6 Salts and Nutrient Source Identification and Loading Estimates

6.1 CONCEPTUAL MODEL

Various sources contribute salts and nutrients to the basin. Sources include non-land use based flows (such as stream percolation, managed aquifer recharge) and land use based flows (such as agriculture, wastewater percolation). **Figure 6-1** provides a conceptual model of the salt and nutrient contributions to the LSCR basin. These concepts will be detailed in this section.

6.2 SUMMARY OF SALT AND NUTRIENT SOURCES

Table 6-1 summarizes the land use and non-land use sources evaluated in the development of the LSCR SNMP. Loading for the sources were derived from existing information and is described in this section. This loading information and assumptions were built into the fate and transport analysis described in **Section 7**.

Table 6-1 Summary of Salt and Nutrient Sources

Non-Land Use Based Inflows	Land Use Based Inflows
Percolation of stream flows	Irrigation
Managed aquifer recharge	Agricultural irrigation with surface water
Recharge of precipitation	Agricultural irrigation with groundwater
Mountain front recharge	Urban irrigation with municipal supply
Groundwater underflow from outside the LSCR basin	Urban irrigation with recycled water
Groundwater flow between subareas, with net flow from east to west	Septic systems
Groundwater flow between Upper Aquifer System and Lower Aquifer System	Wastewater treatment percolation ponds
Naturally occurring salts	

6.2.1 Non-Land Use Based Sources and Loadings

6.2.1.1 Percolation of Stream Flows

Percolation of stream flows are based on UWCD's Lower Santa Clara River Routing and Percolation model (McEachron, 2005). UWCD provided updated results for water years 1996-2012. The model results include estimates of percolation for the following stream reaches (**Figure 6-2**):

- SCR from Newhall to Torrey Road
- Piru Creek
- SCR from Torrey Road to Cavin Road
- Hopper Creek
- SCR from Cavin Road to Sespe Creek
- Sespe Creek
- Santa Paula Creek

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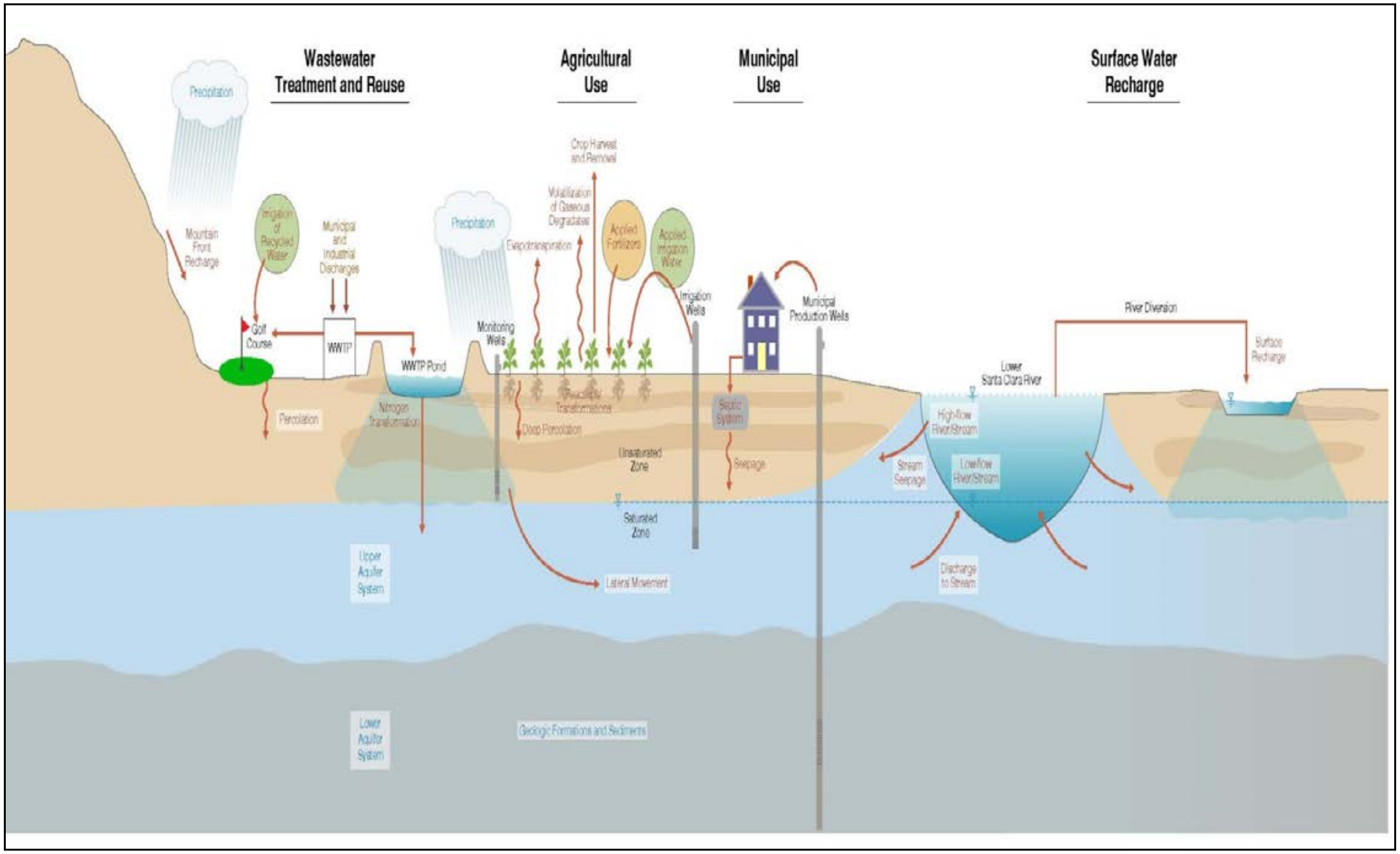

Figure 6-1 Conceptual Model of Salt and Nutrient Contributions

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The Routing and Percolation model does not provide results for percolation in Pole Creek so percolation was estimated based on Hopper Creek and the ratio of the watershed areas. The Pole Creek watershed area is approximately 39% of the Hopper Creek watershed area (VCWPD, 2006). The Routing and Percolation model also provides an estimate for discharge of rising groundwater to the SCR when it occurs between Torrey Road and Cavin Road. The discharge of rising groundwater to the SCR between Sespe Creek and Willard Road can be calculated from Sespe Creek flow data and Routing and Percolation model results for Sespe Creek percolation and flow in the SCR above Sespe Creek and at Willard Road. The discharge flows to the SCR are used as part of the water balance to calculate groundwater flows between subareas (**Subsection 6.2.1.7**) and between the UAS and LAS (**Subsection 6.2.1.8**).

There are significant losses in SCR flow between Willard Road and the Freeman Diversion. It is likely that some percolation occurs in the Santa Paula basin upstream of the Freeman Diversion, but it is difficult to estimate because of the diversions along this reach (McEachron, 2014). Therefore, no percolation in this reach is included as input. The Routing and Percolation model does not estimate percolation downstream of the Freeman Diversion in the Oxnard Forebay, but UWCD has provided estimates for this percolation for Water Years 1996-2012 (McEachron, 2014b).

Percolation from the stream reaches need to be distributed as inflows to subareas for inclusion in the mass balance model. In order to distribute these flows, reaches are divided into subareas based on reach length. Also, in cases where the reach defines the boundary between upgradient and downgradient subareas, flow from the reaches are distributed to the downgradient subarea. The proportional distribution of percolation from stream reaches to subareas is shown in **Table 6-2**.

Table 6-2 Proportional Distribution of Percolation from Reaches to Subareas

Percolation Reach	Lower Piru		Fillmore			Santa Paula
	East of Piru Creek	West of Piru Creek	Pole Creek Fan	South of SCR	Remaining	East of Peck Road
SCR Newhall to Torrey	89%	11%	0%	0%	0%	0%
Piru Creek	0%	100%	0%	0%	0%	0%
SCR Torrey to Cavin	0%	100%	0%	0%	0%	0%
Hopper Creek	0%	100%	0%	0%	0%	0%
SCR Cavin to Sespe	0%	14%	43%	43%	0%	0%
Sespe Creek	0%	0%	0%	0%	100%	0%
Santa Paula Creek	0%	0%	0%	0%	0%	100%
Pole Creek	0%	0%	100%	0%	0%	0%

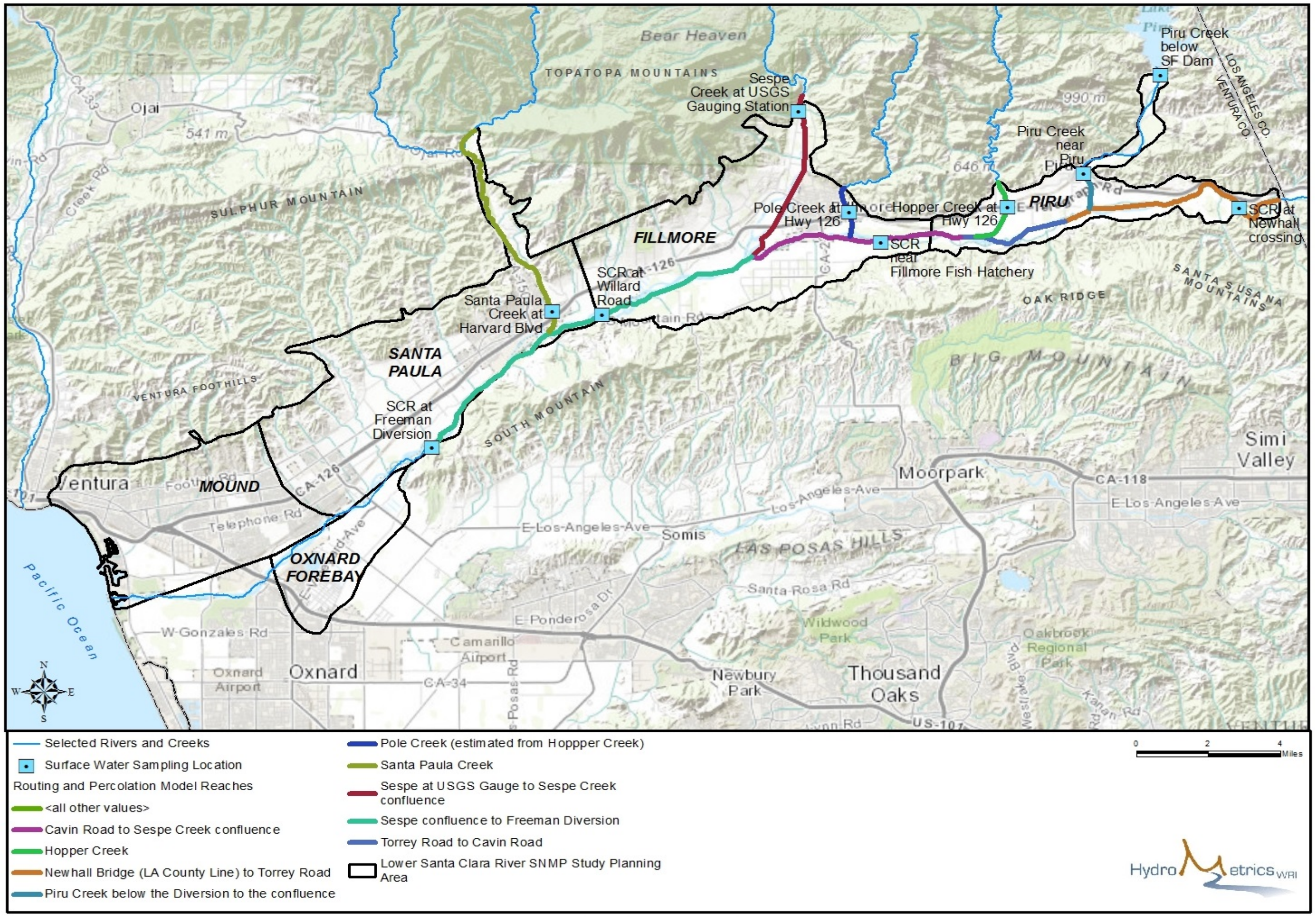

Figure 6-2 Lower Santa Clara River Routing and Percolation Model Reaches and Surface Water Quality Sampling

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Concentrations for the percolation inflows are based on available surface water quality data from 1996-2012. Median concentrations for each water year are used. For years without sampling results, concentrations are based on whether the water year was classified as wet, dry, or average. The average concentrations for years with the same classification were used in years without sampling results. The assignment of water years (1996-2012) as wet, dry, and average was based on precipitation at the Fillmore Fish Hatchery (**Figure 6-3**).

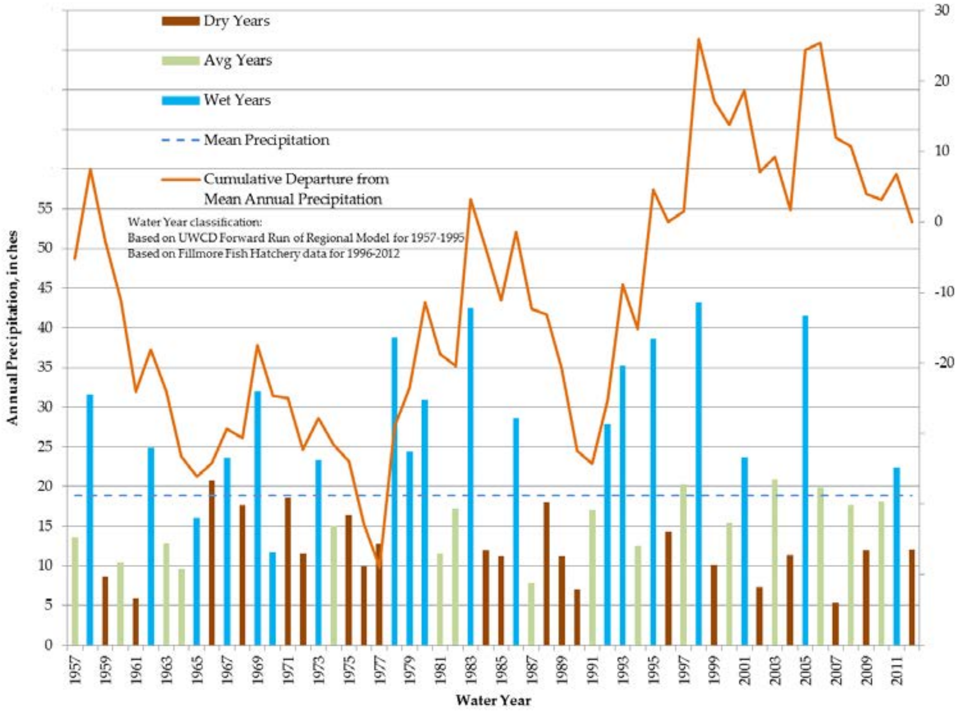

Figure 6-3 Water Year Classification Used for Regional Groundwater Model and Mass Balance Model

Table 6-3 shows the assignment of surface water quality sampling locations (**Figure 6-2**) to each percolation reach along with the range of concentrations for 1996-2012. The water quality for SCR reach from Torrey Road to Cavin Road is calculated based on concentrations from Piru Creek near Piru and the SCR at Newhall. The weighted average concentration is based on percentage of SCR at Torrey Road stream flow coming from Piru Creek (53% in 2011 and 90% in 2012). Concentrations from the Piru Creek near Piru station are used for this reach and the Piru Creek reach instead of concentrations just below Santa Felicia Dam because loading from percolation is the largest loading in the Piru Basin. Groundwater concentrations in the Piru Basin indicate that surface water concentrations are higher than what is measured just below Santa Felicia Dam. Concentrations in percolation into each subarea (**Table 6-4**) are based on the distribution in **Table 6-3**.

Table 6-3 Assignment of Surface Water Quality Sampling Locations to Percolation Reaches

Percolation Reach	Surface Water Quality Sampling Location
Santa Clara River Newhall to Torrey Rd.	Santa Clara River Newhall
Piru Creek	Piru Creek near Piru
SCR Torrey to Cavin	Calculated for SCR downstream of Piru Creek
Hopper Creek	Hopper Creek
SCR Cavin Rd to Sespe Creek	SCR at Fillmore Fish Hatchery
Sespe Creek	Sespe Creek
Santa Paula Creek	Santa Paula Creek
Pole Creek	Pole Creek
Oxnard Forebay	SCR at Freeman Diversion

Table 6-4 Average Concentrations of Stream Percolation to Subareas by Water Year Classification (1996-2012)

Subarea	1996-2012 Concentrations (mg/L)		
	TDS Wet-Avg-Dry	Chloride Wet-Avg-Dry	Nitrate as N Wet-Avg-Dry
Lower Piru East of Piru Creek	938-925-942	105-123-126	2.1-2.4-2.1
Lower Piru West of Piru Creek	851-914-897	57-72-71	1.1-1.1-1.0
Fillmore Pole Creek Fan	886-957-952	53-59-57	2.4-2.4-2.4
Fillmore South of Santa Clara River	886-7	53-59-57	2.4-2.4-2.4
Fillmore Remaining	620-651-638	52-45-59	0.1-0.1-0.4
Santa Paula East of Peck Road	428-598-709	14-29-38	0.4-1.2-1.0
Oxnard Forebay	969-1129-1183	51-63-66	1.1-1.4-1.2

6.2.1.2 Managed Aquifer Recharge

UWCD's records for diversions to the Piru Spreading Grounds and from the Freeman Diversion to the Saticoy, El Rio, and Noble recharge basin are used for inflows to the mass balance spreadsheet. Diversions from Piru Creek to the Piru Spreading Grounds occurred from 1996-2008 before the Piru Diversion was taken out of use. This inflow is applied to the Upper Piru subarea. Managed aquifer recharge from the Freeman Diversion on the SCR occurs in the Oxnard Forebay subarea.

Surface water quality for each year is based on 1996-2012 median results with years missing data using the averages for wet, dry, and average years in the same manner as stream percolation concentrations (**Table 6-5**). Managed aquifer recharge in the Upper Piru subarea is based on surface water quality sampled in Piru Creek below Piru Dam. Managed aquifer recharge in the Oxnard Forebay is based on surface water quality sampled in the SCR at the Freeman Diversion.

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Table 6-5 Average Concentrations for Managed Aquifer Recharge to Subareas (1996-2012)

Subarea	Surface Water Quality Sampling Location	1996-2012 Concentrations (mg/L)		
		TDS Wet-Avg-Dry	Chloride Wet-Avg-Dry	Nitrate as N Wet-Avg-Dry
Upper Piru	Piru Creek below Dam	603-640-618	40-47-47	0.4-0.4-0.9
Oxnard Forebay	Santa Clara River at Freeman Diversion	969-1,130-1,183	51-63-66	1.1-1.2-1.4

6.2.1.3 Recharge of Precipitation

Recharge inflows from precipitation are based on input to the Forward run of the regional groundwater model updated in 2006 (HydroMetrics LLC, 2006). The regional groundwater model covers Las Posas Basins, Pleasant Valley, and Oxnard Plain in addition to the LSCR. The Forward run is based on climatic conditions throughout the region from 1944 to 1998 with each year classified as wet, dry, or average. The average recharge from precipitation is calculated for each subarea by climatic classification. The average wet, dry, and average recharge from precipitation is applied to the classification of water years 1996-2012 based on rainfall at the Fillmore Fish Hatchery as shown in **Figure 6-3**.

The concentration of TDS precipitation recharge is assigned 10 mg/L based on the State Water Board Groundwater Ambient Monitoring and Assessment (GAMA) Program's groundwater information sheet on salinity (SWRCB, 2010).

The concentration of chloride and nitrate precipitation recharge is based on data from the National Atmospheric Deposition Program. Data from Chuchupate (CA 98, NADP, 2014a) in Ventura County are only available 1983-1995, but correlations with data from Tarbank Flat (CA 42, NADP, 2014b) in Ventura County allow for extrapolation of the Chuchupate data to 1996-2012. Average concentrations for chloride and nitrate and N for the extrapolated period were approximately 0.1 mg/L so that is the value used for calculating loading.

6.2.1.4 Mountain Front Recharge

Inflows representing mountain front recharge are based on output of the Forward run of the regional groundwater model updated in 2006 (HydroMetrics LLC, 2006). Mountain front recharge is represented in the groundwater model as injection wells along the model boundary. The USGS program ZONEBUDGET was used to extract flows from the model results for 1944-1998 and average flows for the wet, dry, and average years as defined for the Forward run of the regional groundwater model were calculated. The average wet, dry, and average mountain front recharge is applied to water years 1996-2012 based on the classification shown in **Figure 6-3**. These flows were adjusted to improve fit of calculated subarea concentrations with existing water quality.

There are no available data or references for the water quality of mountain front recharge. The mountain front recharge inflows were assigned concentrations equaling precipitation.

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6.2.1.5 Groundwater Underflow from Basins Outside Lower Santa Clara River area: Upper Santa Clara River Basin

Inflows representing underflow from the SCR East sub-basin to the lower Piru subarea east of Piru Creek are based on output of the Forward run of the regional groundwater model updated in 2006 (HydroMetrics LLC, 2006). Flow from the Upper SCR basin into the lower Piru subarea east of Piru Creek is represented in the groundwater model as injection wells along the model boundary. The USGS program ZONEBUDGET was used to extract flows from the model results for 1944 to 1998 and average flows for the wet, dry, and average years as defined for the Forward run of the regional groundwater model were calculated. The average wet, dry, and average underflow from the SCR East sub-basin is applied to water years 1996-2012 based on the classification shown in **Figure 6-3**.

In the absence of groundwater concentration data at this boundary surface water concentrations used to define existing water quality near the boundary (**Subsection 4.4.1**), are used as concentrations of this inflow. The TDS concentration assigned to this inflow is 970 mg/L (**Figure 4-8**). The chloride concentration assigned to this inflow is 121 mg/L (**Figure 4-7**). Nitrate concentrations were assigned the average groundwater in lower Piru subarea east of Piru Creek.

6.2.1.6 Groundwater Underflow from Basins Outside Lower Santa Clara River area: Oxnard Plain and Offshore

Inflows representing underflow from the Oxnard Plain basin and offshore to the Mound basin are adjusted to balance inflows and outflows in each subarea supplemented by output of the Forward run of the regional groundwater model updated in 2006 (HydroMetrics LLC, 2006). Total groundwater outflow from a subarea is calculated so that total outflows equal inflows. The total outflow is distributed to other subareas and basins outside the study area based on the distribution in the Forward run results. The distributed outflows to other subareas are used as inflows to those downgradient subareas. UWCD considers inter-basin flows to be a weakness in the regional groundwater model and is developing a new model, but the existing regional model is currently the best available tool for estimating flows between basins. Flows from the outside the LSCR area into the Mound basin are represented in the groundwater model as calculated flows between model cells. The USGS program ZONEBUDGET was used to extract flows at the boundaries of the Mound and offshore from the model results. Average flows for the wet, dry, and average years as defined for the Forward run of the regional groundwater model were calculated. For years with net inflow into the Mound basin from the Oxnard Plain and offshore, the net inflow is applied based on the classification of water years 1996-2012 based as shown in **Figure 6-3**.

Water quality for inflow from the Oxnard Plain is based on the average of median concentrations of TDS, chloride, and nitrate at the City of Ventura golf course wells 5 and 6 for water years 1996-2012. Water quality for inflow from offshore is based on the median concentration for water years 1996-2012 for the deepest completion at the Marina coastal well, which has higher concentrations than the medium completion (**Table 6-6**). The shallow completion was not used in the assimilative capacity analysis because it is in a perched aquifer. The concentrations observed in the deepest completion at the Marina coastal well do not indicate any seawater intrusion occurring in the Mound.

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Table 6-6 Concentrations Used for Inflow from Outside Lower Santa Clara River Area into Mound Subarea

Inflow From	TDS (mg/L)	Chloride (mg/L)	Nitrate as N (mg/L)
Oxnard Plain	1,174	57	12
Offshore	1,285	85	0.4

6.2.1.7 Groundwater Flow Between Subareas

Inflows from each upgradient subarea are adjusted to balance inflows and outflows in each subarea supplemented by output of the Forward run of the regional groundwater model updated in 2006 (HydroMetrics LLC, 2006). Total groundwater outflow from a subarea is calculated so that total outflows equal inflows. The total outflow is distributed to other subareas and basins outside the study area based on the distribution in the Forward run results. The distributed outflows to other subareas are used as inflows to those downgradient subareas. UWCD considers inter-basin flows to be a weakness in the regional groundwater model and is developing a new model, but the existing regional model is currently the best available tool as guidance for estimating flows between basins. Flows between subareas are represented in the groundwater model as calculated flows between model cells. The USGS program ZONEBUDGET was used to extract flows at the boundaries between subareas from the model results. Average flows for the wet, dry, and average years were calculated. The distribution of flows between subareas is applied based on the classification of water years 1996-2012 as shown in **Figure 6-3**.

The concentrations used for these inflows are based on the calculated concentrations for the upgradient subarea from the previous year.

A specific area of controversy with using output of the regional groundwater model to estimate flows between subareas is the distribution of flows into the Mound basin. The regional groundwater model simulates the main inflow into the Mound basin as groundwater flow from the Oxnard Forebay basin. The City of Ventura has concluded that primary inflow is from the Santa Paula basin based on degraded water quality in the Mound basin and east to west flow of groundwater that parallels the basin axis (Hopkins, 2014). The implications of this alternative distribution of flow are discussed along with the results of the mass balance model for the Mound basin.

6.2.1.8 Groundwater Flow Between Upper Aquifer System and Lower Aquifer System

Vertical flows between the UAS and LAS are adjusted as part of the balance of inflows and outflows discussed above in **Subsection 6.2.1.7**. As discussed in **Section 7**, subarea concentrations are modeled based on the volume of the UAS for each subarea. The inflows equal the outflows for the UAS in each subarea in a water balance that includes the inflows from or outflows to the LAS. The direction of flow is based on output of the Forward run of the regional groundwater model updated in 2006 (HydroMetrics LLC, 2006). The magnitude of flow is based on the proportion of the vertical flow relative to horizontal flows between subareas (**Subsection 6.2.1.7)** in the output of the Forward run.

The concentrations used for inflows into the UAS from the LAS are the calculated concentration in the LAS from the previous year.

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6.2.1.9 Naturally Occurring Salts

As noted in **Section 4**, in some localized areas, higher TDS and chloride concentrations were observed that are likely naturally occurring. In the Fillmore basin-south side of the Santa Clara River subarea, high chloride concentrations are found along the southern boundary of the subarea Here concentrations are in excess of 190 mg/L. Because only the southern portion of the subarea has elevated chloride despite similar land use across the subarea, connate water that was trapped during deposition of the basin's sediments is its most likely cause.

A similar situation exists in the Santa Paula basin-west of Peck Road subarea and Oxnard Forebay basin. There is an area of elevated TDS in the northern portion of the Oxnard Forebay basin, north and west of the Saticoy recharge basins, extending across the basin boundary slightly into the west of Peck Road subarea of the Santa Paula basin. The cause of this area of elevated TDS concentrations appears to be connate water confined by the north trace of the Oak Ridge fault and beyond the influence of recharge activities by UWCD.

Finally, connate water trapped in marine sediments has been suggested as the source of higher chloride and TDS concentrations found in the Mound basin (Geotechnical Consultants, 1972).

While loadings from connate water are not included in the mass balance analysis discussed in **Section 7**, the mass balance spreadsheet model sets initial concentrations based on existing concentrations for each subarea. Therefore, historical loadings from connate water are reflected in the modeled initial conditions. It is assumed that on-going loadings are not significant at the time scale of the analysis.

6.2.2 Land Use Based Sources and Loadings

6.2.2.1 Irrigation

Irrigation contributes salts and nutrients in agricultural and urban areas in the following ways:

- Urban landscape irrigation with potable or recycled water – Infiltration contributes to transport to groundwater. Runoff is collected in stormwater collection systems, and discharged to surface waters that may recharge groundwater basins.
- Agricultural irrigation with untreated groundwater or surface water – Infiltration contributes to transport to groundwater. Runoff is conveyed to surface water discharges.

Agricultural and urban landscape irrigation volumes were estimated based on land and crop use data. Irrigation rates were adapted from Ventura County (2009). Land use based irrigation volumes were checked and adjusted based on well data and may be further modified based on agricultural and production well data.

Ventura County 2012 Crop Layer was used to estimated crop type and acreages. Some crops were aggregated into more general categories for the purpose of applying irrigation and fertilization rates.

Ventura County General Plan Land Use data were used to estimate urban area boundaries. DWR (2000) Land Use data were used to estimate cemeteries and golf courses. The acreages of these uses were assumed to be the same as in 2000. Other irrigated areas within urban boundaries were estimated based on USGS estimates of pervious surfaces and an approximate percentage of the

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pervious surfaces that would be subject to irrigation. This percentage was adjusted based on the production well volumes.

6.2.2.1.1 Source Water Quality

The source water quality for agricultural irrigation was revised to be consistent with water quality used for non-land use based inflows. Source water quality for surface water is made equivalent to concentrations calculated for percolation and managed recharge in the subarea (**Table 6-4** and **Table 6-5**). Source water quality for groundwater is made equivalent to concentrations calculated for the subarea mixing cell the previous year.

6.2.2.1.2 Groundwater Irrigation Consistent with Pumping Records

Groundwater irrigation volumes were made consistent with pumping records by using the higher value for any subarea, except where there is a known transfer of water between subareas. There is a known transfer of groundwater pumped in the Lower Piru subarea west of Piru Creek to the Lower Piru subarea east of Piru Creek and of groundwater pumped in the Santa Paula subarea west of Peck Road to the Santa Paula subarea east of Peck Road.

Applied water quality of groundwater irrigated in the subareas receiving a transfer of groundwater is based on the groundwater concentrations calculated for the UAS of the source subareas and the proportions shown in **Table 6-7**. Using water quality of groundwater in the UAS for application of groundwater is conservative because it results in greater accumulation of salts and nutrients calculated for the UAS, which will be used in the fate and transport analysis to evaluate the effect of loadings on water quality of the subarea (**Subsection 7.1.1**)

The groundwater pumping values were applied as outflows for the UAS in the subarea to be consistent with using water quality from the UAS for application groundwater quality. Groundwater production is used as part of the water balance to calculate groundwater flows between subareas (**Subsection 6.2.1.7**) and between the UAS and LAS (**Subsection 6.2.1.8**).

Table 6-7 Proportion of Applied Irrigation Water Source for Subareas Receiving Groundwater Transfer

	Lower Piru East of Piru Creek	Lower Piru West of Piru Creek	Santa Paula East of Peck Road	Santa Paula West of Peck Road
Lower Piru East of Piru Creek	53%	47%		
Santa Paula East of Peck Road			32%	68%

6.2.2.1.3 Infiltration of Applied Irrigation

Only a fraction of applied irrigation volumes return to groundwater, as water is lost to evapotranspiration from plants. This return fraction is the inverse of irrigation efficiency. Irrigation efficiency of 70% is used for agricultural irrigation and application of recycled water, the same value used in development of the regional groundwater model (Hanson et al., 2003). More recent estimates of irrigation efficiency have not been developed for Ventura County, although distribution uniformity has been estimated as 80% (ITRC, 2010). Distribution uniformity can be considered an upper limit on overall irrigation efficiency so it is consistent

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with using 70% for irrigation efficiency. For 70% irrigation efficiency, 30% of applied water infiltrates.

The percentage of municipal irrigation that infiltrates was adjusted downward to 50% to better match model results with existing groundwater concentrations, particularly in the Mound basin.

The concentration of salts in the infiltration of applied water is complex. While water is lost to evapotranspiration, salt mass can be conserved resulting in higher concentrations in infiltrating water than applied water. For this analysis, it is assumed that all salt mass is conserved from application to infiltration. Based on this analysis, concentrations are 233% greater in infiltration than application for the irrigation efficiency of 70% used for agricultural irrigation and recycled water application. Concentrations will be 100% greater in infiltration than application for the irrigation efficiency of 50% used for municipal irrigation. However, there exists the potential that salt mass will not be entirely conserved as salts may be removed by plant uptake or other attenuation processes which would reduce the load to groundwater.

For nitrates, the calculation assumes that nitrates in source water are taken up by plants along with fertilizer. This assumption only applies to nitrates from the source water.

6.2.2.2 Fertilizer Application

Fertilizer application on urban, residential and agricultural areas contributes nitrate loads (after transformations and losses) in the following ways:

- Fertilization in urban areas – Loads from fertilizers are transported with water from irrigation or precipitation.
- Fertilization in agricultural areas – Loads from fertilizers are transported with water from irrigation or precipitation.

Fertilizer application was assumed for crops and landscaped areas (lawns, parks, golf courses, cemeteries). Fertilizer was assumed to only contribute nitrate to the groundwater. Application rates, as well as losses to harvest and atmosphere were estimated using the rates in UC Davis (2012).

The calculation for the load of nitrate to groundwater in UC Davis (2012):

NGW = NDEPOSIT + NIRRIG + NAPPLIED - NHARVEST - NLOSS - NRUNOFF

N GW = N loading to groundwater

Assumptions:

NDEPOSIT = Atmospheric deposition

NRUNOFF = Runoff from fields

N IRRIG = N in irrigation water

N APPLIED = N applied

N HARVEST = Amount taken up by crop and removed in harvest

N LOSS = Losses to atmosphere, gaseous emission

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6.2.2.3 Septic Systems

Salt and nutrient loads from septic systems are transported to the basin though outflows or leaky septic tanks are transported directly into the groundwater through infiltration.

The number of septic systems (outside sewered areas) was based on data from Ventura County. Loading rates and flows were based on the assumptions of 2.82 persons/dwelling unit.

Wastewater reclamation facility effluent concentrations were assumed for the concentrations of septic systems.

6.2.2.4 Wastewater Treatment Percolation Ponds

Salt and nutrient loads from wastewater treatment plants are transported to the basin through the discharge of treated effluent into infiltration ponds. Loads from WWTPs were estimated based on effluent flow rates and average concentrations.

The locations of WWTP percolation ponds are shown on the maps in **Section 4**. The Saticoy WWTP is located near the boundary between the Santa Paula basin and the Oxnard Forebay basin, but within the Santa Paula basin as defined for the water quality objectives used in this plan (**Figure 4-15** through **Figure 4-20**). However, the discharge permit for the Saticoy WWTP identifies receiving basin as the Oxnard Forebay basin. In addition to being consistent with the permit, loads from the Saticoy WWTP are assigned to the Oxnard Forebay basin because they are more likely to affect average water quality in the Oxnard Forebay basin due to the ponds' location just upgradient of that basin

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