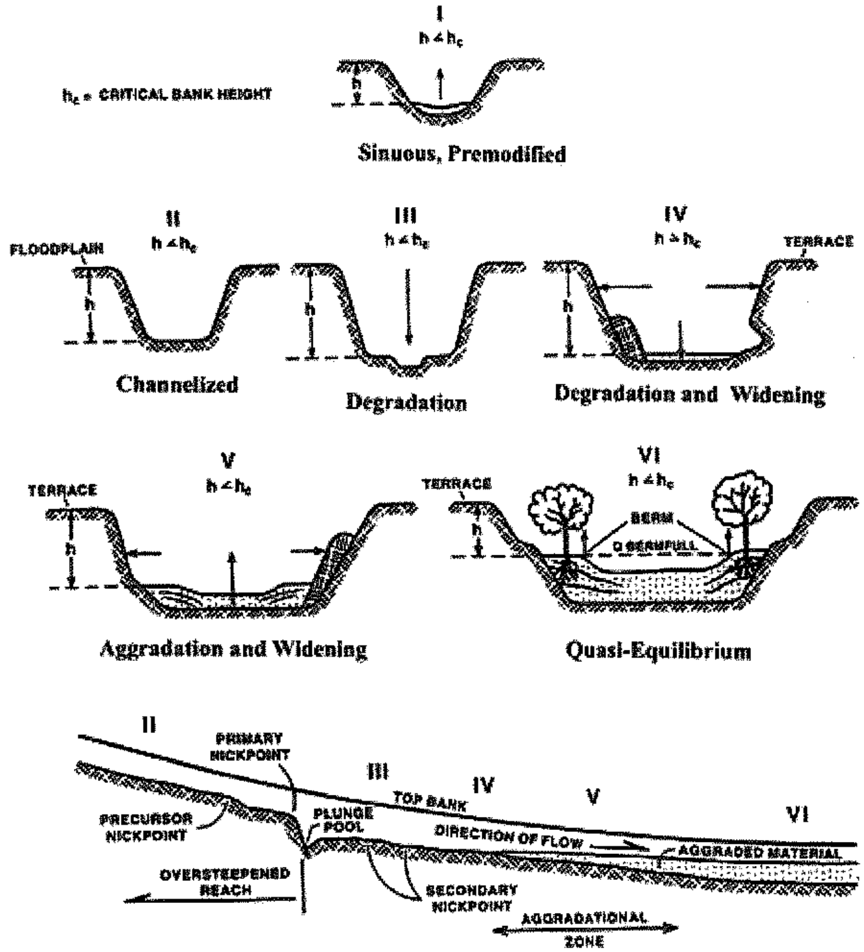


Figure 1.12 The Rosgen system of channel classification.

(Rosgen, 1996)

The temporal evolution in geomorphology, if any, of the surveyed stream segment will be compared to the six-stage Channel Evolution Model defined by Simon, as well as the previous year cross section data, to correlate any potential impacts of urbanization to this change of stream channel geomorphology (Simon et al., 1992). Figure 5-2 illustrates the six-stage sequence of incised channel evolution (Simon et al., 1992). A stream segment will be considered stable over time if features of the stream segment (such as dimension, pattern, and profile) are maintained, and the stream system neither aggrades nor degrades. The channel classification procedure is described in more detail in Appendix A.

Figure 5-2: Six-Stage Channel Evolution Model



(Simon et al, 1992)

Monitoring in the upper watershed

Upper watershed monitoring (channel surveys) is recommended to eliminate confounding lower watershed variables that would skew the analysis and minimize the potential for reaching meaningful conclusions. In addition, monitoring streams whose geomorphology is not influenced by sedimentation basins or any type of flood control retarding basin is critical.

Monitor representative locations and one reference station

Six geographically representative stations should be sufficient to account for spatial and temporal variability of the conditions present in the Santa Ana River Watershed Region of San Bernardino County. The reference monitoring station would be located in a watershed for which no upstream development (existing or future) is anticipated. This reference station will be located upstream of another test monitoring station that will assess the effectiveness of the proposed hydromodification measures downstream of a planned development. Data from the reference station can be used to supplement pre-project condition data obtained at the representative monitoring sites, since the amount of pre-project condition data that can be obtained at such sites is dependent on the land development process. Providing six representative stations balances the need to characterize spatial variability against the cost of monitoring.

Evaluate the effectiveness of the HMP by monitoring benthic macroinvertebrate communities.
An examination of benthic macroinvertebrate organisms will be conducted to assess both biological and geomorphologic health of the streams. Additionally, channel assessment cross sections at selected locations, coincident with the IBI sampling locations, will be selected.

Stream bioassessment for the purpose of determining HMP effectiveness may be coupled with the Urban Stream Bioassessment and be reported annually in the Orange County Unified Program Effectiveness Assessment (PEA) (OCDP, 2010). Several bioassessment monitoring sites already exist for both the SWAMP, which is developed on a five-year cycle, and the annual PEA. At each of these existing sites, historical bioassessment data is readily available for the establishment of pre-project conditions. Several reference monitoring sites are also readily available including, but not limited to, three urban bioassessment sites. The ultimate selection of bioassessment sites should consider integrating one or several of these existing sites if consistent with the objectives of the HMP Effectiveness Plan.

Biological organisms provide essential information to the overall health of a stream. The evolution of benthic macroinvertebrate communities may be the precursor to an impacted or improved stream. Benthic communities should be monitored once a year, preferably in late spring, at defined monitoring stations. Bioassessment should be done by computing the IBI score and comparing it to historical levels in the same stream. Ultimately, the Benthic Macroinvertebrate Index (BMI) could be used once it has been developed by SCCWRP, however at this time there is no estimated date as far as completion. The geomorphologic evolution of a stream segment, if any, will also be compared to the annual bioassessment to determine if the observed aggradation or degradation is associated with changes in the benthic macroinvertebrate communities.

5.3 HMP Effectiveness Evaluation

The effectiveness of the HMP is to be evaluated into two main axes:

- BMP inspections and maintenance
- Performance protocol

5.3.i BMP Inspections and Maintenance

Section 8 of the 2013 TGD for WQMP requires regular periodic inspections and maintenance of on-site post-construction BMP. Maintenance activities shall ensure that the systems are properly controlling runoff volume, velocity, duration, and time of concentration to meet the HCOC requirements defined in the Permit Section XI.E.5.d.(2).(c).

5.3.ii Performance Protocol

As defined in Section 5.2, channel section surveys are to be monitored on a regular basis at representative locations in the Santa Ana River Watershed Region of San Bernardino County. If a significant degradation of a stream segment has been detected, a hydrologic analysis shall be performed. A significant degradation of the stream segment will be subjectively interpreted by the analyst as a sudden decline in the IBI, or a rapid change of the morphology of the channel (cross-section). A drastic change in IBI scores may indicate that flow conditions have consequently changed. A significant improvement of the IBI scores may validate the approach taken in this HMoP.

The hydrologic analysis, if required, shall determine if the significant degradation of the stream segment is associated to the 2-year return frequency storm, as defined in the Permit. A significant difference between expected and observed volume, velocity, duration, and time of concentration, as well as flow duration curve would automatically trigger a performance protocol. The objective of the performance protocol is to correct any performance deficiencies in the existing hydrologic controls. If the stream degradation was caused by flows outside the critical range (higher than a 10-year return frequency storm), the extensive hydrologic analysis may terminate and no further investigation is needed.

The performance protocol is an iterative process that consists of investigating the tributary area of the impacted stream segment to identify the potential source(s). Hydrologic controls of one or several priority projects will be examined to determine if they are under-performing due to a lack of maintenance or poor design. In this case, the lack of performance may appear to be directly responsible for the drastic change in stream conditions (morphology). Rehabilitation of the stream segment may be required. It is expected that initial conclusions regarding the effectiveness of the HMP will be drawn after a minimum of five years of observations.

5.4 Selection of Monitoring Sites

Technical concepts and constraints specific to the Santa Ana River Watershed Region of San Bernardino County were taken into consideration when selecting the monitoring stations that would effectively provide information regarding the performance of hydromodification measures. Several criteria were evaluated and weighted, including:

- Ensuring that the selected monitoring stations focus primarily on stream sections found to present a high susceptibility risk during Phase I investigations of the WAP. In zones as defined by the San Bernardino County Flood Control District where opportunities to monitor streams of high susceptibility risks are not available, monitoring of streams of medium susceptibility risks representative of the local conditions were considered.
- The existence of historical records of Rapid Stream Risk Classification: only the sections of streams that were surveyed during Phase I of the WAP were evaluated to facilitate the tracking of geomorphic evolution, if any.
- The existence of upstream new developments and the potential for future developments in the tributary drainage area. The presence of future developments was determined based on the most recent release of the San Bernardino County General Plan maps with a particular emphasis on the land use zoning district maps. Establishing monitoring stations right downstream of development areas will help evaluate the effectiveness of hydromodification measures on directly affected downstream channels.
- Ensuring that the spatial distribution of the selected monitoring stations captures the different San Bernardino County Flood Control District zones.

The monitoring stations initially selected are listed in Table 5-1. These sites will be further evaluated for their effectiveness as a representative location. The Program will submit a revised list of monitoring stations to the SARWQCB for approval prior to implementation of the HMoP. The majority of channels within zone 1 and zone 2 are EHM, thus are deemed not susceptible to hydromodification. The determination of the exact locations of the selected monitoring stations will ensure that the domain of analysis, as defined by SCCWRP, is not influenced by the downstream confluence.

Table 5-1 – HMP Preliminary Monitoring Locations

Stream	Zone	City	Susceptibility risk
24th Street Storm Drain	1	Rancho Cucamonga	High
Demens Creek Channel	1	Rancho Cucamonga	High
English Canyon	1	Chino Hills	High (medium)
Mill Creek	3	Redlands	High
Wilson Creek[1]	3	Yucaipa	High
Oak Glen Creek	3	Yucaipa	High
Cucamonga Channel	1	Ontario	

Notes:

1 There will be two proposed stations on Wilson Creek: one station will be located upstream of the sedimentation basin #3 to a point where the domain of analysis will not be influenced by these basins and will serve as a test station for the Live Oak watershed. The second station will be located at the boundary line with the San Bernardino National Forest and will serve as a reference station. Wilson Creek was characterized by the Rapid Stream Risk

Classification as high risk. Based on the General Plan, future developments are scheduled to occur in the drainage area located between the Wilson Creek test and reference stations.

5.5 Summary and Conclusions

The HMoP will include the following specific activities:

Baseline Monitoring Plan Requirements:
- Development of QAPP (to be provided to Regional Board staff for review and comment)
- Annual data analysis
- Mid-term evaluation of the HMP Effectiveness after review of initial

Monitoring stations:
- Monitoring locations – Representative monitoring stations located in areas to be determined based on the approved HCOC Exemption map, and a minimum of one reference station.

Bioassessment
- Bioassessment monitoring station analysis and installation
- Bioassessment conducted once a year
- Annual sampling, preferably during spring season

Channel Assessments:
- Annual geomorphic assessments, cross-section survey, and Rapid Stream Risk Classification at each monitoring location to assess channel condition and response.

6.0 References

Alameda Countywide Clean Water Program (ACCWP). 2005. Hydrograph Modification Management Plan. May 2005.

Amos, C.B., Burbank, D.W. 2007. Channel width response to differential uplift. Journal of Geophysical Research. Vol. 112.

Beighley, R.E., J.M. Melack, and T. Dunne. 2003. Impacts of California's Climatic Regimes and Coastal Land Use Change on Streamflow Characteristics; Journal of the American Water Resources Association.

Bendaa, L., Miller, D., Bigelowa, P., Andrasa, K. 2003. Effects of post-wildfire erosion on channel environments, Boise River. Forest Ecology and Management 178 (2003)105–119

Bicknell, B.R., Imhoff, J.C., et al. 1997. Hydrological Simulation Program - FORTRAN, User's Manual for Version 11: U.S. Environmental Protection Agency, National Exposure Research Laboratory, Athens, Ga., EPA/600/R-97/080, 755 p.

Bledsoe, B.P. 2001. Relationships of Stream Responses to Hydrologic Changes, Linking Stormwater BMP Designs and Performance to Receiving Water Impact Mitigation. Proceedings of an Engineering Foundation Conference, August 19-24, 2001, Snowmass Village, CO.

______. 2002. Stream Erosion Potential and Stormwater Management Strategies. Journal of Water Resources Planning and Management

128: 451.

______. 2007. Assessment of Stream response to Urbanization. Cities of the Future: Towards Integrated Sustainable Water and Landscape Management.

Bledsoe, B.P., Hawley, R., and Stein E. 2008. Channel Classification and Mapping Systems with Implications for Assessing Susceptibility to Hydromodification in Southern California. Southern California Coastal Water Research Project.

Booth, D.B. 1990. Stream Channel Incision Following Drainage Basin Urbanization. Journal of the American Water Resources Association 26(3): 407-417.

______. 1991. Urbanization and the Natural Drainage System—Impacts, Solutions, and Prognoses. The Institute for Environmental Studies 7(1).

Booth, D.B. and C.R. Jackson 1997. Urbanization of Aquatic Systems: Degradation Thresholds, Stormwater Detection, and the Limits of Mitigation. Journal of the American Water Resources Association 33(5): 1077-1090.

Brown and Caldwell. 2007. Development of San Diego County Interim Hydromodification Criteria. October 30.

______. 2008. HMP Submittal Requirements. September 25.

______. 2008. Using Continuous Simulation to Size Stormwater Control Facilities. May.

______. 2009. Flow Threshold Analysis for the San Diego HMP. April 30.

______. 2009. Lower Flow Threshold Alternatives. April 30.

______. 2009. Minimum Criteria for Evaluation of Storm water Controls to Meet Interim Hydromodification Criteria. April 30.

______. 2009. Summary of Evaporation and Evapotranspiration Data for the San Diego Region. April 30.

______. 2009. Summary of HSPF Modeling Efforts in Southern California. April 30.

Butcher, J. 2007. Comparison of BAHM and Contra Costa Approaches to Hydromodification Management Plan Requirements. Tetra Tech, Inc. Memorandum to Janet O'Hara (CA RWQCB Region 2). December 7, 2007.

California Regional Water Quality Control Board – San Diego Region. 2009. Order No. R9-2009-0002. December 16.

California Stormwater Quality Association (CASQA). 2003. Stormwater Best Management Practice Handbook. New Development and Redevelopment. January 2003.

Chin, A. and K.J. Gregory (2005). Managing urban river channel adjustments. Geomorphology 69:28-45.

Clear Creek Solutions, Inc., 2007. Bay Area Hydrology Model User Manual, Prepared for Alameda Countywide Clean Water Program, San Mateo Countywide Water Pollution Prevention Program, Santa Clara Valley Urban Runoff Pollution Prevention Program. July 2007.

Coleman, D., C. MacRae, and E.D. Stein. 2005. Effect of increases in peak flows and imperviousness on the morphology of southern California streams. Research Project Technical Report #450. Report from the Stormwater Monitoring Coalition, Southern California Coastal Water, Westminster, CA.

Contra Costa Clean Water Program (CCCWP). 2004. Work Plan and Literature Review for the Hydrograph Modification Management Plan.

______. 2005. Hydrograph Modification Management Plan. Prepared by Philip Williams & Associates. May 15, 2005.

Donigan, A.S., and H.H. Davis. 1978. User's Manual for Agricultural Runoff Management (ARM) Model. EPA-600/3-78-080. U.S. Environmental Protection Agency.

Dunne, T. and L.B. Leopold. 1978. Water in Environmental Planning. New York, W.H. Freeman and Company. 818 pp.

Federal Interagency Stream Restoration Work Group (FISRWG). 1998. Stream Corridor Restoration: Principles, Processes, and Practices. United States Department of Agriculture.

Fischenich, C. 2001. Stability of Stream Restoration Materials. ERDC TN-EMRRP-SR-29

Geosyntec Consultants. 2004. Evaluation of the Range of Storms for HMP Performance Criteria. Memorandum to Onsite Management Measures Subgroup, Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP). April 1, 2004. Revised Final Draft.

Henshaw, P.C. and D.B. Booth 2000. Natural Restabilization of Stream Channels in Urban Watersheds. Journal of the American Water Resources Association 36(6): 1219-1236.

Hey, R. D., and Thorne, C. R. 1986. "Stable Channels with Mobile Gravel Beds," Journal of Hydraulic Engineering, American Society of Civil Engineers, Vol. 112, No. 8, pp. 671-689.

Hollis, G.E. 1975. The Effect of Urbanization on Floods of Different Recurrence Intervals. Water Resources Research.

Kirkby, M.J. 1995. Modeling the links between vegetation and landforms. Geomorphology 13, 319-35.

Lane, E. W. 1955. The importance of fluvial morphology in hydraulic engineering. Proceedings, American Society of Civil Engineers, No. 745, July.

Leeder, M.R., T. Harris, et al. 1998. Sediment supply and climate change: implications for basin stratigraphy. Basin Research 10(1): 7-18.

Leopold, L.B., M.G. Wolman, J.P. Miller. 1964. Fluvial Processes in Geomorphology. San Francisco, W.H. Freeman and Company. 522 pp.

Los Angeles Regional Water Quality Control Board. 2002. TMDL to Reduce Bacterial Indicator Densities at Santa Monica Bay Beaches During Wet Weather. June 21.

MacRae C.R., 1997. Experience from Morphological Research on Canadian Streams: Is Control of the Two-Year Frequency Runoff Event the Best Basins for Stream Channel Protection? Effects of Watershed Development And Management Of Aquatic Ecosystems, L.A. Roesner, ed., ASCE Reston, VA., 144-162.

MacRae, C.R. 1993. An Alternate Design Approach for the Control of Instream Erosion Potential in Urbanizing Watersheds. Sixth International Conference on Urban Storm Drainage, Niagara Falls, Ontario.

Mangarella, P. and Palhegyi, G. Geosyntec Consultants. 2002. Santa Clara Valley Urban Runoff Pollution Prevention Program Hydromodification Management Plan Literature Review.

National Climatic Data Center. 2011. Climatic Data. October.

National Oceanic and Atmospheric Administration, 2011. Mean Higher High Water level. Website: http://tidesandcurrents.noaa.gov/ . December

Palhegyi, G.,P. Mangarella, et al. 2004. Developing Management Plans to Address Impacts from Urbanization on Stream Channel Integrity, ASCE.

Paul, M.J. and J.L Meyer. 2001. Streams in the Urban Landscape. Annual Review of Ecologic Systems. 32:333–65

Phillip Williams and Associates. 2003. Sources of nonlinearity and complexity in geomorphic systems. Progress in Physical Geography 27(1):

______. 2009b. Literature Review for the San Diego Hydromodification Management Plan. October 19.

Orange County Department of Planning.

Orange County Department of Planning. 2010. 2009-2010 Unified Program Effectiveness Assessment.

Orange County Department of Planning. 2011. Model Water Quality Management Plan. March22.

Orange County Department of Planning. 2011. Technical Guidance Document for The Preparation of Conceptual/Preliminary and/or Project Water Quality Management Plans (WQMPs). March 22.

Orange County Department of Public Works. 1986. Orange County Hydrology Manual. October.

Orange County Department of Public Works. 2005. Orange County Countywide Storm Drain Inventory.

Orange County Department of Public Works. 2011. ALERT system. October.

Richman, T., P. E. Jill Bicknell, et al. 2004. Start at the Source: Site Planning and Design Guidance Manual for Storm water Quality Protection, ASCE.

Riley, A.L. 1998. Restoring Streams in Cities: A Guide for Planners, Policymakers, and Citizens. March.

Ripple, W.J., E.J. Larsen, et al. 2001. Trophic cascades among wolves, elk and aspen on Yellowstone National Park's northern range. Biological Conservation 102(3): 227-234.

Rosgen D.L. 1994. A classification of natural rivers. Catena 22, pp 169-199

Rosgen D.L. 1996. Applied River Morphology. Wildland Hydrology. Pagoosa Springs, CO.

Sacramento Stormwater Quality Partnership. 2009. Pilot Project to Assess Decision Support Tools for Hydromodification Management in the Sacramento Area. March.

San Bernardino County Areawide Stormwater Program. 2013. Draft Technical Guidance Document for Water Quality Management Plans.

San Bernardino County. 1986. Hydrology Manual. August.

San Diego Permittees. 2011. Hydromodification Management Plan. March.

San Diego Regional Water Quality Control Board. 2008. TMDLs for Indicator Bacteria in Baby Beach and Shelter Island Shoreline Park. June 11.

San Diego Regional Water Quality Control Board. 2007. TMDLs for Indicator Bacteria Project 1 – Beaches and Creeks in the San Diego Region. December 12.

San Diego Regional Water Quality Control Board. 2002. Baseline Geomorphic and Hydrologic Conditions, Rancho Mission Viejo: Portions of the San Juan and Western San Mateo Watersheds. PCR, PWA, and Balance Hydrologics, Inc. February.San Mateo Countywide Stormwater Pollution Prevention Program (STOPPP). 2005.

Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP). 2005. Hydromodification Management Plan Final Report. April 21.

Santa Clara Valley Urban Runoff Pollution Prevention Program. 2006. Santa Clara Hydromodification Management Plan (HMP). February.

Schueler, T. 1998. Basic Concepts in Watershed Planning. Chapter 1 from The Rapid Watershed Planning Handbook, Center for Watershed Protection, Ellicott City, MD.

Schumm S.A., M.D. Harvey, and C.C. Watson. 1984. Incised channels. Morphology, dynamics and control. Water Resource Publication, Littleton, Colorado.

Simon, A. 1992. Energy, time, and channel evolution in catastrophically disturbed fluvial systems. Geomorphology 5, 345-372.

Simon, A.,M. Doyle, M. Kondolf, F.D. Shields, Jr., B. Rhoads, and M. McPhillips. 2007. Critical evaluation of how the Rosgen Classification and Associated Natural Channel Design Methods fail to Integrate and Quantify Fluvial Processes and Channel Response. Journal of the American Water Resources Association. 43(5):1117-1131.

Southern California Coastal Water Research Project (SCCWRP). 2005. Evaluating HSPF in an Arid, Urbanized Watershed; Journal of the American Water Resources Association.

_______. 2007. Surface Water Ambient Monitoring Program (SWAMP) Report on the San Juan Hydrologic Unit. Prepared for the California Regional

_______. 2010. Hydromodification Screening Tools: Field Manual for Assessing Channel Susceptibility. Technical Report 606.

_______. 2011. Hydromodification Effects on Flow Peaks and Durations in Southern California Urbanizing Watersheds. Technical Report 654.

_______. 2012. Hydromodification Assessment and Management in California. Technical Report 667.

State of California. 2011. The California Environmental Quality Act, Title 14. California Code of Regulations, Chapter3. Guidelines for Implementation of the California Environmental Quality Act, Section 15332. In-fill Development Projects.

State of California Water Quality Control Board, San Diego Region (Region 9). July.

_______. 2011. SCCWRP 2011-2012 Research Plan - Bioassessment. Items 1(a)(b)(c). June.

Tetra Tech, Inc. 2003. Lake Elsinore and Canyon Lake Nutrient Source Assessment for Santa Ana Watershed Authority. January.

Thomas, M.F. 2001. Landscape sensitivity in time and space—an introduction. Catena 42(2-4): 83-98.

Trimble, S.W. and A.C. Mendel 1995. The cow as a geomorphic agent—A critical review. Geomorphology 13(1-4): 233-253.

United States Army Corps of Engineers. 2007. Guidelines for Sampling Bed Material, Technical Supplement 13A, Part 654 of National Engineering Handbook, New England District. August.

United States Environmental Protection Agency. 2008. Managing Weather with Green Infrastructure Municipal Handbook. December.

United States Environmental Protection Agency. 2000. BASINS Technical Note 6 - Estimating Hydrology and Hydraulic Parameters for HSPF. July.

United States Environmental Protection Agency. 2007. National Management Measures to Control Nonpoint Source Pollution from Hydromodification. Office of Wetlands, Oceans and Watersheds. July.

USGS Web Site. Water Resources Applications Software. Summary of HSPF - Hydrologic Simulation Program - FORTRAN.

Viessman, Warren, Lewis, Gary L, and Knapp, John W. 1989. Introduction to Hydrology. Harper & Row, New York

Waananen, AO and Crippen, Jr. 1977. Magnitude and frequency of floods in California. US Geological Survey Water-Resources Investigation 77-21. 96 p.

Watson, C.C., D.S. Biedenharn and B.P. Bledsoe. 2002. Use of incised channel evolution models in understanding rehabilitation alternatives. Journal of the American Water Resources Association 38:151-160.

Watson, C.C., and W. Annable. 2003. Channel Rehabilitation: Processes, Design, and Implementation. Notes for Applied Fluvial Geomorphology and River Restoration Short Course, sponsored by the Guadalupe-Coyote Resource Conservation District. Held at the Santa Clara Valley Water District, San Jose, CA, July 14-18.

Western Regional Climate Center. Climatic data. October. [YEAR?]

Wolman, M.G. and J.P. Miller. 1960. Magnitude and Frequency of Forces in Geomorphic Processes, Journal of Geology.

APPENDIX A – Stream Classification Procedure

The procedure derives from the "Stream Stability Validation" approach that is described by Rosgen (1996). Stream stability over time may be assessed by monitoring the stream channel for five factors: (1) aggradation (2) degradation (3) shifting of particle sizes of stream bed materials (4) changing the rate of lateral extension through accelerated bank erosion (5) morphological changes following the CEM (Simon et al., 1992). If any hydrological changes or disturbance occurs in the watershed, the five elements defined above are critical to analyze the channel response to the implementation of HMP mitigation measures.

One reference stream station will be used for comparison purposes and should coincide with the station selected for the bioassessment. The reference station should be located in a stream that shows the same lithology, sediment regime, and morphometric parameters as the study stream stations. Annual comparisons of channel stability will be carried out at the same time of the year, at the end of the spring season, thus maximizing the chances to monitor similar weather patterns.

Channel stability will be evaluated, on an annual basis, at selected cross-sections in the San Juan hydrologic unit. Evaluation of the vertical or bed stability will serve as the reference method to understand the geomorphological changes of a channel stream over time. Vertical or bed stability will be evaluated at each of the identified cross-sections: this field method will identify a potential aggradation or degradation, if any, of the stream. Rate, magnitude, and direction of vertical change, if any, will be quantified.

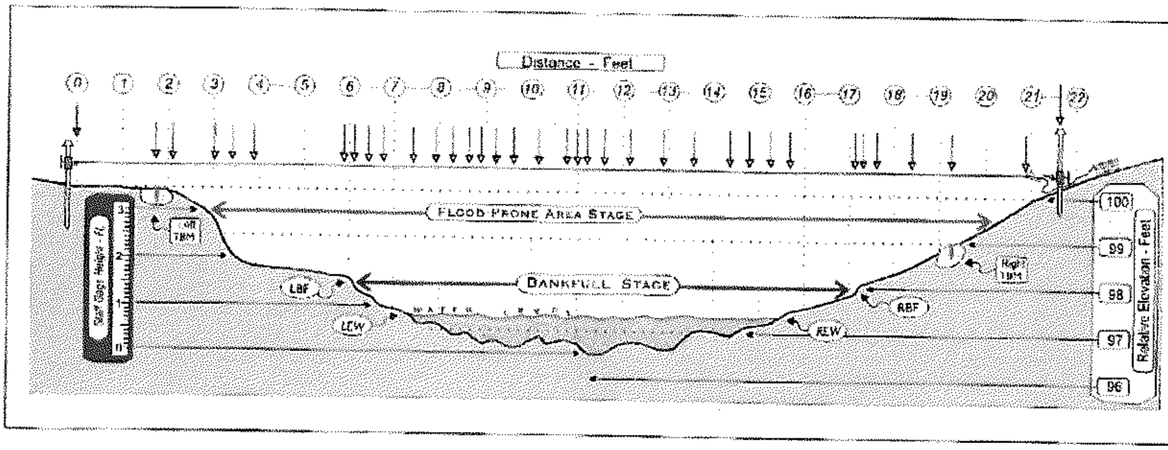
Vertical or bed stability:

Rosgen (1996) has documented a couple methods including one, known as the "Monumented cross-sections method". At each selected site, the method consists of setting permanently monumented cross-sections that are located on a riffle and pool segment (or step/pool segment), i.e., two monumented cross-sections per site. Annual measurements at the two monumented cross-sections per site will be compared to the reference elevations taken during the initial survey.

Initially, one permanent bench mark should be installed on each bank of the stream: a left temporary bench mark and a right temporary bench mark. These should be made permanent by digging a hole in which a 10-inch stove bolt will be set up by a pad of concrete. The intent is to avoid vandalism damage. These two bench marks will be located at the cross-section on a stable site above and away from the bankfull channel. Additionally, an elevation cross-section is often needed if the left or right side of the cross-section is located on an unstable slope. An elevation bench mark is established and often does not represent a true representation, but rather a relative elevation set at 100 feet.

During each cross-section survey, a leveled tape line is set above the stream channel. Measurements originate from the intercept of the rod with the leveled tape line (**Figure A-1**).

Figure A-1: Typical permanent channel cross-section with benchmark locations and points of measurement - Rosgen (1996)



Simple measurements are made with the measuring tape and elevation rod method as described by Rosgen (1996):

- Locate the permanent bench mark on both sides of the stream (or, if on one side, a bearing for the transect is needed)
- Stretch the tape very tight with spring clamp and tape level
- Locate tape at same elevation as reference bolt on bench mark
- Read distance and elevation reading of rod intercept with tape
- Measure major features, such as:
  - Left bench mark (LBM)
  - Left terrace/floodplain (LT, LFP)
  - Left bankfull (LBF)
  - Left bank (LB)
  - Left edge of water (LEW)
  - Various bed features, bars, etc.
  - Thalweg (TW)
  - Inner berm features (IB)
  - Right edge of water (REW)
  - Right bank (RB)
  - Right bankfull (RBF)
  - Right terrace/floodplain (RT, RFP)
  - Right benchmark (RBM)

Measurements must include the floodplain, terraces, and stream adjacent slopes. Other surveying procedures such as auto or laser levels and total station surveys may be adapted from the described "measuring tape and elevation rod" method. If technically feasible, any exceptional event associated with level higher than the bankfull level needs to be marked and indicated on the cross-section. The cross-section needs to be plotted for each measurement and compared to previous cross-sections to evaluate bed stability.

Finally, the longitudinal slope will be assessed based on measurements taken at two consecutive cross-sections. Rosgen (1996) also recommends developing a vicinity map and detailed site map indicating the locations of monumented cross-sections, as well as upstream and downstream photographs for site documentation. Channel dimensions for stream classification need to be correlated in order to document morphological comparisons for extrapolation.

Each stream segment being surveyed will be classified on an annual basis per the simplified Rosgen system of channel classification (Rosgen, 1996). Classification will be possible upon identification of the following parameters: floodprone width, bankfull width, bankfull depth, and longitudinal slope. **Figure A-2** shows the different types of channels per Rosgen channel classification (Rosgen, 1996).

Figure A-2: Simplified Rosgen Channel Classification (Rosgen, 1996)

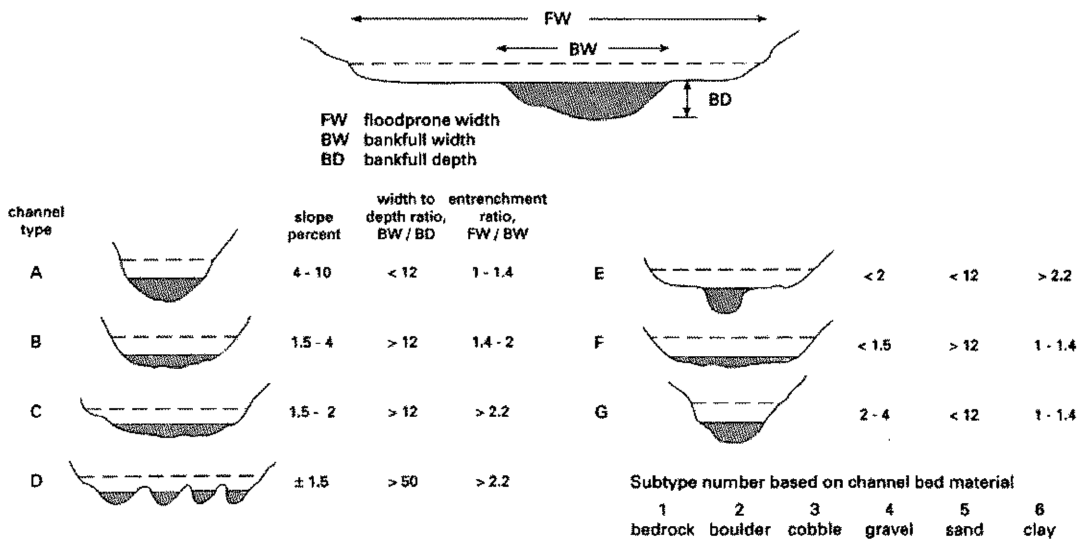


Figure 1.12 The Rosgen system of channel classification.

APPENDIX B – TRAINING DOCUMENTATION

COUNTY OF SAN BERNARDINO
Stormwater Program

WAP Training
July 18, 2012

SIGN IN SHEET

NAME	ORGANIZATION	PHONE	E-MAIL
Lynn Merrill	Rialto	951-217-1201	LCMURAND@AOL.COM
Matt Wirz	Grand Terrace	909-430-2255	mwirz@cityofgrandterrace.org
Jeff Peterson	Loma Linda	799 4407	
Linda Ceballos	Rancho Cucamonga	477-2740	Linda.ceballos@cityofrc.us
Steve Wilson	Ontario	395-2389	swilson@ci.ontario.ca.us
Marc A Rodabaugh	County of San Bernardino	909-387-8112	marc.rodabaugh@dpw.sbcounty.gov
Joe Cyewik	Big Bear Lake	909-866-5831	
Tanya Honeycutt	City of Montclair	909-625-9481	thoneycutt@cityofmontclair.org
Saul Martinez	City of Upland	909-291-2941	smartinez@ci.upland.ca.us
Scott Rapp	City of Rancho Cucamonga	909 477-2740 x4064	scott.rapp@cityofrc.us
Andrea Saavedra	City of Highland	909-864-8732 ext 271	asaavedra@cityofhighland.org
Melissa Morgan	City of Highland	909-864-8732 ext 230	mmorgan@cityofhighland.org
Dwight Woodward	City of Chino Hills	909-364-2720	dwoodward@chinohills.org
Tony Mata	City of Fontana	909-350-6772	tmata@fontana.org
Sarah Basta	DPW, San Bernardino Co.	909-387-8145	sbasta@dpw.sbcounty.gov
Jonathan Dillon	DPW, SB County	909-387-7468	jdillon@dpw.sbcounty.gov
Anthony Pham	" "	" " - 8229	apham@dpw.sbcounty.gov
Wade Caffrey	VCS Environmental	949-489-2700	wcaffrey@vcsenvironmental.com
[illegible]	City of [illegible]	(909) 797-7499	[illegible]

Gary Akers	SB City	909-384-5225	akers_ga@sbcity.org
Bob Whitlock	C/SB	909-384-5154	whitlock_r@sbcity.org.

COUNTY OF SAN BERNARDINO
Stormwater Program

WATERSHED ACTION PLAN TRAINING
September 12, 2012
1:30-3:30PM

SIGN IN SHEET

NAME	ORGANIZATION	PHONE	E-MAIL
Paul D Baum	City of Upland	(909) 931-4317	pbaum@ci.upland.ca.us
Ruben Valdez	Chino	909-464-0744	rvaldez@cityofchino.org
Miguel Sotomayor	Ontario	(909) 395-2108	msotomayor@ci.ontario.ca.us
Mike Escalante	Ontario	(909) 395-2132	mescalante@ci.ontario.ca.us
Saul Martinez	City of Upland	909-291-2941	Smartinez@ci.upland.ca.us
Andrew Simmons	City Big Bear Lake	909 866-5831	asimmons@citybigbearlake.com
Michael Diaz	City of Montclair	909-625-9432	mdiaz@cityofmontclair.org
Jos Rosales	"	909 625 9470	jrosales@cityofmontclair.org
Cecilia Griego	City of Redlands	909-798-7527 x2	cgriego@cityofredlands.org
Jason Montgomery	"	909-798-7584 x5	jmontgomery@cityofredlands.org
Chad Nottingham	DPW	387-1819	CNOTTINGHAM@DPW.SBCOUNTY.GOV
Goutam Dobey	City of Redlands	909-798-7584 x2	gdobey@cityofredlands.org
Laura Weidemann	City of S.B	909-384-5574	weidemann_la@sbcity.org
Lori Farris	City of San Bernardino	909-384-5057 x3328	Farris_Lo@sbcity.org
Robert Houston	Upland	909 291-2967	rhouston@ci.upland.ca.us
Alan Collett	Redlands	909-798-7585, x4	acollett@cityofredlands.org
Chris Boatman	Redlands	909-798-7555	cboatman@cityofredlands.org
Tabitha Kevari	Redlands	909 798-7555	[illegible]

NAME	ORGANIZATION	PHONE	E-MAIL #
Melanie Sotelo	Highland	909-835-0313	msotelo@aercasc.com
Gary Akers	City SB	909 384 5225	akers_ga@sbcity.org
Ed M. Rama	City of Chino Hills	909-364-2774	frama@chinohills.
TERRY FRITZ	Redlands		TFRITZ@CITYOFREDLANDS
Cyrus Nekooee	City of Rialto	909/820-2530	CNEKOOEE@RIALTOCA.GOV
Tad Garrety	City of Chino Hills	909-364-2722	tgarrety@chinohi[illegible]
Steve Nawa	City of Fontana	909-350 6523	Snawa@Fontana.org
Jeff Schafer	City of San Bernardino	909-384-5502	schafer_je@sbcity.org
DONALD GRANGER	CITY OF RANCHO CUCAMONGA	909-477-2750	donald.granger@cityofrc.
Dwight Woodward	City of Chino Hills	909-364-2720	dwoodward@chinoHills.
SCOTT MURPHY	CITY OF ONTARIO	909.395.2419	smurphy@ci.ontario.ca.us
BETTY DONAVANIK	CITY OF CHINO HILLS	909 364-2777	bdonavanik@chinohills.org
HENRY NOH	"	909 364-2761	hnoh@chinohills.org
EDUARD VARGA	COUNTY OF SAN BERNARDINO	909 387-8132	evarga@dpw.sbcounty.gov
MIKE SMITH	CITY OF RANCHO CUCAMONGA	909 477.2750	MICHAEL.SMITH@CITYOF RC.US
STEVE FOWLER	" " " "	" " "	STEVEN.FOWLER@CITYOFRC.US
TABE VANDERZWAAG	" "	"	tabe.vanderzwaag@ "
BETTY MILLER	City of Rancho Cucamonga	909 477 2740	betty.miller@cityofrc.us
MARC RODABAUGH	SBCFCD	909-387-8112	marc.rodabaugh@dpw.sbcounty.gov

COUNTY OF SAN BERNARDINO
Stormwater Program

WATERSHED ACTION PLAN TRAINING
September 12, 2012
9:00-10:00AM

SIGN IN SHEET

NAME	ORGANIZATION	PHONE	E-MAIL
Mike Hudson	Montclair	909.625.9441	mhudson@cityofmontclair.org
Joe Rosales	Montclair		
Rosemary Hoerning	~~Ca~~ Upland	291-2931	
Harrison Nguyen	Upland	291-2970	
Richard Shields	Grand Terrace	825.3825	rshields@GrandTerrace.org
Carlos Zamano	Highland	864-6861 x254	czamano@cityofhighland.org
Ernie Wong	Highland	864-686 X212	ewong@cityofhighland.org
Raymond Lee	Ontario	909-395-2109 ~~909-~~	rlee@ci.ontario.ca.us
LOUIS ABI-YOUNES	"	9093952141	
Jeff Schafer	City San Bernardino	909-384-5902	schafer_je@sbcity.org
Bill Hemsley	City of Yucaipa	909 797.2489	bhemsley@yucaipa.org
Mark Steuer	Rancho Cucamonga	909.477-2740	Mark.Steuer@cityofrc.us
OSCAR W. ORCI	City of Redlands	909-798-7598	oorci@cityofredlands.org
Reggie Torres	City of Colton	(909) ~~370~~ 370-5065	rtorres@ci.colton.ca.us
RUBEN VALDEZ	CITY OF CHINO	909-464-0744	RVALDEZ@CITYOFCHINO.ORG
Joann Lombardo	Chino Hills	909 364 2741	jlombardo@chinohills.org

NAME	ORGANIZATION	PHONE	E-MAIL #
Fred Moussavipour	City of Redlands	798-7553	Fmoussavipour@cityofredlands
Jerd Thaipejr	City of Loma Linda	799-2811	
Annesley Ignatius	SB County Public Works	ADMIN	aignatius@dpw.sbcounty
MARC RODABAUGH	SBCFCD	387-8112	marc.rodabaugh@dpw.sbcounty.gov
Gia Kim	SBCFCD	387-8145	Gkim@dpw.sbcounty.gov