San Gabriel Valley Groundwater Basin Salt and Nutrient Management Plan

Main San Gabriel Basin
WATERMASTER

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LIST OF ACRONYMS

AC	Assimilative Capacity
AF	Acre-feet
Af/yr	Acre-feet Per Year
AGR	Agricultural Supply
AQUA	Aquaculture Supply
APT	Aqua Performance Test
Area 3OU	Area 3 Operable Unit
bgs	below ground surface
BGWEMP	Basinwide Groundwater Elevation Monitoring Program
BGWQMP	Basinwide Groundwater Quality Monitoring Program
BMPs	Best Management Practices
BPO	Basin Plan Objective
BPOU	Baldwin Park Operable Unit
ClO_4	Perchlorate
CAWC	California American Water Company
CCR	California Code of Regulations
CDPH	California Department of Public Health (now the SWRCB Division of Drinking Water)
CDWC	California Domestic Water Company
CEQA	California Environmental Quality Act
CECs	Constituents of Emerging Concern
CDWR	California Department of Water Resources
CPUC	California Public Utilities Commission
CTC	Carbon Tetrachloride
DDW	Division of Drinking Water
EDT	Electronic Data Transfer
GM	General Mineral
GP	General Physical
IND	Industrial Service Supply

IRRP	Indirect Reuse Replenishment Project
LACDPW	Los Angeles County Department of Public Works
LACFCD	Los Angeles County Flood Control District
LACSD	Sanitation Districts of Los Angeles County
LARWQCB	Los Angeles Regional Water Quality Control Board
lbs	pounds
MCL	Maximum Containment Level
mg/l	milligrams per liter
msl	mean sea level
MUN	Municipal and Domestic Supply
MWD	Metropolitan Water District of Southern California
ND	Not Detected
NO_3	Nitrate
PCE	Tetrachloroethylene
PM2.5	Particulate Matter 10 micrometers or less in diameter
PM10	Particulate Matter 2.5 micrometers or less in diameter
PROC	Industrial Process Supply
PWRP	Pomona Wastewater Reclamation Plant
RWQCB	Regional Water Quality Control Board
SJCWRP	San Jose Creek Wastewater Reclamation Plant
SFSG	Santa Fe Spreading Grounds
SGVWC	San Gabriel Valley Water Company
SNMP	Salt Nutrient Management Plan
SOC	Synthetic Organic Chemicals
SVOC	Semi-Volatile Organic Chemicals
SWP	State Water Project
SWRCB	State Water Resources Control Board
TCE	Trichloroethylene
TDS	Total Dissolved Solids
ug/l	micrograms per liter
USCOE	United Sates Army Corps of Engineers

USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
VOC	Volatile Organic Chemicals
WDR	Waste Discharge Requirements

EXECUTIVE SUMMARY

The State Water Resources Control Board approved Resolution No. 2009-0011 to adopt the Recycled Water Policy in February 2009. Included in that resolution is a requirement for a Salt and Nutrient Management Plan (SNMP) to be prepared for all groundwater basins. The Main San Gabriel Basin Watermaster is the lead agency for the preparation of the San Gabriel Basin SNMP. The primary stakeholders include Upper San Gabriel Valley Municipal Water District, San Gabriel Valley Municipal Water District, Three Valleys Municipal Water District, the Metropolitan Water District of Southern California, the Los Angeles County Sanitation Districts, and the Los Angeles County Department of Public Works.

The SNMP reviewed the geology, hydrology and hydrogeology of the San Gabriel Basin (also herein "Basin"), along with the institutional and management structure for the San Gabriel Basin. TDS, Nitrate, Sulfate, and Chloride were identified as the primary ~~constituents~~ salts and nutrients of concern. Sources of loading (precipitation, subsurface inflow, infiltration of applied water, storm runoff and untreated imported water replenishment) and unloading (groundwater pumping and subsurface outflow) were included in a spreadsheet computer model, along with average water quality data for TDS, Nitrate, Sulfate, and Chloride, on an annual basis. Watermaster developed this spreadsheet model as a tool to calculate the impacts of loading and unloading from numerous water supply components.

The SNMP determined the assimilative capacity of the primary constituents of concern and evaluated potential and hypothetical groundwater replenishment projects in order to determine the loadings and impacts resulting from the projects. In an effort to provide an extremely conservative approach to the calculation of assimilative capacity of the San Gabriel Basin, it was assumed 1) the volume of the San Gabriel Basin available for mixing was about 6,000,000 acre-feet (75 percent of the total volume of about 8,000,000 acre-feet); and 2) only the water quality objectives for the westerly portion of the San Gabriel Basin (450 mg/l) would be used in the calculation, but recognizing the water quality objective for the easterly portion of the San Gabriel Basin is 600 mg/l.

The Recycled Water Policy sets an interim goal that no single project is to use more than 10 percent of the available assimilative capacity, or combination of projects to use more than 20 percent of the available assimilative capacity. Consequently, as part of this SNMP, the antidegradation analysis calculated the collective amount of water from potential future projects using a particular water quality that could be replenished in the San Gabriel Basin without exceeding the very conservative value of 10 percent of the available assimilative capacity. The water quality selected for analysis in the hypothetical scenarios is representative of water quality from likely replenishment water sources under extreme quality conditions. Historical supply sources for replenishment water have been primarily stormwater runoff and SWP, with Colorado River water and recycled water contributing to groundwater replenishment to a lesser extent.

The Upper San Gabriel Valley Municipal Water District's proposed Indirect Reuse Replenishment Project (IRRP), consisting of 10,000 acre-feet of recycled water recharge, was evaluated to determine the cumulative percentage of the assimilative capacity utilized before equilibrium is reached. The IRRP is not anticipated to exceed 10 percent of the available AC of the San Gabriel Basin, although such a limitation is not mandated. TDS would be the controlling and limiting constituent for the IRRP. Long term recharge operations would result in equilibrium reached at approximately 7.2 percent utilization of the TDS assimilative capacity. Nitrate, Sulfate and Chloride would each have less impact on their respective available assimilative capacities.

The San Gabriel Basin has been managed for many decades by the Watermaster, in conjunction with other stakeholders, in order to control salt and nutrient loading to preserve the high quality groundwater supplies. The SNMP acknowledges the historical practice of replenishing the San Gabriel Basin with significant amounts of stormwater runoff and supplemented with untreated imported water from the SWP, both of which have high quality water, particularly regarding TDS.

The San Gabriel Valley has experienced unprecedented drought conditions since calendar year 2006. As a result, the groundwater elevation at Baldwin Park Key Well has decreased from about 250 feet msl during the Spring of 2005 to about 189 feet msl as of December 2009. Since 1972, when the Basin was adjudicated, to present, the Basin Watermaster has actively managed water quality through existing implementation measures. Nonetheless, water quality generally improves (i.e. water quality concentrations decrease) coincident with significant rainfall events/recharge of stormwater runoff and the water quality tends to degrade during drought periods. Consequently, despite the long-term implementation measures the Basin Watermaster has in place, recent drought conditions have had a greater influence on water quality trends over the past 10 years and may give the appearance of an increasing trend in salt and nutrient conditions.

The SNMP identifies a variety of existing and potential activities including continued basin management practices, pursuit of potential new replenishment sites, water quality monitoring, and coordination between agencies which will help manage salts and nutrients in the San Gabriel Basin. The SNMP is a tool by which salts and nutrients can continue to be managed into the future.

The implementation of the SNMP will satisfy the requirements of the Recycled Water Policy by providing a framework for the long-term management of salts and nutrients in the San Gabriel Basin, while encouraging and allowing for increased use of recycled water areas.

CHAPTER I

INTRODUCTION

In February 2009, the State Water Resources Control Board of the State of California (State Water Board or SWRCB) approved the Resolution No. 2009-0011 to adopt the Recycled Water Policy (Policy) to encourage the use of recycled water from municipal wastewater sources as a safe alternative source of water supply while complying with the Resolution No. 68-16 to *"achieve highest water quality consistent with maximum benefit to the people of the State."* The goal of this Policy is to increase the use of recycled water over 2002 levels by at least one million acre-feet per year (af/yr) by 2020 and at least two million af/yr by 2030. Recognizing that some groundwater basins in the state contain salt and nutrients that exceed or threaten to exceed water quality objectives established in the Water Quality Control Plans (Basin Plans), and that not all Basin Plans include adequate implementation procedures for achieving or ensuring compliance with the water quality objectives for salt and nutrients, the State Water Board determined the appropriate way to address salt and nutrient issues is through the development of regional or sub-regional salt and nutrient management plans (SNMPs) rather than through imposing requirements solely on individual recycled water projects. The SNMP development process should include applicable compliance with the California Environmental Quality Act (CEQA) and participation by Regional Water Board's staff, and the Plans should be submitted to the appropriate Regional Water Board within five years from the effective date of the Policy, i.e. May 14, 2014. Watermaster has received an extension from the RWQCB to submit the San Gabriel SNMP by May, 2016. The Policy requires Regional Water Boards to review the plans and consider each for adoption as basin plan amendments within one year of submittal.

In accordance with the Policy, a science advisory panel (Panel) was convened to provide guidance on future actions related to monitoring constituents of emerging concerns (CECs) in recycled water. The Panel in its report entitled *"Monitoring Strategies for Chemicals of Emerging Concern in Recycled Water – Recommendations of a Scientific Advisory Panel"* and dated June 25, 2010, provided recommendations for monitoring specific CECs in recycled water used for groundwater recharge reuse. The State Water Board incorporated the Panel's recommendations into a proposed revision of the Policy dated September 14, 2012 (Revised

Policy). Copies of the Resolution No. 2009-011, the Resolution No 68-16, the Policy, and the Revised Policy are included as Appendix A.

Section 6.b(1)(a) of the Recycled Water Policy (see Appendix A) states in part "…the local water and wastewater entities, together with local salt/nutrient contributing stakeholders, will fund locally driven and controlled, collaborative processes open to all stakeholders that will prepare salt and nutrient management plans…" In compliance with the Policy, the Regional Water Boards act as an overseer and facilitator of the SNMP development process. In the Los Angeles Region, Board staff has attended stakeholder meetings for various groundwater basin/subbasin groups to provide support and information. In the San Gabriel Valley Groundwater Basin (Basin), the Main San Gabriel Basin Watermaster (Watermaster) is the lead agency for the development of the SNMP for the Basin (San Gabriel SNMP). In the Basin, the sources of salt/nutrient loading are recharge of stormwater runoff; recharge of imported water from the State Water Project (SWP) and from the Colorado River water; and recycled water discharges to the San Gabriel River and the Rio Hondo in the southerly most portion of the Basin. Consequently, the "local salt/nutrient contributing stakeholders" have been identified as the Upper San Gabriel Valley Municipal Water District (Upper District), San Gabriel Valley Municipal Water District (San Gabriel District), Three Valley's Municipal Water District (Three Valley's District), the County of Los Angeles Department of Public Works (LACDPW) which is responsible for stormwater recharge; and Metropolitan Water District of Southern California (MWD) which collectively are responsible for the delivery and recharge of imported water in the Basin; and the Sanitation Districts of Los Angeles County (LACSD) which is responsible for the release of recycled water in the Basin.

Watermaster has held numerous meetings with the "local salt/nutrient contributing stakeholders" including meetings held on November 12, 2012; May 1, 2013; October 8, 2013; October 24, 2013; November 19, 2013; December 18, 2013; and November 19, 2014. The primary source of salt and nutrient unloading is through groundwater extraction by Basin groundwater producers. Watermaster staff regularly informed the Basin producers during the Basin Water Management Committee meetings. Discussion of activities from Basin Water Management Committee meetings are included in Watermaster's Board meeting minutes which are available on Watermaster's website. Watermaster staff has coordinated closely with the Regional Water

Board/Los Angeles Region (LARWQCB) staff on the development progress and the contents of the San Gabriel SNMP. Following the annual stakeholder workshop on November 15, 2011, LARWQCB staff authorized Watermaster to proceed with the development of the San Gabriel SNMP. In the letter dated October 4, 2012 Watermaster described its assimilative capacity approach to LARWQCB staff. Subsequently, in a letter dated December 21, 2012, LARWQCB staff provided a response approving the proposed assimilative capacity approach. Furthermore, Watermaster staff participated in LARWQCB SNMP workshops held on November 15, 2010; November 15, 2011; November 15, 2012; November 14, 2013; and December 4, 2014.

The development of the San Gabriel SNMP considers the document entitled *"Regional Water Board Assistance in Guiding Salt and Nutrient Management Plan Development in the Los Angeles Region"* (Guidance). The final Guidance, which was dated June 28, 2012, is included as Appendix B. The purpose of the Guidance is to provide information and guidance to assist on certain aspects of the SNMP development identified by stakeholder groups to ensure the final product is compliant with the specific requirements of the Policy and state and federal water quality laws, but the *"stakeholders have the flexibility to apply any scientifically defensible methodology to make these determinations,"* i.e. estimates of basin/subbasin assimilative capacities and mass loadings. Watermaster staff organized the San Gabriel SNMP and developed an approach for determining the Basin salt/nutrients loadings and assimilative capacities.

The San Gabriel SNMP has been developed for San Gabriel Valley Groundwater Basin as identified in the Main San Gabriel Basin Judgment. To that end, the Puente Basin and the Six Basins are the subject of separate court adjudications and consequently are excluded from this San Gabriel SNMP. Likewise, Spadra sub-basin in not included in the Main San Gabriel Basin Judgment and is excluded from this SNMP.

Watermaster developed a spreadsheet model as a tool to calculate the impacts of loading and unloading from numerous water supply components. Loading components consist of precipitation on the valley floor, percolation of water applied for irrigation (groundwater, local surface water, treated imported water, and recycled water), percolation of local stormwater and untreated imported water, percolation of recycled water discharged from LACSD water reclamation plants to unlined portions of the San Gabriel River, San Jose Creek and Rio Hondo, and subsurface inflow. Unloading components consist of groundwater production and subsurface outflow. Water quality concentrations were applied to the various loading/unloading components to the extent data was available. The rise and fall of the groundwater table through soils in the vadose zone may impact groundwater quality beyond the water quality of the water being percolated. In addition, the groundwater basin contains approximately 8,000,000 acre-feet of fresh water at all times while annual loading/unloading is about 250,000 acre-feet per year. The San Gabriel Basin contains high quality water and is over 30 times the volume of the annual loading and unloading. As a result, there are only very gradual changes in water quality as the result of the annual loading/unloading process.

The spreadsheet model used in this San Gabriel SNMP is a tool to calculate how existing water management practices and potential future projects may impact salts and nutrients in the San Gabriel Basin. The majority of the loading is the result of percolation of very high quality water from precipitation, stormwater run-off and untreated imported water. Unloading is primarily from production of groundwater. The components of loading (Total Dissolved Solids, Nitrate, Chloride and Sulfate) have lower concentrations than the groundwater being unloaded (there is a persistent net unloading on a year to year basis) and consequently overall Basin water quality changes very little.

The Upper District is developing its Indirect Reuse Replenishment Project (IRRP) which is the only planned ~~replenishment project~~recycled water recharge project ~~for~~ within the San Gabriel Basin. Potential projects to be developed in the future may include, but not are limited to, construction of new facilities that may increase the amount of high quality stormwater runoff that can be captured and percolated, changes to untreated imported water quality (including the source of imported water quality supply), and development of recycled water projects for direct replenishment.

The San Gabriel SNMP was prepared to fulfill the Policy specific requirements. Chapter II describes the Policy's mandate for the use of recycled water. Chapter III describes the San Gabriel SNMP including its goal and objectives, characterization of the Basin, sources of salt and nutrients including their fate and transport, methodology for determining salt/nutrient loadings and assimilative capacities, estimates for salt/nutrient loadings and assimilative capacities, and implementation measures for recycled water, stormwater recharge, and others. Chapter IV provides an antidegradation analysis. Chapter V describes the basinwide salt/nutrient monitoring plan including a description of the monitoring network, monitoring schedule and frequency, and responsible stakeholders. A summary and recommendations for future activities are provided in Chapter VI.

CHAPTER II

MANDATE FOR THE USE OF RECYCLED WATER

II.1. BACKGROUND

On February 9, 2009, the State Water Board adopted Resolution 2009-0011 that created the "Recycled Water Policy". The Recycled Water Policy recognized that "…collapse of the Bay-Delta ecosystem, climate change, and continuing population growth have combined with a severe drought on the Colorado River, and failing levees in the Delta, to create a new reality that challenges California's ability to provide the clean water need for a healthy environment, a healthy population and a healthy economy, both now and in the future." The Recycled Water Policy encourages appropriate water recycling, water conservation and use of stormwater to increase water supplies within California. The mandates contained within the Recycled Water Policy are briefly addressed below.

II.2. SUMMARY OF MANDATES

Section 4 of the Recycled Water Policy provides the "Mandate for the Use of Recycled Water" and is summarized below.

"*a. The State Water Board and Regional Water Boards will exercise the authority granted to them by the Legislature to the fullest extent possible to encourage the use of recycled water, consistent with state and federal water quality laws.*

(1) The State Water Board hereby establishes a mandate to increase the use of recycled water in California by 200,000 afy [acre-feet per year] by 2020 and by an additional 300,000 afy by 2030. These mandates shall be achieved through cooperation and collaboration of the State Water Board, the Regional Water Boards, the environmental community, water purveyors and the operators of publicly owned treatment works. The State Water Board will evaluate progress toward these

mandates biennially and review and revise as necessary the implementation provisions of this Policy in 2012 and 2016.

(2) Agencies producing recycled water that is available for reuse and not being put to beneficial use shall make that recycled water available to water purveyors for reuse on reasonable terms and conditions. Such terms and conditions may include payment by the water purveyor of a fair and reasonable share of the cost of the recycled water supply and facilities.

(3) The State Water Board hereby declares that, pursuant to Water Code sections 13550 et seq., it is a waste and unreasonable use of water for water agencies not to use recycled water when recycled water of adequate quality is available and is not being put to beneficial use, subject to the conditions established in sections 13550 et seq. The State Water Board shall exercise its authority pursuant to Water Code section 275 to the fullest extent possible to enforce the mandates of this subparagraph.

b. These mandates are contingent on the availability of sufficient capital funding for the construction of recycled water projects from private, local, state, and federal sources and assume that the Regional Water Boards will effectively implement regulatory streamlining in accordance with this Policy.

c. The water industry and the environmental community have agreed jointly to advocate for $1 billion in state and federal funds over the next five years to fund projects needed to meet the goals and mandates for the use of recycled water established in this Policy.

d. The State Water Board requests the California Department of Public Health (CDPH), the California Public Utilities Commission (CPUC), and the California Department of Water Resources (CDWR) to use their respective authorities to the fullest extent practicable to assist the State Water Board and the Regional Water Boards in increasing the use of recycled water in California." [1]

As a result of these mandates and coordination with LARWQCB staff, Watermaster has taken the role of lead agency to develop the SNMP for the San Gabriel Valley groundwater basin. The SNMP, and the spreadsheets models which have been developed, will be used as a tool to evaluate the impacts of future projects on the existing water quality of the groundwater basin.

CHAPTER III

SALT AND NUTRIENT MANAGEMENT PLAN

III.1. GOAL AND OBJECTIVES

The primary goal of the San Gabriel SNMP is to assist Watermaster and participating/potential stakeholders to comply with the Policy regarding the use of the recycled water from municipal wastewater treatment facilities as a safe source of water supply, while maintaining the water quality objectives for salt and nutrients in the Basin Plan established by the LARWQCB.

The primary objective of the San Gabriel SNMP is to comply with the specific requirements described in the Policy. They include (1) characterization of the Basin, (2) identification of sources of salt, nutrients, and constituents of emerging concern (CECs) (~~if~~ when deemed necessary by the Recycled Water Policy) and their fate and transport, (3) estimation of salt, nutrients, and CECs (if necessary) loadings and assimilative capacities, (4) identification of water recycling and stormwater recharge/use goals and objectives, (5) verification of compliance with Resolution No. 68-16 through antidegradation analyses, and (6) development of a monitoring plan to verify compliance with the Basin water quality objectives.

III.2. BASIN PLAN WATER QUALITY OBJECTIVES

The Basin is one of 24 groundwater basins located within the Los Angeles Region under jurisdiction of the LARWQCB, extending from Rincon Point (on the coast of western Ventura County) to the eastern Los Angeles County line, as shown on Plate III.1. The LARWQCB adopts and implements the Basin Plan that serves as a basis for its regulatory program. The current Basin Plan, ~~as amended~~adopted in 1994 and as amended through ~~1994~~ 2011 [2], combines and replaces the earlier plans: the *Water Quality Control Plan: Santa Clara River Basin* [3] *and* the *Water Quality Control Plan: Los Angeles River Basin* [4].

The Basin Plan establishes water quality standards for the surface and ground waters of the Los Angeles Region based upon designated beneficial uses of water and numerical water quality objectives that must be maintained or attained to protect those uses. Beneficial uses for regional groundwater basins generally include:

- Municipal and Domestic Supply (MUN) for community, military, or individual water supply systems including, but not limited to, drinking water supply;
- Industrial Service Supply (IND) for industrial activities that do not depend primarily on water quality including, but not limited to, mining, cooling water supply, geothermal energy production, hydraulic conveyance, gravel washing, fire protection, and oil well repressurization;
- Industrial Process Supply (PROC) for industrial activities that depend primarily on water quality;
- Agricultural Supply (AGR) for farming, horticulture, or ranching including, but not limited to, irrigation, stock watering, and support of vegetation for grazing livestock; and
- Aquaculture Supply (AQUA) for aquaculture or mariculture operations including, but not limited to, propagation, cultivation, maintenance, and harvesting of aquatic plants and animals for human consumption or bait purposes.

The Basin designated beneficial uses, as listed in Table 2-2 of the Basin Plan [2], include MUN, IND, PROC, and AGR. The Basin groundwater is subjected to the following objectives:

Bacteria, Coliform

In ground waters designated as MUN, the concentration of coliform organisms over any seven-day period shall be less than 1.1/100 milliliters.

Chemical Constituents and Radioactivity

Ground waters designated as MUN shall not contain concentrations of chemical constituents and radionuclides in excess of the limits specified in the following provisions of Title 22 of the California Code of Regulations which are incorporated by reference *into this plan: Table 64431-A of Section 64431 (Inorganic Chemicals), Table 64431-B of Section 64431 (Fluoride), Table 64444-A of Section 64444 (Organic Chemicals), and Table 4 of Section 64443 (Radioactivity). This incorporation by reference is prospective including future changes to the incorporated provisions as the changes take effect. (See Tables 3-5, 3-6, 3-7, and 3-9.)*

Ground waters shall not contain concentrations of chemical constituents in amounts that adversely affect any designated beneficial uses.

Mineral Quality

Numerical mineral quality objectives for individual groundwater basins are contained in Table 3-10.

Nitrogen (Nitrate, Nitrite)

Ground waters shall not exceed 10 mg/L nitrate-nitrogen (nitrogen in the form of nitrate, NO_3-N) or nitrate-nitrogen plus nitrite-nitrogen (NO_3-N + NO_2-N), 45 mg/L as nitrate (NO_3), or 1 mg/l as nitrite-nitrogen (NO_2-N).

Taste and Odor

Ground waters shall not contain taste and odor or odor-producing substances in concentrations that cause nuisance or that adversely affect beneficial uses.

The numerical water quality objectives for the Basin groundwater, which are based on the June 21, 2012 update of Title 22 of the California Code of Regulations (CCRs) [5], are summarized in Table III.1. Neither the Basin Plan nor Title 22 of the CCRs has established the numerical water quality objectives for taste and odor.

The LARWQCB also implements State and federal antidegradation policies to maintain high quality of both surface and ground waters in California (Resolution No. 68-16 [31] and 40 CFR

131.12 [6]). Under the State Nondegradation Objective, whenever the existing quality of water is better than that needed to protect all existing and probable future beneficial uses, the existing high quality shall be maintained until or unless it has been demonstrated to the State that any change in water quality will be consistent with the maximum benefit of the people of the State, and will not unreasonably affect present and probable future beneficial uses of such water. Therefore, unless conditions are met, background water quality concentrations (the concentrations of substances in natural waters which are unaffected by waste management practices or contamination incidents) are appropriate water quality goals to be maintained. If it is determined that some degradation is in the best interest of the people of California, some increase in pollutant level may be appropriate. However, in no case may such increases cause adverse impacts to existing or probable future beneficial uses of waters of the State.

III.3. SAN GABRIEL VALLEY GROUNDWATER BASIN

The San Gabriel Valley was characterized in Appendix A of Bulletin No. 104-2, which contains engineering details on a program for effective utilization of the groundwater resources of the valley initiated in the 1960s by the California Department of Water Resources (CDWR) [7]. Since then, additional data and information on geology, hydrology, hydrogeology, water quality, and groundwater management have become available and provide a better understanding of its characteristics and responses to groundwater management measures. For the purposes of this SNMP, CDWR Bulletin No. 104-2 was used as the basis for the Basin characterization; however, its engineering details may be updated using available data and information, if appropriate, to reflect the existing conditions of the Basin.

The San Gabriel SNMP includes only the portion of the San Gabriel Valley Basin included in the Basin Judgment. The Puente Basin and the Six Basins are subject of separate court adjudications and are not included as part of the San Gabriel SNMP; the Spadra sub-basin is currently not adjudicated, and likewise, not included in this SNMP.

III.3.1. Geography

The Basin underlies the San Gabriel Valley located in southeastern Los Angeles County, and is identified by the CDWR as Groundwater Basin Number 4-13, as shown on Plate III.2. The Basin is bounded by the line of contact between alluvium and the crystalline and metamorphic rocks of the San Gabriel Mountains on the north, by the Raymond fault on the northeast, by the line of contact between the sedimentary rocks of a system of low rolling hills (Repetto, Merced, Puente, and San Jose Hills) on the west and south, and by the bedrock high between San Dimas and La Verne on the east. The Whittier Narrows, a 1.5-mile gap between the Merced and Puente Hills, forms the only exit for the Basin surface water and groundwater, as shown on Plate III.3. The Basin ground surface slopes downward from approximately 1,200 feet above mean sea level (msl) in the San Dimas area, 850 feet msl in the Pomona area on the east, and 600 feet msl in the Alhambra area on the west to approximately 200 feet msl in the Whittier Narrows area on the southwest. According to the CDWR, the Basin surface area is approximately 167 square miles (mi^2) or 106,880 acres [7].

III.3.2. Land Uses

In the 20th century, the San Gabriel Valley *"has undergone a cultural change, progressing from a predominantly rural and agricultural community to a residential and commercial urban complex. Agricultural lands increased from 6,300 acres [about 6 percent of the Basin] in 1880 to 60,300 acres [about 56 percent] in 1924, then decreased steadily to 15,300 acres [about 14 percent] in 1960; urbanization, on the other hand, increased constantly – from 1,700 acres [about 2 percent] in 1904 to 74,500 [about 70 percent] in 1960"* [7]. A recent study conducted by USGS indicates that land use in the Basin is approximately 84 percent urban, 16 percent natural, and 1 percent agricultural [14]. Generalized land use in the San Gabriel Valley is shown on Plate III.4.

III.3.3. Geology

According to the CDWR, the Basin is a structural basin filled with permeable alluvial deposits (water-bearing formations) and underlain and surrounded by relatively impermeable rocks (nonwater-bearing formations) [7]. The Basin also contains many geological features and faults that may influence groundwater movement into, through, or within the Basin. The general geology of the San Gabriel Valley is shown on Plate III.5.

III.3.3.1 Nonwater-Bearing Formations

The nonwater-bearing formations include the igneous and metamorphic rocks (the basement complex rocks and the Glendora Volcanics) and most of the sedimentary Tertiary formations, as shown on Plate III.5. Although these formations are considered nonwater-bearing, wells drilled into them may intersect fractures containing water and can produce up to 15 gallons per minute (gpm) [7]. These formations are assumed as the boundaries of the San Gabriel Valley groundwater basin.

The basement complex rocks (Bc) comprise the main mass of the San Gabriel Mountains. The Glendora Volcanics (Mv) are found in the foothills of the San Gabriel Mountains near Glendora, in the South Hills, and in the northeast end of San Jose Hills. The Tertiary sedimentary rocks, ranging in age from Miocene to Pliocene, consist of the Punchbowl (Ms), Topanga (Ms), Puente (Ms), Repetto (Pr), and Pico (Pp) Formations. These sedimentary formations are found underlying and flanking the unconsolidated alluvial sediments in the east and south of the Basin, as shown on Plate III.5.

III.3.3.2 Water-Bearing Formations

The principal water-bearing formations of the Basin are unconsolidated and semiconsolidated nonmarine sediments of Recent and Pleistocene age varying from boulders and coarse gravel, in areas near the mountain front, to medium- and fine-sand containing a larger amount of silt and clay, in areas away from the mountains. Materials comprising the formations were derived chiefly from the San Gabriel Mountains and extend to a maximum depth of more than 4,000 feet [7]. Primarily, these materials consist of the older alluvium, which constitutes the main valley fill material and is exposed around the margins of the entire Basin, the recent alluvium, which blankets the center of the valley floor, and the transition zone deposits, which lie along San Dimas Wash in the eastern part of the Basin, as shown on Plate III.5.

The older alluvium (Qoal) deposits consist of unsorted yellowish to reddish-brown, angular to subrounded continental debris, derived from the surrounding mountains. These deposits vary from silt to boulders more than two feet in diameter. The thickness of the older alluvium deposits ranges from approximately 300 feet in the northern part of the Basin in the vicinity of the mouth of the San Gabriel River to approximately 4,100 feet in the vicinity of Whittier Narrows. Clay is also present in the older alluvium, probably due to the weathering process after the sediments were deposited [7]. Results from groundwater contamination cleanup activities conducted by the United States Environmental Protection Agency (USEPA) within the Basin [8-13] indicate that clay layers of various thicknesses are embedded within the old alluvium at varying depths. These clay layers act as aquitards, i.e. semi-confining or confining layers, stratifying the water-bearing formations, i.e. aquifers, and restricting hydraulic communication between these aquifers. The cross-section locations are shown on Plate III.6a. The presence and significance of these clay layers are dominant in the southern and western portions of the Basin, especially in the Alhambra area, as shown on the East-West cross-section on Plate III.6b and the North-South cross-section on Plate III.6c.

The transition zone (Qat) deposits are limited in a zone of approximately 2 two miles wide along San Dimas Wash from San Dimas to Baldwin Park, as shown on Plate III.5. These deposits contain gravels found in both the older and Recent alluvium. These deposits are thin (less than 30 feet thick) and lie above the water table [7].

The Recent (Qal) alluvium deposits overlie the older alluvium along the front of the San Gabriel Mountains and in the central part of the Basin. These deposits consist of predominantly coarse boulders, gravels, and sands, ranging in thickness from a few inches to roughly 100 feet in Whittier Narrows [7]. The thickest portions are found along the San Gabriel River channel and its adjacent floodplains.

III.3.3.3 Geological Features and Faults

Numerous geological features and faults have been delineated in the Basin, as shown on Plate III.5; however, only a few of these faults influence groundwater movement in the Basin [7]. According to the CDWR, these faults may be formed by impervious rock brought into contact with water-bearing material, by an offsetting aquifer, by impervious gouge formed in bedrock or alluvium as a result of movement along a fault plane, by fractures in bedrock sealed by impervious deposits, and by permeable or open areas along the line of faulting that act as a conduit carrying water laterally along the fault line. The faults that affect groundwater movement in the Basin are the Raymond fault and the Duarte fault.

The Raymond fault forms the boundary between the Basin and the Raymond Basin from the City of South Pasadena on the west to the City of Monrovia on the east. It is likely a thin and impervious gouge formed in alluvium because it creates a significant difference in water level elevation through a relatively short distance of approximately 2,700 feet between Del Mar Well of California American Water Company (CAWC) and Well No. 3 of San Gabriel County Water District, as shown on Plate III.7. In addition to the difference in water level elevation, the barrier effect of the Raymond fault also is shown by the presence of artesian conditions during periods of high water level, and by the creation of ponds and swampy areas north of the fault line [7]. Based on semi-annual groundwater contour maps generated by Watermaster, the Raymond fault appears to impede groundwater movement southward from the Raymond Basin into the Basin. The groundwater mound in the vicinity of the City of Monrovia, as shown on Plate III.7, appears to be caused by recharge water from the Sawpit Canyon fault.

The Duarte fault crosses the upper portion of the alluvial fan at the mouth of San Gabriel Canyon, passes under the City of Azusa, and continues to the east possibly as far as South Hills, as shown on Plate III.5. This fault, like the Raymond fault, appears to be a thin and impervious gouge formed in alluvium because of a significant difference in water level elevation in a short distance between CAWC Las Lomas Well No. 2 and Crown Haven Well, approximately 2,350 feet across the fault line, as shown on Plate III.8. Based on the highest water level elevations at CAWC Las Lomas Well No. 2 and Encanto Well, the elevation of the top of the Duarte fault at the mouth of San Gabriel Canyon is estimated at approximately 400 feet msl. As a result, groundwater from the San Gabriel Canyon is able to cascade across the fault into the Basin and occasionally create a groundwater mound in the vicinity of CAWC Crown Haven Well, as shown on Plate III.8.

Based on data and information obtained from remedial investigation for the Area 3 Operable Unit (Area 3 OU), USEPA suggests “the presence of a structural bedrock discontinuity that bisects the western and eastern portions of Area 3” [11], as shown on Plates III.9a and III.9b. Further review of the drillers logs in that area indicates that only clay is present below the depth of 275 feet at Well MW1-1 while pervious layers are found to the depth of 460 feet at Well MW1-2AB. This suggests the presence of a vertical aquifer offset along Atlantic Boulevard that creates a difference in water level elevation in the western portion of the Area 3 OU, as shown on Plate III.9b.

III.3.4. Hydrology

III.3.4.1 Surface Water System

The Basin is located within the San Gabriel River and Rio Hondo watershed. The area of this watershed at Whittier Narrows is estimated at approximately 313,600 acres or 490 mi^2. The Basin surface water system consists of two major streams, i.e. the San Gabriel River and the Rio Hondo. The San Gabriel River and its tributaries (Fish Canyon, Rogers Canyon, Big Dalton, Little Dalton, San Dimas, Walnut, and San Jose Creeks) drain the Eastern portion of the San Gabriel River watershed, and the Rio Hondo (which is a distributary of the San Gabriel River) and its tributaries (Alhambra, Rubio, Eaton, Arcadia, Santa Anita, and Sawpit Washes) drain the western portion of the San Gabriel River watershed. Surface water in the San Gabriel River and Rio Hondo exits the Basin at Whittier Narrows, a narrow gap between the Merced and Puente Hills, as shown on Plate III.10.

Historically, surface water flowed freely in the San Gabriel River and the Rio Hondo with improvement no more than a trash dike by farmers [7]. During the summer months, most streams were dry except at Whittier Narrows where perennial flow existed due to rising water. Since 1960, surface water has been significantly modified by flood control reservoirs, dams, and channels constructed by the Los Angeles County Department of Public Works (LACDPW) and the United States Army Corps of Engineers (USCOE). Major flood control reservoirs include Cogswell, San Gabriel, Morris, Big Dalton, Eaton, and Puddingstone Reservoirs. Major flood control dams include Santa Fe Dam and Whittier Narrows Dam. All stream channels have been improved. Most stream channel improvements consist of concrete-lined bottom and sides. The San Gabriel River between Santa Fe Dam and Whittier Narrows Dam and the San Jose Creek west of Elsah Avenue, however, have a pervious bottom allowing surface water percolation for groundwater recharge.

III.3.4.2 Precipitation

The San Gabriel River and Rio Hondo watershed is located within a region of both semiarid and Mediterranean climate, consisting of intermittent rain during the winter months and no rain during the summer months. The majority of the annual rainfall occurs between December and March. Precipitation in the San Gabriel River and Rio Hondo watershed has been monitored by a network of precipitation stations operated by LACDPW. For the purposes of this SNMP, only stations with the longest continuous records were selected, as shown on Plate III.10 and Table III.2. The annual precipitations at the selected stations were obtained from LACDPW and are included in Appendix C. They were used to calculate the annual average precipitations for the mountains watershed (including Station Nos. 63, 68, 89, 144, 223, 235, 334, 338, 390, 425, and 683), the valley floor (including Station Nos. 95, 108, 167, 387, 610, 742, 1037, 1041, and 1140), and the southern low hills watershed (including Station Nos. 96, 201, 356, 1114, and 1260). During the period from water year 1924-25 through 2010-11, the average precipitation ranged from 9.77 to 67.41, averaging 27.28 inches per year (in/yr) for the mountains watershed, from 5.72 to 45.42, averaging 18.57 in/yr for the valley floor, and from 5.06 to 38.91, averaging 16.88 in/yr for the southern low hills watershed, as shown on Plate III.11a and Table III.2. The runoff coefficient was determined using the total volume of inflow at designated streamflow gauges as shown in Appendix D as a percentage of the total volume of precipitation as shown in Table III.2.

A cumulative departure from average precipitation curve has been used to evaluate wet-dry cycles for a hydrologic period. This curve is a time-series plot of the summation of the differences between the annual and average precipitation (departures) from the beginning of the hydrologic period. Upward sloping trends on the curve correspond to wet cycles, and downward sloping trends correspond to dry cycles. The cumulative departure curves for the San Gabriel River and Rio Hondo watershed for the period from 1926-27 to 2010-11 indicate that the watershed has experienced numerous wet-dry cycles in the past, as shown on Plate III.11b. The most prolonged dry cycle occurred between 1944-45 and 1964-65 following the most prolonged wet cycle from 1933-34 to 1943-44.

III.3.4.3 Streamflow

Streamflow in the San Gabriel River, the Rio Hondo, and their tributaries has been monitored at stream gaging stations established by various agencies including LACDPW, CDWR, USCOE, USGS, MWD, and the San Gabriel River Water Committee, as described in Attachment No. 4 of the CDWR's Bulletin No. 104-2 [7]. For the purposes of this SNMP, only stream gaging stations located at critical locations were selected for calculating surface water inflow and outflow of the San Gabriel Basin. They include the LACDPW gaging stations below Morris Dam and Whittier Narrows Dam and the LACDPW gaging stations at the mouth of the San Gabriel River and Rio Hondo tributaries, as shown on Plate III.10. The annual flows at these gaging stations were obtained from LACDPW and are included in Appendix D.

The annual surface water inflow of the San Gabriel Basin or runoff of the San Gabriel River and Rio Hondo watershed at Whittier Narrows was calculated as the sum of the annual streamflow at the LACDPW gaging stations below Morris Dam and at the mouth of the San Gabriel River and Rio Hondo tributaries. During the period 1949-50 through 2010-11, inflow varied from approximately 5,140 to 852,940 af/yr, averaging 188,050 af/yr, as shown on Plate III.12 and Appendix D. The annual streamflow at the LACDPW gaging station below Whittier Narrows Dam, was assumed as the annual surface water outflow of the San Gabriel Basin, and varied from approximately 560 to 274,240 af/yr, averaging 58,230 af/yr, as shown in Appendix D. This outflow, however, includes recycled water released by the San Jose Creek Wastewater Reclamation Plant (SJCWRP) to San Jose Creek since 1972-73. The annual surface water inflow and outflow of the San Gabriel Basin from 1949-50 through 2010-11 are shown on Plate III.12.

Using the annual average precipitation for the mountains watershed, the valley floor, and the southern low hills watershed since 1973-74, as shown in Appendix C, and the areas of the mountains watershed, the valley floor, and the southern low hills watershed, the annual volume of precipitation in the San Gabriel River and Rio Hondo watershed was calculated to vary from approximately 149,100 to 1,472,800 af/yr, averaging approximately 592,700 af/yr, as shown on Table III.2. As a result, runoff coefficient of the San Gabriel River and Rio Hondo watershed was estimated to vary from 6% to 62%, averaging 33%.

III.3.5. Hydrogeology

The Basin is a structural basin filled with permeable alluvial deposits, which is underlain and surrounded by relatively impermeable rock. It forms an aquifer, i.e. *"a geologic unit that can store and transmit water at rates fast enough to supply reasonable amounts to wells"* [15]. The Basin aquifer is stratified in some areas by confining or semi-confining layers consisting of impermeable or less-permeable materials such as clay or silt. In these areas, the Basin aquifer is an aquifer system that may include an unconfined or water-table aquifer overlying individual confined or artesian aquifers separated by semi-confining or confining layers. Groundwater in the confined aquifers is normally under pressure; therefore, water will rise in a well drilled to these aquifers to a level above their overlying confining layer, which is called the potentiometric surface [15]. In general, the Basin aquifer is considered unconfined because the semi-confining or confining layers are not continuous across the Basin, as shown on Plates III.6b and III.6c.

III.3.5.1 Aquifer Characteristics

Performance of an aquifer depends on two characteristics or parameters: transmissivity (T) and storage coefficient or coefficient storage or storativity (S). The transmissivity of an aquifer is defined as *"the amount of water that can be transmitted horizontally by the full saturated thickness of the aquifer under a hydraulic gradient [or slope] of 1"* [15]. It is the product of the hydraulic conductivity or permeability (K) and the saturated thickness of the aquifer (b), T = bK. Common units are gallons per day per square foot (gpd/ft^2) or feet per day (ft/d) for K and gallons per day per foot (gpd/ft) or square feet per day (ft^2/d) for T. The storage coefficient or storativity of an aquifer is defined as *"the volume of water that a permeable unit will absorb or expel from storage per unit surface area per unit change in head"* [15]. It is a dimensionless quantity and representative of the aquifer condition. It is usually less than 0.005 for confined aquifers and ranges from 0.02 to 0.30 for unconfined aquifers.

The aquifer characteristics or parameters may be determined by different methods, but the aquifer performance test (APT) method appears to be most accurate [16]. During the APT, a production well would be pumped at a constant-rate for an adequate time period while monitoring the water level in one or more observation wells located close to the pumping well and having similar well construction design.

As part of its investigation of the Basin in the 1960s, CDWR conducted 22 APTs on wells distributed throughout the Basin to determine the characteristics of the Basin aquifer. The locations of the APTs conducted by CDWR are shown on Plate III.13. The Basin aquifer characteristics estimated by CDWR, as shown in Table III.3, range from 33,000 to 875,000 gpd/ft (or 4,412 to 116,979 ft^2/d) for transmissivity, from 512 to 4,900 gpd/ft^2 (or 68 to 655 ft/d) for hydraulic conductivity, and from 0.00006 to 0.018 for coefficient of storage.

Since 1991, as part of its groundwater resources management activities, Watermaster has conducted 33 APTs primarily to obtain field data for calibration of its two-dimensional finite-difference San Gabriel Basin Groundwater Flow Model. The locations of the APTs conducted by Watermaster are shown on Plate III.13. The Basin aquifer characteristics estimated from these APTs, as shown in Table III.4, range from 13,400 to 1,167,300 gpd/ft (or 1,791 to 156,056 ft^2/d) for transmissivity, from 91 to 3,400 gpd/ft^2 (or 12 to 455 ft/d) for hydraulic conductivity, and from 0.000073 to 0.36 for coefficient of storage. Most of the Basin aquifer acts as a semi-confined aquifer, but in some areas, it acts as a confined or unconfined aquifer.

III.3.5.2 Groundwater Level and Movement

Groundwater levels in production or monitoring wells throughout the Basin have been measured by various agencies such as the well owners, LACDPW, CDWR, USGS, USEPA, San Gabriel Valley Protective Association, and Watermaster since the beginning of the 20th century; however, LACDPW and Watermaster appear to hold most complete water level measurement records, prior to 1993 for LACDPW and thereafter for Watermaster. The water table or potentiometric surface of the Basin aquifer can be found at or near ground surface in the Whittier Narrows area or at depths exceeding 300 feet bgs along the Raymond and Duarte faults, as shown on Plates III.6.b and III.6.c.

A well located in the City of Baldwin Park has been designated by Watermaster as the key well, i.e. the Baldwin Park Key Well (Key Well), whose water levels are used to represent the Basin hydrogeologic conditions. The Key Well location is shown on Plate III.14. Historic water levels in the Key Well indicate that the water table or potentiometric surface of the Basin appears to respond to hydrologic conditions, i.e. wet-dry cycles, as shown on Plate III.15; however, responses at individual wells across the Basin are different. Historic data from the Watermaster Basinwide Groundwater Elevation Monitoring Program (BGWEMP), as shown on Plate III.16, indicate that Groundwater levels in the wells located east of Rio Hondo (such as Well No. 1 of the City of Covina and CAWC Santa Fe Well and Blue Ribbon Well No. 1) appear more sensitive to the hydrologic conditions than those located west of Rio Hondo (such as Well No. 10 of San Gabriel County Water District and Garfield Well of the City of Alhambra) and along the Basin perimeter (such as LACDPW Well 2947F and Well 155W-2 of Suburban Water Systems (SWS)). The water level spikes observed at CAWC Santa Fe Well (Recordation Number 1900354), as shown on Plate III.16, are immediate responses to surface water spreading at the LACDPW Santa Fe Spreading Grounds (SFSG). The SFSG is located adjacent to CAWC Santa Fe Well, as shown on Plate III.14.

The direction of groundwater movement in some areas of the Basin such as the area north of the Duarte fault, the eastern portion east of Azusa Avenue, and the Puente valley remains the same as that during earlier periods. In other portions of the Basin, the direction of groundwater movement is affected naturally by hydrologic conditions and geological features and artificially by groundwater resources management measures such as extraction and/or groundwater recharge.

Prior to development, "*the general direction of ground water movement across all of the San Gabriel Valley was from the perimeter of the valley toward Whittier Narrows, the only area where subsurface outflow from the San Gabriel Valley is known to take place"* [7]. The direction of groundwater movement is perpendicular to the water level contours, as shown on Plate III.17a. Due to groundwater extraction for early development, a groundwater low was formed in the vicinity of the City of Alhambra, causing groundwater in the northwestern portion of the valley to flow towards this groundwater low (also known as the Alhambra pumping hole) rather than towards Whittier Narrows, as shown on Plate III.17b.

Since July 1996, as part of its BGWEMP, Watermaster has generated groundwater contour maps for the entire Basin using the water levels at approximately 130 primary wells and 40 secondary wells measured in January and July to represent the wet and dry periods for each year. The groundwater contours were generated manually on an USGS-Quad map using the measurements at the primary wells as primary data points and those at the secondary wells as supplemental data points. Physical boundaries such as hills and faults, especially the Duarte and Raymond faults, were taken into consideration when preparing the groundwater contours.

The Watermaster semi-annual groundwater contour maps indicate that groundwater movement in the Basin may be affected locally by groundwater extraction and recharge. In the vicinity of major pumping centers, groundwater may flow towards cones of depression caused by large extraction from production wells, as shown on Plate III.17c. Groundwater movement in the Basin portion bounded by the Duarte fault on the north, the San Gabriel River on the west, the Walnut Creek on the south, and Azusa Avenue on the east is highly affected by groundwater recharge activities at the SFSG, as shown on Plate III.17d, or by groundwater cascading across the Duarte fault at the mouth of the San Gabriel Canyon, as shown on Plate III.17e. The groundwater mound created by groundwater recharge at the SFSG or by groundwater cascading from the San Gabriel Canyon reverses the "normal" east-west direction of groundwater movement in the area just south of the Duarte fault and east of the San Gabriel River. This reversed groundwater commingles with that from the east and then flows in a northeast-southwest direction towards Whittier Narrows, as shown on Plates III.17d and III.17e.

III.3.5.3 Subsurface Inflow

According to CDWR, *"ground water moves into the San Gabriel Valley from the Raymond Ground Water Basin across the Raymond fault on the northwest,… Some subsurface inflow also takes place from the San Gabriel Mountains on the north, as a result of stored water moving out of fractures in the Basement Complex into the alluvial fill, and a negligible quantity of water may be enter the valley from the hills on the south… The seasonal subsurface inflow varied from a minimum of 14,400 acre-feet in 1950-51 to a maximum of 21,700 acre-feet in 1943-44...*

The groundwater contours prepared by LACDPW, as shown on Plates III.18a and III.18b, and by the Chino Basin Watermaster, as shown on Plate III.18c do not indicate groundwater movement from the Chino Basin to the San Gabriel Valley since 1957. Based on these groundwater contours, the Chino Basin appears separated from the San Gabriel Basin by a groundwater divide in the La Verne area and from the Puente Basin by a groundwater divide at its northeast end. As a result, there is no subsurface flow from the Chino basin to the San Gabriel and Puente Basins.

"Underflow into San Gabriel Valley across the Raymond fault varied from 2,000 to 12,000 acre-feet per year during the base period [from 1943-44 to 1959-60]. This subsurface flow did not occur at the same rate along the length of the fault, but varied from west to east. The lowest rates occurred near the western edge of the basin where the Raymond fault constitutes a nearly impervious barrier to ground water movement, and the highest rates occurred near Santa Anita where the barrier effect is negligible. Estimates of underflow across the Raymond fault were based on values of ground water gradients between water levels north of the fault" [7].

The groundwater contours prepared by LACDPW, as shown on Plates III.18a and III.18b, and by the Raymond Basin Management Board, as shown on Plates III.18d and III.18e, do not indicate north-south groundwater gradients between water levels north of the fault since 1957. Groundwater in the Raymond Basin appears to flow southeasterly along the Raymond fault towards cones of depression created by production wells. Since October 2007, groundwater in the easterly portion of the Raymond Basin between Eaton Wash and Santa Anita Wash appears to flow northerly away from the Raymond fault, as shown on Plates III.18d and III.18e. As a result, there should be no subsurface flow from the Raymond Basin to the San Gabriel Basin because north-south groundwater gradients between water levels north of the fault have not been observed, at least since 1957.

Subsurface inflow occurs from the Puente Basin into the Main Basin. Groundwater measurements are made semi-annually and subsurface inflow is calculated annually pursuant to the Puente Narrows Agreement. Subsurface inflow has ranged from 658 acre-feet per year to 985 acre-feet per year, while the long-term average has been 857 acre-feet per year, as shown on Table III.6. The seasonal amounts of subsurface inflow calculated by the CDWR and River Watermaster are included in Appendix E.

III.3.5.4 Subsurface Outflow

Subsurface outflow through Whittier Narrows was calculated using Darcy's equation by the CDWR (from 1933-34 to 1959-60) and by the San Gabriel River Watermaster (River Watermaster) (since 1964-65). During the period from 1933-34 to 1959-60, *"subsurface outflow varied from a low of 21,800 acre-feet in 1941-42 to a high of 34,000 acre-feet in 1949-50"* [7] averaging 28,400 af/yr. Since 1964-65, subsurface outflow varied from 15,000 af/yr in 1965-66 to 38,200 af/yr in 2007-08, averaging 26,488 af/yr [20]. As a result, the average subsurface outflow through Whittier Narrows for the period from 1933-34 through 2010-11 is approximately 27,200 af/yr. The seasonal amounts of subsurface outflow calculated by the CDWR and River Watermaster are included in Appendix E.

The calculated subsurface outflow does not appear to follow the Basin hydrologic conditions. For example, during the wet period from 1935-36 to 1941-42, the CDWR subsurface outflow decreased significantly from approximately 33,500 af/yr to approximately 21,800 af/yr. Similarly, during the dry period from 1973-74 to 1976-77, the River Watermaster subsurface outflow increased significantly from approximately 23,300 af/yr to approximately 37,500 af/yr.

III.3.6. Groundwater Storage Capacity and Groundwater in Storage

The groundwater storage capacity of an individual basin is determined by the CDWR as the product of the total volume of that basin (from ground surface to the base) and its average specific yield. The storage capacity is constant and is dependent on the geometry and hydrogeologic characteristics of the aquifer(s) [17]. As a result, the storage capacity defined by the CDWR is the amount of groundwater that can be drained by gravity from the completely saturated basin, i.e. the amount of groundwater that can be extracted from the basin. The CDWR groundwater storage capacity does not include the amount of groundwater that is retained in small pore spaces due to surface retention; therefore, it is less than the total volume of groundwater that can be stored in the basin, which is the sum of these two amounts or the product of the total volume of the basin and its effective porosity, which is the specific yield plus the specific retention.

Groundwater in storage, according to the CDWR, is the amount of groundwater that can be drained (or extracted) from a basin between the water table and its base. Like the groundwater storage capacity, groundwater in storage defined by the CDWR is less than the amount of groundwater stored in the basin between the water table and its base.

The groundwater storage capacity of the San Gabriel Valley (from ground surface to the base of fresh water) was estimated by the CDWR to be 9,500,000 af in 1966 [7], 10,438,000 af in 1975 [18], and 10,740,000 af in 2004 [19].

The amount of groundwater in storage was estimated to be 9,700,000 af in 1960 [7]. Watermaster has been using the groundwater in storage estimated by the CDWR in 1960, i.e. 9,700,000 af, and its rule of thumb for changes in groundwater in storage, i.e. 8,000 af for each linear foot of change in groundwater elevation at the Key Well, to evaluate the Basin groundwater storage. During the period from 1933 to 2012, groundwater in storage in the Basin varied from approximately 7,510,000 af in 2009 to approximately 8,470,000 af in 1944 averaging approximately 7,860,000 af, as shown on Plate III.19. The estimated volume of groundwater in storage for this SNMP is shown in Table III.6. As an extremely conservative approach, this SNMP assumes that only 75 percent of the Basin volume, or about 6,000,000 acre-feet is included in mixing calculations. Extraction wells in the Main Basin typically are about 500 feet to 1,000 feet deep and are screened over large (several hundred feet) intervals, facilitating vertical mixing. Likewise, mixing also occurs as the groundwater flows in the general direction from east to west. Consequently, assimilative capacity calculations in Section III.4.3 use a value of 6,000,000 acre-feet for Basin volume and consider the 25 percent reduction from 8,000,000 acre-feet as a margin of safety.

III.3.7. Water Production

The Basin water production comes from groundwater extracted from the Basin, surface water diversion from the San Gabriel River, groundwater imported from the Raymond Basin, and surface water imported from the State Water Project. A portion of the Basin water production, however, has been exported by producers to serve their service areas in the Central Basin.

III.3.7.1 Basin Groundwater Extraction and Surface Water Diversion

The Basin seasonal groundwater extraction during the period from 1933-34 to 1959-60 was reported in the CDWR Bulletin No. 140-2 [7]. During the period from 1933-34 to 1954-55, it was estimated by the CDWR to vary from 119,800 af/yr in 1934-35 to 177,800 af/yr in 1950-51. During the period from 1955-56 to 1959-60, it was recorded to vary from 164,700 af/yr in 1956-57 to 199,000 af/yr in 1958-59, as shown on Plate III.20.

Since 1973-74, annual groundwater extraction and surface water diversion have been reported in the Watermaster Annual Reports [21]. Approximately 500 groundwater production wells were drilled in the Basin, but only 229 wells are currently active or standby. The locations of the active or standby wells are shown on Plate III.14. The annual groundwater extraction and surface water diversion from 1973-74 to 2010-11 are included in Appendix F. During this period, groundwater extraction varied from 181,240 to 270,380 af/yr, averaging 228,040 af/yr. Surface water diversion varied from 4,690 to 22,820 af/yr, averaging 15,870 af/yr, as shown on Plate III.20. Table III.6 shows the total water production from the San Gabriel Basin.

III.3.7.2 Imported Water

Annual imported water for direct municipal water use and groundwater recharge from 1963-64 through 2010-11 was obtained from the Watermaster annual reports [21] and Raymond Basin Management Board (Raymond Board) annual reports [22], as shown in Appendix G. Water for direct municipal water use is either treated imported water or groundwater imported from water producers in the Raymond Basin. Treated surface water imported from Upper District and Three Valleys Municipal Water District (Three Valleys District) for municipal uses varied from 250 to 50,760 af/yr, averaging 16,030 af/yr. Groundwater imported from the Raymond Basin for municipal uses varied from 520 to 6,200 af/yr, averaging 3,310 af/yr. Surface water from the State Water Project is imported for groundwater recharge by the Upper District, the San Gabriel Valley Municipal Water District (San Gabriel District), and Three Valleys. During this period, surface water imported from State Water Project varied from 0 to 79,040 af/yr, averaging 31,320af/yr. The total imported water varied from 5,240 to 119,630 af/yr, averaging 50,670 af/yr. The annual imported water is included in Appendix G and Table III.6.

III.3.7.3 Exported Water

California Domestic Water Company (CDWC), San Gabriel Valley Water Company (SGVWC), SWS, and the City of Whittier have delivered water from their wells in the Basin to their service areas in the Central Basin. Annual groundwater exported from the Basin, as shown in Appendix H and Table III.6), was reported in the River Watermaster's annual reports [20]. During the period from 1955-56 through 2010-11, groundwater exported from the Basin varied from 25,500 to 44,200 af/yr at an average of 35,700 af/yr. Annual groundwater exported from the Basin by these producers is shown on Plate III.21.

III.3.8. Groundwater Balance Model and Safe Yields

According to the CDWR, deep percolation, i.e. groundwater recharge to the Basin, includes artificial recharge, streambed percolation, percolation of delivered water, and percolation of precipitation. The amount of deep percolation of each component was determined as the "residual" of the amounts of surface water supply, use, and disposal [7]. During the period from 1933-34 to 1959-60, deep percolation varied from a minimum of 92,700 af/yr in 1950-51 to a maximum of 459,500 af/yr in 1940-41.

For the purposes of this San Gabriel SNMP, groundwater recharge to the Basin consists of natural recharge and artificial recharge. The input and output parameters of recharge and discharge were formulated into a groundwater balance model. Furthermore, the Basin natural safe yield is defined as the difference between the natural groundwater recharge and subsurface outflow through Whittier Narrows (no subsurface inflow), and the sum of the natural safe yield and artificial recharge is considered as the Basin managed safe yield.

III.3.8.1 Groundwater Balance Model

The annual groundwater recharge since 1973-74 was estimated using a spreadsheet groundwater balance model that includes components for recharge and discharge within the Basin. Recharge components consist of natural recharge (percolation of precipitation on the valley floor, percolation of runoff from surrounding watersheds, and subsurface inflow from adjacent basins) and artificial recharge (direct spreading of local runoff or imported water, incidental percolation of water discharged into unlined portions of the San Gabriel River, and return flow from water usage within the Basin). Discharge components consist of groundwater extraction and subsurface outflow to the Central Basin through Whittier Narrows.

Recharge Components

The natural recharge components, consisting of percolation of precipitation, percolation of runoff, and subsurface inflow from the Puente Basin, have previously been discussed in Sections III.3.4.2, III.3.4.3, and III.3.5.3, respectively.

Artificial recharge through direct spreading of local and imported water at the spreading grounds within the Basin from 1930-31 through 2010-11 were obtained from the LACDPW annual hydrologic reports [23]. The locations of the spreading grounds are shown on Plate III.14. The annual surface water spreading at the spreading grounds are included as Appendix I and Table III.6. During this period, surface water spreading within the Basin varied from 0 to 427,790 af/yr at an average of 74,020 af/yr, as shown on Plate III.22.

Artificial recharge through return flow includes municipal and recycled water percolated to the Basin from surface uses, such as irrigation. Artificial recharge through incidental percolation of water discharged into the unlined portions of the San Gabriel River and San Jose Creek includes recycled water from the SJCWRP and PWRP that comingles with local stormwater in the River. Annual incidental percolation was estimated as the difference between the annual recycled water released into San Jose Creek from the SJCWRP and the annual streamflow at Station F-263. Percolation is assumed to not occur if the annual streamflow at F-263 is greater than the annual release of recycled water. During the period from 1949-50 to 2010-11, annual incidental percolation of recycled water released into San Jose Creek and San Gabriel River was estimated to vary from 0 to 31,040 af/yr, averaging approximately 8,770 af/yr, as shown in Appendix J, Table III.6 and Plate III.23.

Discharge Components

The discharge components, consisting of groundwater extraction and subsurface outflow, have previously been discussed in Sections III.3.7 and III.3.5, respectively.

Calibration

The groundwater elevation at the Key Well, as shown in Plate III.24, was used to calibrate the components of the Basin spreadsheet groundwater balance model, shown on Plate III.25 and Table III.6.

For the groundwater balance model, percolation of runoff from surrounding watersheds was included under the category of percolation of precipitation. Initial coefficients for recharge from precipitation in the valley floor and watersheds were originally set to 0.25. Assumptions in adjusting the coefficients included: essentially no recharge would occur when the annual precipitation was 0.33 to 0.5 times the average precipitation; recharge would increase as precipitation increased to the average; then increase more as precipitation approached the mean of the average and maximum precipitation, and then for annual precipitation exceeding the mean of the average and maximum precipitation. This results in four coefficients each for the valley floor and watersheds for each time period. The coefficients were adjusted until the predicted groundwater level approximated the groundwater elevation at the Key Well. It is assumed the recharge coefficients differ by region due to differences in watershed area, slope, and area of recharge zones.

Initially, a recharge coefficient of 0.09 was used for return flow from water usage on the valley floor and for return flow from direct use of recycled water to represent the fraction of the water that reaches the groundwater table. The coefficient for direct spreading was assumed to be 1.

First, the groundwater balance model was calibrated for the period from 1973-74 to 1993-94. This calibration adjusted the recharge coefficients from precipitation until the simulated water level matched the measured water level at the Key Well. These coefficients, however, were too high for the years following 1981-82; therefore, they were adjusted further for the period from

1981-82 to 1996-97 and from 1997-98 to 2010-11. The decreasing recharge coefficients from precipitation, as shown in Table III.5, appeared to reflect urban development that increased the impervious areas in the Basin during these periods.

The calibrated recharge coefficients for percolation of precipitation were then kept constant while adjusting the recharge coefficient for return flow in an attempt to improve the match, but the match between simulated and observed water levels at the Key Well was no better. Therefore, the initial recharge coefficient for return flow of 0.09 was used for the best calibration. The best match between simulated and observed groundwater elevations at the Key Well are shown on Plate III.24.

The calibrated Basin spreadsheet groundwater balance model, as shown in Table III.6, indicates that, during the period from 1973-74 through 2010-11, the groundwater recharge to the Basin varied from approximately 104,220 to 613,590 af/yr, averaging approximately 251,540 af/yr. Since 2001-02, there have been two drought years, and thereby receiving about 40% less recharge from precipitation, though direct spreading has averaged about 41,500 af/yr more than the long-term average, as shown in Plate III.25. During the period from 1973-74 through 2010-11, the groundwater discharge through extraction and subsurface outflow varied from approximately 208,290 to 296,480 af/yr, averaging approximately 255,500 af/yr.

III.3.8.2 Natural Safe Yield and Managed Safe Yield

Table III.6 also indicates during the period from 1973-74 to 2010-11 the annual natural safe yield, i.e., the difference between the natural groundwater recharge and the subsurface flow to the Central Basin, varied annually from approximately -26,760 to 315,400 af/yr, averaging approximately 53,640 af/yr. The managed safe yield, i.e., the sum of the natural safe yield and the artificial groundwater recharge, varied from approximately 78,120 to 589,490 af/yr, averaging approximately 224,090 af/yr. CDWR deep percolation to the Basin from 1933-34 to 1959-60 is equivalent to the managed safe yield for that period, which averaged approximately 205,100 af/yr [7].

III.3.9. Groundwater Quality

The quality of groundwater extracted in the San Gabriel Basin has been continuously monitored since the early 1900s. Groundwater quality testing has been performed to meet specific requirements such as the SWRCB Division of Drinking Water (DDW)[1] Title 22. In the 1970s, LACDPW initiated a groundwater quality program to sample groundwater production wells, under selected scheduling, in coordination with CDWR. The samples collected under this program are analyzed for major minerals, total dissolved solids (TDS), electrical conductivity, pH, and, in certain cases, phosphate, iron, manganese, fluoride, and boron [24].

Following its creation in 1973, Watermaster assumed responsibility for the DDW-mandated water quality sampling of groundwater production wells in the Basin. DDW Title 22 sampling requires all wells used for potable water supplies to be sampled at least once every three years for chloride (Cl), sulfate (SO4), and TDS, and at least annually for nitrate (NO3). In addition, all wells are sampled for General Mineral, General Physical, Inorganics, Radioactivity, VOC, plus various emerging contaminants on a regular and continuous basis. All data is provided to DDW electronically and maintained on the Watermaster database. Since the late 1970s and early 1980s, groundwater quality monitoring activities have been expanded to include volatile organic compounds (VOCs), and as a result, significant groundwater contamination was discovered in the Basin.

Since fiscal year 1994-95, Watermaster has also implemented its Basinwide Groundwater Quality Monitoring Program (BGWQMP) to sample all production wells (both potable and non-potable) in the Basin at least once a year for VOCs, TDS, and nitrate (NO_3), and once every three years for chloride and sulfate, in addition to the LARWQCB and USEPA monitoring programs [25]. These groundwater quality monitoring programs have resulted in a large volume of water quality records that are currently stored in the databases managed by Watermaster, LARWQCB, USEPA, and DDW. In addition to nitrate, chloride, sulfate, and TDS, other constituents such as tetrachloroethylene (PCE), trichloroethylene (TCE), carbon tetrachloride (CTC), and perchlorate (CLO_4) are considered as CECs for this SNMP. The Basin Plan Objectives for water quality

[1] The Division of Drinking Water was formally under the California Department of Public Health.

defines the objectives for each nutrient/salt constituent: 45 mg/L NO3, 100 mg/L Cl, 100 mg/L SO4, 450 mg/L TDS (Appendix B, Table III.1). Title 22 of the California Code of Regulations defines the maximum contaminant level (MCL) for NO3 as 45 mg/L and the Upper Limits for Cl, SO4, and TDS as 500 mg/L, 500 mg/L, and 1,000 mg/L, respectively. The maximum recommended levels for CL, SO4, and TDS are 250 mg/L, 250 mg/L, and 500 mg/L, respectively. Further, the MCL identified in the Basin Plan Objectives for PCE and TCE have been set to 5 µg/L, CTC to 0.5 µg/L, and ClO_4 to 6 µg/L (Table III.1).

The water quality data presented in this SNMP is the annual average of all production well quality data as sampled in the above mentioned water quality monitoring programs. The LARWQCB has a "political" boundary separating the Main Basin into the East and West Areas; however, there is no geological/hydrogeological distinction between the two Areas established by LARWQCB and this distinction is not recognized by the CDWR. As shown on Plate III.26, the vast majority of all production wells overly the West Area. Because of the geographical location of the production wells as well as the natural movement of groundwater from the northeast towards the west/southwest, natural comingling and mixing occurs between the two Areas. The depths of the production wells in the Basin, along with the geology of the Basin, facilitate vertical mixing of the groundwater. Consequently, the water quality averages are presented as basin-wide averages.

The USEPA has listed four areas of groundwater contamination in the San Gabriel Valley that have been listed on the USEPA's National Priorities List: San Gabriel Valley Area 1, San Gabriel Valley Area 2, San Gabriel Valley Area 3, and San Gabriel Valley Area 4. These areas impact all or portions of the cities of Alhambra, Arcadia, Azusa, Baldwin Park, Industry, Irwindale, El Monte, La Puente, Monrovia, Rosemead, South El Monte, and West Covina. VOCs including PCE, TCE, and CTC were first detected in groundwater in these areas in 1979. Since then, other contaminants including the VOC 1,4-dioxane, the semi-volatile organic compound N-Nitrosodimethylamine (NDMA), and the inorganic chemical perchlorate have been detected. Since 1979, the USEPA has installed cleanup projects, called Operable Units, in each contaminated area. Treated contaminated water to be used for potable purposes is also regulated by DDW. ~~The contaminants PCE, TCE, CTC and CLO~~$\cancel{_4}$ ~~are man-made and are currently being removed from the Basin through treatment, and the treated water used for domestic water supply.~~

The contamination level (concentration) and distribution of NO3, Cl, SO4, TDS, and ~~these~~ the CECs identified for this SNMP are discussed below.

III.3.9.1 Nitrate, NO_3

The NO_3 concentration data is from the Main San Gabriel Watermaster database, as shown in Appendix K. From 1973-74 to 2011-12, the annual average NO_3 concentration of the Basin, i.e. the average concentration of groundwater extracted from the Basin, ranged from 19.0 mg/L in 2011-12 to 34.7 mg/L in 1975-76, averaging 24.2 mg/L, as shown in Appendix K and Plate III.27a. The average nitrate concentration for the most recent 5-year period is 23.3 mg/L.

Elevated NO_3 concentrations were generally found in shallow wells, while low concentrations were found in wells adjacent to streams or spreading grounds. The NO_3 concentrations exceeding 45 mg/L were generally found in the western portion of the Basin west of Alhambra Wash, in the eastern portion of the Basin east of Little Dalton Wash, and in the vicinity of the mouth of the Puente Valley, as shown on Plate III.27b. The annual average nitrate concentration was calculated as the arithmetic average concentration of all available water quality data at the production wells within the Basin. Analysis of the data in Appendix K revealed that NO_3 concentrations generally decreased each decade since the 1970s. The average concentration of all wells sampled in a decade, and the number of wells testing greater than 45 mg/L, both decreased, from an average of 64 mg/L in the 1970s to 31 mg/L or less since 2000-01, as shown in Table III.7. In the 1970s, 78% of the wells tested exceeded the Basin Plan Objective, while 21% or fewer exceeded 45 mg/L since 2000-01. The NO_3 concentrations in some wells in the southeastern portion of the Basin remain above 45 mg/l, as shown on Plate III.27c. The historical high nitrate concentrations by producer are provided in Appendix Q.

III.3.9.2 Chloride

The chloride concentration data was derived from approximately 3,900 observations from production wells across the Basin. The annual average chloride concentration was calculated as the arithmetic average concentration of all available water quality data at the production wells within the Basin. From 1973-74 to 2011-12, the annual average chloride concentration of the Basin, i.e. the average concentration of groundwater extracted from the Basin, ranged from 21 mg/L in 1998-99 to 37 mg/L in 1982-83, averaging 28 mg/L, as shown in Appendix K and Plate III.28. The average chloride concentration for the most recent 5-year period is 31 mg/L.

Elevated chloride concentrations were generally found in shallow wells, while low concentrations were found in wells adjacent to streams or spreading grounds. The chloride concentrations exceeding 100 mg/L were generally found in the western portion of the Basin west of Alhambra Wash, in the eastern portion of the Basin east of Little Dalton Wash, and in the vicinity of the mouth of the Puente Valley. Though some individual wells exceeded the Basin Plan Objective, the average chloride concentration has been below 100 mg/L, as shown in Plate III.28. There have been minor changes in chloride concentrations in each decade since the 1970s, as shown in Table III.7.

III.3.9.3 Sulfate

The sulfate concentration data was derived from approximately 3,900 observations from production wells across the Basin. The annual average sulfate concentration was calculated as the arithmetic average concentration of all available water quality data at the production wells within the Basin. From 1973-74 to 2011-12, the annual sulfate concentration of the Basin, i.e. the average concentration of groundwater extracted from the Basin, ranged from 38 mg/L in 1998-99 to 70 mg/L in 2009-10, averaging 49 mg/l, as shown in Appendix K and Plate III.29. The average sulfate concentration for the most recent 5-year period is 52 mg/L.

Elevated sulfate concentrations were generally found in shallow wells, while low concentrations were found in wells adjacent to streams or spreading grounds. The sulfate concentrations exceeding 100 mg/L were generally found in the western portion of the Basin west of Alhambra Wash, in the eastern portion of the Basin east of Little Dalton Wash, and in the vicinity of the mouth of the Puente Valley. Though several individual wells exceeded the Basin Plan Objective, the average sulfate concentration has been well below 100 mg/L, as shown in Plate III.29. There have been minor changes in sulfate concentrations in each decade since the 1970s,,as shown in Table III.7.

III.3.9.4 TDS

The TDS concentration data is the Main San Gabriel Watermaster database, as shown in Appendix K. From 1973-74 to 2011-12, the annual average TDS concentration of the Basin, i.e. the average concentration of groundwater extracted from the Basin, ranged from 198 mg/L in 1998-99 to 385 mg/L in 2009-10, averaging 338 mg/L, as shown in Appendix K and Plate III.30a. The exceptionally low concentration in 1998-99 is almost certainly a sampling artifact, as it is more than 90 mg/L less than any other observation in the observation period. The average TDS concentration for the most recent 5-year period is 349 mg/L.

The TDS concentrations exceeding 1,000 mg/l were found in the vicinity of the mouth of the Puente Valley, and the TDS concentrations exceeding 500 mg/l were generally found in the eastern portion of the Basin, east of Big Dalton Wash and also in the vicinity of Whittier Narrows, as shown on Plate III.30b. The 2011-12 TDS concentrations in the eastern portion of the Basin and in the vicinity of Whittier Narrows remain above 500 mg/l, as shown on Plate III.30c. The historical high TDS concentrations by producer are provided in Appendix Q, as a composite representative of all salts.

There is an inverse relation between the volume of groundwater in storage and TDS concentration, as shown in Plate III.30d. The mechanism of this interaction is not clear, but when the volume of groundwater in storage decreases, it appears the salts in the water become more concentrated, resulting in increasing TDS concentrations. The volume of groundwater in storage has been decreasing since about 2001, as shown in Plate III.19. This decrease in groundwater volume is reflected in the increase in groundwater TDS concentrations observed in Plate III.30a.

III.3.9.5 Others

PCE, Tetrachloroethylene or Perchloroethylene

Historically maximum PCE concentrations in the production wells across the Basin varied from less than its method detection limit (ND) to 1,200 micrograms per liter (µg/L), averaging 35 µg/L, as shown in Appendix Q. The PCE concentrations exceeding 5 µg/L, which is the MCL, were generally found in areas in the Cities of Azusa, Baldwin Park, La Puente, Industry, Whittier, Monrovia, El Monte, South El Monte, Rosemead, and Monterey Park, as shown on Plate III.31a. When sampled again, a few months to twenty-nine years later, the PCE concentrations in the production wells meeting the water quality objective increased from 59% to 89%, the maximum observed concentration decreased to 980 µg/L, and the average decreased to 22 µg/L, as shown in Appendix Q. The PCE concentrations in some production wells in the Cities of Azusa, Baldwin Park, La Puente, Industry, El Monte, South El Monte, Rosemead, and Monterey Park remain above 5 µg/L, as shown on Plate III.31b.

TCE, Trichloroethylene

Historically, maximum TCE concentrations in the production wells across the Basin varied from ND to 1,315 µg/L, averaging 44 µg/L, as shown in Appendix Q. The TCE concentrations exceeding 5 µg/L, which is the MCL, were generally found in the same areas as PCE, in the Cities of Azusa, Baldwin Park, La Puente, Industry, Whittier, Monrovia, El Monte, South El Monte, Rosemead, Alhambra, and Monterey Park, as shown on Plate III.32a. When sampled again, a few months to thirty-four years later, the TCE concentrations in the production wells meeting the water quality objective increased from 43% to 82%, the maximum observed concentration decreased to 600 µg/L, and the average decreased to 21 µg/L, as shown in Appendix Q. The TCE concentrations in some production wells in the Cities of Azusa, Baldwin Park, Industry, El Monte, Rosemead, and Alhambra remain above 5 µg/L, as shown on Plate III.32b.

CTC, Carbon tetrachloride

Historically, maximum CTC concentrations in the production wells across the Basin varied from ND to 48 µg/L, averaging 6 µg/L, as shown in Appendix Q. The CTC concentrations exceeding 0.5 µg/L, which is the MCL, were generally found in areas in the Cities of Azusa, Baldwin Park, La Puente, Industry, Whittier, Monrovia, and El Monte, as shown on Plate III.33a. When sampled again, a few months to thirty-two years later, the CTC concentrations in the production wells meeting the water quality objective increased from 2% to 61%, the maximum observed concentration decreased to 14 µg/L, and the average decreased to 4 µg/L, as shown in Appendix Q. The CTC concentrations in some production wells in the Cities of Baldwin Park and Industry remain above 0.5 µg/L, as shown on Plate III.33b.

ClO_4, Perchlorate

Historically, maximum ClO_4 concentrations in the production wells across the Basin varied from ND to 390 µg/L, averaging 28 µg/L, as shown in Appendix Q. The ClO_4 concentrations exceeding 6 µg/L, which is the MCL, were generally found in areas in the Cities of Azusa, Baldwin Park, La Puente, Industry, Whittier, Monrovia, and El Monte, as shown on Plate III.34a. When sampled again, a few months to sixteen years later, the CLO_4 concentrations in the production wells meeting the water quality objective increased from 77% to 88%, the maximum observed concentration decreased to 100 µg/L, and the average decreased to 17 µg/L, as shown in Appendix Q. The ClO_4 concentrations in some production wells in the Cities of Baldwin Park and Industry remain above 6.0 µg/L, as shown on Plate III.34b.

III.4. SALT/NUTRIENT SOURCES

III.4.1. Source Identification

III.4.1.1. Salt

Salts in the environment and hydrologic systems have natural and anthropogenic sources. Salts are soluble compounds of anions (negatively-charged particles) and cations (positively-charged particles) that are attracted to each other electrically, as the opposing poles of a magnet attract. Chemically, salts are composed of an acid and a base, though these acid-base mixtures vary greatly in strength of bonding, solubility, and activity in the solution. The solubility of salts in natural systems varies considerably, e.g. the solubility of salts based on the anion is, in decreasing order, nitrates, chlorides, sulfates, bicarbonate, and carbonate. The mobility of salts corresponds to their solubility.

Water moving through soil and the vadose zone always has dissolved salts in it. The concentration of these salts depends upon the concentration in the water and in the mineral solids through which the water travels. Everything in nature seeks an equilibrium. If the concentration of salts is greater in the mineral solids than in the water, salts will dissolve and increase the salt concentration in the water. If the concentration in the water is greater than in the surrounding solids, salts will precipitate from the water into the solid phase, decreasing the concentration of salts in the water.

Natural Sources

The Basin is situated on alluvial fans, terraces, and flood plains comprised of alluvium (river-deposited sediments) weathered from rocks and minerals from several sources: sedimentary, granitic, andesitic, volcanic, and mixed rocks. The associated watersheds in the mountains flow across weathering sediments of andesite, breccia, schist, and metamorphosed volcanic, basic igneous, granitic and metamorphic rocks. These weathering minerals are a primary source of salts in the basin, though the solubility may vary, and the dominant salts found vary from one part of the watershed or basin to another, depending upon the specific mineralogy present.

Soils and geologic materials in the vadose (unsaturated zone above an aquifer) contain minerals of varying solubility that may dissolve in water. The most common salts in the Basin's soils include chlorides, sulfates, and carbonates of calcium, magnesium, potassium, and sodium. The weathered sedimentary materials have the greatest natural salinity of the rocks found in the Basin and associated watersheds.

Once dissolved, salts move with the water. If water flowing through soil and the vadose zone enters a river or stream, the salts enter surface water. If water percolates to the groundwater, the salts leach with it and enter the aquifer. If water is insufficient to leach the salts to the groundwater, the salts will accumulate at characteristic depths in the soil or vadose zone, as determined by their solubility. The solubility and mobility of salts in the soil and vadose zone from least to greatest is carbonates, sulfates, and chlorides. Due to its mobility, chloride is often used as an environmental tracer.

If atmospheric demand for water through evaporation and transpiration exceed precipitation and irrigation (or water spreading), salts will tend to accumulate at the surface. This process is accelerated in the case of shallow water tables that allow salts to wick upward with water through capillary action.

Atmospheric deposition is a minor source of salts, including nitrates, sulfates, chlorides, and fossil fuel combustion products.

Anthropogenic Sources

Many human activities may contribute salts to the environment. These include household sources such as detergents, water softeners, swimming pool treatment chemicals, runoff from washing cars, use of treated municipal drinking water or gray-water reuse in residential irrigation systems, and on-site wastewater treatment facilities, as well as centralized wastewater treatment facilities, and many industrial processes. Return-flow from water used for surface or subsurface irrigation of agricultural crops, golf courses, parks, sports fields and lawns contribute salt, especially when water is added in excess of the amount required to meet the combined evaporation and transpiration needs of a crop. This may be intentional in an effort to manage the salinity in the root zone to meet crop requirements, or unintentional due to inefficient or unmanaged irrigation systems. Salts from some sources may enter storm drains or surface water systems with no treatment. Others are directly applied to, or disposed in, the soil-vadose zone as a treatment media. These non-point sources salt sources are the most difficult to monitor. The most obvious salt contributors are the point-sources originating from industrial or municipal centralized waste treatment facilities.

TDS is a measure of the salts dissolved in a water system. Because TDS is a measure of all dissolved solids, including nitrates, chlorides, sulfates, and their companion cations, the TDS increases with the concentration of these constituents. Although the TDS water quality objective for the eastern portion of the Basin is 600 mg/l (MCL, Table III.1), the objective for the majority of the Basin is 450 mg/l. The more conservative value (450 mg/l) will be used in determining the assimilative capacity and in completing the antidegradation analysis.

The Basin water rights were adjudicated in 1972 and the quantity and the quality of the Basin water supplies have been managed by the Watermaster since 1972. The primary sources of salt loading are from stormwater recharge, untreated imported water replenished in the Basin in response to annual production which may exceed water rights, and incidental recharge of recycled water which is discharged into the San Gabriel River, Rio Hondo, and San Jose Creek by the LACSD. (The discharge of recycled water by LACSD has been approved by LARWQCB through Water Discharge Requirements (WRDs)). Watermaster Resolution 4-96-138 (see ~~Attachment~~ Appendix R) was developed to provide criteria for the delivery of supplemental water (untreated imported water). The Watermaster Judgment and Rules and Regulations directs Watermaster to purchase the highest (best) quality of untreated imported water available. Since the criteria for the delivery of supplemental water was adopted in 1996, Colorado River water has not been used for groundwater replenishment. In the event the highest quality water is not available, the criteria provide a decision tree regarding the delivery and recharge of untreated imported water. To the extent possible, Watermaster's goal is to purchase untreated imported water with TDS concentration no greater than 450 mg/l, chloride concentrations no greater than 100 mg/l and sulfate concentrations no greater than 100 mg/l.

Watermaster historically delivered only SWP water for groundwater recharge purposes. The TDS concentration has ranged from 157 mg/l to376 mg/l and averaged 249 mg/l over the past 39 years. During drought periods the SWP water is more susceptible to sea water influences which may increase TDS and chloride concentrations in the SWP water. However, the TDS concentration of the SWP water is consistent with the historical TDS concentrations throughout the Basin. Stormwater runoff TDS concentrations have ranged from 160 mg/l to 390 mg/l and averaged 232 mg/l over the past 39 years. Historically, Watermaster has had very little Colorado River water delivered to the Basin and has never ordered recycled water for groundwater replenishment purposes.

Watermaster's policy to consistently order and deliver the highest quality of untreated imported water and its support of stormwater recharge has helped to maintain the high quality of groundwater regarding TDS.

Similarly, the chloride and sulfate concentrations in SWP water and stormwater are also below the LARWQCB BPO. This has enabled the chloride and sulfate concentrations to consistently maintain a high quality.

III.4.1.2. Nutrients

At least 18 minerals are recognized as essential for plants, and at least 24 for animals, including humans. In surface water systems, the primary nutrients of concern are nitrogen as nitrate (NO_3^-) or nitrite (NO_2^-), and phosphorus as particulates in runoff water, or dissolved in water as orthophosphates (HPO_4^{2-}, $H_2PO_4^-$). Historically, nitrate has been the primary concern for groundwater quality, but recently more recently, it has been realized that phosphorus may become mobile in the soil and vadose zone, and therefore may be found in groundwater and aquifers [26].

The nutrients for which Basin water quality objectives (BPO) exist are nitrate (as NO_3^-, 45 mg/l), nitrogen (nitrate + nitrite, 10 mg/l), sulfate (SO_4^{2-}, 100 mg/l), chloride (Cl^-, 100 mg/l), and boron (B, 0.5 mg/l) (Table III.1).

Nutrient additions include atmospheric deposition with precipitation of nitrogen as ammonium and nitrate, sulfur, and chloride. Some of these are by-products of fossil fuel combustion, while others are the result of natural phenomena, such as lightning converting atmospheric nitrogen into nitrate, or denitrification in wetlands which releases nitrogen into the atmosphere. Wildfires release nutrients into the atmosphere which may return to the surface through precipitation. Other nutrients remain on the surface after fires, and will enter surface waters during precipitation events that generate runoff. Other natural nutrient additions occur through natural biogeochemical nutrient cycles through microbial decomposition of plant and animal residues in the soil. Nutrients are released into the soil as minerals during decomposition of organic structures by soil microbes. Nutrient cycling is accelerated when lawns and turf areas are irrigated during the dry season. Boron, sulfates, and chlorides are constituents of naturally-occurring minerals, and that are released into the environment as the minerals weather. These naturally-occurring minerals are readily found in the vadose zone at a characteristic depth associated with their solubility. As the irrigation of agricultural or municipal lands increases the volume of water moving through the vadose zone, these minerals leach with the water, and may reach the groundwater.

Anthropogenic sources likely provide the greatest nutrient additions in the Basin. Municipalities, academic institutions, industrial parks, and homeowners maintain turf and lawns with fertilizer. The primary ingredient in most fertilizers is nitrogen, either as urea, ammonium or nitrate. Once in the soil, though, microbes generally convert other nitrogen forms into nitrate. Commercial fertilizers are soluble salts that dissolve in water. Chloride is a common component in many fertilizers due to its high solubility, especially those containing potassium. Sulfates and chlorides are common ingredients in fertilizers and soil amendments. Fertilizer nutrients may enter surface waters through runoff if high-intensity precipitation events occur soon after spreading. Nitrates and chlorides will leach readily if irrigation and/or precipitation exceed the combined atmospheric demand of water from evaporation and transpiration. Nutrients that leach from the plant root zone have the potential to reach the groundwater in irrigation return flows when a sufficient water head exists to move the water and leached nutrients through the vadose zone.

On-site wastewater treatment systems return nutrients to the soil throughout the Basin in areas not associated with a centralized treatment facility. Centralized municipal wastewater treatment systems and some industrial wastewater treatment systems release nutrients into the environment, particularly nitrates, sulfates, and chlorides. The majority of these nutrients are returned in treated wastewater to surface water sources or to the soil, though some may be released into the air, particularly if a portion of the wastewater treatment system occurs under anaerobic conditions. Reduced forms of nitrogen and sulfur may be released into the atmosphere under anaerobic conditions. These gases may be returned to the soil surface with precipitation.

Though agriculture is widely recognized as a contributor of nutrients to surface and groundwater, it is currently a minor contributor in the Basin, as agriculture occupies only about 1 percent of the land area, while about 84 percent is urban and 16 percent is in natural ecosystems. Between about 1950 and 1973, nitrogen fertilizer was inexpensive, and often applied in greater quantities than required. The concurrence of the energy crisis, which drove up commercial nitrogen fertilizer prices, and the Clean Water Act, likely combined to decrease nitrate additions to the groundwater.

Portions of the Basin, particularly those areas easterly of Big Dalton Wash historically have experienced nitrate concentrations above the BPO (and DDW Drinking Water limit) of 45 mg/l. The specific course(s) of the elevated nitrate concentrations have not been thoroughly investigated, but likely influenced by extensive historical agricultural activity and use of septic systems in the area. The area is now highly urbanized and the agricultural activities no longer exist and the residences are all on municipal sewer systems, although the historical sources of nitrate are still in the vadose zone. There are relatively few production wells in the easterly portion of the Basin. Producers manage nitrate concentrations through blend plans approved by DDW. Nitrate, for the most part, has been detected below 5 mg/l in stormwater runoff and SWP water, which is significantly lower than the long-term background water concentrations, as measured by a long-term average groundwater extraction concentration of 24 mg/l.

III.4.1.3. Others

The contaminants of emerging concern, PCE, TCE, CTC, have historically been widely used as solvents and for other purposes. Perchlorate (ClO_4) is a naturally-occurring and synthesized compound used in flares, explosives and rocket fuel. These contaminants enter the environment when released into the air during use, spilled onto soil, disposed in old landfills, and from cleaning facilities that use or manufacture these compounds. Once in the air, they can return to the surface with precipitation. Most are highly water soluble and readily leach through the soil and vadose zone. These contaminants have been addressed by the USEPA through Operable Unit cleanup plans and are being removed for the San Gabriel Basin. Information for these contaminants is provided below, but they are not included in this SNMP.

PCE, Tetrachloroethylene or Perchloroethylene [27]

Tetrachloroethylene is a colorless organic liquid used for aerosol dry-cleaning products and textile processing, as a chemical intermediate, and for vapor-degreasing in metal-cleaning operations. The basin water quality objective is 5 μg/l.

TCE, Trichloroethylene [28]

Trichloroethylene is a chlorinated hydrocarbon used as an industrial solvent to remove grease from fabricated metal parts, as a dry-cleaning agent, as an intermediary in chemical manufacturing, and as a solvent in paint and glues. It was historically used as an anesthetic and analgesic. The basin water quality objective is 5 μg/l.

CTC, Carbon tetrachloride [29]

Carbon tetrachloride is a clear heavy organic liquid used to make refrigerants and propellants for aerosol cans, as a solvent for oils, fats, lacquers, varnishes, rubber waxes, resins, and rubber cement, and as a grain fumigant, insecticide, and a dry-cleaning agent. It was used in early fire extinguishers. The basin water quality objective is 0.5 μg/l.

CLO_4, Perchlorate [30]

Perchlorate is both a naturally-occurring and manmade compound used as an ingredient in solid fuel for rockets and missiles, and in the construction of highway safety flares, fireworks, pyrotechnics, explosives, common batteries, and automobile restraint systems. The basin water quality objective is 6 μg/l.

III.4.2. Fate and Transport

III.4.2.1 Salt

Once salts are in the soil and vadose zone, there are three possible fates: remain where they are, wick upward to the surface with water, leach downward with water. For simplicity in the following discussion, all references to soil apply equally to the vadose zone (unsaturated zone above a permanent groundwater table). On a landscape scale, salts remain in the soil, or they move to surface waters, or to aquifers.

Salts will remain at the same relative depth if the balance of water applied plus precipitation approximately equals atmospheric demand through evaporation from soil surfaces and transpiration from plant leaves.

Salts will move downward if the balance of water applied plus precipitation exceeds atmospheric demand through evaporation from soil surfaces and transpiration from plant leaves.

Salts move little when the balance of water applied plus precipitation is less than atmospheric demand through evaporation from soil surfaces and transpiration from plant leaves. However, in the case of water tables within 4 to 6 feet of the soil surface, depending upon texture of the soils, salts may move upward. Finer-textured soils (silts, loams, and clays) promote upward capillary movement of water in greater quantity, and from greater depths, resulting in greater salt accumulation at the surface than occurs on coarse-textured soils (sands and sandy loams).

Salts move with water, in the same direction, and generally at the same rate. The exception occurs when the soil chemistry alters the form and solubility of the salt. This may occur through several possible chemical reactions, including salts precipitating out of the water as a solid.

Most clay minerals in the soil are negatively charged, and may adsorb some cations (positively-charged ions), e.g., calcium, magnesium, potassium, and sodium to the mineral surfaces. Anions (negatively-charged ions) move through the soil more readily, though some will be attracted to the cations on soil surfaces. The result is preferential movement of anions, such as chloride sulfates, and nitrates through the soil.

The soils in the basin are typical of semiarid and arid region soils that typically have high concentrations of calcium, often in the form of calcium carbonate (often seen as caliche) and gypsum (calcium sulfate). These salts dissociate weakly in the soil solution, allowing the components to move with water, and to participate in chemical reactions. The most common salt reaction in the soil is precipitation. Some anions, such as chloride, moving through the soil solution may precipitate with cations, such as calcium, to form a salt, such as calcium chloride. Once precipitated, the salt does not move until it dissolves and the individual components enter the soil solution again.

All soils have a limit to the cations and anions they can adsorb. Precipitation of salts in the solid phase is controlled by the concentration of salts in the water, and the availability of minerals in the soil to react with the salts in the water. Salts always precipitate when the amount of water is insufficient to continue leaching them. When sufficient water is available, some salts will be dissolved in the water and leach as the water percolates.

If conditions in the soil become anaerobic, due to saturation and lack of free oxygen, some soil bacteria have the ability to "breathe" minerals such as nitrogen, iron and manganese. When this occurs, iron and manganese become more soluble, and also may participate in precipitation reactions in the soil. Precipitation removes ions from the soil solution. However, anaerobic conditions are associated with greater leaching, since these conditions occur with saturation.

Water moves from areas of high potential energy to areas of low potential energy, on a landscape, or in the soil or vadose zone. This is commonly stated as water flows downhill. Though gravity pulls water downward, there are other forces in soil that can pull water upward. A wet soil generally has higher potential energy than a dry soil, and so water typically moves toward drier soil. This is the reason that water moves upward from a water table through the capillary fringe. If the soil surface is within the capillary fringe, water will move to the surface. Salts move with water, so if the water goes to the surface, so do the salts. Once at the surface, the water evaporates, and the salts precipitate on the soil surface. This accumulation of salts is common in arid and semiarid regions with shallow water tables, or in areas where irrigation management does not incorporate necessary leaching fractions to leach the salts out of the root zone. When irrigation results in artificially high water tables, a drainage system must be installed to remove the water from the soil profile and root zone. The salts move with the water through the drainage system, typically into surface water, such as rivers.

The salts will move as far downward in the soil as does the water. In semiarid and arid regions, the long-term historic depth of water penetration from natural precipitation is identified by the presence of a zone of increased chloride concentration, often called chloride bulge. This is the reason chloride is used as a tracer; it is the most soluble, and moves the furthest with water. Other salts of lower solubility, such gypsum, precipitate above the chloride bulge, while calcium carbonate precipitates above the gypsum.

If sufficient water is added to the surface (precipitation and/or irrigation and/or water spreading) to move water through the soil to the groundwater table and aquifer, the salts reach the groundwater and aquifer, as well. Once in the aquifer, the salts remain there unless removed from the aquifer through groundwater pumping or outflow from one basin to another, if a hydraulic connection between aquifers exists.

III.4.2.2 Nutrients

Nutrients in the soil have been classified historically as mobile or immobile, referring to their solubility and tendency to move within the soil. Mobile nutrients have long been recognized as those with the potential to leach below the root zone. However, even “immobile” nutrients may be leached from the soil if sufficient water moves through the soil. Though initially high in calcium and other cations, soils in humid regions often have little calcium remaining because centuries of leaching have washed it out of the soil. More recently, ideas about other immobile nutrients, such as phosphorus, are being revisited as more is learned about the fixation (holding) capacity of soils for a given nutrient. Once the fixation capacity is reached, the nutrient becomes mobile and may leach into groundwater.

Nitrogen is involved in a complex, natural biochemical nutrient cycle, passing through inorganic solid and gas phases, and solid organic compounds through living organisms and decomposition products of dead organisms and waste products. There are no naturally-occurring soil minerals that contain nitrogen. Nitrogen in the soil is most commonly found in organic compounds, and as ammonium, and nitrate. Nitrite is seldom present in large concentrations in soil, except in anaerobic conditions. Naturally-occurring soil organisms readily convert ammonium to nitrite, and nitrite to nitrate, a process called nitrification. Other organisms decompose proteins in organic materials to release ammonium, which then undergoes nitrification. The abundance of these organisms decreases with soil depth, and so does the conversion of nitrogen from one form to another.

Once in the soil, nitrate may be taken up by plants, used by soil organisms, leached, or reduced. The same processes occur when nitrate is added directly to a soil as fertilizer or as a constituent of recycled water. Nitrate reduction occurs under anaerobic conditions when biological oxygen demand is great. Once all the oxygen is consumed by aerobic organisms during the decomposition of organic compounds, decomposition continues by organisms that "breathe" nitrate instead of oxygen. In these circumstances, nitrate is converted to nitrite. However, nitrite may be further converted to gaseous nitric or nitrous oxides, or dinitrogen gas. Depending upon the depth at which this conversion occurs, these gases may be released into the atmosphere, or may remain dissolved in water. Once in these gas forms, they are unusable to plants or animals, and to most soil organisms.

Nitrate and nitrate have the same solubility characteristics as chloride, and so all previous discussion about chloride transport applies equally to nitrate and nitrite.

Sulfur undergoes similar biological reactions in the soil as nitrogen, but also exists in chemical equilibria with sulfur-containing soil minerals. Sulfates are soluble, but not quite as mobile as nitrate or chloride. Sulfates may be taken up by plants, used by soil microorganisms, leached, or reduced under anaerobic conditions with high biological oxygen demand. Reduced sulfur compounds are odorous gasses that are released into the atmosphere or remain dissolved in water.

Boron is present in soils as boric acid, which is highly soluble, and prone to leach in sandy soils. In fine-textured soils, boron leaching is less likely until the fixation capacity is reached.

III.4.2.3 Others

PCE, Tetrachloroethylene or Perchloroethylene [27]

Tetrachloroethylene is more dense than water, therefore tends to sink in a pool of water. It slowly degrades in water into trichloroacetic and hydrochloric acids. There are aerobic and anaerobic soil bacteria that biodegrade PCE. Depending upon the mode of water spreading, much of the PCE in water likely volatilizes into the atmosphere where it will photo-degrade or return to the surface with precipitation. PCE does not bind to the soil, and may leach.

TCE, Trichloroethylene [28]

Trichloroethylene volatilizes from surface water into the atmosphere where it may return to the surface with precipitation. In soil, there is less volatilization because TCE binds to the soil particles. It is slightly soluble in water and persists for long time periods. It is not known to degrade in soil, water, or the atmosphere.

CTC, Carbon tetrachloride [29]

Carbon tetrachloride volatilizes readily from surface water into the atmosphere, where it is very stable, though it may return to the surface with precipitation. CTC does not bind to soil particles, and either volatilizes or leaches. It will biodegrade in soil and water.

CLO4, Perchlorate [30]

Perchlorate is soluble in water and does not bind to soil, so will readily leach. It is not known to degrade in soil or water, and so persists in the environment.

III.5. LOADING ESTIMATES AND ASSIMILATIVE CAPACITY

In compliance with Section 9(c)(1) of the Policy, which states "*the available assimilative capacity of a basin/subbasin shall be calculated by comparing the mineral water quality objective [Basin Plan objective] with the average concentration of the basin/sub-basin [background basin water quality conditions], either over the most recent five years of data available or using a data set approved by the Regional Water Board Executive Officer*."

The annual average nitrate, chloride, sulfate, and TDS concentrations of the Basin were calculated as the arithmetic average concentration of all available water quality data at the production wells within the Basin. The assimilative capacity was determined as the difference in the potential nutrient or salt load, determined by the groundwater volume and the Basin Plan Water Quality Objective, and the current nutrient or salt load in the groundwater. As a result, the assimilative capacity, as specified in Section 9(c)(1), can be calculated for any time period.

III.5.1. Loading Estimates

For the San Gabriel SNMP characterization, loading is defined as the amount of a component entering the groundwater already in storage via groundwater replenishment. Loading estimates were tabulated using components of the groundwater balance model (Table III.6) and existing water quality data for those components (Appendix K). The inputs from the groundwater balance model include: precipitation on the valley floor and runoff from the surrounding watershed, incidental percolation of water discharged into the San Gabriel River, direct spreading of local runoff and imported water replenishment, return flow from direct usage, subsurface flow into and out of the basin, groundwater extraction, water quality data, and exported water (Table III.6). The total amount of groundwater in Basin storage is about 8,000,000 acre-feet. For this characterization, it is assumed that approximately 75 percent of the groundwater in Basin storage (about 6,000,000 acre-feet) is subject to mixing.

III.5.1.1 Loading/Unloading Estimation Models

The quantity of groundwater in storage (ac-ft) and existing water quality data from wells (concentrations of TDS, nitrate, chloride, and sulfate) were used to determine the quantity, expressed in pounds, of each component stored in the groundwater. The quantity of each component of the groundwater balance model (ac-ft/yr) and the concentration of the constituent salts (mg/L) for that component were used to estimate the amount of the constituent salt that was added to, or removed from, the groundwater in storage. A separate loading/unloading spreadsheet model was prepared for each of the nutrients and salts, as summarized in Tables III.9, III.10, III.11, and III.13. The full calculation process for each loading/unloading estimate using the volume of each groundwater balance component and the water quality for each constituent salt in that component is documented in Appendices M, N, O, and P. The discussion below explains how the loading/unloading estimation models were calibrated.

The loading of a nutrient/salt constituent is particularly sensitive to precipitation and runoff from watersheds, which also affects the loading from direct spreading of local runoff. For these reasons, it is important to consider that of the last thirteen years, nine have had below average precipitation in the valley floor, including five of the driest years among 87 years of records; seven have had below average precipitation in the San Gabriel Mountains watershed, including five of the driest years among 85 years of records; and nine have had below average precipitation in the southern low hills watershed, including three of the driest years among 87 years of records. These below average precipitation years resulted in lower than average estimated nutrient/salt loading to the groundwater stored in the Basin. Groundwater extraction has been relatively consistent in the last 15 years, while recharge has varied considerably, as previously seen in Plate III.19. This plate also suggests a three to five-year lag in recharge trends before observing a similar trend in groundwater in storage.

It is not possible to accurately predict the concentration of any constituent salts in any particular year. Therefore, long-term trends in the groundwater concentration of each constituent nutrient/salt were used to calibrate the specific spreadsheet model. The following general assumptions were used to calibrate the spreadsheet model for each constituent nutrient/salt.

III.5.1.2 General Assumptions

- All water, regardless of source, flowing through the vadose zone is subject to chemical equilibria among the minerals in the water, the soil, and the vadose zone. The concentration of nutrients/salts in the water when it reaches the groundwater often is much different than the water quality at the soil surface. In these models, water released into San Jose Creek or used in direct spreading is assumed to bypass the vadose zone.
- The current groundwater concentration for the constituent nutrients/salt represents the historical (geologic time frame) equilibrium for the amount of salt that dissolves or

precipitates as water moves through the vadose zone from natural recharge processes (precipitation, percolation from the watershed and surface waters, subsurface inflow and outflow from the Basin). The current groundwater quality also integrates recent changes to the equilibrium as a result of human activities in the past century.

- The mean groundwater concentration was used as the absolute minimum concentration of a groundwater balance component recharging the aquifer. Any groundwater balance component recharging the aquifer passed through the soil and vadose zone. During this process, it gained or lost nutrients/salt according to the governing chemical equilibria. It was not possible to calibrate the spreadsheet models when values less than the long-term groundwater mean were used for a recharge component such as precipitation and runoff, without violating chemical equilibria constraints on other recharge components such as return flow. The volume of precipitation and runoff was about 4 times that of return flow.
- Precipitation or return flow: When the concentration of the constituent nutrient/salt for components of the groundwater balance model was less than the current groundwater concentration for that constituent, it generally was assumed the concentration of that constituent increased as it moved through the vadose zone.
- Precipitation or return flow: When the concentration of the constituent nutrient/salt for components of the groundwater balance model was greater than the current groundwater concentration for that constituent, it generally was assumed the concentration of that constituent decreased as it moved through the vadose zone so that the concentration matched the groundwater concentration upon recharging the aquifer.
- Direct spreading and incidental percolation of water discharged into the river channels: Generally, the concentration of constituent nutrients/salts in water was assumed not to change as it passed through the vadose zone into the aquifer (the concentration stayed the same).
- The trend in groundwater quality (1973-74 to 2010-2011) for each constituent nutrient/salt was determined using 75 percent of the groundwater in storage volume to estimate the quantity of loading/unloading (lbs/yr).
- The quality of the groundwater in storage is calculated using a mass balance approach to determine the constituent stored in groundwater.

- Concentrations or coefficients (multipliers) for each of the groundwater balance components were adjusted to match the long-term trend identified. These values are reported for nitrate, chloride, and sulfate in Table III.8, and for TDS in Table III.12, and will be discussed in greater detail in the appropriate section.

The loading/unloading model for each constituent salt will be discussed separately.

III.5.1.3 Limitations

All nutrient/salt quantities are rounded to the nearest 1,000 pounds (lbs). The following limitations on this estimate should encourage using these values with caution.

- The groundwater quality varies spatially and with depth. The current groundwater data limit the ability to accurately determine the quantity of each constituent nutrient/salt present.
- The actual quantity of some components in the groundwater model are estimated, but not precisely measured.
- Constituent nutrient/salt data are unavailable at various depths through the vadose zone to the groundwater.
- The concentration of the constituent nutrient/salt in the recharge component when it reaches the aquifer/groundwater is estimated.
- The residence time of the constituent nutrient/salt as it moves through the vadose zone is not known, and varies spatially across the basin. Water from the spreading grounds moves rather quickly to the groundwater, while the time required for return flow to reach the groundwater level is not known. There is no correlation between the constituent nutrient/salt concentrations added to the surface and changes in the groundwater concentration in periods less than 10 to 15 years, depending upon the constituent nutrient/salt. Since only about 40 years of data exist, it is not possible to identify whether a stronger correlation exists on a longer time span.

- The actual groundwater quantity and quality of inflow from Puente Basin and outflow to Central Basin is estimated.
- The aquifer exhibits some degree of concentration/dilution effects. In years when the aquifer level declines, the concentration of the constituent nutrient/salt tends to increase (but not always). Conversely, in years when the aquifer levels rise due to increased recharge, the concentration of the constituent nutrient/salt tends to decrease.
- Water quality for each constituent nutrient/salt is not available for each groundwater balance component for each year. In this case, "means" of data from adjacent years was used. When data were insufficient for that, the mean for the period of observation was used.

The result of these limitations is an inability to accurately predict the concentration of groundwater constituent nutrient/salt on a year-to-year basis. However, the prediction should improve with time as additional data is gathered on a more frequent basis.

III.5.1.4 Calibration

The calibrations for nitrate, chloride, and sulfate were initiated using the assumptions identified above. Then they were adjusted in order to match the long-term trends in groundwater nutrient/salt concentration. The calibration coefficients for these models are presented in Table III.8.

The calibration for TDS required adjustments for groundwater volume and the increasing concentration through the observation period. A similar feature as the groundwater balance model was incorporated to scale the contribution of different volumes of precipitation and runoff, return flow, and surface spreading. The calibration coefficients are presented in Table III.12.

Nitrate Calibration

The coefficients and concentrations used for the nitrate balance model are shown in Table III.8. For many of these water sources, the nitrate concentration of the water source was less than 5 mg/L. It was assumed the groundwater accumulated nitrate as it passed through the vadose zone. Using the actual concentration did not result in an acceptable model, as it would predict that substantially more nitrates were being removed from the system than replaced. The mean groundwater nitrate concentration in the last 20 years varied from about 20 mg/L to 27 mg/L. The water quality assumptions for the groundwater balance model component contributions to the groundwater in storage used a nitrate concentration of 19 mg/L as a minimum concentration returned to the groundwater. This is less than the long-term mean groundwater nitrate concentration (24 mg/L). Since the nitrate concentration in the groundwater has been decreasing throughout the reporting period, this value was chosen to represent improving groundwater quality. This minimum concentration is used for water sources which had a nitrate concentration less than the mean groundwater quality, and it was assumed that the water accumulated nitrate as it passed through the vadose zone. A nitrate concentration of 19 mg/L was used for precipitation and watershed runoff, return flow of treated imported water, and direct spreading of local runoff and untreated imported water.

The actual annual water quality of subsurface flow was used unchanged, as this flow does not pass through the vadose zone. The actual annual water quality of recycled water was used unchanged for the incidental percolation of water discharged into river channels of the Basin, as it was assumed this passed through an abbreviated portion of the vadose zone, or passed through via preferential flow, and therefore did not have time for chemical activity to occur in transit. A 1.5 loading factor was applied to the nitrate concentrations of return flow from direct uses of waters from San Gabriel Basin production, and surface water imported Raymond Basin water. The loading factor suggests the nitrate concentration of these water sources increased as it moved through the vadose zone. This is possible due to the potential for over-application of nitrate-containing fertilizers and other materials often applied to urban landscapes, and to pet manure sources. Sometimes the nitrate concentration of the return flow from direct uses of surface water and imported water was less than the groundwater minimum concentration after applying the 1.5 multiplier; in these cases, 19 mg/L was used. Using these coefficients, the nitrate balance model that matched the long-term concentration trends, as shown in Table III.9.

There was little variation in nitrate extraction and outflow in the past thirteen years. However, due to the recent drought discussed previously, the model predicted below average nitrate loading from precipitation and runoff from watersheds in twelve of those thirteen years, and below average nitrate loading from direct spreading in nine years, primarily due to the decrease in local runoff. The result is the model predicted nitrate unloading in ten of the last thirteen years, with a net unloading of almost 20 million lbs. Plate III.35a demonstrates that unloading trends generally follow the same trends in the nitrate concentration from extraction wells. The inverse relationship between key well groundwater elevations and basinwide nitrate concentrations is shown in Plate III.35b. Table III.9 will be discussed in greater detail in the following section.

Chloride Calibration

The coefficients and concentrations used for the chloride balance model are shown in Table III.8. In the chloride balance, precipitation from the valley floor, runoff from the watershed, San Gabriel Basin production water, surface water, and imported Raymond Basin water typically had chloride concentrations less than 28 mg/L, which is the long-term average groundwater chloride concentration. For these water sources, it was assumed that chloride would dissolve into water as it passed through the soil and vadose zone, resulting in that water having approximately the average groundwater chloride concentration when it reached the groundwater, so 28 mg/L was used for the model. Semiarid and arid region soils commonly have soil and vadose zone strata that are enriched in chlorides. The chloride concentration of all other water sources exceeded the long-term average groundwater concentration. For these sources, the actual annual chloride concentration of the water source was used for the chloride balance model. These included return flow from direct uses of recycled water and imported water, direct spreading of imported water from the State Water Project, incidental recharge of water discharged into river channels of the Basin, and subsurface inflow. Using these coefficients, the chloride balance model matched the long-term concentration trends, as shown in Table III.10.

There was little variation in chloride extraction and outflow in the past thirteen years. However, due to the recent drought discussed previously, the model predicted below average chloride loading from precipitation and runoff from watersheds in twelve of those thirteen years, and below average chloride loading from direct spreading in six years, primarily due to the decrease in local runoff. The result is the model predicted chloride unloading in six of the last thirteen years, with a net unloading of more than 10 million lbs. Plate III.36a demonstrates that unloading trends generally follow the same trends in the chloride concentration from extraction wells. The inverse relationship between key well groundwater elevations and basinwide chloride concentrations is shown in Plate III.36b. Table III.10 will be discussed in greater detail in the following section.

Sulfate Calibration

The coefficients and concentrations used for the sulfate balance model are shown in Table III.8. Using the actual concentration did not result in an acceptable model, as it would predict that substantially more sulfates were being removed from the system than replaced. The mean groundwater sulfate concentration in the last 20 years varied from about 40 mg/L to 70 mg/L. The water quality assumptions for the groundwater balance model component contributions to the groundwater in storage used a sulfate concentration of 49 mg/L as a minimum concentration returned to the groundwater. This minimum concentration is used for water sources which had a sulfate concentration less than the mean groundwater quality, and it was assumed that the water accumulated sulfate as it passed through the vadose zone. Semiarid and arid region soils commonly have soil and vadose zone strata that are enriched in sulfates. Additionally, sulfates are common fossil-fuel combustion by-products, partially responsible for smog in urban regions. These compounds return to the soil surface with precipitation, and are then available to move through the soil and vadose zone into the groundwater. For precipitation and watershed runoff, 49 mg/L was used. The actual annual water quality of subsurface flow was used unchanged, as this flow does not pass through the vadose zone. The actual sulfate concentration was also used unchanged for incidental percolation of water discharged into river channels of the Basin. A 1.5

loading factor was used for return flow from direct uses of San Gabriel Basin production, surface water, imported Raymond Basin water, treated imported water, and recycled water. The sulfate concentration of the return flow from direct uses of surface water was less than the groundwater minimum concentration after applying the 1.5 multiplier; in these cases, 49 mg/L was used. When the sulfate concentration exceeded the groundwater mean, the actual concentration was used for direct spreading of local runoff; when the sulfate concentration was less than the groundwater mean, 49 mg/L was used. A concentration of 49 mg/L was used for return flow from untreated imported water Using these coefficients and concentrations, it was possible to have a sulfate balance model that matched the long-term concentration trends, as shown in Table III.11.

There was little variation in sulfate extraction and outflow in the past thirteen years. However, due to the recent drought discussed previously, the model predicted below average sulfate loading from precipitation and runoff from watersheds in twelve of those thirteen years, and below average sulfate loading from direct spreading in nine years, primarily due to the decrease in local runoff. The result is the model predicted sulfate unloading in eleven of the last thirteen years, with a net unloading of almost 90 million lbs. Plate III.37a demonstrates that unloading trends generally follow the same trends in the sulfate concentration from extraction wells. The inverse relationship between key well groundwater elevations and basinwide sulfate concentrations is shown in Plate III.37b. Table III.11 will be discussed in greater detail in the following section.

Total Dissolved Solids, TDS Calibration

The TDS balance model is more challenging, as the TDS chemistry is the summation of all the individual component nutrient/salts, including nitrate, chloride, sulfate, phosphate, calcium, magnesium, potassium, and sodium, among others. Several iterations were required to obtain a model that matched the long-term trends in groundwater TDS concentration. The actual annual water quality was used in the model for subsurface inflow, recycled water in its various uses, and for treated, imported water. Multi-year TDS concentration cycles are apparent in Plates III.30a and III.30b. Due to these cycles, average groundwater concentration was calculated by decades, as shown in Table III.12. It can be seen that the average groundwater TDS concentration decreased from 1973 through the 1990s, then increased dramatically since 2000. This change in the trend in groundwater TDS concentration required two stages in the calibration of the model: 1973-74 to 1999-2000, and after 2000-01 to 2010-11. The coefficients were applied only to water sources with water quality that generally had lesser TDS concentrations than the average decadal groundwater TDS concentration. These sources included: return flow from precipitation and watershed runoff, return flow from direct uses of San Gabriel Basin (production) water, imported Raymond Basin water, and surface waters, and direct spreading of local runoff, and untreated imported water from the State Water Project. The coefficient (multiplier) was determined as a function of the volume of annual recharge from precipitation on the valley floor, runoff from the watershed, return flow, or surface spreading, relative to the mean for that recharge component. The coefficients were assigned in three categories: less than 75% of the mean for that recharge component, 75% of the mean to the mean for that component, and greater than the mean of that component. The multiplier increased with volume of recharge, assuming more water moving through the vadose zone has the potential to dissolve more salts along the way. The TDS concentration used in the model was the greater concentration of the source or the product of the multiplier and the decadal mean groundwater TDS concentration, as shown in Table III.12. This model was further adjusted to account for the concentration/dilution factor associated with the volume of groundwater in storage, as seen in Plate III.30d. The TDS balance model is shown in Table III.13. However, it should be noted that, even though the model was able to approximate the TDS concentration, the annual net balance TDS load (loading less unloading) does not track changes in groundwater TDS concentration. The TDS balance model is more reliable for predicting concentrations than for modeling quantity of TDS input/output.

There was little variation in TDS extraction and outflow in the past thirteen years. However, due to the recent drought discussed previously, the model predicted below average TDS loading from precipitation and runoff from watersheds in eleven of those thirteen years, and below average TDS loading from direct spreading in five years, primarily due to the decrease in local runoff. The result is the model predicted TDS unloading in six of the last thirteen years. However, it also predicted the two years with greatest TDS loading, resulting in a net load more than 360 million lbs. Plate III.38a demonstrates that unloading trends generally follow the same trends in the TDS concentration from extraction wells. The inverse relationship between key well groundwater elevations and basinwide TDS concentrations is shown in Plate III.38b. Table III.13 will be discussed in greater detail in the following section.

III.5.2 Allowable Load and Assimilative Capacity

For this characterization, the allowable load is defined as the quantity (in pounds) of a constituent salt that may be present in the groundwater in storage without exceeding the Basin water quality objective. This was determined using 75 percent of the volume of the groundwater in storage and the Basin water quality objective for the constituent nutrient/salt, nitrate (as NO_3^-, 45 mg/l), chloride (Cl-, 100 mg/l), sulfate (as SO_4^{2-}, 100 mg/l), and TDS (450 mg/L).
The assimilative capacity is defined as the difference between the quantity of the constituent nutrient/salt stored in the groundwater, and the allowable load of that constituent. This was determined on an annual basis, and the mean of the last ten years (2001-02 to 2010-2011) is used as the assimilative capacity for that constituent.

It is important to realize the allowable load and the assimilative capacity are both dependent upon the quantity of groundwater in storage. Long-term changes in the quantity of groundwater in storage will have concomitant effects on the assimilative capacity. For the reporting period, the groundwater in storage decreased an average of about 2,700 ac-ft/yr. However, in the last ten years, it has decreased about 4,300 ac-ft/yr, and in the last five, about 31,000 ac-ft/yr (Table III.6). A decrease in the volume of groundwater in storage will result in a decrease in the assimilative capacity.

III.5.2.1 Nitrate

Since 1973-74, the groundwater extraction water quality has varied from approximately 19 to 35 mg/l nitrate (Appendix K), averaging 24 mg/L, resulting in nitrate stored in groundwater varying from about 290 to 320 million lbs, with an average of about 300 million lbs, as shown in Table III.9. The Basin Plan water quality objective (45 mg/l) and 75% of the groundwater volume in storage is used to determine the allowable load and estimate the assimilative capacity.

The means from the annual nitrate loading/unloading balance from 2001-02 to 2010-11 are summarized in Plate III.39a. Of the annual nitrate load (about 15 million lbs), direct spreading accounts for about 62 percent, while precipitation and watershed runoff contribute almost 16 percent. Incidental percolation of water discharged into the river channels in the Basin and return flow from direct uses contribute about equally to make up the balance. Groundwater extraction accounts for about 96 percent of the nitrate unloading, and about 4 percent is outflow to Central Basin. For the reporting period, the nitrate concentration has decreased slightly, resulting in a net unloading of less than 1 million lbs/yr.

The current nitrate load is about 300 million lbs, while the allowable nitrate load is about 710 million lbs. The assimilative capacity is about 410 million lbs, the difference between the allowable load and the current load, which is approximately equivalent to 26 mg/L. More than half the allowable load remains available as the assimilative capacity.

III.5.2.2 Chloride

Since 1973-74, the groundwater extraction water quality has varied from 21 to 37 mg/L chloride (Appendix K), averaging 28 mg/L, resulting in chloride stored in groundwater ranging from about 340 to 620 million lbs, with an average of about 450 million lbs, as shown in Table III.10. The Basin water quality objective (100 mg/l) and 75% of the groundwater volume in storage is used to determine the allowable load and estimate the assimilative capacity.

The means from the annual chloride loading/unloading balance from 2001-02 to 2010-11 are summarized in Plate III.39b. Of the mean annual chloride load (about 26 million lbs), direct spreading accounts for about 63 percent. Precipitation and watershed runoff contribute about 14 percent. Incidental percolation of water discharged into the river channels in the Basin contributes about 12 percent, and return flow from direct uses makes up the balance. Groundwater extraction accounts for almost 81 percent of the chloride unloading, while outflow to Central Basin accounts for the remaining 19 percent. For the reporting period, the chloride concentration has decreased slightly, resulting in a net unloading of about 3 million lbs/yr.

The current chloride load is about 510 million lbs, while the allowable chloride load is about 1,580 million lbs. The assimilative capacity is about 1,070 million lbs, the difference between the allowable load and the current load, which is approximately equivalent to 68 mg/L. Approximately 68 percent of the allowable load remains available as the assimilative capacity.

III.5.2.3 Sulfate

Since 1973-74, the Basin water quality has varied from 38 to 70 mg/l sulfate (Appendix K), averaging about 49 mg/L, resulting in sulfate stored in groundwater ranging from about 750to 890million lbs, with an average of about 835million lbs, as shown in Table III.11. The Basin water quality objective (100 mg/l) and 75% of the groundwater volume in storage is used to determine the allowable load and estimate the assimilative capacity.

The means from the annual sulfate loading/unloading balance from 2001-02 to 2010-11 are summarized in Plate III.39c. Of the mean annual sulfate load (about 40 million lbs), direct spreading accounts for about 60 percent. Precipitation and watershed runoff contribute about 16 percent. Return flow from direct uses contributes about 17 percent, and incidental percolation of water discharged into the river channels in the Basin makes up the balance. Groundwater extraction accounts for almost 81 percent of the sulfate unloading, while outflow to Central Basin accounts for the remaining 19 percent. For the reporting period, the sulfate concentration has decreased slightly, resulting in a net unloading of about 3 million lbs/yr.

The current sulfate load is about 835 million lbs, while the allowable chloride load is about 1,580 million lbs. The assimilative capacity is about 745 million lbs, the difference between the allowable load and the current load, which is approximately equivalent to 47 mg/L. Approximately 47 percent of the allowable load remains available as the assimilative capacity.

III.5.2.4 TDS

Since 1973-74, the Basin water quality varied from about 200 to 390 mg/L TDS (Appendix K), resulting in TDS stored in groundwater ranging from about 5.0 to 5.9 billion lbs, with an average of 5.4 billion lbs, as shown in Table III.13. Though the Basin has different TDS water quality objectives for the eastern (600 mg/L) and western areas (450 mg/L), this characterization uses a conservative approach and applies 450 mg/L to the whole Basin, ~~with~~ and only 75% of the groundwater volume in storage, for determination of the allowable load and the assimilative capacity.

The means from the annual TDS loading/unloading balance from 2001-02 to 2010-11 are summarized in Plate III.39d. Of the mean annual TDS load (about 330 million lbs), direct spreading accounts for about 68 percent. Precipitation and watershed runoff contribute about 17 percent. Return flow from direct uses and incidental percolation of water discharged into the river channels in the Basin make up the balance. Groundwater extraction accounts for almost 89 percent of the TDS unloading, while outflow to Central Basin accounts for the remaining 10 percent. For the reporting period, the TDS concentration has increased slightly, resulting in a net loading of about 60 million lbs/yr.

The current TDS load is about 5,500 million lbs, while the allowable TDS load is about 7,100 million lbs. The assimilative capacity is about 1,600 million lbs, the difference between the allowable load and the current load, which is approximately equivalent to 100 mg/L. Approximately 22 percent of the allowable load remains available as the assimilative capacity.

III.5.2.5 Assimilative Capacity and Groundwater Volume in Storage

It was noted earlier that the volume of groundwater in storage fluctuates, as shown on Plates III.19 and III.24. Since the allowable load is a function of the Basin Plan water quality objectives and the volume of groundwater in storage, these fluctuations affect the assimilative capacity ~~(AC)~~. In general, ~~AC~~ assimilative capacity increases with the volume of groundwater in storage, though this trend can be offset by opposing changes in concentration. The worst case scenario for assimilative capacity ~~AC~~ is for the volume of groundwater to decrease while the concentration of a nutrient/salt increases.

The volume of groundwater in storage has decreased about 3 percent in the last decade. In the same period, the nitrate assimilative capacity ~~AC~~ decreased about 3 percent, chloride assimilative capacity ~~AC~~ decreased about 4 percent, sulfate assimilative capacity ~~AC~~ decreased about 1 percent, and TDS assimilative capacity ~~AC~~ decreased about 28 percent, as shown in Plate III.40. The changes in assimilative capacity ~~AC~~ in the last decade reflect the varying increases in groundwater concentration of the constituent nutrient/salt.

The TDS assimilative capacity ~~AC~~ has the least percentage of the allowable load available (20 percent), and so is the most vulnerable to changes in groundwater storage volume. The increasing TDS concentration in the groundwater compounds the challenge. For any project considered that would return additional nutrient/salt constituents to the Basin, TDS will be the most limiting factor.

III.5.3 Assimilative Capacity as a Tool to Assess Future Projects

This assimilative capacity ~~AC~~ model may be used to evaluate the potential effect of releasing water from a recycled water project into the Basin. The baseline period for assimilative capacity is from 2001-02 to 2010-11.

It was previously stated that TDS will be the most limiting factor in evaluating the potential effects of replacing current water use with water from recycled water project. This requires further explanation. The TDS concentration integrates the combinations and concentration of all salts dissolved in the solution, in this case groundwater stored in the aquifer. Salts are composed of negatively-charged ions (anions) and positively-charged ions (cations). The nitrates, chlorides, and sulfates included in this SNMP are elements and compounds that have a negative charge (anions) that contribute to TDS. Other anions that may be dissolved in water include nitrite, sulfite, carbonate, bicarbonate, and borates, among others. As everything in nature seeks an equilibrium, there will be an approximately equal concentration of elements or compounds with a positive charge, cations, to offset the anions in solution. The most common cations found in soil and the vadose zone in semiarid and arid regions include calcium, magnesium, and potassium, though many other alkali earth metals, alkali metals, and metals may be present (elements and compounds from the upper and left sections of the periodic table of the elements). The resultant TDS of a solution is dependent upon which of these salts is present, and the relative concentration and atomic mass of the individual constituents.

In waters analyzed in the Main San Gabriel Basin, nitrate, chloride, sulfate and the associated cations account for 55 to 80 percent of the total TDS. Using these characteristics, Table III.14a identifies a range of TDS values that would be associated with selected concentrations of the constituent nutrient/salt. Nitrate and the associated cations contribute about 20 percent to the total TDS concentration in the ambient groundwater. In water from the State Water Project or imported treated water from the Weymouth Plant, nitrate contributes less than 2 percent of the TDS concentration. The maximum contribution from chloride about 50 percent was found in waters released from the SJCWRP East Plant, 109 mg/L chloride and 622 mg/L TDS, as shown in Appendix K. Sulfate contributed almost 70 percent of TDS in water from the Weymouth Plant, 198 mg/L sulfate and 539 mg/L TDS, as shown in Appendix K. Therefore, it is a chemical and physical impossibility to have chloride or sulfate concentrations of 250 mg/L without having TDS at or above 600 mg/L. In all these cases, TDS is still the limiting factor for assimilative capacity in the Basin.

A proposed groundwater recharge project in the Basin, the Indirect Reuse Replenishment Project, was analyzed to determine the cumulative percentage of assimilative capacity ~~AC~~ utilized after prolonged groundwater recharge with recycled water. In addition, the three hypothetical scenarios presented in Table III.14a were analyzed to determine the maximum volume of recycled water under hypothetical quality conditions each year that could be recharged while still cumulatively utilizing less than 10 percent of the assimilative capacity~~AC~~. The analyses are presented in the subsections below.

III.5.3.1 Project Evaluation – Indirect Reuse Replenishment Project

The Upper District is developing its IRRP which would provide up to 10,000 ac-ft/yr of recycled water from the San Jose Creek Water Reclamation Plant West Plant for groundwater replenishment in the Main Basin, replacing approximately 10,000 ac-ft/yr of untreated imported water previously used for groundwater replenishment. The quality of the SJCWRP West Plant effluent is distinctive from the SJCWRP East Plant effluent that is discharged into the San Jose Creek and percolates to the Basin. The impacts of the IRRP on the Main Basin were evaluated using the assimilative capacity tool developed as part of this SNMP.

For this evaluation, the assumptions include:

- the volume of groundwater stored in the basin is the mean of the last ten years, and does not change;
- 75% of the total groundwater in storage is the mixing volume, or 5,811,700 af;
- the Basin water quality objectives remain constant;
- assimilative capacity for each individual nutrient/salt constituent does not change;
- withdrawal and replenishment remains constant at 250,000 af/yr;
- 10,000 af/yr of recycled water is substituted for 10,000 af/yr of untreated imported water;
- the recycled water quality remains constant and is the ten-year average (2001-02 to 2010-11) of the San Jose Creek Water Reclamation Plant West effluent: nitrate = 27 mg/L; chloride = 110 mg/L; sulfate = 85 mg/L; and TDS = 530 mg/L;
- the balance of loading from recharge is calculated using 240,000 af/yr;
- unloading is determined using 250,000 af/yr and the ambient groundwater quality;
- the yearly ambient groundwater quality increases over time with continued recycled water recharge

Based on the above mentioned assumptions, the Upper District IRRP project would use about 0.3 percent of the San Gabriel Basin's assimilative capacity ~~AC~~ for TDS after the first year of recharging 10,000 ac ft of recycled water, as noted in Table III.14b. The remaining constituents analyzed, chloride, sulfate, and nitrate, utilize a lower percentage of the assimilative capacity ~~AC~~ as compared to TDS. For chloride to be the limiting assimilative capacity ~~AC~~ factor in the Basin, the chloride concentration of the recycled water would have to exceed 160 mg/L while the TDS concentration was 530 mg/L or less, meaning that essentially all salts were magnesium chloride. The same condition would exist for sulfate. This ignores the presence of other salts in the soil, vadose zone, and water source. With the current ambient groundwater conditions in the Basin, it is chemically and physically infeasible for chloride, sulfate, or nitrate to limit assimilative capacity~~AC~~, as demonstrated in Table III.14a.

The IRRP impacts on the Basin TDS concentrations were analyzed further to determine the potential utilization of the assimilative capacity ~~AC~~ resulting from long term recharge of recycled water. The constituent concentrations in the groundwater will eventually stabilize and will not increase despite continued recharge of recycled water. The TDS concentration in the groundwater is estimated to reach equilibrium after more than 100 years of recycled water recharge under the same quality assumptions. Once equilibrium is reached, the TDS concentration in the groundwater will be 364 mg/L, an increase of seven (7) mg/L, which represents approximately 7.2 percent utilization of the available AC. The IRRP utilizes a smaller percentage of the available assimilative capacity of the other constituents analyzed once equilibrium is reached: 1.2 percent for nitrate, 4.6 percent for chloride, and 2.7 percent for sulfate.

The increase in TDS concentration falls within the SWRCB's recommendation that a single project utilize less than 10 percent of the assimilative capacity to prevent significant degradation to groundwaters. Although the chloride and TDS concentrations in tertiary treated recycled water exceed the water quality objectives, the assimilative capacity is great enough such that the minor water quality objective exceedances do not substantially degrade the overall quality of the Main Basin. These estimates of the assimilative capacity utilization are also conservative in nature because the SNMP analyzed the IRRP as the single recycled water project in the basin with loading contributions from direct reuse recycled water projects already accounted for in the overall balance models for the basin. However, the SWRCB recommends that multiple recycled water projects combined limit their utilization of the assimilative capacity to 20 percent. Therefore, if all of the recycled water projects were considered concurrently, the IRRP could utilize a larger percentage of the assimilative capacity. The complete analysis for the IRRP is provided in Table III.14b.

III.5.3.2 Hypothetical Scenarios Evaluation

The three hypothetical scenarios presenting varied replenishment water quality for nitrate, chloride, sulfate, and TDS were evaluated to determine the maximum volume of new replenishment water under varied quality conditions that could be recharged annually without cumulatively exceeding the 10 percent of the assimilative capacity~~AC~~. For these evaluations, the assumptions include:

- the volume of groundwater stored in the basin is the mean of the last ten years, and does not change;
- 75% of the total groundwater in storage is the mixing volume, or 5,811,700 af;
- the Basin water quality objectives remain constant;
- assimilative capacity for each individual nutrient/salt constituent does not change;
- withdrawal and replenishment rates are balanced at 250,000 af/yr;
- new replenishment water of particular quality is substituted for recharge of untreated imported water;
- the replenishment water quality remains constant for each of the three scenarios with the constituent concentrations presented in Table III.14a;
- the ambient groundwater quality increases over time with continued replenishment water recharge.

The water quality selected for analysis in the hypothetical scenarios is representative of water quality from likely replenishment water sources. Historical supply sources for replenishment water have been primarily stormwater runoff and SWP, with Colorado River water and recycled water contributing to groundwater replenishment to a lesser extent. Scenario 1 represents the likely water quality of potential replenishment water from the Colorado River with a high sulfate concentration. Scenario 2 represents likely water quality of potential replenishment water from the State Water Project experiencing salt water intrusion with a high chloride concentration. Scenario 3 represents likely water quality of potential replenishment water with a high sulfate concentration along with a lower nitrate concentration. These scenarios only evaluated the impacts resulting from direct spreading of replenishment water (100 percent of replenishment water reaches groundwater); therefore, it should be noted that indirect use of replenishment water (such as would be likely with recycled water ~~reuse~~irrigation projects) would allow recharge of a significantly greater volume of replenishment water before resulting in an equivalent utilization of the assimilative capacity because it is assumed only nine percent volumetrically of indirect uses reaches the groundwater. Accordingly, it is unlikely that a single indirect replenishment project would utilize 10 percent of the available assimilative capacity due to volumetric and operational constraints.

In Scenario 1, the recharge water quality is as follows: 20 mg NO_3/L, 50 mg Cl/L, 250 mg SO_4/L, and between 605 and 968 mg TDS/L. Using these recharge water quality characteristics for Nitrate, Chloride, and Sulfate, and the average TDS concentration from the TDS range, TDS is the most limiting of the constituents, reaching approximately 10 percent of the assimilative capacity with replenishment and subsequent production of 5,700 acre feet of recycled water annually, as shown on Table III.14c.

In Scenario 2, the recharge water quality is as follows: 1 mg NO_3/L, 250 mg Cl/L, 60 mg SO_4/L, and between 635 and 1,015 mg TDS/L. Using these recharge water quality characteristics for Nitrate, Chloride, and Sulfate, and the average TDS concentration from the TDS range, TDS is the most limiting of the constituents, reaching approximately 10 percent of the assimilative capacity with replenishment and subsequent production of 5,300 acre feet of recycled water annually, as shown on Table III.14d.

In Scenario 3, the recharge water quality is as follows: 1 mg NO_3/L, 60 mg Cl/L, 250 mg SO_4/L, and between 594 and 950 mg TDS/L. Using these recharge water quality characteristics for Nitrate, Chloride, and Sulfate, and the average TDS concentration from the TDS range, TDS is the most limiting of the constituents, reaching approximately 10 percent of the assimilative capacity with replenishment and subsequent production of 5,800 acre feet of water annually, as shown on Table III.14e.

The three hypothetical scenarios evaluated for the AC represent extreme loading characteristics that are not likely to represent the quality of the ~~recycled water~~replenishment water ~~produced~~ utilized in the San Gabriel Valley. However, in the event that replenishment water (including recycled water) intended for either indirect or direct use within the San Gabriel Valley has a quality falling outside of the ranges evaluated in this SNMP, an evaluation would be conducted to determine the estimated utilization of the assimilative capacity.

III.6. IMPLEMENTATION MEASURES

The Basin has been actively managed for many decades to control salt and nutrient loading to preserve the high quality groundwater supplies. Existing programs include support of stormwater runoff replenishment conducted by LACDPW, use of untreated imported water from the State Water Project (which is the highest quality imported water currently available) to annually replenish the water Basin as a result of prior years' over production, and an extensive water quality monitoring program. Basin management is conducted in coordination between the Watermaster, Upper District, San Gabriel District, Three Valleys District, MWD, LACSD, and LACDPW. Historically, stakeholders have coordinated to replenish the groundwater supplies with the greatest amount of high quality water as possible. As a result, significant replenishment of the groundwater Basin with high quality (low TDS) water (such as fiscal year 1991-92 on Tables III.9, III.10, III.11, III.13) may actually result in an estimated net loading of the Basin. However, the additional groundwater volume from such replenishment dilutes the groundwater TDS concentration in the long-term. Because the volume of water in the Basin is so large in comparison with the loading, the loading is insignificant.

The San Gabriel Valley has experienced unprecedented drought conditions since calendar year 2006. As a result, the groundwater elevation at Baldwin Park Key Well has decreased from about 250 feet msl during the Spring of 2005 to about 189 feet msl as of December 2009, as shown on Plate III.24. Since 1972, when the Basin was adjudicated, to present, the Basin Watermaster has actively managed water quality through existing implementation measures (described in greater detail below). Nonetheless, water quality generally improves (i.e. water quality concentrations decrease) coincident with significant rainfall events/recharge of stormwater runoff and the water quality tends to degrade during drought periods. This general inverse relationship between groundwater levels and water quality concentrations is shown on Plates III.35b, III.36b, III.37b, and III.38b. Consequently, despite the long-term implementation measures the Basin Watermaster has in place, recent drought conditions have had a greater influence on water quality trends over the past 10 years and may give the appearance of an increasing trend in salt and nutrient conditions.

Section 6.b(3)(e) of the Recycled Water Policy states in part that a SNMP shall include "…implementation measures to manage salt and nutrient loading on a sustainable basis…" in the Basin. Implementation measures may have two types of impacts to a groundwater basin. Those impacts consist of 1) loading as the result of additional water replenished in the groundwater basin and 2) change to the <u>concentration</u> of salts and nutrients that are included in the water that is replenished. The following sections address existing and potential implementation measures that may impact salt and nutrient loading. Those implementation measures are summarized on Table III.15 and briefly described below.

III.6.1 Groundwater Replenishment

<u>Maintain Spreading Facilities (Existing) –</u> LACDPW maintains a complex system of dams, retention basins, storm channels and off-stream spreading grounds to control stormwater runoff and to maximize replenishment of the stormwater flow. The existing spreading grounds are conjunctively operated to enable both stormwater run-off and untreated imported water to be replenished into the Basin in an efficient and effective manner. Local stormwater and untreated imported water from the SWP replenished in these facilities typically have the lowest concentrations of TDS, Nitrate, Sulfate, and Chloride of the various sources contributing to loading. As shown on Appendices M, N, O, and P, the concentration of the TDS, chloride, nitrate, and sulfate in local stormwater and SWP water (which historically have been used to replenish the water supplies of the Basin) is lower than the quality of the groundwater extracted. Consequently, the quality of the Basin will be maintained over time assuming replenishment is greater than or equal to extractions. During drought conditions with little stormwater runoff, this may not be the case.

Maintain Unlined Portions of Rivers and Streams (Existing) – The San Gabriel River is unlined from Morris Dam to Whittier Narrows Dam, along with portions of the Rio Hondo, Walnut Creek, and San Jose Creek. Stormwater is released under a controlled manner into these unlined water bodies to augment groundwater replenishment that occurs in off-stream spreading grounds. Replenishment of high quality stormwater contributes to the long-term enhancement of groundwater quality.

Groundwater Replenishment Coordinating Group (Existing) - Representatives from the Watermaster, LACDPW, LACSD, and MWD meet approximately every two months to coordinate the planned replenishment of local and untreated imported water with the availability of the sources of supply and the availability of groundwater replenishment facilities. As the highest quality source of water stormwater run-off is typically given the highest priority for replenishment activities.

Optimize Delivery of SWP Water (Existing) – SWP water typically contains the lowest concentration of TDS. Consequently, the Watermaster and MWD have endeavored to maximize delivery of untreated SWP water to replenish the Basin in conjunction with groundwater basin management practices.

Develop New Spreading Facilities (Potential) – The Watermaster and LACDPW continually investigate opportunities to expand the network of spreading grounds. Potential new sites include sand and gravel pits.

III.6.2 Reduce Stormwater Runoff (Potential)

Cities within the Basin are co-permittees for the new MS4 permit. As such, cities are directed to take proactive steps, both individually and collectively, to implement stormwater Best Management Practices (BMPs) to reduce or eliminate stormwater runoff from facilities and consequently reduce flow in storm channels. These practices may result in increased stormwater replenishment. As noted in Section III.6.1, stormwater runoff typically contains the highest (best) quality of water used to replenish the Basin. Increased replenishment of high quality will tend to improve Basin water quality over time.

III.6.3 Recycled Water

Nitrogen Treatment (Existing) - Although recycled water is not a significant component of loading in the Basin, historical loading occurred from the discharge of recycled water into the San Jose Creek, San Gabriel River, and Rio Hondo, and the subsequent infiltration of a portion of that discharge. The LACSD has taken steps to reduce the nitrate (nitrogen) concentration in the recycled water.

III.6.4 Imported Water

Historically the Basin has used SWP water almost exclusively to replenish the groundwater supplies as the result of groundwater production in excess of water rights. This practice ensures reliable groundwater supplies and that the groundwater levels are operated within a historical range of about 100 feet. MWD has taken proactive steps in conjunction with the California Department of Water Resources (DWR) to ensure the TDS concentrations of the SWP water are maintained. As noted in Section III.6.1, long-term replenishment of the Basin with high quality water will tend to improve Basin water quality over time.

III.6.5 Institutional

Main San Gabriel Basin Judgment (Existing) – The Basin Watermaster was created by the court in 1973 to manage both the water quantity and quality of the Basin. These activities include the annual establishment of the Operating Safe Yield which limits the amount of groundwater that can be pumped from the groundwater basin without having to purchase untreated imported water from the SWP. Watermaster coordinates with the LACFCD and MWD to ensure available water supplies are replenished in an efficient manner. Watermaster maintains records of all groundwater produced for the Basin, maintains a database of groundwater quality from all municipal water supply wells, and keeps track of all water entering and leaving the Basin. In addition, the Watermaster also adopted the "Criteria for Delivery of Supplemental

Water" (Criteria) by Resolution No.4-96-138. The Criteria sets forth procedures the Watermaster follows to ensure the highest quality untreated imported water is replenished in the Basin.

III.6.6 Regulatory

<u>Title 22 Water Quality Monitoring (Existing) -</u> All municipal water suppliers are required to adhere to the provisions of Title 22 regarding water quality monitoring of municipal water supply wells. In general TDS, chloride, and sulfate samples are collected once every three years and nitrate samples are collected annually. Based on water quality results, municipal water suppliers may need to construct groundwater treatment facilities and/or develop water quality blending plans to maintain production from wells. In those situations, DDW may require more frequent water quality monitoring than those noted above. The municipal water supply wells are distributed throughout the Basin as shown on Plate III.26 and water quality data from Title 22 water quality sampling will be incorporated into the Basin-wide Salt and Nutrient Monitoring Program described in Chapter V.

<u>SNMP Monitoring Program (Future) -</u> Watermaster will implement a proposed monitoring plan as required by the Recycled Water Policy (See Section V.2). As required by the Recycled Water Policy Section 6.b(3)(a)(iii) water quality data will be reported to the LAWRWQCB at least every three years. The sampling frequency for salts and nutrients will be periodically evaluated and adjusted accordingly as necessary.

CHAPTER IV

ANTIDEGRADATION ANALYSIS

IV.1. REGULATORY BACKGROUND

In 1968, the SWRCB adopted Resolution No. 68-16 (Resolution) as the State's Anti-Degradation Policy. Resolution No. 68-16 states in part:

1. *Whenever the existing quality of water is better than the quality established in policies as of the date on which such policies become effective, such existing high quality will be maintained until it has been demonstrated to the State that any change will be consistent with maximum benefit to the people of the State, will not unreasonably affect present and anticipated beneficial use of such water and will not result in water quality less than that prescribed in the policies.*
2. *Any activity which produces or may produce a waste or increased volume or concentration of waste and which discharges or proposes to discharge to existing high quality waters will be required to meet waste discharge requirements which will result in the best practicable treatment or control of the discharge necessary to assure that (a) o pollution or nuisance will not occur and (b) the highest water quality consistent with maximum benefit to the people of the State will be maintained.* [31~~29~~]

The Policy acknowledges that groundwater recharge with recycled water benefits the public; however, the SWRCB finds that groundwater recharge with recycled water has the potential to degrade water quality in groundwater basins. Therefore, the Policy requires that an antidegradation analysis be included in each salt and nutrient management plan to demonstrate the projects included within the plan will, collectively, satisfy the requirements of the Resolution. The Policy states in part with regards to the Resolution:

- *The proponent of a groundwater recharge project must demonstrate compliance with Resolution No. 68-16. Until such time as a salt/nutrient management plan is in effect, such compliance may be demonstrated as follows:*

  (1) A project that utilizes less than 10 percent of the available assimilative capacity in a basin/sub-basin (or multiple projects utilizing less than 20 percent of the available assimilative capacity in a basin/sub-basin) need only conduct an antidegradation analysis verifying the use of the assimilative capacity. For those basins/sub-basins where the Regional Water Boards have not determined the baseline assimilative capacity, the baseline assimilative capacity shall be calculated by the initial project proponent, with review and approval by the Regional Water Board, until such time as the salt/nutrient plan is approved by the Regional Water Board and is in effect. For compliance with this subparagraph, the available assimilative capacity shall be calculated by comparing the mineral water quality objective with the average concentration of the basin/sub-basin, either over the most recent five years of data available or using a data set approved by the Regional Water Board Executive Officer. In determining whether the available assimilative capacity will be exceeded by the project or projects, the Regional Water Board shall calculate the impacts of the project or projects over at least a ten year time frame.

  (2) In the event a project or multiple projects utilize more than the fraction of the assimilative capacity designated in subparagraph (1), then a Regional Water Board-deemed acceptable antidegradation analysis shall be performed to comply with Resolution No. 68-16. The project proponent shall provide sufficient information for the Regional Water Board to make this determination. An example of an approved method is the method used by the State Water Board in connection with Resolution No. 2004-0060 and the Regional Water Board in connection with Resolution No. R8-2004-0001. An integrated approach (using surface water, groundwater, recycled water, stormwater, pollution prevention,

water conservation, etc.) to the implementation of Resolution No. 68-16 is encouraged.

- *Landscape irrigation with recycled water in accordance with this Policy is to the benefit of the people of the State of California. Nonetheless, the State Water Board finds that the use of water for irrigation may, regardless of its source, collectively affect groundwater quality over time. The State Water Board intends to address these impacts in part through the development of salt/nutrient management plans described in paragraph 6.*

  (1) A project that meets the criteria for a streamlined irrigation permit and is within a basin where a salt/nutrient management plan satisfying the provisions of paragraph 6(b) is in place may be approved without further antidegradation analysis, provided that the project is consistent with that plan.

  (2) A project that meets the criteria for a streamlined irrigation permit and is within a basin where a salt/nutrient management plan satisfying the provisions of paragraph 6(b) is being prepared may be approved by the Regional Water Board by demonstrating through a salt/nutrient mass balance or similar analysis that the project uses less than 10 percent of the available assimilative capacity as estimated by the project proponent in a basin/sub-basin (or multiple projects using less than 20 percent of the available assimilative capacity as estimated by the project proponent in a basin/sub-basin). [Appendix A]

IV.2. PROJECT EVALUATION

To demonstrate compliance with the Resolution pursuant to the guidelines provided in the Policy, an antidegradation analysis was completed to determine the percent utilization of the available assimilative capacity. The baseline period for assimilative capacity is from 2001-02 to 2010-11.

For this antidegradation analysis, mass-balance calculations were performed using the Basin annual groundwater in storage estimated by the spreadsheet groundwater balance model (Table III.6), and the annual water quality data for all water used within the Basin (Appendix K). These mass-balance spreadsheets for nitrate, sulfate, chloride, and TDS are summarized in Tables III.9, III.10, III.11, and III.13.

Section III.5 of this SNMP identified the quantity of new water that could be introduced annually to the Basin before 10 percent of the available assimilative capacity for TDS would be used. The Nitrate, Chloride, and/or Sulfate concentrations in replenishment water are not sufficient for these compounds to become limiting to assimilative capacity before TDS. The antidegradation analysis consists of separate calculations for Nitrate, Chloride, Sulfate, and TDS showing the percentage utilization of each respective assimilative capacity after 1 year, 5 years, 10 years, 20 years, and when equilibrium is reached, as shown in Tables III.14b, III.14c, III.14d, and III.14e. The Recycled Water Policy sets an <u>interim</u> goal that no single project is to use more than 10 percent of the available assimilative capacity, or combination of projects to use more than 20 percent of the available assimilative capacity. Consequently, as part of this SNMP, the antidegradation analysis calculated the collective amount of water from potential future projects that could be replenished in the Basin without exceeding the very conservative value of 10 percent of the available assimilative capacity.

The antidegradation analysis (See Section III.5) considered Upper District's IRRP and three hypothetical scenarios representing varied water quality characteristics of potential replenishment sources. In all cases the 75 percent of the Basin value (about 6,000,000 acre-feet) was used. The resultant calculated value represents the point of equilibrium in the future at such point the continuous annual loading from the new water supply changes the background water quality throughout the Basin by a maximum of 10 percent.

<u>IRRP:</u> The water quality of new water supplies is assumed to be 530 mg/l for TDS, 6 mg/l for nitrate, 110 mg/l for chloride and 85 mg/l for sulfate. Table III .14(b) shows the summary of the calculations and indicates TDS is the central constituent and will use 7.2 percent of the assimilative capacity through annual replenishment of about 10,000 acre-feet of recycled water when equilibrium is reached. Because it has been determined that the IRRP utilizes less than 10

percent of the available assimilative capacity, additional antidegradation analyses are not necessary and the IRRP is fully compliant with the Resolution and with the Policy with regards to groundwater replenishment projects. Additionally, the IRRP will not alter the planned beneficial uses of the Basin.

Scenario 1: The water quality of new water supplies is assumed to be 787 mg/l for TDS, 20 mg/l for nitrate, 50 mg/l for chloride and 250 mg/l for sulfate, indicative of potential water quality of Colorado River water. Table III .14(c) shows the summary of the calculations and indicates TDS is the central constituent and will use 10 percent of the assimilative capacity through annual replenishment of about 5,700 acre-feet when equilibrium is reached.

Scenario 2: The water quality of new water supplies is assumed to be 825 mg/l for TDS, 1 mg/l for Nitrate, 250 mg/l for Chloride and 60 mg/l for Sulfate, indicative of potential water quality of State Water Project water with salt water intrusion. Table III.14(d) shows the summary of the calculations and indicates TDS is the critical constituent and will use 10 percent of the assimilative capacity through annual replenishment of about 5,300 acre-feet when equilibrium is reached.

Scenario 3: The water quality of new water supplies is assumed to be 772 mg/l for TDS, 1 mg/l for Nitrate, 60 mg/l for Chloride, and 250 mg/l for Sulfate. Table III.14(e) shows the summary of the calculations and indicates TDS is the critical constituent and will use 10 percent of the assimilative capacity through annual replenishment of about 5,800 acre-feet when equilibrium is reached.

The antidegradation analysis is extremely conservative, as it assumes no additional constituent removal beyond historical amounts, and does not consider the TDS water quality objective for the eastern portion of the Basin is 600 mg/l. Additionally, the IRRP and the hypothetical scenarios only consider direct spreading where 100 percent of the water is assumed to reach the groundwater. A recycled water project utilizing direct use would only result in a fraction of the recharge water reaching the groundwater; therefore, a significantly greater volume of replenishment water could be used before utilizing 10 percent of the assimilative capacity. In the event that replenishment water (including recycled water) intended for either indirect or direct use within the San Gabriel Valley has a quality falling outside of the ranges evaluated in this SNMP, an evaluation would be conducted to determine the estimated utilization of the assimilative capacity.

IV.3. PREDICTIVE TRENDS

The general water quality trends for chloride, sulfate, and TDS are increasing, excluding the impacts of potential future water projects; the general water quality trend for nitrate is decreasing. Therefore, an evaluation of the compiled historical water data for the period 1973-74 to 2010-11 was conducted to project future groundwater quality assuming no hypothetical scenarios or additional recycled water projects are implemented. First, the linear interpolation of the annual mean extraction well quality was determined for each subarea over the long term time period (1973-74 through 2010-11) to determine the historical trend. Next, the linear interpolation was extrapolated from 2011-12 to 2030-31 to plot the future predictive trends without taking into consideration any additional projects, future implementation measures, or changes in hydrology. Along with the long term trend of the constituent concentration, lines representing 10 percent and 20 percent of the baseline average assimilative capacity and the IRRP trend line were plotted to compare the constituent concentration trends to the recommended acceptable usage of the available assimilative capacity for a single project (10 percent) and multiple projects (20 percent). The baseline period is from 2001-02 to 2010-11.

The results of the trend analyses indicate that nitrate concentration trends are gradually decreasing. Chloride, sulfate, and TDS concentrations are gradually increasing and are anticipated to remain significantly below the water quality objectives through the year 2030. The plots of the extrapolated trends for nitrate, chloride, sulfate, and TDS concentrations are shown on Plates IV.1a, IV.1b, IV.1c, and IV.1d, respectively.

As discussed in Section III.3.9, there is a considerable of degree of annual variation of water quality for each constituent. Salt concentrations vary with several different factors including the volume of groundwater in storage. Constituent concentrations are inversely related to volume of groundwater in storage; therefore, the volume of groundwater in storage has the potential to greatly impact constituent concentration trends. The frequency of sampling impacts at certain impaired wells also affects the mean of the constituent con-centration data set.

These predictive trends have limitations and are broad generalizations of the available data. Consequently, Watermaster will periodically update the data sets and trends for continued evaluation. As discussed in III.3.6, Watermaster is managing current implementation measures and has proposed potential implementation measures with the aim of continuing to manage and maintain the water quality in the San Gabriel Basin.

CHAPTER V

BASIN-WIDE SALT AND NUTRIENT MONITORING PLAN

V.1 BACKGROUND

Section 6.b.(3)(a) of the Recycled Water Policy states in past "Each salt and nutrient management plan shall include the following components:

a) A basin/sub-basin wide monitoring plan that includes an appropriate network of monitoring locations. The scale of the basin/sub-basin monitoring plan is dependent upon the site-specific conditions and shall be adequate to provide a reasonable, cost-effective means of determining whether the concentrations of salt, nutrients, and other constituents of concern as identified in the salt and nutrient plans are consistent with applicable water quality objectives. Salts, nutrients, and the constituents identified in paragraph 6(b)(1)(f) shall be monitored. The frequency of monitoring shall be determined in the salt/nutrient management plan and approved by the Regional Water Board pursuant to paragraph 6(b)(2).

   i. The monitoring plan must be designed to determine water quality in the basin. The plan must focus on basin water quality near water supply wells and areas proximate to large water recycling projects, particularly groundwater recharge projects. Also, monitoring locations shall, where appropriate, target groundwater and surface waters where groundwater has connectivity with adjacent surface waters.

   ii. The preferred approach to monitoring plan development is to collect samples from existing wells if feasible as long as the existing wells are located appropriately to determine water quality throughout the most critical areas of the basin.

   iii. The monitoring plan shall identify those stakeholders responsible for conducting, compiling, and reporting the monitoring data. The data shall be reported to the Regional Water Board at least every three years."

The Main San Gabriel Basin is a large groundwater aquifer with a surface area of approximately 167 square miles. The Basin contains approximately 8 million acre-feet of fresh water on average and supports annual groundwater production of about 240,000 acre-feet. Municipal water supply companies (purveyors) collectively have about 200 active, producing wells. The wells are required to be sampled on a regular basis pursuant to Title 22, Chapter 15 "Domestic Water Quality and Monitoring" (Title 22). As described in the section below, Watermaster staff have been given the responsibility to collect water quality samples to satisfy Title 22 requirements.

The Watermaster will be the primary stakeholder responsible for "…conducting, complying and reporting the monitoring data…" pursuit to Section 6.b(3)(a) of the Recycled Water Policy. Watermaster has implemented a program in conjunction with water purveyors in the Basin, to collect TDS and Nitrate samples from all active potable water supply wells every year. In addition, chloride and sulfate samples will be collected from all active potable water supply wells at least once every three years. This program ensures there is a complete annual record of "salts" and "nutrient" data so that a long-term trend can be established. As noted in Section III.3.9 the average concentrations for the most recent 10-year period are about 357 mg/l TDS, 22 mg/l Nitrate, 31 mg/L Chloride, and 53 mg/L Sulfate. Watermaster prepares a "Five-year Water Quality and Supply Plan" pursuant to Section 28 of Watermaster's Rules and Regulations. The Five-year Plan identifies existing and planned activities to enhance water quality through the Basin, including a summary of cleanup programs to remove contaminants from the Basin. Although these cleanup programs do not contribute or remove salts and nutrients, they are included as added information in the SNMP. Each of these existing programs will be incorporated in the Basin-wide Salt and Nutrient Management Plan, as described in this Chapter.

Watermaster also adopted the "Criteria for Delivery of Supplemental Water" (Criteria) by Resolution No.4-96-138 on April 3, 1996 (see Appendix R). The Criteria sets forth procedures the Watermaster follows to ensure the highest quality untreated imported water is replenished in the Basin. At any time, the highest quality of water is not available, the Criteria has established steps Watermaster follows to determine the impacts of delivering lesser quality water, including a potential option of not delivering untreated imported water until a time when the water quality improves and/or a different source becomes available.

This SNMP proposes to use Watermaster's existing Title 22 water quality monitoring program for groundwater and San Gabriel River water, with increased frequencies of monitoring for TDS and nitrate, to satisfy the monitoring plan requirement of the SNMP. Recycled water is monitored by LACSD and is subject to permit requirements established by the RWQCB. Imported water is monitored by MWD.

V.1.1 Title 22 Water Quality Monitoring Program

There are approximately 200 active and standby potable water supply wells and 50 active irrigation and industrial water wells in the Basin. The location of these wells is shown on Plate III.26. The most productive water supply area is around the central portion of the Basin, near the San Gabriel River. Water quality conditions vary throughout the Basin due to natural and human influences.

Watermaster coordinates the well water sampling program on behalf of all drinking water purveyors in the Basin. Watermaster samples their potable supply wells for the following chemical groups regulated by the California Safe Drinking Water Act (California Health and Safety Code) under the specific drinking water standards contained in the California Code of Regulations: radioactivity, VOCs, Synthetic Organic Chemicals (SOCs are primarily pesticides and herbicides) and inorganics.

Water samples are collected from potable supply wells and then analyzed for a variety of constituents by a State-certified testing laboratory to demonstrate compliance with the requirements of the California Code of Regulations, Title 22, Chapter 15, "Domestic Water Quality and Monitoring" (Title 22). The Title 22 water quality test results summarized in this report have been submitted to the DDW, as required by the following sections of Title 22:

- Sections 64431-64432, Primary Standards -Inorganic Chemicals;
- Section 64449, Secondary Drinking Water Standards;

- Section 64442, MCL and Monitoring-Gross Alpha Particle Activity, Radium-226, Radium-228 and Uranium;
- Sections 64444 to 64445 Organic Chemicals (SVOCs only); and
- Sections 64530 to 64537 Disinfectant Residuals, Disinfection Byproducts, and Disinfection Byproduct Precursors.

A State-certified laboratory, under contract to Watermaster, analyzes the samples and submits results to DDW and Watermaster electronically. Title 22 establishes testing requirements and the format for reporting laboratory results of public water systems' water quality analyses. The regulations require all certified drinking water analytical laboratories to submit water quality data directly to DDW in digital, electronic form. This submittal is referred to as Electronic Data Transfer (EDT). The laboratory provides Watermaster with the EDT electronic files, which are uploaded to Watermaster's water quality database. Watermaster coordinates with Producers to obtain general mineral and general physical water quality results.

Watermaster's Title 22 basin-wide monitoring program provides much of the source water data used to develop the Basin SNMP and is incorporated into a database maintained by Watermaster.

V.1.1.1 Participating Purveyors

Purveyors participating in the Title 22 water quality monitoring program are categorized according to the total number of service connections.

<u>Purveyors with 10,000 or More Service Connections:</u>

1. Alhambra, City of
2. Arcadia, City of
3. Azusa Light and Water
4. California American Water-San Marino
5. Glendora, City of
6. Golden State Water Company-San Dimas
7. Monterey Park, City of

8. San Gabriel Valley Water Company
9. Suburban Water Systems-San Jose
10. Suburban Water Systems-Whittier/La Mirada
11. Valley County Water District
12. Whittier, City of

Purveyors with 200 to 10,000 Service Connections:

1. Amarillo Mutual Water Company
2. California-American Water-Duarte
3. Covina, City of
4. East Pasadena Water Company
5. El Monte, City of
6. Golden State Water Company-South San Gabriel
7. Golden State Water Company -South Arcadia
8. Industry Public Utilities
9. La Puente Valley County Water District
10. Monrovia, City of
11. Rurban Homes Mutual Water Company
12. San Gabriel County Water District
13. South Pasadena, City of
14. Sunny Slope Water Company
15. Valencia Heights Water Company
16. Valley View Mutual Water Company

Purveyors with Less Than 200 Service Connections:

1. Adams Ranch Mutual Water Company
2. Champion Mutual Water Company
3. Del Rio Mutual Water Company
4. Hemlock Mutual Water Company
5. Sterling Mutual Water Company

Wholesalers:

1. California Domestic Water Company
2. Covina Irrigating Company

V.1.1.2 Title 22 Sampling Schedules

Title 22 source water monitoring frequencies are specified by DDW in "Vulnerability Assessment and Monitoring Frequency Guidelines", issued to Basin purveyors every three years. Watermaster develops schedules for source water sample collection according to the monitoring frequencies specified in the "Vulnerability Assessment and Monitoring Frequency Guidelines" and incorporates more frequent monitoring into the schedules when required by Title 22 drinking water regulations.

General Mineral (GM) and General Physical (GP) – Basin purveyors are responsible for source water compliance monitoring of GM/GP constituents, including TDS, chloride, sulfate and nitrate. Appendix S presents typical sampling schedules for each purveyor and each sampling location. The sampling schedule shows: 1) the type of analysis to be performed, 2) the current required frequency of sampling, 3) the date of the last test and 4) date of the next test.

Groundwater sources are required to be sampled at least once every three years for GM/GP constituents. Standby groundwater sources are sampled at least once every nine years. In accordance with DDW regulations, a standby source shall be used only for short-term emergencies of five consecutive days or less, and for less than a total of fifteen days a year.

TDS is one of the parameters included in general mineral analyses. Because approximately one-third of the Basin's active potable supply wells are required to be sampled each year for GM/GP constituents, it would take up to three years to gather TDS data for all of the wells. Since fiscal year 1997-98, Watermaster has conducted annual TDS sampling of all active potable supply wells and selected active non-potable wells in the Basin. In addition, sulfate and chloride sample results are collected every three years.

Producers sample their wells based on requirements and frequencies prescribed in Title 22 and enforced by DDW. Based on the water quality concentration, DDW may require additional sampling. In the event a constituent in a well exceeds an MCL, DDW may require treatment, a blend plan, or that the well ceases production.

Historically, there have been no issues throughout the Basin with chloride and sulfate concentrations in production wells whereby DDW has required increased monitoring beyond once every three years. Any production well which has a nitrate concentration between 50 percent and 100 percent of the MCL (or pumps to a liquid-phase granular activated carbon treatment facility) must be sampled on a quantity basis. DDW has also approved numerous nitrate treatment facilities and blend plans to mainstream production from wells with nitrate at or above the MCL of 45 mg/l. TDS is required by DDW to be sampled at least once every three years and Watermaster has implemented a program to collect samples at all wells every year. Similar to nitrate, DDW staff review water quality results and may require additional sampling based on the TDS concentrations. Historically production wells in the Main Basin have not required blending or treatment for TDS.

Inorganics - Groundwater sources are required to be sampled at least every three years for inorganic chemicals, except for nitrate, which is sampled at least annually. Approximately one-third of the groundwater sources are monitored for inorganic chemicals each year on a rotating basis. Standby groundwater sources are monitored at least once every nine years.

DDW requires quarterly or more frequent nitrate testing of operating wells when 1) a well is being treated or blended to reduce the nitrate level below the MCL, 2) the nitrate concentration in a well exceeds one-half the MCL, or 3) a well which supplies water to a Granular Activated Carbon treatment system. Watermaster schedules and collects quarterly nitrate samples at approximately 90 active wells in the Basin and annual nitrate samples at approximately another 110 active and standby wells. Annual samples are collected at all operating wells which do not meet the quarterly monitoring criteria. In an average quarter, approximately 120 nitrate samples in the Basin are collected by Watermaster.

Radioactivity - On December 7, 2000, USEPA promulgated the final revised drinking water standards for radionuclides, which became effective on December 8, 2003. The DDW adopted the federal standards. The radionuclide rule requires all community water systems to monitor gross alpha. Monitoring frequencies have been determined based on the results of the initial round of quarterly samples.

V.1.2 Criteria for Delivery of Supplemental Water

By Resolution No. 4-96-136 Watermaster adopted the "Criteria for Delivery of Supplemental Water" on April 3, 1996. A copy of the Criteria is included in Appendix R. Pursuant to provisions of the Main Basin Judgment, production in excess of Basin water rights must be replaced through the delivery of untreated imported water, which is referred to as Supplemental Water. The Supplemental Water Criteria provides a background of regulatory and institutional requirements which, must be considered when delivering Supplemental Water, with an emphasis on delivery of the highest quality water at all times.

V.1.3 Five-year Water Quality and Supply Plan

Watermaster prepares and annually updates this Five-Year Water Quality and Supply Plan (Five-Year Plan) in accordance with the requirements of Section 28 of its Rules and Regulations. The objective is to coordinate groundwater related activities so that both water supply and water quality in the Basin are protected and improved. Many important issues are detailed in the Five-Year Plan, including how Watermaster plans to:

1. Monitor groundwater supply and quality;
2. Develop projections of future groundwater supply and quality;
3. Ensure adequate supplemental water is available for groundwater replenishment;
4. Review and cooperate on cleanup projects, and provide technical assistance to other agencies;
5. Assure that pumping does not lead to future degradation of water quality in the Basin;
6. Address emerging contaminants in the Basin;
7. Develop a cleanup and water supply program consistent with the U.S. Environmental Protection Agency (USEPA) plans for its San Gabriel Basin Superfund sites; and

8. Continue to perform responsibilities under the Baldwin Park Operable Unit (BPOU) Project Agreement relating to project administration and performance evaluation.

The Los Angeles County Superior Court created the Main San Gabriel Basin Watermaster in 1973 to resolve water issues that had arisen among water users in the San Gabriel Valley. Watermaster's mission was to generally manage the water supply of the Main San Gabriel Groundwater Basin.

During the late 1970s and early 1980s, significant groundwater contamination was discovered in the Basin. The contamination was caused in part by past practices of local industries that had inappropriately disposed of industrial solvents, as well as by infiltration of nitrates from an earlier agricultural period. Cleanup efforts for industrial contamination were undertaken at the local, state, and federal levels.

By 1989, local water agencies adopted a joint resolution regarding water quality issues that stated that Watermaster should coordinate local activities aimed at preserving and restoring the quality of groundwater in the Basin. The joint resolution also called for a cleanup plan.

In 1991, the Los Angeles County Superior Court granted Watermaster the authority to control pumping for water quality purposes. Accordingly, Watermaster added Section 28 to its Rules and Regulations regarding water quality management. The new responsibilities included: developing the Five-Year Water Quality and Supply Plan, updating it annually, and submitting it to the LARWQCB, and making it available for public review by November 1 of each year. A copy of the Five-Year Water Quality and Supply Plan is included in Appendix T.

The Five-year Water Quality and Supply Plan includes projections of future groundwater production from each well in the Basin along with a tabular summary of VOC, Nitrate, and Perchlorate data. This information is included in the appendices to the Five-year water Quality and Supply Plan.

V.1.4 Basin-wide Water Quality Monitoring Program (BGWQMP)

The BGWQMP was developed in fiscal year 1994-95 by the Watermaster to gather supplemental water quality information in addition to data collected under the DDW Title 22 program. The BGWQMP includes annual water quality sampling for TDS for all potable supply wells in the Basin (DDW requires sampling once every three years). In addition, water quality data for TDS, Nitrate, and VOCs are collected from production wells that are not used for potable water supply. All water quality data is included in the Watermaster database.

V.2 Proposed Monitoring Plan

The Recycled Water Policy, Section 6.b(3)(a) requires a water quality monitoring plan to be developed. Specifically, section 6.b(3)(a)(ii) states "…the preferred approach to monitoring plan development is to collect samples from existing wells if feasible as long as the existing wells are located approximately to determine water quality throughout the most critical areas of the basin…"

The Watermaster is the Court appointed agency which manages both the quality and quantity of water supplies in the Main Basin. The Watermaster also coordinates the existing Title 22 Water validity Monitoring Program described in Section V1.1 of this SNMP. Consequently, Watermaster will serve as the responsible agency to oversee collection of water quality data. The location of production wells subject to Title 22 sampling is shown on Plate III.26. Water quality data will be submitted to DDW pursuant to Title 22 requirements and incorporated into Watermaster's database. As required by the Recycled Water Policy Section 6.b(3)(a)(iii) water quality data will be reported to the LAWRWQCB at least every three years.

Water quality ~~samples~~ sampling for TDS and nitrate will be conducted annually at all production wells, ~~and at least once every three years at all production,~~ and at least once every three years at all production wells for sulfate and chloride. An example of the sampling schedule is shown in Appendix S. The sampling schedule is update on a regular basis as data is received by Watermaster.

CHAPTER VI

SUMMARY AND RECOMMENDATIONS

VI.1 SUMMARY

The SWRCB approved Resolution No. 2009-0011 to adopt the Recycled Water Policy in February 2009. Included in that resolution is a requirement for a SNMP to be prepared for all groundwater basins. The Main San Gabriel Basin Watermaster is the lead agency for the preparation of the San Gabriel Basin SNMP. The primary stakeholders include Upper District, San Gabriel District, Three Valleys District, MWD, LACSD, and LACDPW.

The SNMP reviewed the geology, hydrology and hydrogeology of the San Gabriel Basin, along with the institutional and management structure for the San Gabriel Basin. TDS, Nitrate, Sulfate, and Chloride were identified as the primary constituents of concern. Sources of loading (precipitation, subsurface inflow, infiltration of applied water, storm runoff and untreated imported water replenishment) and unloading (groundwater pumping and subsurface outflow) were included in a spreadsheet computer model, along with average water quality data for TDS, Nitrate, Sulfate, and Chloride, on an annual basis.

In an effort to provide a conservative approach to the calculation of AC of the San Gabriel Basin and the impacts of a potential project, it was assumed 1) the volume of the San Gabriel Basin available for mixing was about 6,000,000 acre-feet (75 percent of the total volume of about 8,000,000 acre-feet); and 2) only the water quality objectives for the westerly portion of the San Gabriel Basin (450 mg/l) would be used in the calculation, but recognizing the water quality objective for the easterly portion of the San Gabriel Basin is 600 mg/l. The Upper District's proposed IRRP project, consisting of 10,000 acre-feet of recycled water recharge, was evaluated to determine the cumulative percentage of the assimilative capacity ~~AC~~ utilized before equilibrium is reached. The project is not anticipated to exceed 10 percent of the available AC of the San Gabriel Basin, although such a limitation is not mandated. After one year of recharge, the IRRP project would use about 0.3 percent of the assimilative capacity for TDS (as shown on the last column of Table III. 14.b), which would be the controlling constituent, and would reach equilibrium at approximately 7.2 percent assimilative capacity ~~AC~~ utilization for TDS. Nitrate, Sulfate and Chloride would each have less impact on their respective available assimilative capacities.

The SNMP acknowledges the historical practice of replenishing the San Gabriel Basin with significant amounts of stormwater runoff and supplemented with untreated imported water from the SWP, both of which have high quality water, particularly regarding TDS. –The SNMP identifies a variety of existing and potential activities including continued basin management practices, pursuit of potential new replenishment sites, water quality monitoring, and coordination between agencies which will help manage salts and nutrients in the San Gabriel Basin.

VI.2 RECOMMENDATIONS

The Main San Gabriel Watermaster manages the San Gabriel Basin, in cooperation with other stakeholders, and has successfully managed the salt and nutrient loading over the past 40 years. The Watermaster recognizes the SNMP is a tool by which salts and nutrients can continue to be managed into the future.

On-Going Activities

The following are recommendations for on-going salt and nutrient management in the San Gabriel Basin.

- Regularly update the SNMP spreadsheet data so that impacts of potential future projects on salt and nutrient loading may be evaluated.
- Continue to collect water quality data throughout the San Gabriel Basin.
- Continue to meet with stakeholders on a regular basis to coordinate San Gabriel Basin management activities with an emphasis on stormwater runoff replenishment and continued use of SWP water for groundwater replenishment

Potential Activities

The following are recommendations for potential activities for salt and nutrient management in the San Gabriel Basin.

- Develop new/expand existing groundwater replenishment facilities to increase stormwater replenishment capabilities.
- Encourage local planning efforts which result in reduced stormwater runoff and enhanced stormwater capture.

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