TABLE 3.1-4

Historical Mean Flows and Concentrations for Water Quality Parameters in the IID Water Service Area

Parameter	Historical WQ Data (1970-1999)							Fresh Water Quality Criteria[4]
	Colorado River Irrigation Delivery	New River			Alamo River			
	AAC	International Boundary	Surface Drains [2]	Outlet to Salton Sea	International Boundary	Surface Drains [2]	Outlet to Salton Sea	
Daily mean flow (cfs)	3,934	250	—	622	—	—	843	NA
Instantaneous flow (cfs)	—	193	—	—	2	—	—	NA
TDS (mg/L)	771	3,894	2,116	2,997	3,191	2,375	2,458	4,000
TSS (mg/L)	86	117	193	313	360	318	479	200 or NA [5]
Se (µg/L)	2.5	3.0	7.4	3.9	5.9	7.9	7.7	5.0
NO3 (mg/L)	0.28	0.84	7.49	4.37	1.87	8.14	7.81	NA
Total phosphorus (mg/L)	0.05	1.42	0.78	0.81	0.47	0.84	0.63	NA
Total P in sediment (mg/kg)	—	535	1,300	1,600	—	—	1,100	NA
DDT (µg/L)	0.001	0.088	0.013	0.016	0.011	0.020	0.016	1.1/0.001
DDT in sediment (µg/kg)	—	0.1	2.6	11.0	0.1	14.6	0.1	NA
DDD (µg/L)	0.001	0.046	0.010	0.017	0.011	0.017	0.011	0.00083
DDD in sediment (µg/kg)	—	—	5.4	—	—	6.3	—	NA
DDE (µg/L)	—	—	—	—	—	—	—	0.00059
DDE in sediment (µg/kg)	—	9.8	44.1	9.8	18.0	15.7	30.0	NA
Toxaphene (µg/L)	0.001	0.272	0.946	0.013	0.100	0.995	0.014	0.73/0.0002
Toxaphene in sediment (µg/kg)	—	10.0	9.5	18.3	5.0	26.6	2.5	NA
Diazinon (µg/L)	—	—	0.025	—	—	—	0.025	0.025
Chlorpyrifos (µg/L)	—	—	0.025	—	—	—	0.025	0.041
Dacthal (µg/L)	0.007	—	—	—	—	—	—	NA
Boron (µg/L)	170	1,600	804	1,172	1,798	683	695	5,000

[1]Includes the Greeson Drain and the Trifolium 12 Drain.

[2]Includes the Holtville Main Drain and the South Central Drain.

[3]Multiple significance criteria may apply (i.e., Aquatic Life criteria for chronic and acute exposure, or Human Health Criteria for consumption of fish (see Significance Criteria in Section 3.1.4.2). NA indicates

[4]Multiple significance criteria may apply (i.e., Aquatic Life criteria for chronic and acute exposure, or Human Health Criteria for consumption of fish (see Significance Criteria in Section 3.1.4.2). NA indicates no significance criteria available.

[5]200 mg/L based on proposed Phase 4 TMDL criteria for the Alamo River (see Significance Criteria in Section 3.1.4.2). TSS TMDLs are not yet available for the New River or IID surface drains.

— = Data Not Available.

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- It should be noted that the water quality data shown in the following figures do not include water quality values for the entire list of COCs. Rather, the graphs only show concentration trends for TDS, selenium, and TSS. The graphs are limited to TDS, selenium, and TSS because the sample population base for the organophosphorus insecticides and organochlorine insecticides and herbicides is not large enough to show trends in the data, analytical data indicate that boron does not exceed state or federal water quality standards, and water quality standards are not available for nitrogen and phosphorous (see Section 3.1.4.2).

IID Irrigation Delivery Water. With the exception of rainfall and minor contributions from groundwater sources, surface water that is diverted from the Colorado River is the only water available to IID for agricultural use.

AAC: Other than concentration by evaporation, TDS concentrations in water entering the IID water service area through the AAC change little between the input at the Imperial Dam and the outlet of the AAC to the IID water service area (EPA STORET database).

Annual average TDS concentrations in Colorado River delivery water to IID for the period 1973 to 1998 are shown on the graph presented in Figure 3.1-18.

Alamo River Drainage Basin. This section provides a summary of the water quality in the Alamo River drainage basin and includes water quality data for the Alamo River at the International Boundary, the Alamo River surface drains (including the South Central Drain and the Holtville Main Drain), and the outlet of the Alamo River to the Salton Sea (see Figure 3.1-19).

Alamo River at the International Boundary: Except for approximately 2 KAF of inflow across the International Boundary, virtually all of the flow in the Alamo River originates as discharge from the IID water service area. Water quality data collected at the International Boundary is included to provide historical data at this location. The historical (1970 to 1999) data set indicates that concentrations of selenium, boron, and TDS were significantly higher at this site than in IID irrigation delivery water. In addition to selenium, boron, and TDS, the mean and range of concentrations for nitrate as nitrogen, phosphorus, DDT, DDD, and toxaphene were also higher than the concentrations in irrigation delivery water. Concentration values for DDE, Dacthal, chloropyrifos, and diazinon in irrigation delivery water were unavailable for comparison with values observed in the Alamo River at the International Border (see Table 3.1-4).

IID Surface Drain Discharge to the Alamo River: Water quality data for COC concentrations in irrigation discharge from the Alamo River surface drains show concentration values for selenium, boron, and TDS that were higher than the concentrations in irrigation delivery water (see Table 3.1-4). In addition, the mean selenium concentrations for the surface drains are above state and federal water quality standards of 5 µg/L (see Section 3.1.4.2—Significance Criteria).

Alamo River at the Outlet to the Salton Sea. Concentration values for the COCs in Alamo River water at the outlet to the Salton Sea (see Figure 3.1-20) show that selenium concentration values are above the significance criteria of 5 µg/L established by the Basin Plan. However, TDS concentrations at the outlet to the Salton Sea fall below both the historical concentration

Note:
TDS concentration data collected in the Colorado River below Imperial Dam

Figure 3.1-18
Annual Average TDS Concentrations in Colorado River Water Delivered to IID (1973-1998)
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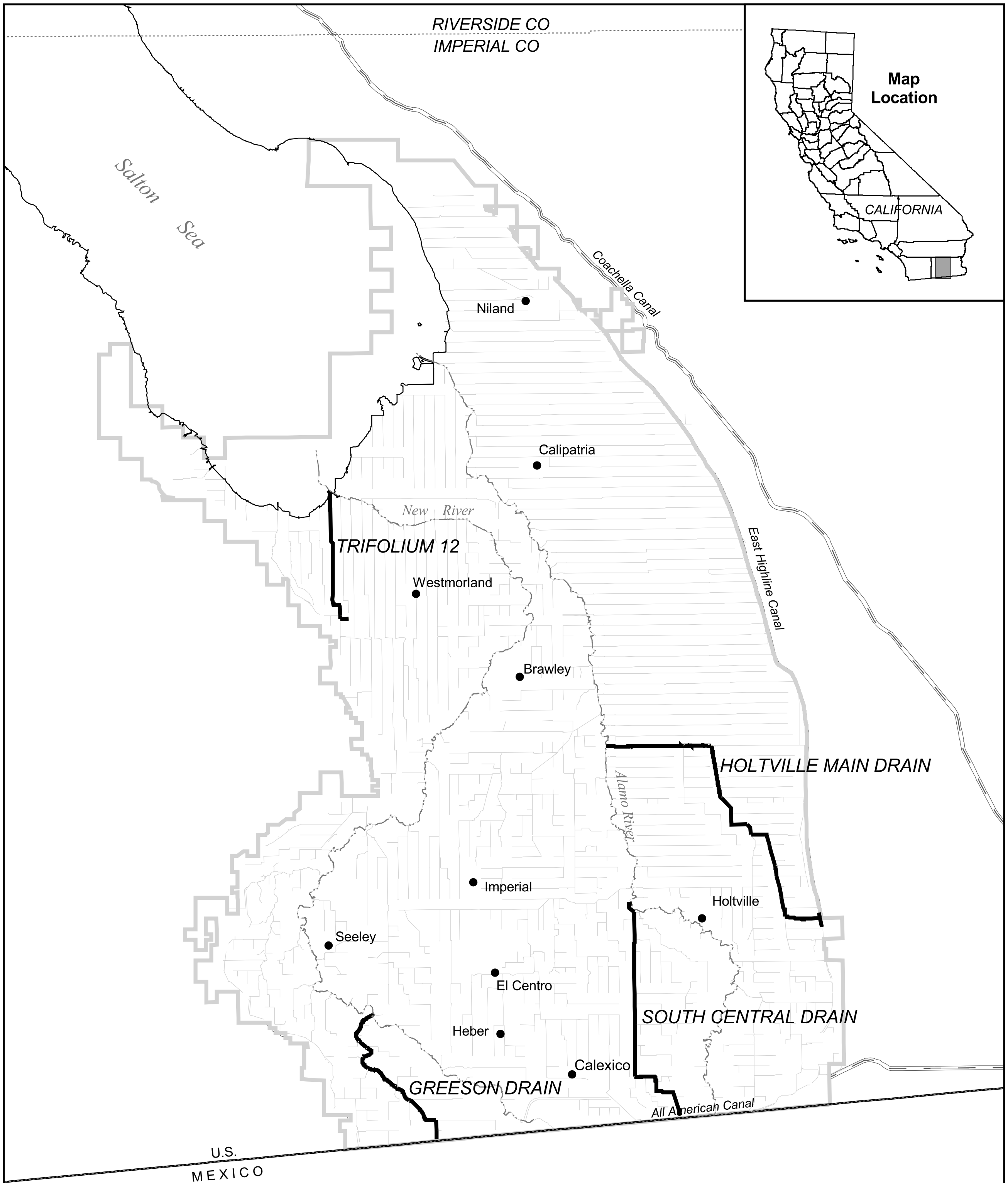

DRAINS
AQUEDUCT/CANAL
COUNTY LINE
INTERNATIONAL BORDER
RIVER
IID WATER SERVICE AREA
CITIES

N

Sources:
University of Redlands, 1999; DOI, 1999; Reclamation, 1999

5 0 5 Miles
SCALE IS APPROXIMATE

Figure 3.1-19
Locations of the South Central, Holtville Main, Greeson, and Trifolium 12 Drains in IID
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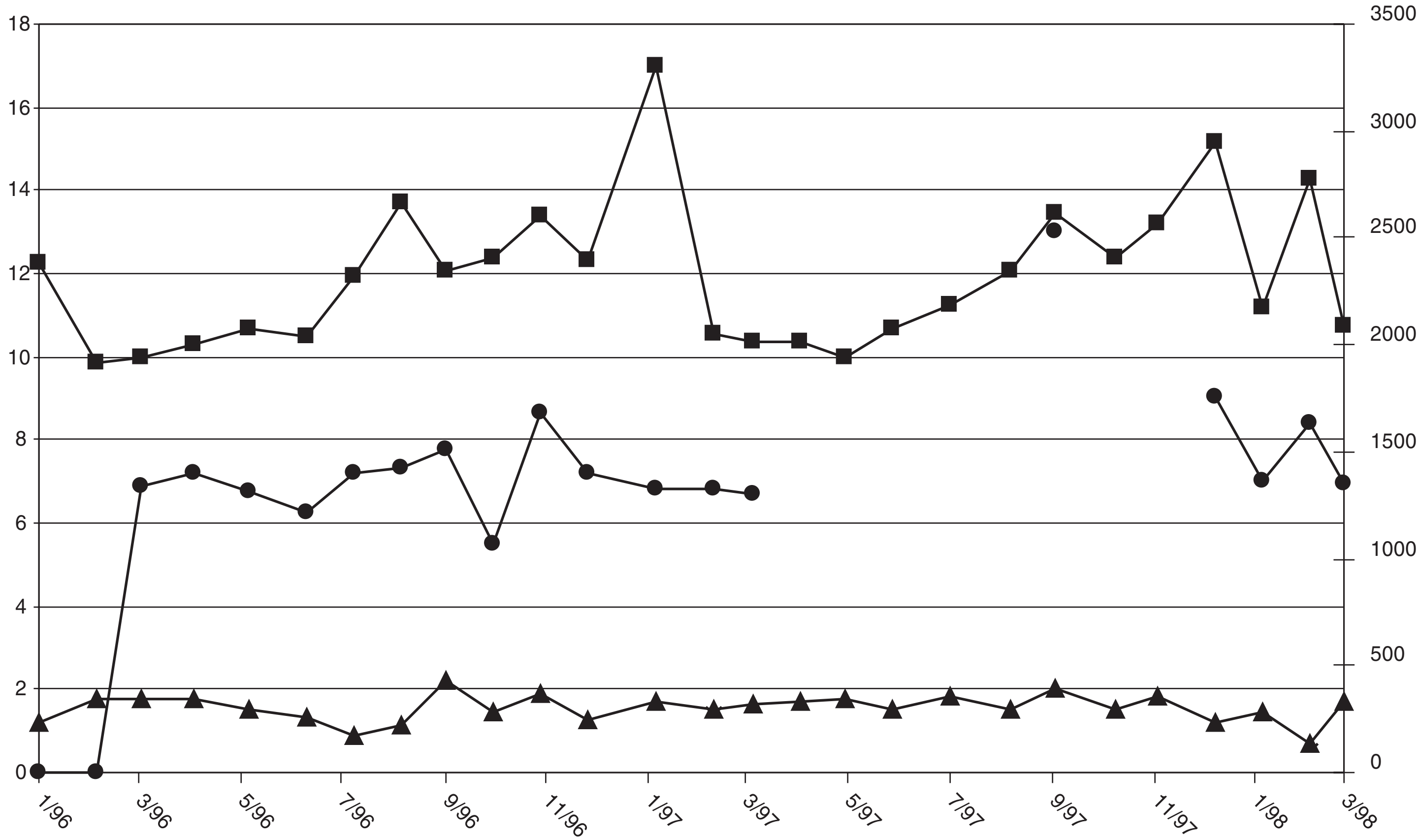

LEGEND (Left Scale)

Selenium µg/L

LEGEND (Right Scale)

Total Dissolved Solids mg/L

Total Suspended Solids mg/L

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Note:
"0" indicates concentration was below detection limits.

Figure 3.1-20
COC Concentrations in the Alamo River at the Outlet to the Salton Sea
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in the Alamo River at the International Boundary and the significance criteria of 4,000 mg/L established by the Basin Plan.

TDS values at the outlet to the Salton Sea are substantially similar to the TDS values detected in historical samples collected from IID surface drains.

New River Drainage Basin. This section provides a summary of the water quality in the New River drainage basin and includes water quality data for the New River at the International Boundary, the New River surface drains (including the Greeson Drain, the Trifolium 12 Drain), and the outlet of the New River to the Salton Sea.

New River at the International Boundary: The New River also enters the IID water service area from Mexico but, unlike the Alamo, the New River serves as an open conduit for untreated municipal sewage, heavy metals, and agricultural drainage waters high in pesticide residues from northern Mexico. Phosphorus has elevated concentrations relative to water in the New River drains or at the New River outlet to the Salton Sea. The historical water quality data also show that both boron and TDS values were significantly elevated in comparison to AAC irrigation delivery water and water in surface drains that discharge to the New River.

IID Surface Drain Discharge to the New River: Historical water quality data for COC concentrations in irrigation discharge from the New River surface drains showed concentration values for selenium, boron, and TDS that were higher than those found in IID irrigation delivery water, and the mean selenium concentration values were above the significance criteria of 5 µg/L established by the Basin Plan.

New River at the Outlet to the Salton Sea: The mean selenium concentration value for the New River at the outlet to the Salton Sea fell below the significance criterion of 5 µg/L established by the Basin Plan (see Figure 3.1-21). The historical water quality data showed concentrations of DDT, DDD, and toxaphene that were lower in the New River at the outlet to the Salton Sea than at the International Boundary.

COC CONCENTRATIONS IN SEDIMENTS

Irrigation Delivery: Information regarding COC concentrations in sediments within the IID irrigation delivery canal system is unavailable. However, historical data from the LCR show a median selenium concentration in sediments of 0.180 mg/kg (Radtke et al. 1988). In USGS samples taken in the vicinity of Imperial Dam, the reported selenium ranged from 6.2 to 7.1 mg/kg. This work demonstrated that mainstream Colorado River sediment less than 63 microns in diameter appeared to be acting as a sink for selenium, especially in backwater areas with higher concentrations of organic matter. Boron also was reported in one sample at a concentration of 1.4 mg/kg. DDT was not found but DDD was reported at 0.3 µg/kg and DDE at a concentration of 4.1 µg/kg

Alamo River Drains: Mean concentrations of DDT (14.6 µg/kg), DDD (6.3 µg/kg), DDE (15.7 µg/kg), and toxaphene (26.6 µg/kg) were detected in sediments found in surface drains discharging to the Alamo River. The data for pesticides (including DDT and its metabolites) suggest that some residual organochlorines are being collected from agricultural drainages (Eccles 1979). However, most of these pesticides have low solubilities and might be expected to remain associated with particulates and sediments.

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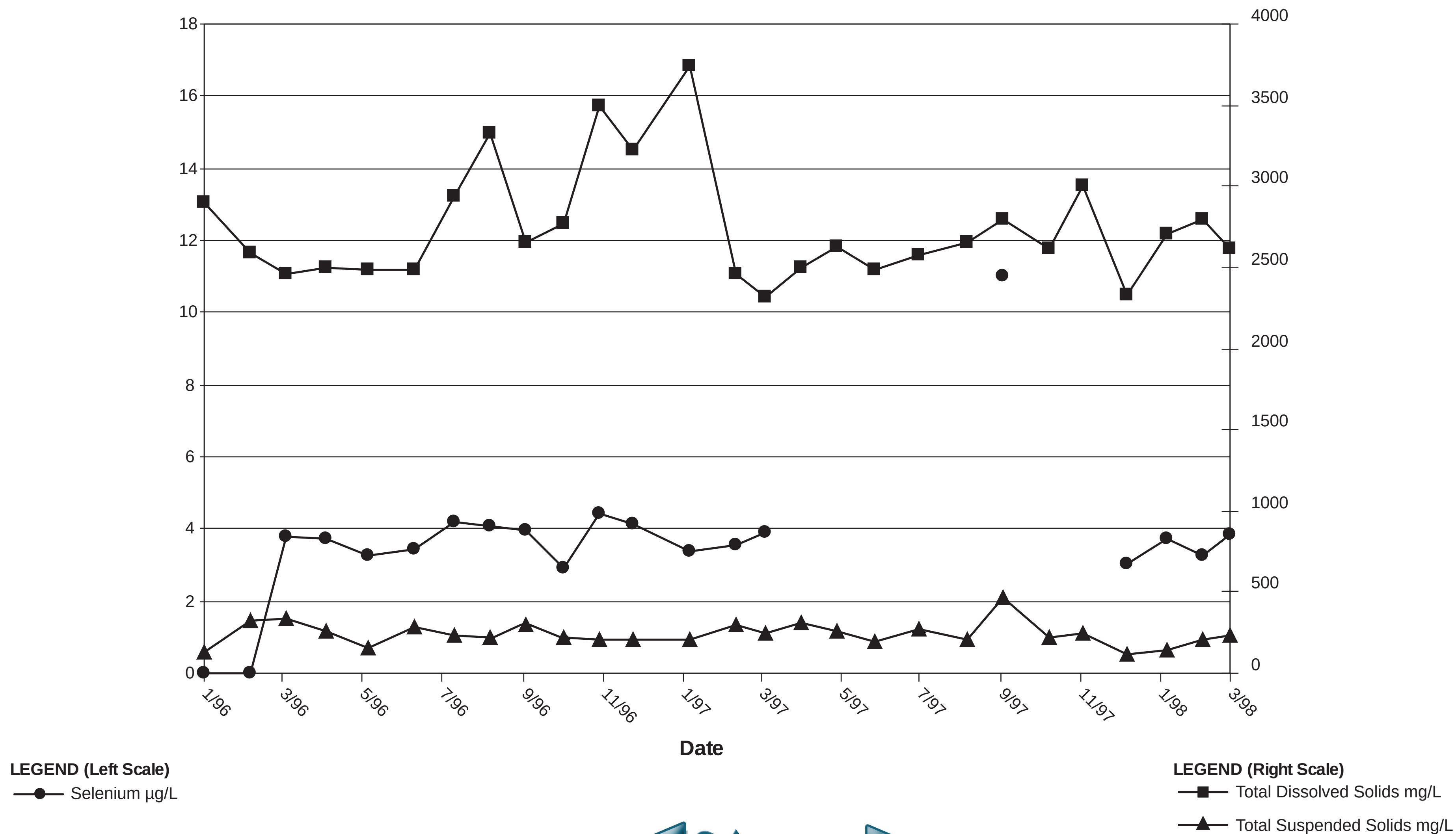

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Note:
"0" indicates concentration was below detection limits.

Figure 3.1-21
COC Concentrations in the New River at the Outlet to the Salton Sea
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Organochlorine residues are mobilized off agricultural fields in particle-rich tailwater runoff and/or by sediment resuspension in the rivers or drains (Setmire et al. 1993).

Alamo River at the Outlet to the Salton Sea: Mean concentrations of DDE (30.0 µg/kg) and toxaphene (2.5 µg/kg) were detected in sediments collected from the Alamo River at the outlet to the Salton Sea.

New River Drains: Mean concentrations of DDT (2.6 µg/kg), DDD (5.4 µg/kg), DDE (44.1 µg/kg), and toxaphene (9.5 µg/kg) were detected in sediments found in surface drains discharging to the New River. Mean concentrations of total phosphorus at 1,300 mg/kg were detected in sediments collected from IID surface drains which discharge to the New River.

New River from the International Boundary to the Outlet of the Salton Sea: The mean concentration of total phosphorus in sediments in the New River increased from 535 mg/kg at the International Boundary to 1,600 mg/kg at the outlet to the Salton Sea. DDT and toxaphene also increased in concentration from 0.1 µg/kg and 10.0 µg/kg at the International Boundary to 11.0 µg/kg and 18.3 µg/kg at the outlet to the Salton Sea. However, the mean concentration for DDE remained the same at 9.8 µg/kg at the International Boundary and at the outlet to the Salton Sea.

GROUNDWATER

The IID water service area is located within the Imperial Valley Basin, a 1,870 square-mile regional groundwater basin located within the Colorado Desert Hydrologic Area (DWR 1975, 1980). The entire Imperial Valley Basin lies within the Salton Basin Region of the Salton Trough, a large, sediment-filled topographical depression that is approximately 130 miles long and as much as 70 miles wide. The Salton Basin Region includes sub-basins and portions of sub-basins (i.e., Imperial Valley and other nearby sub-basins) within the Salton Trough which drain directly into the Salton Sea (Norris and Webb 1976). The Salton Basin is bordered on the north by the Salton Sea, on the northeast by the Chocolate Mountains, on the southeast by the Sand Hills and Cargo Muchacho Mountains, on the west by the Vallecito and Jacumba Mountains, and on the south by the northern Mexicali Valley and the Mexican-American international border (the International Boundary) (see Figure 3.1-22).

Imperial Valley Basin water-bearing units that underlie IID are made up of older and younger alluvium with a storage capacity estimated to range from approximately 7 MAF (County of Imperial 1997a) to 14 MAF (DWR 1975). Deep exploration holes drilled to find oil or water have shown that most of the IID water service area is underlain by thick, water-saturated lacustrine and playa deposits overlying older sediments

(Loeltz et al. 1975). As a result of surface application of irrigation water and the low permeability of much of the IID soil, a perched water table exists throughout much of the Imperial Valley (IID 1994). The fine-grained deposits that are characteristic of the IID water service area have transmissivities of only 1,000 to 10,000 gallons per day per foot to depths of 500 feet. At greater depths, transmissivities are likely to be even less for a similar thickness of deposits. Thus, the potential for development of groundwater beneath the IID water service area to meet irrigation and domestic demands is severely limited. Except for withdrawals currently made for geothermal energy production, the aquifer at depths

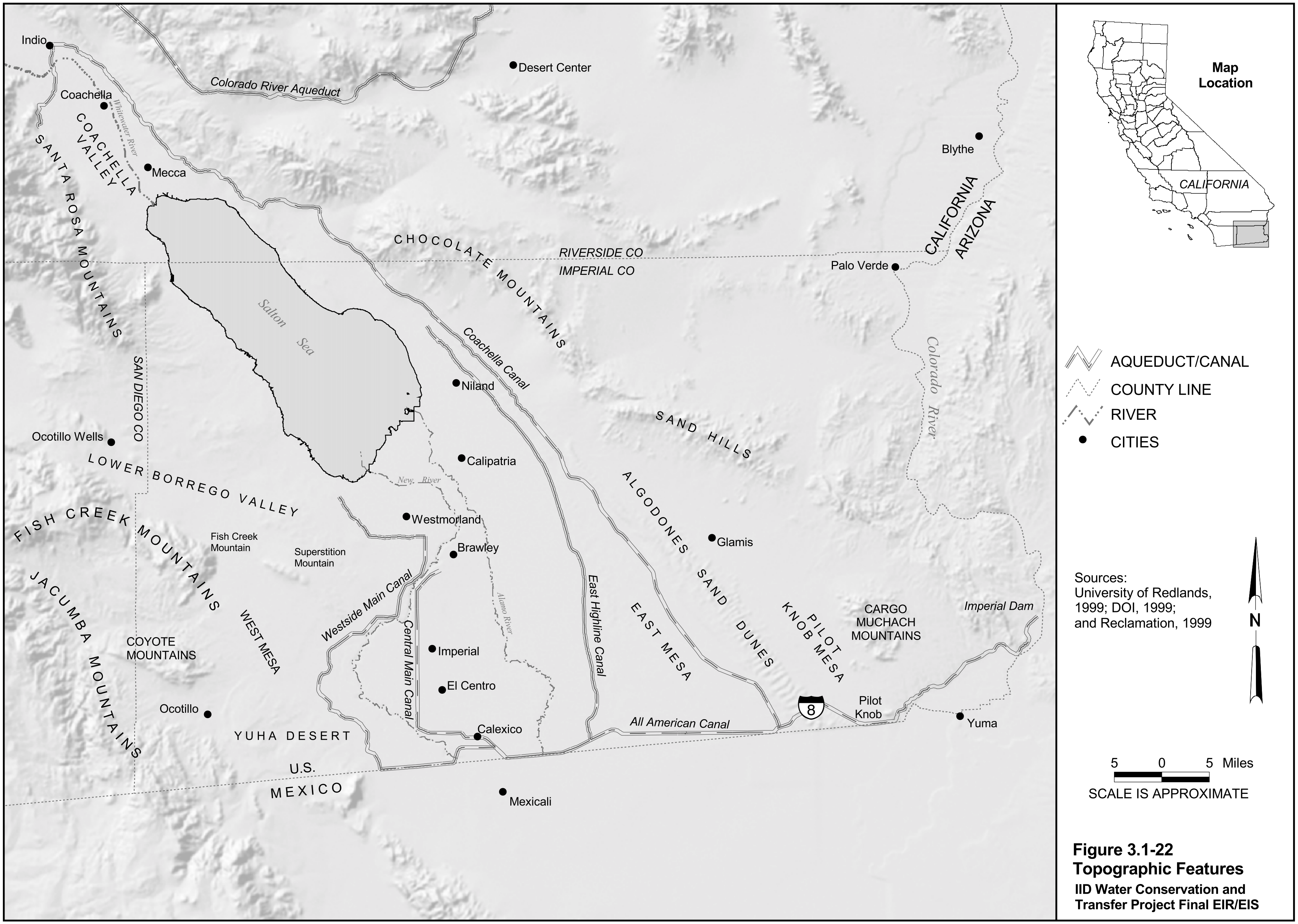

Figure 3.1-22
Topographic Features
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CH2M Hill RDD ArcView Project File \\thor\cart1\rddgis\iid\aesthetics.apr iid_fi 0-7-2002

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greater than several thousand feet is too saline for irrigation and most other uses. It is believed that the hydraulic connection between the water within the deeper deposits and that within the upper part of the groundwater reservoir is poor (Loeltz et al. 1975).

The Imperial Valley Basin is hydraulically connected to other adjacent and nearby sub-basins within the Salton Basin Region. However, imported Colorado River irrigation water, discharged as seepage or spillage from the IID canal system, and/or percolation that bypasses the tilewater system constitute the primary sources of groundwater inflow into the aquifer(s) underlying the IID water service area. In comparison to imported water, groundwater inflow into the IID water service area is small, with the total inflow estimated at approximately 22 KAFY, consisting of 15 KAFY originating from the East Mesa area and 7 KAFY from the West Mesa area and Mexican territory (CH2M HILL 1994).

Regionally, groundwater generally mimics surface flow, moving toward the center of the IID water service area and then northwest toward the Salton Sea. On a smaller scale, groundwater follows the regional pattern, with groundwater moving from the eastern and western sides of the IID water service area toward the New and Alamo Rivers, and then northwest toward the Salton Sea (see Figure 3.1-23).

Principal areas of groundwater discharge include: groundwater discharge directly into the New and Alamo Rivers, subsurface discharge into the Salton Sea, shallow groundwater intercepted by IID's open drainage collection system, and evapotranspiration. In comparison with surface waters, groundwater recharge to the Salton Sea is a small component of the total inflow to the Salton Sea. The IID water service area's contribution of groundwater to the Salton Sea amounts to about 2 KAFY.

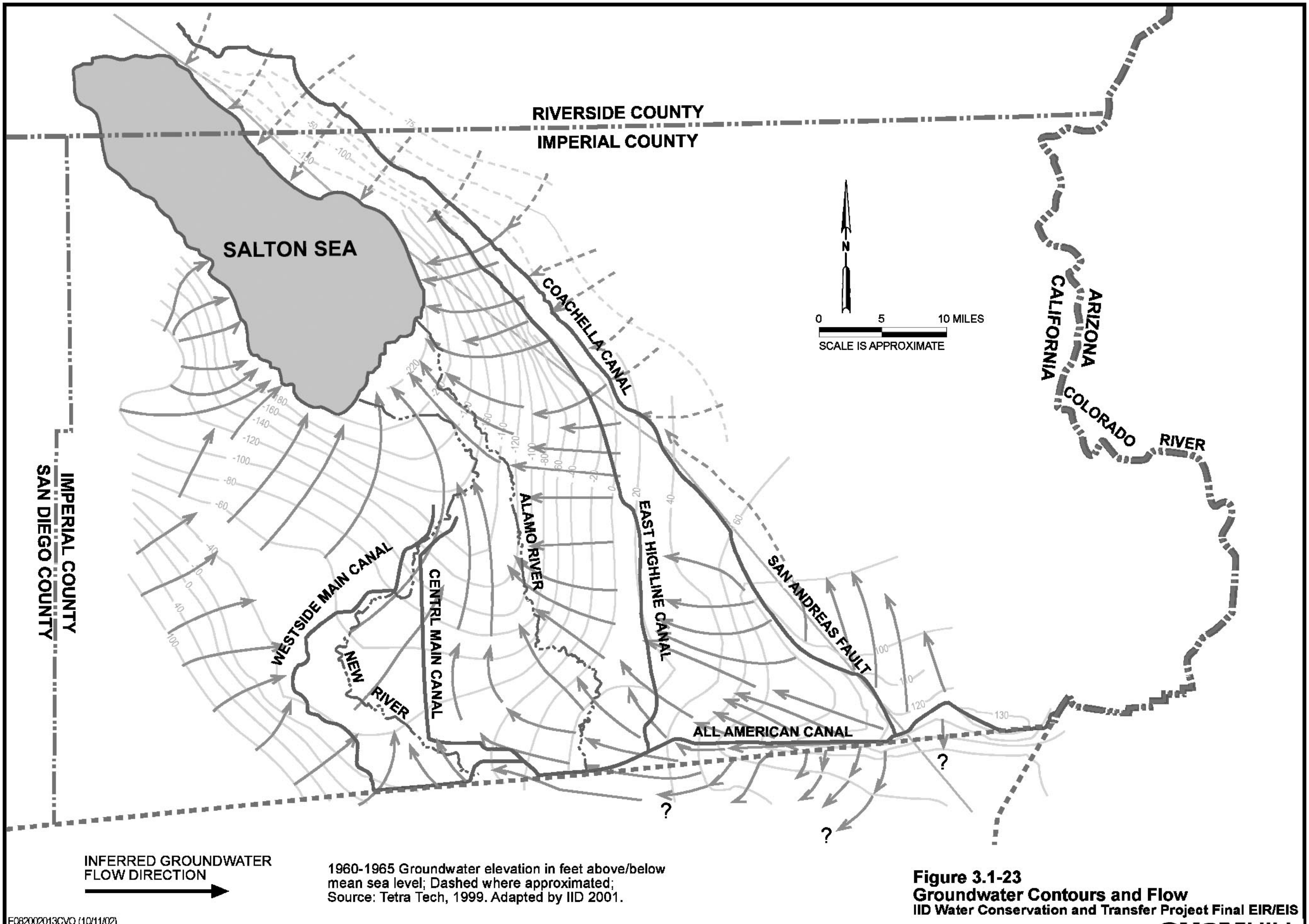
While the amount of groundwater stored in the Imperial Valley Basin is large, few wells have been drilled for production purposes because the yield is low and the water is of poor quality (Montgomery Watson 1995). The chemical quality of groundwater within the Imperial Valley Basin varies greatly. For example, TDS concentrations range from a few hundred to more than 10,000 mg/L. Concentrations of fluoride above the MCL of 4.0 mg/L for drinking water are common (Tetra Tech 1999).

3.1.3.3 Salton Sea

The environmental setting discussion for surface water resources of the Salton Sea includes discussions of the Sea's:

- Watershed
- Water balance
- Inflow trends
- Physical characteristics
- In-Sea circulation patterns
- Water quality
- Sediment quality

The Salton Sea is a terminal lake with no surface water discharges. It is located approximately 35 miles north of the US/Mexico border and 90 miles east of San Diego. The Salton Sea Basin comprises the western arm of the LCR delta system. At one time, the Salton Sea represented the northernmost tip of the Gulf of California. As the Colorado River deposited huge volumes of sediment in the delta system, the sediment collected onto a



1960-1965 Groundwater elevation in feet above/below mean sea level; Dashed where approximated;
Source: Tetra Tech, 1999. Adapted by IID 2001.

Figure 3.1-23
Groundwater Contours and Flow
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broad fan that formed uplands and physically isolated the Salton Sea Basin from the Gulf of California. The Colorado River occasionally flowed into the Salton Sea Basin, forming a prehistoric water body known as Lake Cahuilla named after the local Native Americans. The lake fluctuated greatly in size over time and is thought to have at one time occupied an area more than 20 times as large as the current Salton Sea. When the river meandered from the Salton Sea basin toward the Gulf of California, the lake began to evaporate and become more saline. The repeated periods of evaporation resulted in the deposition of thick salty sediments and layers of marine fossil shells (Setmire et al. 1990). Lake Cahuilla is thought to have existed in its most recent form until about 300 to 500 years ago (Ogden 1996).

During the 1800s, shallow ephemeral lakes periodically formed in the Salton Sea Basin as the Colorado River rose and fell prior to its damming. Reported episodes of inundation occurred in 1828, 1840, 1849, 1852, 1859, 1862, 1867, and 1897 (Littlefield 1966). The flood of 1891 spawned a water body of approximately the same surface area as the current Salton Sea.

The Salton Sea reached its present form in 1905 when Colorado River floodwaters breached a temporary diversion that had been designed to bypass a silted-up section of the Imperial Canal. On October 11, 1905, a dike failed, and nearly the entire flow of the Colorado River ran uncontrolled into the Salton Sea Basin for the next 18 months. When the breach was finally repaired in 1907, the elevation of the Salton Sea had reached -195 feet msl and had a surface area of 520 square miles. The Sea has existed continuously from that 1905 event to the present.

The water level in the Salton Sea fell to almost 250 feet below msl during the decade following the 1905 flood, rose slowly through the mid-1980s, and has been relatively constant since then. The water level fell rapidly after the initial flood and then gradually rose from elevation –250 feet msl to its current level of approximately –228 feet msl (Weghorst 2001). The water surface elevation has been fairly constant during the past decade, ranging from –228.7 feet msl to –226.6 feet msl, indicating that the sum of the inflows approximately equals the rate of evaporation on an average annual basis.

Data provided by Reclamation indicate that at its current elevation of approximately -228 feet, the Salton Sea surface area is approximately 232,000 acres and its volume is approximately 7.39 MAF. The very shallow slopes of the near-shore areas result in large changes in water surface area given small changes in water level elevation. For example, a drop of elevation of one foot from the current elevation reduces the surface area by 2,100 acres. At the current elevation, the depth of the Sea at its deepest point is approximately 50 feet (Weghorst 2001).

The Sea currently receives some inflow from precipitation and groundwater seepage, but the majority of inflows are from agricultural and municipal drainage. The source of most of the agricultural inflow is water imported to the region from the Colorado River. It should be noted that although the average groundwater inflow from CVWD for 1950 to 1999 is 1539 AFY, currently the Sea is losing water to Coachella Valley (366 AFY in 1999) groundwater overdraft and the trend is continuing to increase as a result of increasing groundwater overdraft.

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In the Salton Sea watershed, some of the surface water used to irrigate crops infiltrates into the groundwater system. Some of the seepage might be intercepted by agricultural drainage tile systems and some infiltrates to greater depths. Flow from the tile drains discharges into open channel drains and, eventually, to the Salton Sea. Similarly, the water that percolates to greater depths in the Imperial Valley eventually flows to the Salton Sea through the subsurface. Thus, both surface water and groundwater contribute to the volume and thus the elevation of the Salton Sea, as described below.

Water Balance. The Salton Sea watershed comprises approximately 8,360 square miles, draining a small portion of San Bernardino County that is tributary to the Whitewater River, the southern area of Riverside County, most of Imperial County, the eastern portion of San Diego County, and part of the State of Baja California in the Republic of Mexico. The main natural tributaries to the Salton Sea are the Whitewater River, which flows into the north end of the Sea, and the Alamo and New Rivers, which flow into the Sea from the south, as shown in Figure 3.1-22.

The total average annual inflow to the Salton Sea for the period 1950 to 1999 is estimated at approximately 1.34 MAFY. By far, the largest component of this inflow originates as agricultural drainage. And, agricultural drainage from the IID water service area is the single largest contributor of inflow to the Sea (Table 3.1-5). Other components of inflow include precipitation and groundwater discharge. Surface flow from Salt Creek and San Felipe Creek also discharge to the Sea, but these flows are estimated to contribute less than 1 percent of the total inflow.

TABLE 3.1-5
Annual Average Historical Water Balance for Salton Sea (Period 1950 - 1999)

Source of Inflow	Total Average Annual Inflow (AF)	Percent of Contribution to Total Inflow
Alamo River	623,678	46.4
New River	441,475	32.9
IID Drains Direct to the Salton Sea	93,250	6.9
Surface Water Flows From CVWD (Includes Whitewater R.)	115,053	8.6
Subsurface Flows From CVWD	1,539	0.1
Unmeasured Inflows [1]	68,400	5.1
Total Inflow	1,343,395	100.0

[1]Unaccounted-for direct runoff, unmeasured inflows from IID and CVWD, as well as errors and/or omissions resulting from the development of this historical water balance

Source: Salton Sea Accounting Model (Weghorst 2001)

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With the exception of the average subsurface flows from CVWD, the data provided by Reclamation in Table 3.1-5 do not specify the relative contribution from groundwater included in the Unmeasured Inflows and precipitation (included in net evaporation). However, Reclamation’s Salton Sea Accounting Model does provide a description of how components of the water balance, such as precipitation and evaporation, were derived (see Section 3.1.4.1 and Appendix F). In addition, historical data provide some indication of the volume of inflow that is contributed by precipitation and groundwater inflow. For example, it is estimated that only about 3 percent of the water that flows into the Salton Sea comes from rainfall within the watershed. The Imperial and Coachella Valleys receive an average of about 2.3 and 2.8 inches of rainfall per year, respectively (MacGilhivray 1980, 1981). Direct annual precipitation on the Salton Sea is estimated to be about 48.3 KAFY (Hely et al. 1966). However, this varies depending on the surface area of the Sea and the actual precipitation. It should also be noted that the Coyote Mountains east of the Salton Sea receive about 8 inches per year (in/yr). In contrast, the upper San Jacinto and San Bernardino Mountains west of the Salton Sea receive as much as 30 to 40 in/yr (RWQCB 1994). Although most of the precipitation and runoff occurs from November through April, with the exception of San Felipe Creek, flows rarely reach the Salton Sea. During the summer, most of the rainfall is from short, intense thunderstorms.

Inflow Trends. Table 3.1-5 illustrates the relative contributions of the different sources of inflow for an average annual water budget for the years 1950 to 1999. However, flow rates from the various sources change over time. For example, variations in Colorado River diversions by IID and CVWD and rainfall affect the rate of surface water inflows, and variations in ambient air temperature, wind, and humidity result in changes to the evaporation rate between years.

Inflows to the Salton Sea vary among years and also within any given year. Estimated annual inflows were greatest (estimated at over 15 MAFY [Cohen et al. 1999]) during the uncontrolled flooding that occurred during 1905 -1907, which created the Sea in its current form (Setmire et al. 1993). For several decades after the initial flooding, annual inflows averaged under 1 MAFY. Estimated annual inflows have remained relatively constant during the past 50 years at approximately 1.35 MAFY (Cohen et al. 1999). Variations that do occur in inflows are mainly a result of changes in agricultural usage in the Imperial, Coachella, and Mexicali valleys. Various crops consume different amounts of water. In the Imperial Valley, evapotranspiration from alfalfa was estimated to be about 81 inches of water (6.7 FY), while citrus crops consumed only about 3.84 FY (MacGillivray 1980). Similar values apply to the Coachella Valley. As with inflow trends between years, trends in flow within a given year are also determined primarily by agricultural practices and schedules for crop irrigation. Inflows are generally higher in the spring and lower in the fall and winter. This variation is shown on Figure 3.1-24 which depicts the average monthly variation of inflows and corresponding elevations for the period 1950-1999.

In-Sea Circulation Patterns. Circulation patterns within the Salton Sea affect the distribution of nutrients and other contaminants, dissolved oxygen, mixing of freshwater, and temperature gradients. Energy regimes generated by circulation also have an effect on shoreline erosion and sediment deposition patterns. Studies of Salton Sea circulation have been conducted by the Water Resources and Environmental Modeling Group of the

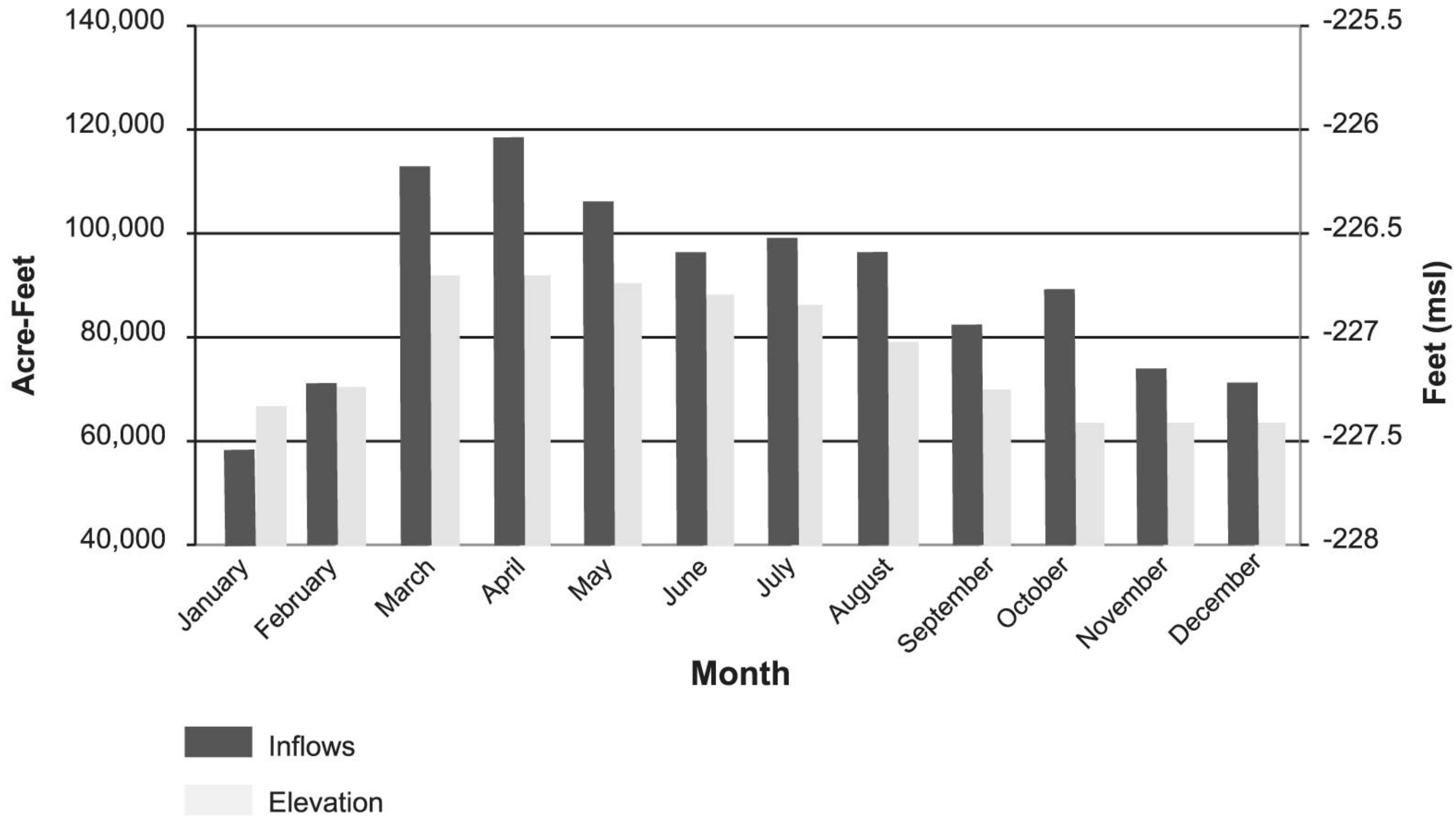

Figure 3.1-24
Estimated Average Monthly Elevations and Inflows to the Salton Sea, 1950-1999
IID Water Conservation and Transfer Project Final EIR/EIS

Department of Civil and Environmental Engineering at the University of California at Davis (Modeling Group), under contract to the SSA. A three-dimensional model (RMA-10) was used to simulate current velocities that may vary with depth or that may be affected by differences in water density resulting from suspended sediment, temperature, and salinity (Cook et al. 1998). The model is capable of accounting for many variables, but it has been demonstrated that wind velocity and direction are the dominant factors in creating the observed pattern of currents in the Salton Sea (Cook et al. 1998) The model was configured to account for the effects of major tributary inflows from the Alamo, New, and Whitewater rivers, and to simulate changes in salinity and temperature.

The model consists of a finite element network designed to represent the physical boundaries of the system based on a detailed bathymetric survey conducted by Reclamation (Ferrari and Weghorst 1997). The motion of water in the Sea results from the transfer of energy from wind, freshwater inflows, and solar heat at model boundaries. The model solves equations describing the energy flow through the system. Physical properties of the system that affect simulated circulation include the roughness of the bottom, wind stress, and inflow rates. The model was also used to predict changes in current patterns, salinity, and temperature that would occur if the elevation or shoreline geometry of the Sea were altered.

The model found that a north-to-south wind pattern results in a system of currents dominated by two large gyres, rotating in opposite directions in each of the Sea's two basins. In the northern basin the currents rotate clockwise, and in the southern basin the currents rotate counterclockwise. The speed of rotation is typically much higher in the southern basin. Evidence of this pattern of currents has been observed in satellite photos of the Salton Sea. The model simulations, confirmed by field observations, suggest that the current velocity pattern near the surface of the Sea is much the same as near the bottom, suggesting a well-mixed system, at least under the influence of prevailing winds.

Freshwater is less dense than saltwater, and when freshwater flows into a more saline environment, the freshwater will "float" for a time over saltier water, creating a salt wedge at the point of inflow. However, in the Salton Sea, freshwater inflows from tributaries generally mix rapidly with the ambient saltwater due to the prevailing wind action, forming a fairly abrupt transition from freshwater to saltwater. This rapid mixing suggests that inflows attain the physiochemical characteristics of the Sea's water within a short distance from the mouths of tributaries, although a delta area of less saline water exists near the river inflows.

Water Quality. The Salton Sea is mainly a receiving body for agricultural and municipal wastewater. In 1998, the Salton Sea was listed by RWQCB as an impaired surface water body in accordance with Section 303(d) of the CWA. Four of the tributaries to the Salton Sea were also listed as impaired: the New River, the Alamo River, the Coachella Valley Stormwater Channel, and the Imperial Valley Drains (RWQCB 1998).

During the 1960s and 1970s, water contact recreation (including, but not limited to, swimming and water-skiing) was an important, beneficial use of the Sea. Water contact recreation remains one of the beneficial uses of the Salton Sea to be protected, as established by the Basin Plan. That, and other identified beneficial uses of the Salton Sea, include the following:

- Non-contact water recreation
- Contact water recreation
- Aquaculture
- Warm freshwater habitat
- Wildlife habitat
- Protection of threatened and endangered species

Sustaining the beneficial uses of the Salton Sea depends on maintaining water quality constituents at appropriate concentrations. The concentration of chemicals in the Salton Sea depends on both external loads and internal processes, such as sediment resuspension and chemical cycling. Dissolved or suspended constituents in inflows to the Sea constitute an external pollutant loading. The loading rate depends on both the constituent concentration and the rate of flow. A small flow containing a high concentration can result in the same loading as a high flow containing a lower concentration.

Under the CWA, state regulatory agencies are defining TMDLs for constituents believed to adversely affect receiving waters that have been identified as having impaired water quality. The RWQCB is in the process of defining TMDLs for certain COCs flowing into the Salton Sea (see Section 3.1.2.2, State Regulations and Standards).

COCs. Several COCs have been identified for the Salton Sea. The Salton Sea COCs are similar, but not identical, to COCs listed for the LCR and other water bodies discussed in this report. The following list includes constituents most likely to be associated with impacts to beneficial uses of the Salton Sea:

- Salinity
- Selenium
- Boron
- Nitrogen
- Phosphorus

The following COCs are also discussed in this section of the EIR/EIS:

- Salinity
- Pesticides and herbicides
- Metals
- Nutrients and other organic parameters (see Tables 3.1-7 and 3.1-8 beginning on page 3.1-62)

In Section 3.1.4, Impacts and Mitigation Measures, water quality criteria are compared to possible impacts to determine the potential for threats to these beneficial uses. Although freshwater criteria apply to the rivers and canals discussed elsewhere in this report, in many ways, the Salton Sea is a unique environment, with its own issues, to which neither freshwater nor ocean water standards would necessarily be appropriate or protective. The exception to this statement is selenium, for which the EPA has identified a maximum concentration of 5.0 µg/L (see Table 3.1-14a on page 3.1-84). A brief introduction to each COC, and a summary of existing data describing temporal and spatial characteristics of each COC, are presented below.

Background and Historical Studies. Inflows to the Sea consist mainly of agricultural and municipal wastewater, with only a small component of natural storm drainage. Water used in irrigation comes into contact with various agricultural chemicals and fertilizers, as well as the native mineral and organic substances contained in soils. Municipal wastewater, depending on the degree of treatment it receives, contains varying amounts of dissolved and suspended organic material, nutrients, metals, hydrocarbons, and other compounds that originate from domestic, industrial, and urban runoff sources. The water also carries with it sediment derived from soil erosion. Therefore, while most of the salts discussed above originate from the Colorado River and are simply concentrated because of evaporation, other constituents are added to the water from sources both external to and inside the basin.

The earliest detailed water quality study for constituents other than salts was conducted by Carpelan based on sampling that occurred between July 1954 and July 1956 (Carpelan 1958). Historical data on the major ionic composition of the Sea were reviewed, and depth profiles of temperature, dissolved oxygen, and pH were developed. Nutrient concentrations (ammonia, nitrate, and phosphate) were measured in samples from depths near the surface and near the bottom at four locations in the Sea. The nutrient analyses indicated that significant spatial trends in concentrations occurred both vertically and horizontally. Water samples from near the bottom contained much higher concentrations of ammonia and phosphate than surface samples, and samples taken at near-shore locations contained higher nutrient concentrations than samples from mid-Sea locations.

During 1963 to 1969, the Federal Water Quality Administration (FWQA) and DWR conducted a study of nutrient loading and its effects on the Sea (FWQA 1970). The Sea was described as eutrophic, with over-enrichment through high nutrient concentrations leading to high rates of algal growth. High photosynthesis and respiration by algae were thought to result in high concentrations of dissolved oxygen in near-surface waters, while oxygen depletion at depth resulted from the oxygen-demanding processes associated with decaying algae and other organic matter.

Salinity. Salt loads and loads of other constituents entering the Salton Sea tend to accumulate in the Sea by virtue of lack of an outlet. With an evaporation rate of nearly 6 FY and minimal precipitation, the entire volume of the Salton Sea would evaporate within about 10 years if all inflows were stopped.

Salinity of the Sea will continue to increase as long as dissolved salt continues to be concentrated by evaporation. However, the proportions of ionic constituents in the inflows differ from ambient conditions in the receiving water, and some of the constituents are precipitated from the water by biological and chemical processes. Thus, the relative proportions of dissolved constituents that contribute to the salinity of the Sea will likely not remain constant over time or space. For example, calcium carbonate is removed from the water column during the formation of shells and skeletons of organisms or through chemical precipitation enhanced by certain algae. Similarly, calcium and magnesium sulfates are chemically precipitated as the concentrations of these compounds reach their solubility limits in the Sea's water.

The proportions of major salt constituents in the inflows to the Sea vary by source. Sodium and chloride are the principal constituents of inflow from the New River, while sodium and sulfate are the principal constituents of Whitewater and Alamo River inflows. Overall, these four constituents, along with bicarbonate (which is replenished from atmospheric carbon dioxide), represent the bulk of the dissolved material entering the Sea (Hely et al. 1966).

In 1966, USGS published a detailed study of the historical hydrologic regime of the Salton Sea. Included was an estimated water budget, time series of water level changes, an evaluation of the major dissolved constituents, and temperature profiles (Hely et al. 1966). The data showed that salinity increased significantly between 1907 and about 1925 as the pre-existing salt pan on the basin floor dissolved into the Sea, and the salts were subsequently concentrated in the decreasing water volume. By 1923, the elevation of the Sea had declined to about -255 feet msl, and the salinity had reached a peak of about 37,600 mg/L. In later years, inflows and the volume of the Sea varied, and salinity fluctuated between about 31,000 and 39,000 mg/L during the next 40 years. The average concentrations of major ionic constituents measured by USGS in four sampling events between September 1962 and May 1964 are shown in Table 3.1-6.

TABLE 3.1-6
Average Concentrations of Major Ions (mg/L) in the Salton Sea

Year(s)	Calcium	Magnesium	Sodium	Bicarbonate	Sulfate	Chloride	TDS
1962 to 1964[1]	786	972	9,743	176	7,130	13,825	32,525
1999[2]	942	1,398	12,340	249	11,515	17,470	43,918

Sources:
[1]Hely et al. 1966
[2]Holdren and Montano, in preparation.

A graph showing more recent trends (i.e., for the period 1950 to 2000) in the annual inflow to the Salton Sea and the corresponding salinity concentrations is presented in Figure 3.1-24a.

Between 1980 and 1993, RWQCB conducted sampling of tributaries, drains, and a single location in the approximate middle of the Salton Sea. For most parameters, 30 to 40 samples were collected from the Sea. The sampling program focused on parameters other than major ions. However, sulfate was included among the analytical parameters. The sulfate concentration in nine samples ranged from about 9,000 to 12,000 mg/L during the sampling period. The sulfate concentration steadily increased until 1990, when it reached its peak value. From 1990 to 1993, the concentration fluctuated between 10,000 and 12,000 mg/L. The fluctuation in concentration might have been related to changes in inflow rather than to precipitation of gypsum (Schroeder et al. 1993).The composition of Salton Sea water is being monitored at three locations in the Sea and at the mouths of the three major tributaries in a reconnaissance study currently being conducted for the Salton Sea Science Subcommittee (Holdren and Montano, in preparation). The summary results of this program for major

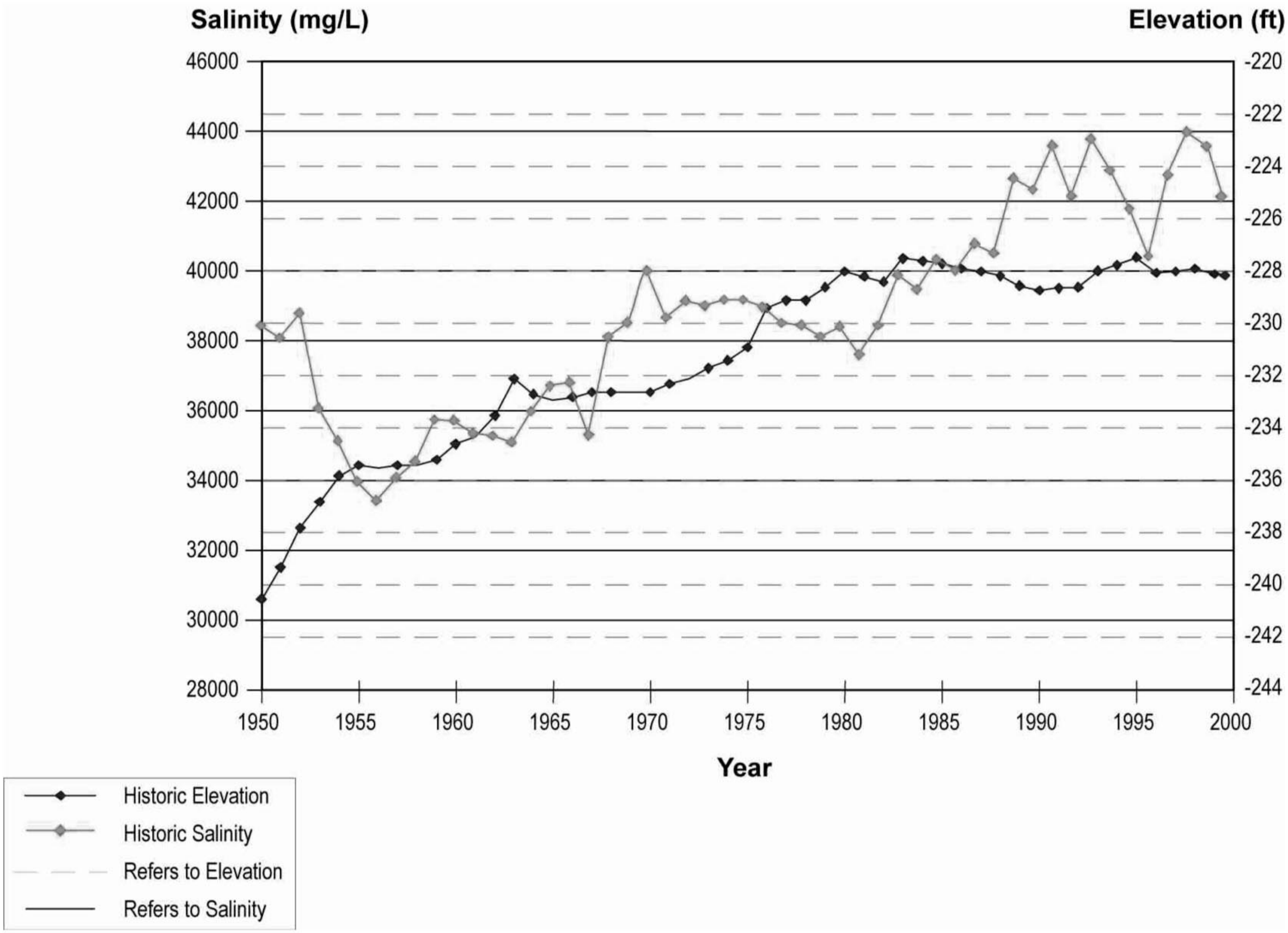

Figure 3.1-24a
Historic Elevation and Salinity for the Salton Sea, 1950-2000
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ionic constituents are presented in Table 3.1-6. Although samples were taken near the surfaces and at depths at each sampling site, the data presented are depth-averaged. The relatively stable sulfate concentration since 1992 might provide further evidence that the sulfate concentration in the Sea is limited by the solubility of gypsum. Table 3.1-6 shows all reported constituents increasing between 1962 to 1964 and 1999. Causes of the reported differences might be real increases in concentrations, changes in sampling and analytical techniques, or variation in sampling locations.

Pesticides and Herbicides. USGS conducted a study of pesticide and herbicide inputs to the Salton Sea during the period August 1969 to June 1970 (Irwin 1971). Samples were collected from the New and Alamo Rivers and the AAC and East Highline Canal. The results showed that a number of pesticides were present in the inflows to the Salton Sea. DDT and its degradation products—dieldrin, methyl parathion, 2,4-D, and silvex—were reported in most of the samples collected from near the outlets of the New and Alamo Rivers. Other pesticides and herbicides were also reported, but with less frequency.

Metals. USGS initiated a series of studies in 1985 as part of the National Irrigation Water Quality Program. In 1985, RWQCB concluded that tile drains were the main source of selenium in the Imperial Valley, although concentrations of selenium as high as 0.029 mg/L were also found in San Felipe Creek (Setmire and Schroeder 1998). Subsequent sampling of drain water by USGS in 1986 confirmed that selenium concentrations were highest in tilewater but were generally below the drinking water standard in collector drains; they were less than 0.002 mg/L in both the Colorado River and in the Salton Sea. USGS studies continued until 1995 (Setmire et al. 1990, 1993, and Setmire and Schroeder 1998).

Although the principal objective of these studies was to investigate sources of selenium in agricultural drain water, other constituents, including trace elements, major ions, nutrients, pesticides, and herbicides, were also assessed. The focus of the assessments was to identify sources, rather than to evaluate the water quality of the Salton Sea itself. The studies concluded that the selenium found in drain water originates from the water imported from the Colorado River, but is concentrated, along with other salts, by evapotranspiration. Thus, the loading to the Sea was said to be a function of the amount of Colorado River water imported, rather than of the leaching of selenium from minerals in the soil.

Arsenic, boron, mercury and other parameters were also investigated in the USGS studies. Results of sampling at stations in the National Stream Quality Accounting Network in the Imperial Valley have shown that arsenic occasionally exceeds the EPA's water quality criterion of 0.005 mg/L for protection of aquatic life in the New River. Further studies by Setmire suggest that the arsenic might originate from groundwater sources within the Basin (Setmire et al. 1993).

In addition to the studies described above, various agencies have collected, or continue to collect, data that are not widely disseminated. CVWD has collected data on major ions and heavy metals in drain water since the 1960s, IID has collected major ion data at selected drain locations, and RWQCB collected data for various contaminants and water quality indicators from tributaries, drains, and from the center of the Sea from 1980 to 1990, as noted previously.

Studies indicate that the concentration of selenium in the Salton Sea is significantly lower (typically by one to two orders of magnitude) than the concentrations in drains and tributaries. In contrast, analyses of sediment samples reveal that the concentration of selenium is generally two or three times greater in bottom sediments from the Salton Sea than in sediments from upstream locations. This suggests that selenium is transferred from the water column to the sediments by physical, chemical, and/or biological processes (Setmire et al. 1993). For example, selenium may be taken up by bacteria and chemically reduced. The reduced forms of selenium (i.e., selinite, elemental selenium, and hydrogen selenide) are less soluble in water than selenate. Also, selenium may be incorporated by biological reactions in organic molecules capable of volatilizing to the atmosphere. Alternatively, some of the selenium may precipitate with dead plant material, or it might chemically precipitate under the low oxygen conditions found at the bottom of the Sea.

Nutrients and Other Organic Parameters. Table 3.1-7 presents a summary of RWQCB data on selected analytes. The results of their evaluation indicate that the New and Alamo Rivers are major sources of nitrogen loads into the Sea. Phosphate concentrations in the Sea are similar to those in the tributaries. By contrast, chemical and biological oxygen demand (COD and BOD, respectively) are higher in the Sea than in the tributaries. COD and BOD are measures of the amount of biological and nonbiological matter capable of depleting dissolved oxygen in the water column. The range of dissolved oxygen concentrations in the Sea tends to be greater than in the tributaries. However, other studies have indicated that dissolved oxygen in the Sea decreases rapidly with depth, and concentrations are often close to zero at depths of 10 feet or more.

In addition to the parameters shown herein, RWQCB samples were analyzed for suspended and settleable solids, pH, and other parameters. A few samples were analyzed for selected metals, including two samples that were analyzed for selenium. The selenium concentrations in the two samples were 0.002 and 0.005 mg/L (2 to 5 parts per billion [ppb], respectively).

Table 3.1-7 also shows that the New and Alamo Rivers contain large concentrations of fecal coliform bacteria. Fecal coliform bacteria are generally an indicator of human waste but may not survive in the highly saline conditions found in the Sea. In addition to the data gathered by RWQCB, IID has sampled coliform bacteria at a number of near-shore stations around the Sea.

As described above, a reconnaissance water quality study of the Salton Sea (Holdren and Montano, in preparation) is being conducted for the SSA science subcommittee. Preliminary results of that study, with monthly sampling completed for the period January to December 1999, are summarized in Table 3.1-8. The results are generally consistent with the results of monitoring by RWQCB from 1980 to 1993.

TABLE 3.1-7
Comparison of Selected Water Quality Results (mg/L) in Tributaries and the Salton Sea, 1980 to 1993

	Ammonia	Nitrate	Phosphate	BOD	Dissolved Oxygen	Fecal Coliform[1]	COD
Salton Sea near Midpoint							
N	37	36	38	39	35	40	36
Average	0.83	0.19	0.34	13	10.8	3	401
Maximum	3.00	1.00	1.42	51	20.0	20	2,192
Minimum	0.01	0.005	0.03	2	0.1	2	65
New River at Discharge to Salton Sea							
N	38	38	38	39	35	40	39
Average	1.50	4.96	0.89	9	6.2	15,640	43
Maximum	3.50	17.0	1.86	17	9.3	160,000	143
Minimum	0.22	1.50	0.01	3	3.6	500	12
Alamo River at Discharge to Salton Sea							
N	39	38	37	39	35	40	39
Average	1.04	8.05	0.68	6	7.7	16,102	38
Maximum	2.86	24.0	2.04	26	10.2	240,000	143
Minimum	0.28	3.90	0.12	2	5.2	170	10
Whitewater River at Discharge to Salton Sea							
N	39	38	38	39	37	39	39
Average	0.23	0.50	0.24	2	9.7	87	8
Maximum	1.20	1.90	2.00	11	15.3	540	39
Minimum	0.01	0.06	0.02	1	7.1	2	1

Source: RWQCB 1999
[1]Fecal coliform reported in units of mpn/100mL

TABLE 3.1-8
Average Concentrations of Nutrients and Selenium (mg/L) in Salton Sea, January to December 1999 (n=12)

Total Alkalinity	Ammonia Nitrogen	Nitrate/Nitrite Nitrite	Total Phosphorous	TSS	Selenium (total)[1]
244	1.29	0.134	0.07	34	0.74

Source: Holdren 1999
[1]Selenium is reported in µg/L.

Summary. Based on the data presented above and on other information, the following generalizations regarding Salton Sea COCs can be made (SSA and Reclamation 2000):

- With the exception of TSS, concentrations of conservatively measured components are lower and more variable in the three tributary rivers than in the Sea.
- The Alamo and New Rivers carry heavy sediment loads, with TSS concentrations often greater than 200 mg/L. TSS levels in the Whitewater River are lower than in the other two rivers, but are still often greater than 100 mg/L.

- Thermal stratification occurs in the Salton Sea, with observed differences between surface and bottom temperatures of up to 8 °C. The stratification is not stable, however, and both depth of stratification and temperature differences between surface and bottom waters vary depending on season and inflow rates.
- Dissolved oxygen levels near the surface are usually above saturation concentrations as a result of primary production. In contrast, dissolved oxygen levels near the bottom are frequently less than 1 mg/L.
- The oxidation-reduction potential is negative in areas with low dissolved oxygen.
- Phosphorus appears to be the nutrient limiting algal growth in the Salton Sea. Dissolved ortho-phosphate concentrations have been observed below the detection limit of 0.005 mg/L on several occasions, and the maximum observed value was only 0.035 mg/L.
- High nitrate-N concentrations occur in the New, Whitewater, and Alamo River samples. Nitrate concentrations in the New and Alamo Rivers are often between 3 and 7 mg/L, while concentrations in the Whitewater River generally range from 12 to 15 mg/L. The latter concentrations exceed the drinking water standard of 10 mg/L.
- In contrast to the high nitrate levels in the New, Whitewater, and Alamo River samples, most nitrate concentrations observed in the Sea have been lower than 0.2 mg/L. Denitrification in the bottom waters of the lake and algal uptake from the surface waters are the most likely explanations for the observed results.
- Ammonia-N concentrations in the New, Whitewater, and Alamo River and receiving water samples are relatively high for surface waters. High ammonia concentrations in the Sea, which are frequently greater than 1 mg/L, coupled with typical pH levels near 8.3 at the surface, are of potential concern to the Sea's fishery. Although un-ionized ammonia concentrations do not appear to be reaching toxic levels, un-ionized ammonia may combine with other stressors, such as low dissolved oxygen concentration and high temperatures, to contribute to fish kills in the Sea.
- Dissolved organic carbon and dissolved silica levels in the Salton Sea are relatively stable. Dissolved organic carbon is typically in the range of 45 mg/L, while most dissolved silica concentrations are between 5 and 7 mg/L.
- Sodium is the dominant cation in the Salton Sea. It is likely that calcium and magnesium concentrations are being at least partially controlled through precipitation reactions.
- Chloride and sulfate are the dominant anions in the system. Carbonate is present at relatively low concentrations and is probably being limited through precipitation as $CaCO_3$. Some sulfate salts are also relatively insoluble, and the precipitation of sulfates may help slow future increases in salinity if water inputs are reduced. Fluorides may also be precipitating, but available fluoride concentration values are not reliable and are being reevaluated.
- Trace metal concentrations do not appear to be of major concern in the Sea; however, most metal values are being reevaluated. Dissolved selenium concentrations ranged from 2.55 μg/L in the Whitewater River to 7.7 μg/L in the Alamo River and are high

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enough to be of concern. Concentrations were lower in the Sea samples; however, they were often less than 1 µg/L. Selenium concentrations were similar in dissolved and total fractions, indicating that most of that COC is present in dissolved forms.

- Concentrations of semivolatile organics and chlorinated pesticides/polychlorinated biphenyls (PCBs) were below analytical detection limits for the New, Whitewater, and Alamo rivers and in-Sea samples.

Sediment. This section summarizes sediment quality in the Salton Sea. Particulate and dissolved contaminants enter the Salton Sea via surface water, and groundwater inflows transport dissolved constituents, as discussed above. Much of the dissolved material stays within the water column, but suspended particulate matter and precipitated chemicals settle to the bottom of the Sea and may accumulate. The distribution of contaminants in sediments depends on the location of the inflow points, the concentration of contaminants in the inflows, physical characteristics of the suspended material (i.e., size, chemical composition), and the depositional environment. The depositional environment relates to the physical characteristics of the Sea body and is influenced by water depth, energy regime, in-Sea currents, and wind-driven resuspension.

Extensive research has been undertaken in and around the Salton Sea to evaluate biological impacts from contaminants, and to characterize water quality. Data on the bottom sediment characteristics and contaminants of the Salton Sea are limited, however.

Background and Historical Studies. Previous studies regarding various constituents in sediment of the Salton Sea have identified the presence of a number of inorganic and organic chemicals, including organochlorine pesticide residues of DDT and its derivatives, DDD, and DDE in the sediments. DDT, DDD, DDE, dichloromethane (DCA), PCBs, polynuclear aromatic hydrocarbons (PAHs), pesticides, selenium, and boron have been measured in river sediments feeding into the Salton Sea (Bechtel 1997, Eccles 1979, Hogg 1973, Setmire et al. 1993, and Setmire et al. 1990).

Sediment Source, Size, and Characteristics. Historically, distribution of heavy residues and mineralogical composition suggest local sources of the some sediments; however, about 75 percent of the sediment was transported by the LCR into the Salton Sea (Arnal 1961). The Colorado River carried eroded debris from the Colorado Plateau, depositing sand and mud in the southern part of the Basin. Sediment deposits from sources at the Basin margins were deposited on the Sea bottom, barrier beaches, braided streams, and alluvial fans (Van de Kamp 1973).

Sediment samples on the bottom of the Sea consisted of silt, clay, and finer-grained sands, with higher sand percentages near the mouths of the New and Alamo Rivers, near Salton City along the western shore, and extending into the central, deeper parts of the Sea. The lower velocity Whitewater River Delta was predominantly silt (Vogl et al. 1999). Sands were present predominantly to depths greater than 3 feet within 500 feet offshore; clay predominantly to depths of greater than 3 feet, between 500 and 12,000 feet offshore; and clay predominantly to a depth of 2.75 feet, underlain by sand, beyond 12,000 feet offshore (Bechtel 1997).

A variety of physical and chemical properties and reactions regulated the pH of the sediments (e.g., carbonates, organic matter, carbon dioxide, and organic acids from the decomposition of plant and animal matter). The distribution of organic content was influenced by texture of the sediments, currents, and phytoplankton. Low organic content (less than 1 percent) was found along the shore, higher values (4 to 6 percent) were found in the central part of the Sea, and a maximum content (greater than 6 percent) was sampled near Fish Spring, 3 miles offshore (Arnal 1961).

Chemical Data. There is a lack of routine sediment monitoring data for the Salton Sea (Holdren 1999). The following is a discussion of chemical data found in the limited published material on Salton Sea sediments. Summarized available sediment data are presented in Tables 3.1-9 and 3.1-10 (Vogl et al. 1999).

Spatial Distribution of Constituent Concentrations: For general purposes, it should be noted that concentrations of inorganic chemicals in the sediments were generally higher in the northern part of the Salton Sea and in the upper 1 foot of sediment (Vogl et al. 1999). Conversely, organic chemical concentrations were high, in general, in samples collected in the southern part of the Salton Sea; in particular, some of the highest concentrations of DDT metabolites were found in the bottom sediments at the outlets of the Alamo River, New River, and Trifolium Drain 1 (Levine-Fricke 1999b, Setmire et al. 1993).

Inorganic Constituents: Detailed analyses of selenium and boron in water, sediment, and biota samples were presented by Setmire et al. (1990 and 1993). Setmire and Schroeder (1998) presented a more detailed analysis of selenium results, including data from 1994 through 1995, presented in Table 3.1-9. The presence of various inorganic constituents in the Salton Sea, offshore of the Salton Sea Test Base was also reported (Bechtel 1997). The Salton Sea Test Base is located along the west shore of the Sea, south of Salton City. The military site was historically an aeroballistic marine target area used to test inert atomic weapons. Approximately 3,750 nonexploding test units were dropped into the Sea. Most units weighed between 5,000 and 40,000 pounds, and consisted of stainless steel casings; arming, fuse, and firing components; batteries; and metal or concrete ballast. Approximately 10,000 pounds of material has been recovered, but the majority of the test units remain on the Sea floor (Levine-Fricke 1999b).

Inorganic chemicals, organochlorine pesticides, and, to a limited extent, organophosphorous pesticides were analyzed. Chemicals were identified as being of concern if detected above the maximum “baseline value” for soils of the western US. The following chemicals were identified (with median concentrations) as being of concern: chromium [less than 2 milligrams per kilogram (mg/kg)], nickel (25 mg/kg), selenium (0.7 mg/kg), thorium (10.6 mg/kg), uranium (4.9 mg/kg), and zinc (78 mg/kg). Other chemicals detected included arsenic (5.6 mg/kg), silver (less than 2 mg/kg), barium (less than 2 mg/kg), cadmium (less than 2 mg/kg), copper (28 mg/kg), lead (21 mg/kg), molybdenum (less than 2 mg/kg), and vanadium (77 mg/kg) (Setmire et al. 1990).

A naturally occurring selenium removal process at the mouth of the Alamo River was investigated. Selenium concentrations were reported to vary without any discernable pattern of distribution (e.g., 0.2 and 0.3 mg/kg in the river sediment samples, 0.2 to 2.5 mg/kg throughout the Alamo River Delta, and 1.3 to 2.5 mg/kg in the embayments) (Setmire et al. 1993).

TABLE 3.1-9
Concentrations of Inorganic Chemicals in Sediment from the Salton Sea and Surrounding Tributaries Determined to be of Concern

Location	Chemical (concentrations in mg/kg)													
	Antimony	Arsenic	Barium	Cadmium	Chromium	Copper	Molybdenum	Nickel	Selenium	Thallium	Thorium	Uranium	Vanadium	Zinc
Maximum Baseline Value mg/kg[a]	—	22	1,700	—	200	90	4	66	1.4	—	20	5.3	270	180
Salton Sea median concentration (mg/kg) [b]	—	5.6	550	—	58	28	—	25	0.7	—	10.6	4.9	77	78
Whitewater River Upstream from Hwy. 111[b]	—	2.4	690	<2	81	34	<2	30	0.1	—	56	14.6	140	110
Whitewater River at Outlet[b]	—	5	710	<2	210	64	3	170	0.5	—	18.9	5.5	130	510
Alamo River at International Boundary[b]	—	6.3	510	<2	58	26	<2	26	1.6	—	12.2	4.8	77	97
Trifolium Drain 1[b]	—	5.8	550	<2	53	28	<2	24	1.9	—	9	4.4	72	78
Ave. 64 Evacuation Channel at Hwy. 195[b]	—	4.4	620	<2	75	61	2	2	0.4	—	21.3	5.1	120	130
New River at Midpoint (08/11/86 and 08/14/86) [b]	—	5.4, 11.0	580, 780	<2, <2	63, 73	30, 27	<2, 2	25, 35	0.6, 1.3	—	10.6, 12.0	6.1, 7.5	77, 96	75, 120
New River at Outlet[b]	—	4.7	720	<2	70	23	<2	22	0.6	—	19.2	7.7	82	71
East Highline Canal[b]	—	4.5	690	<2	50	23	<2	22	0.9	—	12.7	5.9	60	70
Alamo River Delta[c]	—	—	—	—	—	—	—	—	0.2	—	—	—	—	—
Shoreline Disposal Area[d]	—	0.9	315		33.9	68.7				0.31	—	—	2.6	8.6
Offshore Aeroballistic Marine Target SSTB[d]	9.9	27.4	—	1.6	—	—	14.5		8.4	—	—	14.2	52.5	—
Imhoff Tank[d]	—	—	—	—	—	—	—	—	--	0.26	—	—	—	—

[a]Shacklette and Boerngen 1984
[b]Setmire et al. 1990
[c]Setmire et al. 1993
[d]Bechtel 1997 (maximum concentrations reported)

Source: Levine-Fricke (1999a)

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TABLE 3.1-10
Concentrations of Organic Chemicals in Sediment from the Salton Sea and Surrounding Tributaries Determined to be of Concern

	Chemical (concentration in µg/kg)															
Location	**Acetone**	**Carbon disulfide**	**Chlordane**	**DDT**	**DDD**	**DDE**	**Dieldrin**	**Ethyl-benzene**	**Gamma-Chlordane**	**Heptachlor**	**Meth-oxychlor**	**PAHs***	**PCBs**	**Toluene**	**Toxaphene**	**Xylenes**
Whitewater River Upstream from Hwy. 111[b]	—	—	<1.0	—	<0.1	0.6	—	—	—	—	<0.1	—	<1	—	10	—
Alamo River Outlet[b]	—	—	<1.0	—	20	64	—	—	—	—	<0.1	—	<1	—	<10	—
Alamo River at International Boundary[b]	—	—	<1.0	—	2.3	18	—	—	—	—	<0.1	—	9	—	<10	—
Trifolium Drain 1[b]	—	—	<1.0	—	3.7	41	—	—	—	—	<0.1	—	<1	—	<10	—
Trifolium Drain 1[e]	—	—	—	—		110	—	—	—	—		—	—	—	—	—
Trifolium Drain 4[b]	—	—	<1.0	—	12	56	—	—	—	—	<0.1	—	<1	—	40	—
Vail Drain 4[b]	—	—	<1.0	—	7.8	57	—	—	—	—	45	—	<1	—	<10	—
Ave 64 Evacuation Channel at Hwy. 195[b]	—	—	1	—	5.8	56	—	—	—	—	<0.1	—	<1	—	<10	—
Ave 64 Evacuation Channel at Hwy. 195[e]	—	—	—	—		67	—	—	—	—	—	—	—	—	—	—
New River at Midpoint (08/14/86)[b]	—	—	5	—	3.5	7.4	—	—	—	—	<0.1	—	4	—	<10	—
New River at International Boundary[b]	—	—	20	—	24	7.6	—	—	—	—	<0.1	—	24	—	<10	—
East Highline Canal[b]	—	—	<1.0	—	2.3	18	—	—	—	—	<0.1	—	9	—	<10	—
Shoreline Disposal Area[d]	23	2	—	3.1	4.9	6.6	3	2	3.4	3.5	14	85	—	15	—	11
Imhoff Tank[d]	—	—	—	—	—	3.2	0.6	—	190	290	—	—	—	—	—	—
1 Mile from Whitewater River Outlet[f]	0-11.5 cm 11.5-23 cm	—	—	<25 <25	5 <5	5 <5	<5 <5	—	—	—	—	—	—	—	—	—
2.5 Miles from Whitewater River Outlet[f]	0-11.5 cm 11.5-23 cm	—	—	<25 25	5 20	5 23	<5 <5	—	—	—	—	—	—	—	—	—
5 miles from Whitewater River[f]	0-11.5 cm 11.5-23 cm	—	—	<25 25	12 5	14 5	<5 5	—	—	—	—	—	—	—	—	—

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TABLE 3.1-10
Concentrations of Organic Chemicals in Sediment from the Salton Sea and Surrounding Tributaries Determined to be of Concern

	Chemical (concentration in µg/kg)															
Location	**Acetone**	**Carbon disulfide**	**Chlordane**	**DDT**	**DDD**	**DDE**	**Dieldrin**	**Ethyl-benzene**	**Gamma-Chlordane**	**Heptachlor**	**Meth-oxychlor**	**PAHs***	**PCBs**	**Toluene**	**Toxaphene**	**Xylenes**
1 mile from Alamo River Outlet[f]	0-11.5 cm	—	—	25	5	5	92	—	—	—	—	—	—	—	—	—
	11.5-23 cm			25	5	5	100									
2.5 miles from Alamo River Outlet[f]	0-11.5 cm	—	—	25	5	16	49	—	—	—	—	—	—	—	—	—
	11.5-23 cm			82	5	18	880									
5 miles from Alamo River outlet[f]	0-11.5 cm	—	—	25	5	5	60	—	—	—	—	—	—	—	—	—
	11.5-23 cm			25	5	5	43									

* Polycyclic Aromatic Hydrocarbon (PAHs) values are for Benzo(a)anthracene and Chrysene
[a]Shacklette and Boerngen 1984
[b]Setmire et al. 1990
[c]Setmire et al. 1993
[d]Bechtel 1997 (maximum data reported)
[e]Eccles 1979
[f]Hogg 1973

Source: Levine-Fricke 1999a

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Setmire has since reported a potentially discernable relationship between grain size and selenium concentration (Setmire 2000a and b). In bottom sediment sampled at 11 sites in the Salton Sea, a median concentration for selenium of 2.7 parts per million (ppm), with a range of 0.58 to 11 ppm, was detected. When comparing particle size distribution with a plot of Salton Sea contours, very fine sediment [less than 0.002 millimeters (mm)] in the deepest parts of the Salton Sea correlated to the highest selenium concentrations.

Setmire and Schroeder reported selenium concentrations in bottom sediments of the Alamo River Delta that ranged from 0.2 to 2.5 mg/kg, with no readily apparent spatial pattern in their distribution (Setmire and Schroeder 1998). A composite sample of Alamo River Delta sediment collected in 1986 contained a selenium concentration of 3.3 mg/kg, with a dissolved organic content of 1 percent (Levine-Fricke 1999b). A sediment sample collected near the south buoy (deepest location in the Salton Sea) in 1996 had a selenium concentration of 9.3 mg/kg, with a corresponding dissolved organic carbon content of 9.2 percent. The core was composed of very low-density material. Setmire and Schroeder concluded that the high selenium concentration and the high dissolved organic carbon content of this sample show that selenium is likely incorporated into biomass, which degrades and concentrates in the deepest parts of the Salton Sea.

A variety of inorganic constituents in the sediment at the shoreline disposal area, offshore target area, and Imhoff Tank area (sanitary waste treatment) of the Salton Sea Test Base were detected (Bechtel 1997). From the sediment of the offshore marine target area, elevated maximum concentrations were reported of cadmium (1.6 mg/kg), arsenic (27.4 mg/kg), antimony (9.9 mg/kg), molybdenum (14.5 mg/kg), selenium (8.4 mg/kg), and vanadium (52.5 mg/kg). One localized area of elevated uranium (maximum 14.2 mg/kg) was reported. In the sediment samples from the Imhoff Tank area, thallium (maximum 0.26 mg/kg) was detected.

Organic Constituents: Chlorinated hydrocarbon pesticides in water, sediment, and tissue samples from the Salton Sea were examined in 1970 and 1971 (Hogg 1973). DDT and its metabolites were found in 146 out of 159 samples, and dieldrin and its metabolites were found in 66 of 159 samples (see Table 3.1-10).

Additionally, Setmire presented results of organochlorine pesticide analyses from sediment and biota samples. Although the use of DDT was banned in the US in 1972 and in Mexico in 1983, DDT metabolites were detected in most samples. The highest DDE concentration (64 µg/kg) was detected in the Alamo River at the outlet to the Salton Sea, immediately upstream of the Alamo River Delta. The sample from the Alamo River at the outlet had a DDD concentration of 20 µg/kg. The lowest concentrations of DDD and DDE were detected at the Whitewater River, upstream of Highway 111, outside the limits of the Salton Sea (Setmire 1990 and Setmire et al. 1990 and 1993).

A variety of organic constituents were present in the sediment at the shoreline disposal area, offshore marine target area, and Imhoff Tank area of the Salton Sea Test Base. From the shoreline disposal area, the presence of organochlorine pesticides, PAHs, and volatile organic compounds (VOCs) (acetone, carbon disulfide, ethylbenzene, toluene, and xylenes) was reported in sediment samples. From the Imhoff Tank area, organopesticides (DDE, dieldrin, gamma-chlordane, and/or heptachlor) and phenol (one sample) were detected in the sediment samples (Bechtel 1997).

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A volume of 10,400 pounds of total DDT and its metabolites was calculated in the upper 3.5 inches of sediment over the entire Sea (Hogg 1972). Mean values for residues of the pesticides dieldrin, DDT, DDD, and DDE are presented in Table 3.1-10.

Nutrients: Samples were collected for selected nutrients in sediments. In the Salton Sea composite, organic-nitrogen was detected at a concentration of 1,500 mg/kg, and organic-carbon was detected at a concentration of 10 mg/kg. The highest concentration of total phosphorous detected was in the New River at the outlet to the Salton Sea (1,600 mg/kg), and the lowest detected concentration was in the Whitewater River outlet (320 mg/kg) (Setmire et al. 1990).

Sediment Inflow Volume. Sediment inflow volume (measured in AFY) is important both hydraulically, as a means of altering inflow and in-Sea circulation patterns, and biologically, playing an important role in providing suitable habitat to support ecological functions for fish and benthos. Section 3.2 of this EIR/EIS discusses the potential for biological impacts from sediment inflows.

The following sediment inflow data were computed using IIDSS, the IID Water Conservation Model, and are based on flow-weighted average TSS concentrations recorded at the mouths of the New and Alamo Rivers (outlets to the Salton Sea). Data used by the IIDSS to compute the sediment inflow values spanned from 1969 to 1998, and are based on information available through EPA's STORET database. Between 1969 and 1998, the average flow in the New River was calculated at 622 cfs, and 843 cfs for the Alamo River. An analysis of TSS data for the same period gives a flow-weighted average sediment concentration in the New River at 313 mg/L, and 479 mg/L in the Alamo River. With respect to actual sediment inflow volumes, these discharge rates translate to an estimated annual suspended sediment load in the New River of approximately 192,000 tons per year, while the average annual sediment load for the Alamo River is estimated at 398,000 tons per year. At an estimated bulk density of 70 pounds per cubic foot (Chow 1964), this translates to an annual sediment contribution to the Salton Sea from the New River of 126 AFY, and 261 AFY from the Alamo River.

Stephen, Arnal, and DOI have completed estimates of sediment load. The suspended sediment load carried within the New River was estimated by Stephan to be approximately 551,000 tons per year (Stephen 1972). This translates to a deposited volume of 361 AFY (at 70 pounds per cubic foot). Arnal estimated the average annual sediment contribution from the Alamo River and New River to be 340 and 370 AFY, respectively (based on an average flow rate and a 10 percent bedload pickup) (Arnal 1961). Finally DOI estimated a suspended sediment load of approximately 476,000 tons per year for the Alamo River, for an average discharge of approximately 1,000 cfs, and a calculated sediment concentration of 0.0475 percent was estimated. The annual suspended sediment volume for the Alamo River would be 310 AFY (DOI 1970). DOI also estimated a suspended sediment load of 519,000 tons, or 340 AFY, for the New River, at an average annual discharge of 660 cfs, an average measured sediment concentration of 0.0795 percent, and a unit weight of 70 pounds per cubic foot. Adding 10 percent bedload pickup, the average annual sediment contribution from the New River would be 370 AFY.

For the Alamo River, the sediment concentrations used in calibrating the model's sediment algorithm are identical to that reported by DOI. Therefore, the modeled results closely parallel findings reported by DOI. The difference in sediment loading is explained by differences in flow data used for the river (1000 cfs for the DOI data vs. 843 cfs for the flow derived from the STORET database). However, for the New River, there is a significant discrepancy between the TSS concentrations computed from the STORET database and the concentrations reported by Stephen and DOI. Given the relatively low sediment concentrations reported in the New River at the International Boundary, it stands to reason that TSS values reported at the mouth of the New River would be lower than those observed at the mouth of the Alamo River. This is the case when analyzing the data provided in the STORET database. It is not understood why the reverse is purported by the Stephen / DOI values.

Regardless, even when using the larger sediment discharge volumes reported in the earlier findings, the sediment accumulation rate for the Alamo River and New River deltas in the Salton Sea was estimated to be 2 in / yr, as opposed to a sedimentation rate for the central part of the Salton Sea of 0.02 in / yr (Arnal 1961). Further, sediment volume inflow to the Salton Sea is reported not to be a problem on the scale of reservoir sedimentation. The estimated sediment inflow volume to the Salton Sea is small compared to total storage volume of the Sea. The future, long-term average sediment inflow volume to the Salton Sea is estimated to be 4 KAF. The 50-year estimated sediment volume of 200 KAF would represent less than 4 percent of the gross water storage volume of the Salton Sea, at a water surface elevation of -232 feet msl (DOI 1970).

Recent and Current Studies. Levine-Fricke (1999b) recently reported their findings from a study that evaluated the overall distribution of sediment types and contaminants throughout the Salton Sea and its three major tributaries: the Whitewater River, the New River, and the Alamo River (Levine-Fricke 1999b). Vogl presented the data from the Levine-Fricke report to the Wetlands and Remediation International Conference in November 1999, as discussed below (Vogl et al. 1999). Beginning in the winter of 1998 to 1999, 57 grab-sample sites and 16 core sites were analyzed for 17 inorganic chemicals (including metals and metalloids), organic chemicals [including VOCs, semivolatile organic compounds (SVOCs) and PCBs], and agricultural pesticides, herbicides, and their major breakdown products.

Inorganic Constituents: Within the Salton Sea, cadmium, copper, molybdenum, nickel, zinc, and selenium were determined to be elevated inorganic constituents of potential concern, with the most elevated being selenium (see Table 3.1-11). A determination of the forms of the contaminants, especially selenium, would be valuable in evaluating potential mobility and bioavailability (Levine-Fricke 1999b, Vogl et al. 1999).

Organic Constituents: Elevated concentrations of organic chemicals detected in sediment were limited to predominantly VOCs. Out of 118 sediment samples analyzed for VOCs, 114 samples contained detectable amounts of acetone, carbon disulfide, and / or 2-butanone (see Table 3.1-12). Detectable amounts of o-xylenes, 1,3,5-trimethylbenzene, 1,2,4-trimethylbenzene, naphthalene, and n-propylbenzene were reported in only a few other sediment samples. SVOCs, chlorinated pesticides, PCBs, organophosphate and nitrogen pesticides, and chlorinated herbicides were not detected in any sediment samples (Levine-Fricke 1999b, Vogl et al. 1999).

TABLE 3.1-11
Reported Values for Inorganic Constituents of Potential Concern in Salton Sea Sediments

Constituent	Low mg/kg	High mg/kg	Location of Highest Concentrations
Cadmium	0.67	5.8	North-central part of the Salton Sea
Copper	8.1	53	Near mouth of Whitewater River
Molybdenum	11	194	North and central part of the Salton Sea
Nickel	3.3	33	Mouth of the Whitewater River and deeper portion of the Sea
Zinc	5.4	190	Mouth of Whitewater River and Salt Creek
Selenium	0.086	8.5	Just offshore of Desert Shores

Source: Levine-Fricke 1999b, Vogl et al. 1999

TABLE 3.1-12
Measured Organic Constituents of Potential Concern in Salton Sea Sediments

Constituent	Low µg/kg	High µg/kg	Location of Highest Concentrations
Acetone	32	840	Near the mouth of the New River
Carbon disulfide	15	1,800	Near the mouth of the Whitewater River
2-butanone	11	150	Offshore from Salton Sea State Park in the northern portion of the Sea

Source: Levine-Fricke 1999b, Vogl et al. 1999