CHAPTER 3

AFFECTED ENVIRONMENT

This chapter is divided into resource sections covering all aspects of the human environment that may be affected by the Salton Sea Restoration Project. The focus is mainly on areas that would be affected by Phase 1 actions. Areas that may be affected by Phase II restoration activities are addressed in Chapter 6 at a programmatic level of detail, consistent with the level of planning information currently available.

Each of the resource sections includes an overview of the resource and the associated study area and a description of the affected environment for the various elements of the resource area. The sections are provided in sufficient detail for the reader to understand the environmental consequences of the program, as discussed in Chapter 4.

3.1 SURFACE WATER RESOURCES

3.1.1 Introduction and Scope of Discussion

The affected environment discussion for surface water resources at the Salton Sea includes surface water hydrology, water circulation patterns, water quality and salinity, and water use and management. The Phase I study area for surface water resources is defined by watershed boundaries of the Salton Basin. The Salton Sea watershed contains the Salton Sea and the Coachella and Imperial valleys. The Salton Sea is a terminal lake, with no outlet to the ocean. It receives sporadic inflow from precipitation. The bulk of the inflow is from agricultural and municipal drainage. The ultimate source of this most inflow is water imported to the region from the Colorado River.

The Phase I study area also includes that portion of the Colorado River and Delta below Imperial Dam that is affected by flood flows because up to 300,000 acre-feet of flood flows may be diverted in some years to the Salton Sea.

Water resources include both surface water and ground water resources. Surface water is simply the water exposed at earth's surface, and ground water is found beneath earth’s surface at any particular time. Sometimes it is appropriate to view surface water and ground water together, as interactive parts of the hydrologic cycle. Thus, for example, some of the surface water applied to irrigate crops infiltrates and recharges the water in the ground. Some of this seepage may be intercepted by agricultural drainage tile systems, and some infiltrates to greater depths. The drains discharge to ditches and eventually to the Salton Sea. Similarly, because the Salton Sea Basin has no outlets for either surface or ground water, even the water that percolates to greater depths eventually flows to the Salton Sea through the subsurface. Thus, both surface water and ground water contribute to maintain the elevation of the Salton Sea.

3.1.2 The Salton Sea Watershed and Surface Water Hydrology

The watershed of the Salton Sea encompasses about 8,360 square miles. It includes a small corner of San Bernardino County that drains to the Whitewater River, some 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 principal 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. The watershed is shown on Figure 3.1-1.

The Colorado River Basin Regional Water Quality Control Board (CRB-RWQCB) has divided the Salton Sea watershed into planning areas. With the exception of the southern boundary with Mexico, the boundaries of these planning areas are defined by hydrologic boundaries. In addition to the Salton Sea Planning Area, the study area includes the Coachella Valley Planning Area, the Imperial Valley Planning Area, and the Anza-Borrego Planning Area.

Only about three percent of the water that flows into the Salton Sea comes from rainfall within the watershed. Imperial and Coachella Valleys receive an average of about 2.3 and 2.8 inches of rainfall per year, respectively (MacGillivray 1980; 1981). Direct annual precipitation on the Salton Sea is estimated to be about 2.5 inches (Hely et al 1966). The Coyote Mountains east of the Salton Sea receive about eight inches per year. The upper San Jacinto and San Bernardino mountains west of the Salton Sea receive as much as 30 to 40 inches (CRB-RWQCB 1994). Most runoff occurs from November through April and from August through September. During the summer, most of the rainfall is from short, intense thunderstorms.

The total amount of water lost to evaporation from the Sea is currently estimated at about 1.36 MAFY, and since the elevation is approximately steady, this must be equivalent to the sum of the inflows. Table 3.1-1 shows the major sources of inflow to the Sea. The average tributary inflow values were calculated from published stream gage records for water years 1960/1961 through 1997/1998,

Table 3.1-1
Sources of Salton Sea Inflow

Source of Inflow	Total Average Annual Inflow (Acre-feet)	Percent Contribution of Total Inflow
Alamo River	620,000	46.1
New River	438,000	32.5
Agricultural Drains	106,000	7.9
Whitewater River	79,000	5.9
Ground Water	50,000	3.7
Direct Precipitation	46,500	3.5
San Felipe Creek	5,500	0.4
Salt Creek	1,000	0.1
Other	17,000	1.3
Total	1,346,000	100.0%

Source: USGS Stream gage data 1960-1998; Hely et al 1966; Ogden 1996

where available. (For example, the record for San Felipe Creek does not extend beyond 1991, and the record for Salt Creek begins in 1974). Agricultural drainage is the source of most of the New River, Alamo River, Whitewater River, and agricultural drain flows shown in Table 3.1-1.

The rate of ground water inflow was estimated by the U.S. Geological Survey (Hely et al 1966). At the time, it was estimated that about 30,000 AFY entered from Coachella Valley, and about 10,000 AFY were from flow beneath alluvium of San Felipe Creek. Only about 2,000 AFY was estimated to come from alluvium of the Imperial Valley. Ground water conditions in the Coachella Valley have changed since that time, and the current ground water component may be less than the estimate shown. Imperial Valley Drains are estimated to account for about 106,000 AFY (Ogden 1996). About 17,000 AFY in Table 3.1-1 represents inflow not otherwise accounted for. Of this amount, about 10,000 AFY may represent ungaged stream flow (Hely et al 1966).

The table suggests that more than 90 percent of the inflow to the Sea originates from sources outside the basin, mainly from the Colorado River. Some of the flow in the New River originates from Mexico. The average annual flow measured by the U.S Geoogical Survey in the New River at the International Border between 1980 and 1997, was about 182,000 AFY, and since the early 1960’s, inflow from Mexico has contributed about 30 to 35 percent of the flow in the New River. By contrast, the Alamo River generally receives less than 2,000 AFY from Mexico, or less than 0.03 percent of its flow (Tetra Tech 1999).

The values shown in Table 3.1-1 are meant to illustrate the relative contributions of different sources of inflow, but the reader should not place too much emphasis on any single reported value. Older records do not necessarily reflect current water use and management patterns, and historical records that cover different periods of time may not be comparable. Flow records for the gage at the mouth of the New River are available from 1943 until the present. Annual flows in the New River have ranged from about 378,000 to 540,000 AFY during this period. The average annual flow in water years prior to 1960/1961 was about 474,000 AFY, and the average was about 451,000 AFY since 1960. Also, in water years from 1960 to 1998, discharge to the Salton Sea from the Alamo River averaged about 620,000 AFY, but ranged from 492,000 AF in 1986 to 718,000 AF in 1963. Similarly, although average inflows from Salt Creek since 1974 were about 4,000 AFY, discharge has declined to less than 1,000 AFY in recent years. Most of the flow in Salt Creek originates from seepage from unlined portions of the Coaschella Canal. If the Canal is relined, one of the mitigation measures may be to artifically supplement the flows in Salt Creek with releases from the canal (Tetra Tech 1999).

Development of the Salton Sea

The current Salton Sea was formed when flood flows from the Colorado River broke through a temporary diversion that had been designed to bypass the Imperial Canal. The Imperial Canal, which was routed from the Colorado River to the Imperial Valley through Mexico, was completed in 1901, but by 1904 it had become blocked by sediment. On October 11, 1905, a dike failed and nearly the entire flow of the Colorado River flowed uncontrolled into the Salton Basin for the next 18 months. It flooded the railroad line, railroad stations, and the salt works on the basin floor. When the breach was finally repaired in 1907, the elevation of the Salton Sea had reached –195 ft msl, and had a surface area of 520 square miles.

The rate of evaporation from the Salton Sea has been varioiusly estimated at between 5.5 to 6.5 feet per year (for example, see Ormat 1989; CVWD 1999a). For purposes of this report, the average annual rate is taken to be 69 inches (5.78 feet) per year, as estimated by the U.S. Geological Survey (Hely et al 1966). At this high rate of evaporation, the Salton Sea would have soon dried up, as lakes in the area have for thousands of years, had it not been for importation of water from outside the basin.

Figure 3.1-2 shows how the elevation of the Salton Sea has changed from 1907 until the present. As can be seen in the figure, the elevation has been fairly constant during the past 10 years or so. Since the inflow during any given period is equal to the change in volume of the Sea plus any losses that have occurred due to evaporation, a constant elevation indicates that the rate of inflow is approximately equal to the rate of evaporation. Although the average rate of inflow to the Salton Sea has averaged about 1.36 million af/yr for the past 50 years or so, the rate of inflow during any one year has ranged from between about 1.15 maf/yr

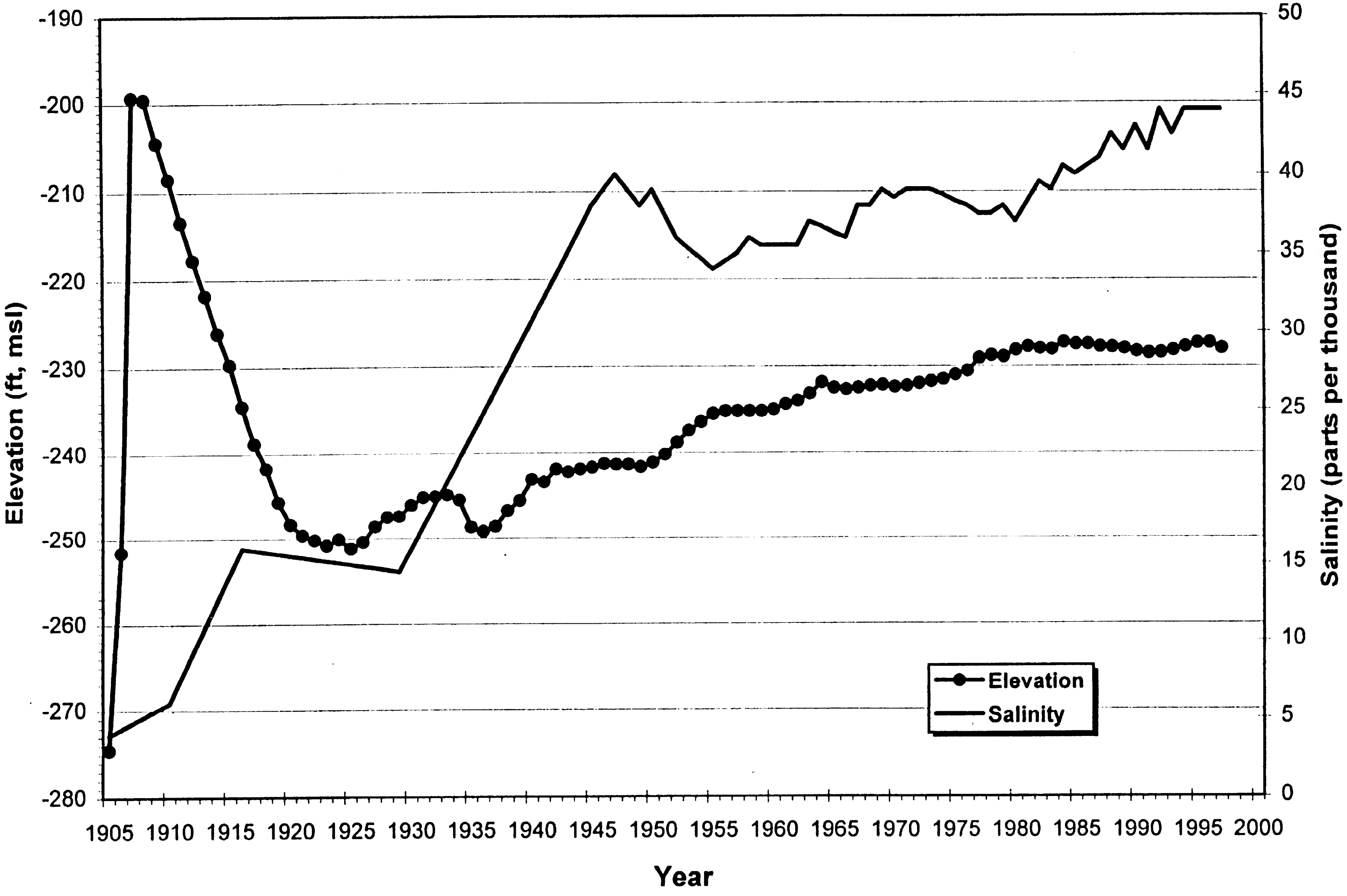


Figure 3.1-2 Historic Change in Elevation and Salinity of Salton Sea

and 1.65 maf/yr. Probably the main reason for the fluctuations in inflow are changes in cropping patterns in the Imperial, Coachella Valleys, and Mexicali valleys. Different crops consume different amounts of water. For example, in the Imperial Valley, evapotranspiration from alfalfa is estimated to consume about 80.6 inches of water (6.7 feet) per year, while citrus crops consume only about 46.1 inches (3.84 feet) per year (MacGillivray. 1980). Similar rates apply to the Coachella Valley. Variations in the amount of water that ends up in agricultural drains is, therefore, highly dependent on market forces.

3.1.3 Salton Sea Circulation

Studies of Salton Sea circulation recently have been conducted by the Water Resources and Environmental Modeling Group of the Department of Civil and Environmental Engineering (Modeling Group) at the University of California Davis (UC Davis), under contract to the Salton Sea Authority. The Modeling Group developed a model of the Salton Sea, based on an existing model called RMA-10, to predict the effects of Salton Sea Restoration Project alternatives on circulation patterns in the Sea (King 1998). These circulation patterns are believed to affect the distribution of nutrients, dissolved oxygen, mixing of fresh water, temperature gradients, and other water quality parameters in the Salton Sea, as well as to have a potential effect on shoreline erosion and sediment deposition patterns. A three-dimensional model was used to simulate current velocities that may vary with depth or that may be affected by differences in water density due to suspended sediment, temperature, and salinity. While the model is capable of accounting for many variables, it has been found that wind velocity is the dominant factor in creating the observed pattern of currents in the Salton Sea. The model was configured to account for the effects of the major tributary inflows from the Alamo River, New River, and Whitewater River and to simulate changes in salinity and temperature.

The model was calibrated to a set of field measurements of wind velocity, temperature, salinity, and current velocities obtained over the period from October 8 through October 29, 1997. A detailed description of the collection of the calibration data, and the calibration process, is presented in a report prepared by the Modeling Group (Cook, et al 1998), and is briefly summarized here.

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 the Bureau of Reclamation (Ferrari and Weghorst 1995). The motion of water in the Sea results from the transfer of energy, from wind, fresh water inflows, or solar heat, at network boundaries. The model solves equations describing the energy flow through the system, when certain physical properties of the system are mathematically defined. These properties include the roughness of the bottom, wind stress, inflow rates, etc. Some of these specified values are based on observation, and others are estimated through trial and error.

The accuracy of assumptions used in constructing the model were tested by calibrating the model against observed patterns of current velocity, conductivity (salinity), and temperature that developed in response to measured hydrologic and meteorologic conditions. It was found early in the calibration process, that the pattern of currents observed in the Sea is controlled primarily by wind velocity.

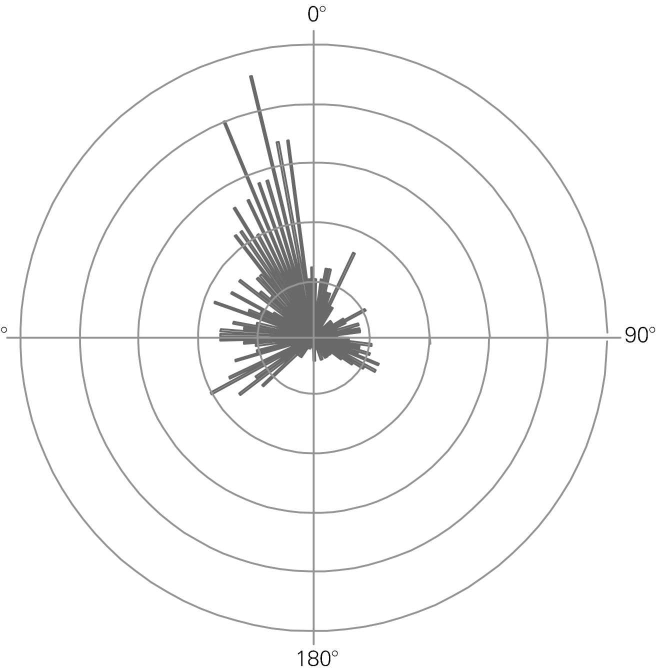
In order to investigate the changes in current patterns, salinity, and temperature that would occur if the elevation or shoreline geometry of the Sea were altered, model simulations were perfored using the same October 1997 meteorologic data set used in calibrating the model.

The predominant wind direction throughout the year, and the predominant wind direction observed in the October 1997 data, is from northwest to southeast, with a more pronounced eastward component across the southern portion of the Sea. Figure 3.1-3 shows wind rose diagrams illustrating the frequency with which wind was blowing during the period used as input to the hydrodynamic model, and over the entire year in 1997, using wind data from stations at Salton City (CMIS Station 127), and at the State Recreation Area on the northeast shore (CMIS Station 154). The diagrams show the direction from which the wind was blowing in 3 compass degree increments, sampled hourly. The length of the lines is proportional to the frequency.

During the modeled period, the average wind speed increased from less than about 3.4 mph in the northern end of the Sea to more than 7.8 mph in the southern end. Water current speeds were roughly one-tenth of wind speeds. Figure 3.1-4 illustrates the change in the model-simulated current speed at a point in the southern portion of the Sea. The location is roughly 4 miles northwest of the mouth of the Alamo River, but the pattern of change in current speed is fairly typical of any point in the southern part of the Sea, because it occurs in response to changes in wind speed. The two peaks in current speed on October 10, and on October 23, result from two storms that moved through the basin during this period.

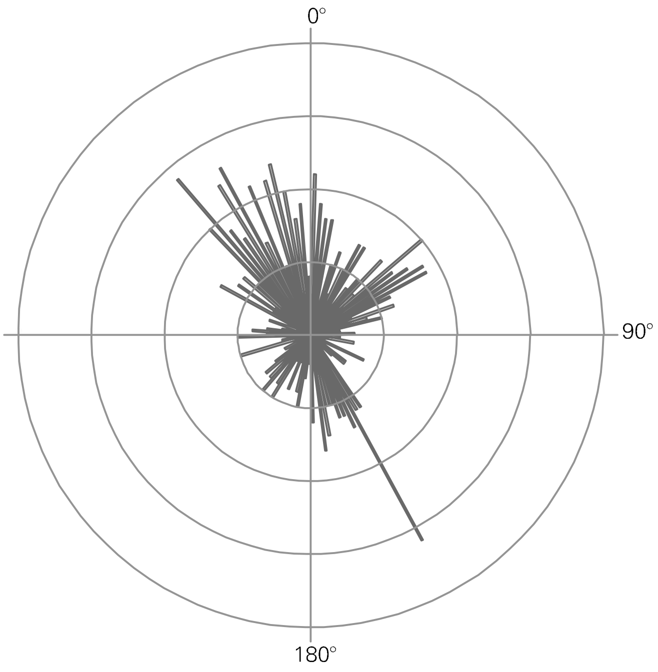
The north-south wind pattern results in a pattern of currents dominated by two large gyres, rotating in opposite directions in each of the two “basins” of the Sea; in the northern basin, the currents rotate clockwise and in the southern basin, the currents rotate counterclockwise. The speed of rotation 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.

Fresh water is less dense than salt water, and in some estuary environments fresh water will “float” for a time over saltier water, creating a salt wedge at the mouth of a river, for example. However, in the Salton Sea, freshwater inflows from



Salton City
October 9-30, 1997

Salton City
Jan. 1 - Dec. 31, 1997



State Recreation Area
October 9-30, 1997

State Recreation Area
Jan. 1 - Dec. 31, 1997

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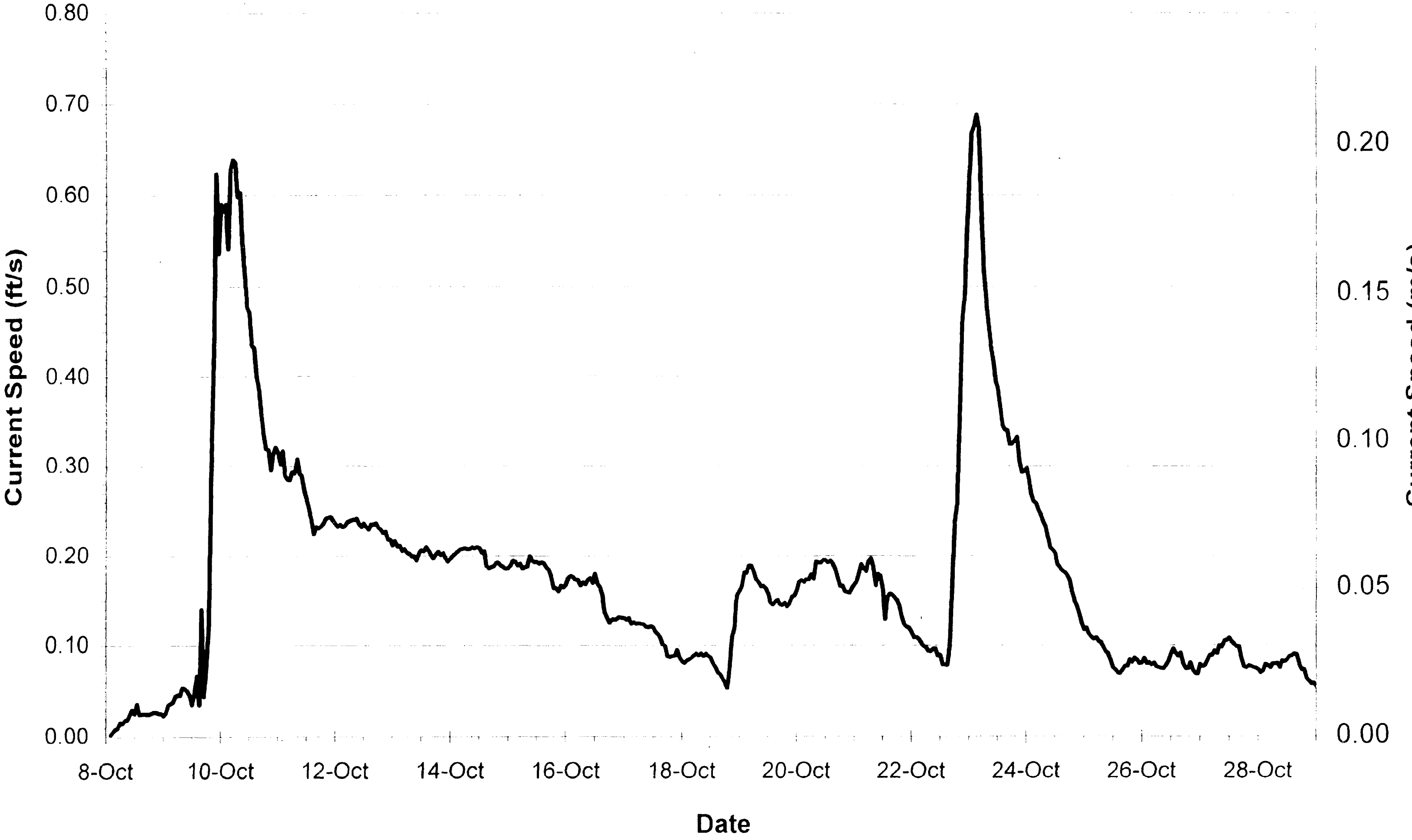
Diagrams show numerical frequency of hourly wind directions plotted by the direction from which wind blows. Length of lines are proportional to number of observations per 3-degree compass sector.

Wind Rose Diagrams for October 9 - 30 and for Year at Two Locations

Salton Sea, California

Figure 3.1-3

Figure 3.1-4 Example of Variation in Current Speed
Surface of Salton Sea (-227 ft msl)
October 9 - 27, 1997 (Node 109) Offshore of Alamo River



tributaries mix rapidly with the ambient salt water, forming a fairly abrupt transition from freshwater to salt water. Thus, with respect ot salinity, and probably all dissolved constituents, the Sea is remarkably homogeous throughout its volume, within a short distance of the mouths of tributaries.

3.1.4 Water Quality and Salinity of the Salton Sea

The Salton Sea is a repository for agricultural and municipal wastewater. In 1998, the Salton Sea was listed by the CRB-RWQCB as an impaired surface water body, in accordance with Section 303(d) of the Clean Water Act. Four of the tributaries to the Salton Sea also are listed as impaired: the New River, the Alamo River, the Coachella Valley Stormwater Channel, and the Imperial Valley Drains (CRB-RWQCB 1998 [#10, pp 2-3]). During the 1960's and 1970's, body contact recreation (swimming, water skiing, etc.), was an important beneficial use of the Sea. As a result, body contact recreation remains one of the listed beneficial uses protected by the Colorado River Region Basin Plan.

The Salton Sea is a sump not only for the water that flows into the Sea but also for all of the salts, sediments, and other constituents dissolved in or transported by that water. These constituents constitute the "load" transported to the Sea by the various sorces of inflow. The quantity of constituents per unit volume of water is the "concentration" of the constituents. However, the loading rate depends on both the 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. The concept of loading has special significance because under the Clean Water Act state regulatory agencies must begin defining "total maximum daily loads" (TMDLs) for constituents believed to adversely affect receiving waters that have been identified as having impaired water quality. The purpose of setting TMDLs is to achieve water quality standards in impaired water bodies, where many sources contribute to the impairment. Currently, the CRB-RWQCB plans to define TMDLs for selenium, salt, and nutrients flowing into the Salton Sea. The target date for the salt TMDL is 2001, for the selenium TMDL is 2007, and for the nutrient TMDL is 2010. In addition, TMDLs are planned for pesticides, silt, bacteria, nutrients, and volatile organic compounds in the New River; for pesticides, selenium, and silt in the Alamo River; for pesticides, selenium, and silt in Imperial County drains; and for bacteria in the Coachella Valley Stormwater Channel. The silt TMDLs will be developed first for the Alamo River and Imperial County Drains, which are targeted for completion in 2000. The silt TMDL for the New River is targeted for completion in 2002, and the TMDL for bacteria in the New River is targeted for completion in 2005 (RWQCB 1999).

Salinity

Units of Concentration. Before discussing salinity, it is important to clarify the the units of measure that salinity values are reported in. Concentrations of dissolved constituents are frequently given in terms of the weight of the constituents per weight of a volume of water. Typically the metric system is used because metric units are easy to use. Two types of concentrations are used widely in reports. One type of concentration is the mass of dissolved substance per unit mass of solution. This type of concentration unit is commonly used for salinity measurements, which are frequently given in parts of salt per thousand parts of solution, (parts per thousand, or ppt). The other commonly used type of concentration gives the mass of dissolved substance per unit volume of solution. Units of miligrams per liter (mg/L) are commonly used. Pure water weighs 1,000 grams per liter, and there are 1,000 milligrams in a gram. So when the substance is dissolved in water and the concentration is low, milligrams per liter volume are nearly equivalent to parts per million mass (ppm). However, when the concentration is high, such as in the range of concentrations of Salton Sea water, a liter of solution weighs significantly more than a liter of pure water. For example, the current concentration of Salton Sea water, 44,000 mg/L, is equivalent to a salinity of about 42.5 ppt, and a salinity of 60 ppt is equivalent to about 63.3 mg/L. In this report, all concentrations are reported in units of mass per volume of solution, and mass per mass concentrations have been converted.

In addition to the confusion that may occur because of the two reporting methods, the way in which salinity measurements are made can also confuse the issue. The concentration of all of the dissolved salts in a solution is known as "total dissolved salts" or TDS for short. Technically, however, salinity is defined by comparing the electrical conductivity of an unknown solution to the electrical conductivity of a known solution of potassium chloride that has similar electrical properties to ocean water. Electrical conductivity measurements can be made rapidly, at low cost, and in place in the field, using a hand-held conductivity instrument. Direct measurement of the mass of dissolved solids in a solution requires that a samle be collected and the analysis be done in a laboratory. For many purposes, the results obtained from the two methods are similar. The concentration of dissolved solids can be estimated from conductivity measurements if the correct conversion factor is used (which depends on the concentration, nature of the dissolved solids, and in some cases, on the temperature). The lack of standardization in the way that concentrations have been reported in the past probably introduces uncertainty of several percent in the reported values.

Salinity Trends in the Salton Sea. The Salton Sea has no outlet, so the salt load and the loads of some other constituents entering the Salton Sea accumulate in the Sea. With an evaporation rate of 5.78 feet per year, the entire volume of the Salton Sea, with its maximum depth currently at about 50 feet, would evaporate within about 10 years if all inflow sources were stopped.

There is no question that the salinity of the Sea will continue to increase as dissolved salts are carried into the Sea and are concentrated by evaporation. However, the relative proportions of dissolved constituents that contribute to the salinity will continue to change because the proportions of the constituents in the inflow differ from the proportions in the Sea, and because some of the constituents are precipitated from the water by biological and chemical processes. Thus, for example, calcium carbonate is removed in the formation of shells and skeletons of organisms or by chemical precipitation enhanced by certain algae. Similarly, calcium and magnesium sulfates will be chemically precipitated as the concentrations of these compounds reach the limits of their solubilities in Sea water. It is difficult to accurately predict the rates at which the individual chemical constituents will precipitate because solubilities vary depending on the chemical species present and their concentrations, along with many other factors. Some of these other factors, including the water temperature, organisms, pH, dissolved gases, dissolved and suspended organic and particulate matter, oxydation-reduction potential, may be constantly changing. In general, however, the Sea is expected to become enriched in the constituents that are most soluble in water, such as sodium, potassium, and chloride, and to become depleted in the constituents that form insoluble compounds, such as calcium.

The proportions of the major salt constituents in the inflow 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.

In 1966, the U.S. Geological Survey published a detailed study of the historical hydrologic regime of the Salton Sea, including an estimate of the water budget (inflows and outflows from various sources), changes in elevation over time, and an evaluation of the major dissolved constituents and temperature profiles (Hely et al 1966). They showed that the salinity increased rapidly between 1907 and about 1925, as the existing salt pan on the basin floor dissolved in the Sea, and the salts were concentrated in a decreasing volume. By 1923 the elevation of the Sea had declined to about –255 ft msl, and the salinity had reached a peak of about 37,600 mg/L. Subsequently, inflows to the Sea increased, and the elevation (and volume) of the Sea began to increase. As a result, salinity fluctuated between about 31,000 and 39,000 mg/L during the next 40 years. During this period however, the total mass of salts in the Sea continued to increase. The average concentrations of major ionic constituents measured by the U.S. Geological Survey in four sampling rounds between September 1962 and May 1964 are shown in Table 3.1-2.

Table 3.1-2
Average Concentrations of Major Ions (mg/L) in Salton Sea, 1962-1964

Calcium	Magnesium	Sodium	Bicarbonate	Sulfate	Chloride	TDS
786	972	9,743	176	7,130	13,825	32,525

Source: Hely et al, 1966

Between 1980 and 1993 the Regional Water Quality Control Board conducted sampling of tributaries, drains, and the Salton Sea itself, at a point near the middle near the county line. The number of samples from the Salton Sea varied, but for many of the parameters about 35 to 40 samples were collected. The focus of the sampling program was on parameters other than major ions. However, sulfate was included among the analytical parameters. Nine samples were analyzed for sulfate. The concentration ranged from about 9,000 to 12,000 mg/L during the sampling period. The concentration steadily increased until 1990, when it reached the peak value. From 1990 to 1993, the concentration fluctuated between 10,000 and 12,000 mg/L. The fluctuation in concentration may have been related to changes in inflow rather than to control by precipitation of gypsum, however.

The composition of Salton Sea water has recently been 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 1999). The summary results for major ionic constituents are presented in Table 3.1-3. Although samples were collected at different depth intervals, the results indicate that the water is chemically well mixed, and the samples from different depths have been averaged together in Table 3.1-3. The lack of increase in the concentration of sulfate since 1992 may be an indication that the sulfate concentration is limited by the solubility of gypsum.

Table 3.1-3
Average Concentrations of Major Ions (mg/L) in Salton Sea, January to July, 1999

Calcium	Magnesium	Sodium	Bicarbonate	Sulfate	Chloride	TDS
1,006	1,384	12,356	246	11,236	16332	43,277

Source: Holdren, 1999

Other Water Quality Constituents

As discussed above, the inflows to the Sea derive mainly from agricultural and municipal wastewater, with a relatively small component of natural storm drainage. Water used in irrigation comes into contact with various agricultural chemicals and fertilizers, as well as the natural mineral and organic substances contained in soils. Municipal waste water, 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 a certain amount of sediment derived from soil erosion. Therefore, while most of the salts discussed in the previous section originate from the Colorado River and are simply concentrated due to evaporation, other constituents are added to the water from sources inside the basin.

The earliest detailed study of constituents other than salts was performed by Carpelan (1958; 1961) during a one-year period between July 1954 and July 1956. In addition to reviewing historical data on the major ion composition of the Sea, these studies presented depth profiles of temperature, dissolved oxygen and pH. Nutrient concentrations (ammonia, nitrate, and phosphates) were measured in samples from depths near the surface and near the bottom at four locations in the Sea. The results of nutrient analyses indicated that there were significant differences in concentrations depending on depth and location. For example, water samples from near the bottom were much higher in concentrations of ammonia and phosphate than were samples from near the surface, and samples from near Mullet Island contained higher concentrations of nutrients than samples from mid-Sea locations.

During the period from 1963 to 1969 the Federal Water Quality Administration (FWQA) and the California Deparment of Water Resources conducted a study of nutrient loading and its effects on the Sea (FWQA. 1970). The report described the Sea as eutrophic, meaning that nutrient concentrations caused high rates of algal growth, leading to high concentrations of dissolved oxygen in near-surface waters and oxygen depletion in waters at depth.

An issue of general concern at this time was the potential for persistent pesticides and herbicides from agricultural practices to enter the ecosystem. The U.S. Geological Survey performed a study of pesticide and herbicide inputs to the Salton Sea during the period from August 1969 to June 1970 (Irwin, 1971). Samples were collected from the New and Alamo Rivers and the All American and East Highline Canals. 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.

Partly as a result of observations of the effects of selenium on waterfowl at the Kesterson Reservoir in the San Joaquin Valley, the U.S. Geological Survey initiated a series of studies in 1985 as part of the National Irrigation Water-Quality Program. The Regional Water Quality Control Board had concluded in 1985 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 1998). Subsequent sampling of drain water by the U.S. Geological Survey in 1986 confirmed that selenium concentrations were highest in tilewater, but were generally below the drinking water standard in collector drains, and were less than 0.002 mg/L in both the Colorado River and in the Salton Sea. The U.S. Geological Survey studies continued until 1995 (Setmire et al. 1990; Setmire et al., 1993; 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 studies, however, was on identifying sources, rather than evaluating water quality of the Salton Sea itself. The U.S. Geological Survey 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 would be a function of the amount of Colorado River water imported, rather than the leaching of selenium from minerals in the soil.

In addition to selenium, arsenic, boron, mercury and other parameters were investigated. Results of sampling at stations in the National Stream Quality Accounting Network in the Imperial Valley have shown that arsenic occassionally exceeds the U.S. EPA water quality criterion for protection of aquatic life of 0.005 mg/L in the New River. Further studies by Setmire et al (1993) suggested that the arsenic might originate from ground water sources within the basin.

In addition to the studies described above, various agencies have collected, or continue to collect data that are not widely disseminated. The Coachella Valley Water District has collected data on major ions and heavy metals in drain water since the 1960's. The Imperial Irrigation District has collected major ion data at selected locations, including five shoreline stations, twice a year. The Regional Water Quality Control Board collected data for various contaminants and water quality indicators from the tributaries, drains, and from the center of the Sea, from 1980 to 1990.

Table 3.1-4 presents summary statistics for selected analytes. The results indicate that the Alamo and New Rivers are a source of nitrogen loading to the Sea. Phosphate concentrations in the Sea are similar to those in the tributaries. Chemical and biological oxygen demand (COD and BOD, respectively) are higher in the Sea than in the tributaries. These are measures of the amount of biological and non-biological matter capable of using up dissolved oxygen. The range of dissolved oxygen concentrations in the Sea tends to be wider 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 in Table 3.1-4, the samples were analyzed for suspended and settleable solids, pH, and other parameters. A few samples were analyzed for selected metals. For example, two samples were analysed for selenium. The concentrations of the two samples were 0.002 and 0.005 mg/L (2 to 5 parts per billion, respectively).

Table 3.1-4 also indicates that the New and Alamo Rivers contain large amounts of bacteria relative to the Sea. Fecal coliform bacteria are 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 the Regional Board, IID has been sampling for coliform bacteria at a number of nearshore stations around the Sea. Further discussion of public health issues is presented in Section 3.14.

Table 3.1-4
Comparison of Selected Water Quality Results (mg/L) in Tributaries and Salton Sea, 1980-1993

	Ammonia	Nitrate	Phosphate	BOD	Dissolved Oxygen	Fecal Coliform [(1)]	COD
Salton Sea							
n	37	36	38	39	35	40	36
Average	0.83	0.19	0.34	13	10.8	3.08	401
Maximum	3.00	1.00	1.42	51	20	20	2,192
Minimum	0.01	0.005	0.03	2	.07	2	65
New River							
n	38	38	38	39	35	40	39
Average	1.50	4.96	0.89	8.66	6.20	15,640	42.9
Maximum	3.50	17	1.86	17	9.3	160,000	143
Minimum	0.22	1.5	0.01	3.0	3.6	500	12
Alamo River							
n	39	38	37	39	35	40	39

Average	1.04	8.05	0.68	5.93	7.66	16,102	37.8
Maximum	2.86	24	2.04	26	10.2	240,000	143
Minimum	0.28	3.9	0.12	2.0	5.2	170	10
Whitewater River							
n	39	38	38	39	37	39	39
Average	0.23	0.50	0.24	1.91	9.71	86.6	7.97
Maximum	1.20	1.9	2.0	11	15.3	540	39
Minimum	0.01	0.06	0.02	1.0	7.1	2.0	1.0

Source: CRB-RWQCB, 1999; (1) fecal coliform reported in units of MPN/100 ml

As described above, a reconnaissance water quality study of the Salton Sea is currently being conducted for the Salton Sea Science Subcommittee. Preliminary results of those studies, covering the period from January to July, 1999, are summarized in Table 3.1-5. The results are generally in accord with the results of trend monitoring by the Regional Water Board from 1980 to 1993.

Table 3.1-5
Average Concentrations of Nutrients and Selenium (mg/L) in Salton Sea, January to July, 1999

Total Alkalinity	Ammonia Nitrogen	Nitrate/ Nitrite	Total Phosphorous	Total Suspended Solids	Selenium
258	1.072	0.174	0.07	39	0.0011

Source: Holdren, 1999

The low concentration of selenium in the Salton Sea, relative to its concentration in the drains and tributaries suggests that there is a mechanism for removal of selenium at work in the Sea. Analysis of sediment samples reveals that the concentration of selenium is generally two or three times greater in bottom sediments from the Salton Sea than in sediments in upstream locations. Selenium may be taken up by bacteria, and chemically reduced. The reduced forms of selenium (selinite, elemental selenium, and hydrogen selenide) are lesss soluble in water than the 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 may even chemically precipitate under the low-oxygen conditions found at the bottom of the Sea.

Although elevated concentrations of selenium, boron, and pesticides were found in tissue samples of waterfowl and fish, direct exposure to these contaminants in water does not appear to be an important exposure route. Rather, birds probably ingest fish, sediments, plants, or other organisms in which the compounds have become concentrated.

Other Water Quality Parameters. As part of the restoration program, Reclamation has been collecting samples in 1999 from three stations in the Salton Sea and from each of the three major tributaries: the Alamo River, the New River, and the Whitewater River. The following preliminary findings are based on this data:

- With the exception of total suspended solids, concentrations of most measured components are much lower, and much more variable, in the three river stations than in the Sea.
- The Alamo and New Rivers carry a very heavy sediment load., with total suspended solids concentrations usually greater than 200 mg/L. Suspended solids levels in the Whitewater River are lower than in the other two rivers, but are still usually greater than 100 mg/L.
- Thermal stratification occurs in the Salton Sea, with observed differences between surface and bottom temperatures of up to 8 EC. The stratification is not stable, however, and both depth of stratification and temperature differences between surface and bottom waters vary.
- Dissolved oxygen levels are usually above saturation concentrations as a result of photosynthesis in the surface waters. In contrast, dissolved oxygen levels near the bottom of the lake 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 orthophosphate concentrations have been below the detection limit of 0.005 mg/L on several occasions and the maximum observed value is only 0.035 mg/L.
- Very high nitrate-N concentrations occur in the river samples. Nitrate concentrations in New and Alamo Rivers are usually beween 3 and 7 mg/L, while concentrations in the Whitewater River are usually between 12 and 15 mg/L. The latter concentrations exceed the drinking water standard of 10 mg/L.
- In contrast to the high nitrate levels in the river samples, most nitrate concentrations observed in the lake samples have been less 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 both river and lake samples are relatively high for surface waters. These high ammonia concentrations in the lake, which are frequently greater than 1 mg/L, coupled with typical pH levels around 8.3 in the surface water, are of potential concern to the lake'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 lake.
- Dissolved organic carbon and dissolved silica levels in the Salton Sea are relatively stable. Dissolved organic carbon is usually around 45 mg/L, while most dissolved Si 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 CaCO3. Some sulfate salts are also relatively insoluble, and the precipitation of sulfates may help slow future increases in salinity if water inputs drop. Fluorides may also be precipitating, but fluoride concentrations are uncertain and are being re-checked.
- Trace metal concentrations do not appear to be of major concern in the Sea itself (most metals are being re-analyzed). Dissolved selenium concentrations ranged from 2.55 micrograms per liter in the Whitewater River to 5.89 micrograms per liter in the Alamo River, which are high enough to be of concern. Concentrations were lower in the lake samples, however, ranging from 1.02 to 1.25 micrograms per liter. Selenium concentrations were similar in dissolved and total fractions, indicating that most Se is present in dissolved forms.
- Concentrations of semi-volatile organics and chlorinated pesticides/PCBs were below analytical detection limits for both river and lake samples.

3.1.5 Water Use and Management

The use and management of water in the Salton Sea watershed is affected by the complex interaction or water regulations and the needs of the water users. Water use and management issues include water rights, water imports and distribution, irrigation and drainage, and water conservation.

Water Rights

The rights of the Colorado River Seven States and Mexico to use Colorado River water is governed by a body of permits, agreements, contracts, court decrees, acts, laws, and treaties collectively referred to as the “Law of the River” or “Colorado River Law.” The use of the water has been allocated by Supreme court decrees, the California Seven-Party Agreement, contracts with the Secretary of the Interior, and agreements among water entitlement holders.

The Colorado River Compact of 1922 provided for the allocation of 15 maf of Colorado River water per year for beneficial use in the Seven Basin States of Arizona, California, Colorado, Nevada, New Mexico, Wyoming, and Utah, with 7.5 maf being apportioned to the three Lower Basin States of Arizona, California, and Nevada.

The Boulder Canyon Project Act of 1928 authorized the construction of Hoover Dam, Imperial Diversion Dam, and the All-American Canal. The Act provided for the division of the lower basin’s 7.5 maf apportionment, which were later solidified via the Secretary’s contracts and confirmation in the 1963 Arizona V. California et al Supreme Court decision. Therefore, the three lower basin apportionments to Colorado River

Water per year are as follows: Arizona 2.8 maf and 46 percent of any surplus, California 4.4 maf and 50 percent of any surplus, and Nevada .3 maf and 4 percent of any surplus. The Act requires all non federal Colorado River water users to have a contract with the Secretary of the Interior for use of Colorado River water.

The Law of the River has allocated the first right to use Colorado River water of 131,400 acre- feet per year to five Indian Communities located along the Colorado River, and another 5,001 acre-feet to Miscellaneous present perfected rights holders.

In 1931, the seven major California Colorado River Water users (Palo Verde Irrigation District, City of Los Angeles, Imperial Irrigation District, Coachella Valley Irrigation District, the Metropolitan Water District, and the City and County of San Diego), signed an agreement setting the water right priorities for the allocation of California’s apportionment of Colorado River water. This allocation was adopted by the Secretary in a general regulation and incorporated into the water delivery contracts. Under the California-Seven Party Agreement, agriculture users hold entitlements to the next 3,850,000 acre-feet of Colorado River water use. When available, the Metropolitan Water District of Southern California has an entitlement to 1,212,000 acre-feet of water for use in Southern California, then another 300,000 acre-feet for agriculture, and 1,000 acre-feet for the Bureau of Land Management. California's use of Colorado River water has, therefore, exceeded 4.4 maf when the water was available.

Under the Mexican water Treaty of 1944, as provided for in the 1922 compact and the Boulder Canyon Project Act of 1928, Mexico has an apportionment of 1.5 maf per year in a normal year and the possibility of as much as 1.7 maf when available, and is required to take a shortage in a less than normal year. As provided for in the 1922 Compact if the United States shall recognize the right of Mexico to the use of any water of the Colorado River System, such waters shall be first supplied from the waters which are surplus over and above the 15 maf. It also provided that if such surplus shall prove insufficient for this purpose, the Mexican deficiency is to be borne equally by the Upper and Lower Basins. In effect the treaty increased the apportioned amount of Colorado River water from 15 maf to 16.5 maf per year.

In 1946, the City and County of San Diego assigned its entitlement of Colorado River water to The Metropolitan Water District of Southern California.

In 1968, the Colorado River Basin Project Act which authorized the construction of the Central Arizona Project gave California’s 4.4 maf year apportionment priority over the Central Arizona Project’s use of Colorado River water in times of shortage.

Water Imports and Distribution

The water allocated to the Imperial and Coachella valleys is diverted via the All American Canal from a point of diversion at the Imperial Dam in Yuma, Arizona. The canal is about 80 miles long and runs roughly parallel to the border with Mexico to the western edge of the Imperial Valley. When it was constructed in 1940, the canal was unlined; because of this, it leaks large quantities of water into the sand sediments it crosses. Reclamation estimates that about 68,000 af/yr of water could be conserved by lining the canal from Pilot Knob near Yuma to Drop 4 on the East Mesa, about three miles east of the point of diversion to the East Highline Canal (Bureau of Reclamation 1994).

About 20 miles west of Yuma, at Drop 1, the Coachella Canal branches from the All American Canal and heads north. The design capacity of the All American Canal above Drop 1 is 10,155 cfs. About 86 percent of the water in the All American Canal is used in the Imperial Valley, and about 14 percent is used in the Coachella Valley (CRB-RWQCB 1992).

The Coachella Canal is about 123 miles long, all but 32 miles of which has been lined. Between 1960 and 1980, the flow in the Coachella Canal measured at the All American Canal ranged from about 500,000 af/yr to 600,000 af/yr. During the 1980s, the flows averaged closer to 400,000 af/yr (CRB-RWQCB 1992). DWR (1994) estimated that the agricultural water demand in the Coachella Valley in 1990 was about 300,000 af/yr, while urban water demand was about 200,000 af/yr. All of the municipal water supplies in the Coachella Valley are from ground water (CRB-RWQCB 1992).

Below Drop 1, the capacity of the All American Canal is about 7,600 cfs (Bureau of Reclamation 1994).

Between 1960 and 1990, IID's share of the flow in the All American Canal ranged from about 3.1 maf/yr to about 2.5 maf/yr. IID supplies about 98 percent of the water it receives to agriculture, while about two percent is used for domestic purposes (IID 1997). IID supplies water to the cities of Calexico, Holtville, El Centro, Imperial, Brawley, Westmorland, Calipatria, Niland, Seeley, and Heber. The actual discharge in the All American Canal below Drop 1 varies from about 2,000 cfs in January to about 5,000 cfs in May. Between April and October, it generally remains above 4,250 cfs (Bureau of Reclamation 1994).

Within the Imperial Valley, irrigation water is distributed through about 1,500 miles of canal.s and laterals, to about 79,000 acres of farmland (Setmire, 1998). Different crops require different amounts of water. In 1995, about 80 percent of the irrigated cropland was planted with field crops (e.g., alfalfa, wheat, sudan grass, sugar beets), of which about 30,000 acres was in alfalfa. About 17 percent was planted in garden crops (e.g., lettuce and carrots).

In order to maintain the flow of water through the canals, water in excess of the amount needed for irrigation is required. This "operational loss" water does not get applied to fields, and eventually discharges to drains. It represents about 15 percent of the flow in the Alamo River at the outlet to the Salton Sea (Setmire, 1998). Some of the water that is applied to fields by flood irrigation methods discharges to drains at the tail of the field. This "tailwater" has about the same composition as the applied water, although it tends to have a higher load of silt, pesticides, and nutrients through contact with the ground surface. The remaining water either infiltrates or is lost to evapotranspiration. Much of the water that infiltrates is collected in subsurface tile drains designed to prevent the water table from rising into the root zone of the crops. The "tile" water discharges to a network of about 1,300 miles of drains that discharge to the New or Alamo Rivers, or directly to the Salton Sea (Setmire 1998). According to Setmire (1998), nearly all of the flow in the Alamo River results from tile water, operation loss, canal seepage, tailwater, and occasional storm water. Setmire (1998) estimated that about 25 percent of the water in the Alamo River came from tilewater in 1995, while the remainder comes from water with about the same composition as Colorado River water.

A portion of the water imported to the Salton Basin is used to maintain wetlands and wildlife areas. DWR (1994) has estimated the total environmental water needs at about 40,000 AFY, nearly as much as domestic water use in the Imperial Valley.

Inflows from Mexico via the Alamo and New River from 1960 until 1978 were fairly constant, at about 0.1 maf/yr. During the 1980s, inflows from Mexico increased to as high as about 0.4 maf/yr (CRB-RWQCB). By the treaty of 1944, Mexico is guaranteed 1.5 maf/yr of the flows in the Colorado River. However, in recent years Mexico has received more than this amount because of unusually high runoff in the Colorado River. From 1983 to 1986, for example, Mexico received more than 45 MAF, or an average of about 11 maf/yr (CRB-RWQCB 1992). Some of the excess flows were diverted to the Mexicali Valley for irrigation and ground water recharge, and this contributed to the higher than usual flows observed between 1983 and 1986.

Irrigation and Drainage

The presence of fine-grained soils requires farmers in most of the Imperial Valley to install subsurface drain systems to prevent waterlogging and accumulation of salts in shallow soils irrigated by flood irrigation methods. In this type of irrigation system, water is applied at the head of the field and is allowed to flow downslope to a drainage ditch and sump at the tail end of the field. The design of the irrigation and drainage system depends mainly on the properties of soils and the slope of the field. Slopes can be adjusted by leveling to achieve optimum infiltration rates. For clayey soils with relatively flat slopes, the distance from head to tail of the field can be as much as a half mile. For sandy soils, the distance may be 300 feet or less (Setmire 1993).

Ideally, most of the applied water should percolate through the soil, and very little water should flow into the ditches at the tail of the field (tail water). The water applied to the field accomplishes several objectives. The amount of water applied maintains plant growth and offsets water lost through the leaves of the plants (transpiration) and from direct evaporation. (The combination of evaporation and transpiration is called evapotranspiration.) Different crops consume different amounts of water. For example, alfalfa consumes about 5.2 AF/acre, cotton consumes 3.45 AF/acre, tomatoes require 2.23 AF/acre, and carrots use about 1.21 AF/acre (Imperial County 1997). On average, there are 525,000 acres, requiring 1.77 MAF of water, under cultivation each year in Imperial Valley, representing an average agricultural water consumption rate of 3.37 AF/acre (Imperial County 1997).

Evapotranspiration causes the salts that were already in the irrigation water or those that dissolve from the soils to accumulate in the root zone of the plants. To prevent the salts from accumulating in the root zone, more irrigation water must be applied to flush the dissolved salts downward past the root zone. A shallow water table or clayey soils can inhibit this downward flushing of salts. To prevent this, subsurface tile drains are installed, consisting of parallel lines of drain tiles that are typically installed about six feet below the ground surface.

Water Conservation Measures

The IID has pursued water conservation programs aimed at reducing water consumption. Because inflows to the Salton Sea are primarily the result of wastewater generated by various sources, these conservation measures can decrease inflows to the Salton Sea.

IID has entered into an agreement with the MWD to implement water conservation programs that could result in conserving 106,110 AFY of water. In return for funding the conservation programs, MWD would be allowed to divert an amount of water equivalent to the water saved by IID at its diversion to the Colorado River Aqueduct at Lake Havasu in Arizona.

Among the other water conservation programs that IID is studying are reusing drain water on idle lands, constructing storm detention basins on the East and West mesas, alternating irrigation with drain water and canal water, using drain water to maintain wetlands, and separating tailwater from tile drain flows to enable the reuse of the tailwater (Imperial County 1997).

3.1.6 Surface Water Conditions in the Colorado River Delta

Figure 3.1-5 shows the historic annual volumes of flows into Mexico since 1894 (IBWC 1999). The historical changes in Colorado River flows are due to human activities superimposed on natural variations in runoff from watersheds in the U.S. Flows in the Colorado River began to be regulated by filling of Boulder Dam in 1933. Until then, flows of more than 15 MAFY were not uncommon. Since 1944, the minimum amount of water delivered to Mexico has been set by international treaty at 1.5 MAFY, with an additional 0.2 MAFY provided in wet years.

The term “flood flows,” as used in this report, refers to the quantity of water that is delivered to Mexico above the amount that the U.S. is obligated to deliver under the 1944 Treaty. Flood flows represent excess water that is released from, or passed through the storage and conveyance system in the U.S. in order to maintain adequate flood storage space, based on the capacities and operating rules of the various facilities in the system (Bureau of Reclamation 2000). This water represents water above the amount that can be used by water users in the U.S. There are currently no requirements to provide any water for environmental purposes in Mexico.

Figure 3.1-6 shows how much of the total water delivered to Mexico since 1950 has been diverted to irrigation canals at Morelos Dam, and how much has been released to the Colorado River below Morelos Dam (IBWC 1999). As can be seen in the figure, relatively little of the water in excess of the 1.5 to 1.7 MAFY treaty allocation is diverted for irrigation. Diversions to irrigation canals below Morelos Dam exceeded 1.7 MAFY in only 14 of the 24 years since 1950 in which deliveries to Mexico were greater than 1.7 MAFY. In those 14 years, an average of about 523,000 AFY was diverted to irrigation canals. By contrast, an average of 5.1 MAFY of flood flows were available during those 14 years. Therefore, on average, about 10 percent of the flood flows were diverted for irrigation in those 14 years. The remainder of the flood flows were released to the Colorado River below Morelos Dam.

From about 1964 until 1978 Mexico received only the amount of water allotted by treaty because Lake Powell was being filled during this period. A brief period of wet years occurred from 1979 through 1981, and some flood flows were released to Mexico. Then, a series of very wet years occurred between 1983 and 1987. The average annual flood flow during this five year period was nearly 10 MAFY.

Figure 3.1-5 Total Annual Water Deliveries to Mexico (1894-1998)

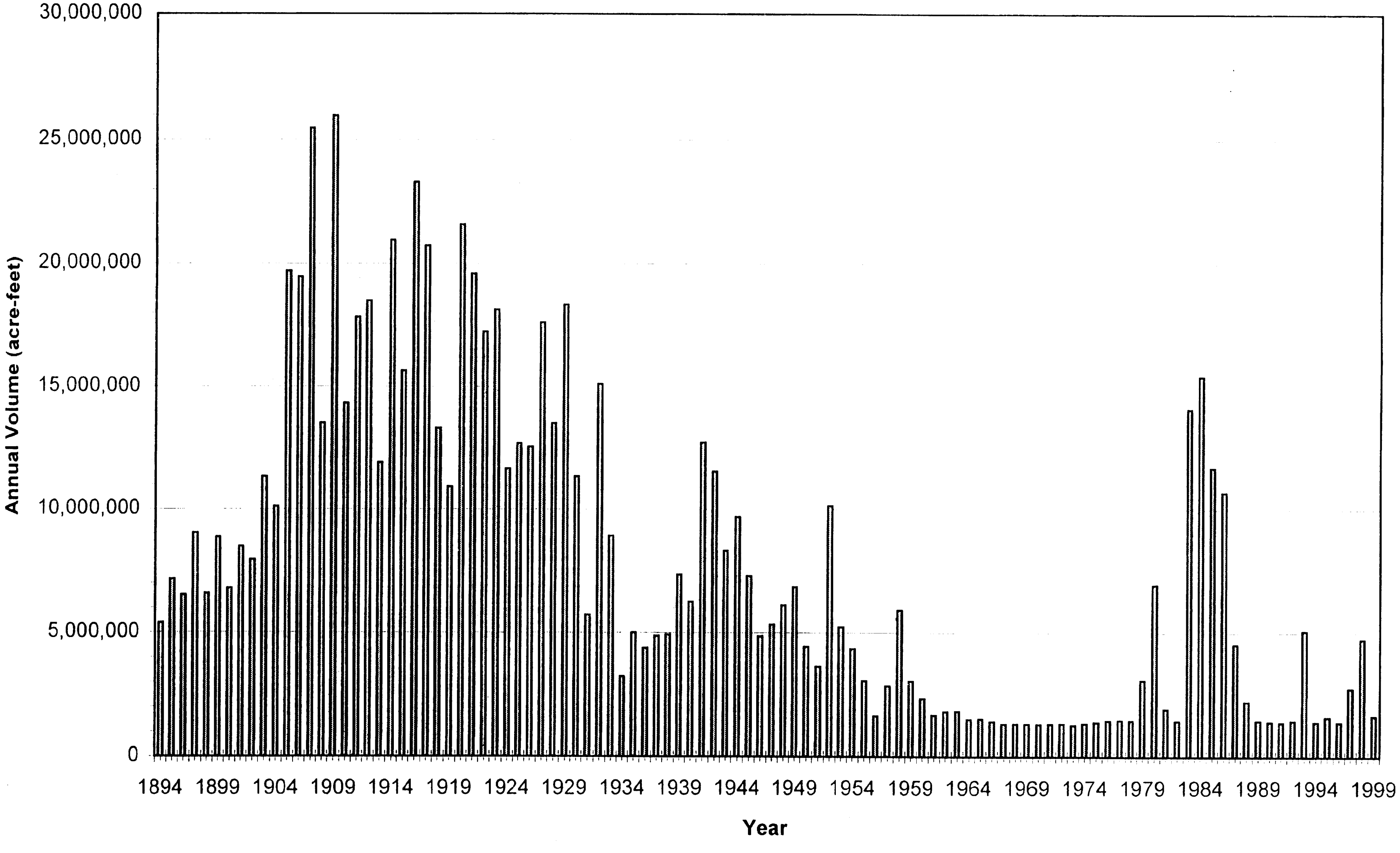
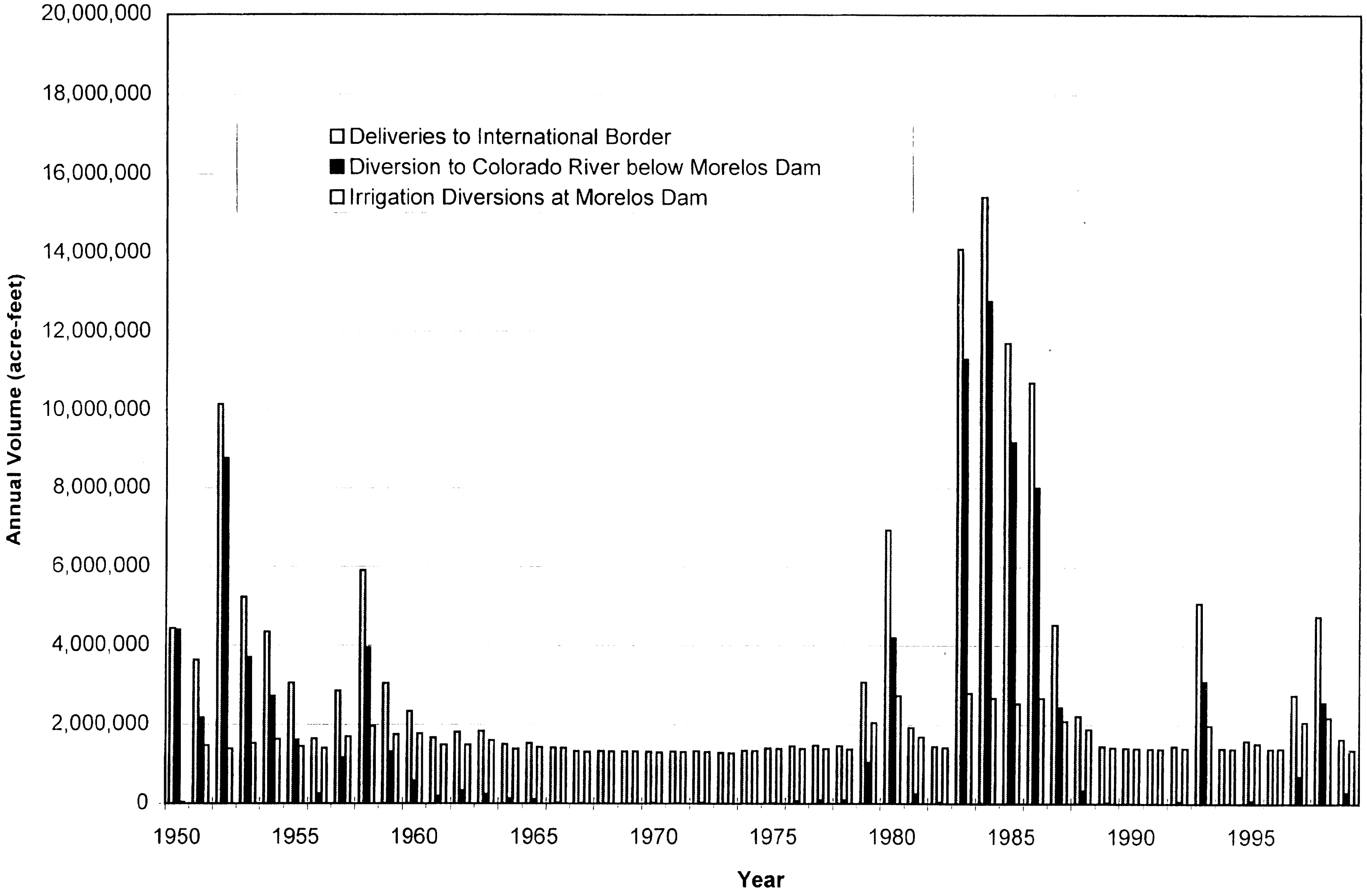


Figure 3.1-6 Total Annual Water Deliveries to Mexico and Releases to Colorado River (1950-1999)



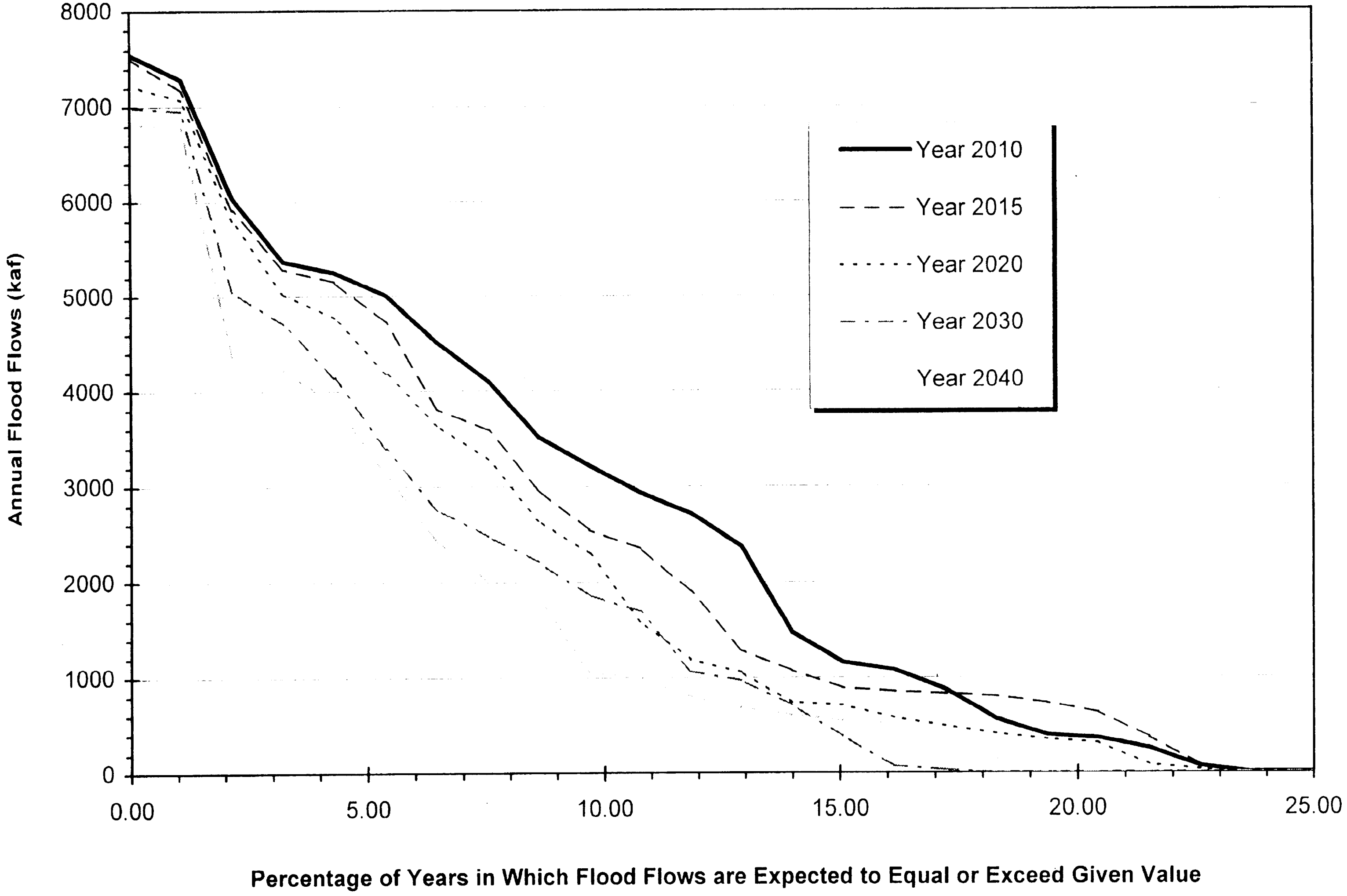
Prior to 1983, a natural dam in the channel of the Colorado River, about 22 miles from the mouth of the river, caused water to back up into the flood plain of the Rio Hardy, creating a large fresh/brackish water wetland. The Rio Hardy is a branch of the Colorado River that flows along the west side of the Delta. During the time that Lake Powell was being filled, almost no water flowed in the main channel of the Colorado River. The source of flows into the Rio Hardy wetland was primarily geothermal well discharge and irrigation return flows. In 1973, the Rio Hardy wetland covered about 45,000 acres (Glenn et al 1996). In 1979 and 1980, flood flows were again released into the Colorado River. Then, in 1983 flood flows exceeded 12 MAFY. These flows caused damage to flood control structures and irrigation facilities. The high water breached the natural dam in the channel of the Colorado River that had been responsible for the Rio Hardy wetlands. In 1983, theRio Hardy wetlands covered nearly 150,000 acres.

Following the flooding of 1983-1986 the banks of the main channel of Colorado River were built up as a flood control measure, to promote drainage and prevent the river from overflowing into irrigated fields. This, and the loss of the natural dam, had the effect of reducing flows into the Rio Hardy wetlands. In addition, a canal was constructed to allow water in the Rio Hardy wetlands to drain to the Laguna Salada for evaporation. By 1986 the Rio Hardy wetlands had been reduced to about 94,000 acres, and by 1988, the area of wetlands was reduced to only about 3,200 acres (Glenn et al 1996). As can be seen by comparing to the graph in Figure 3.1-6, the reduction in acreage of the Rio Hardy wetland occurred very rapidly in conjunction with reduced flood flows. Furthermore, flood flows resumed in 1993, and with them, the Rio Hardy wetlands expanded to about 24,000 acres (Glenn et al 1996).

Figure 3.1-7 shows the expected change in the availability of flood flows delivered to Mexico over the next 40 years expressed in terms of probability distributions. The probability distributions describe the liklihood that flows of a certain size will occur, based on current information about historical flows and assumptions about future water use (Bureau of Reclamation 2000). It is necessary to describe these future conditions in terms of probabilities, because flood flows depend on precipitation and runoff in the Colorado River and Gila River watersheds, and these conditions vary widely and unpredictably from year to year. In addition, the quantity of flood flows depend on the demand for water, and on decisions and strategies governing the storage and distribution of water. These strategies may change in response to hydrologic, demographic, and soci-economic factors. A more detailed discussion of the derivation of these probability functions, and the assumptions underlying hydrologic modeling, is presented in the Salton Sea Restoration Program Appraisal Report (Bureau of Reclamation 2000).

The vertical axis of the graph on Figure 3.1-7 shows the annual volume of flood flows, in thousands of acre-feet per year. The horizontal axis shows the percentage probability, in each year, that a given volume of flood flows will occur or be

Figure 3.1-7 Probability Distributions of Future Colorado River Flood Flows Delivered to Mexico



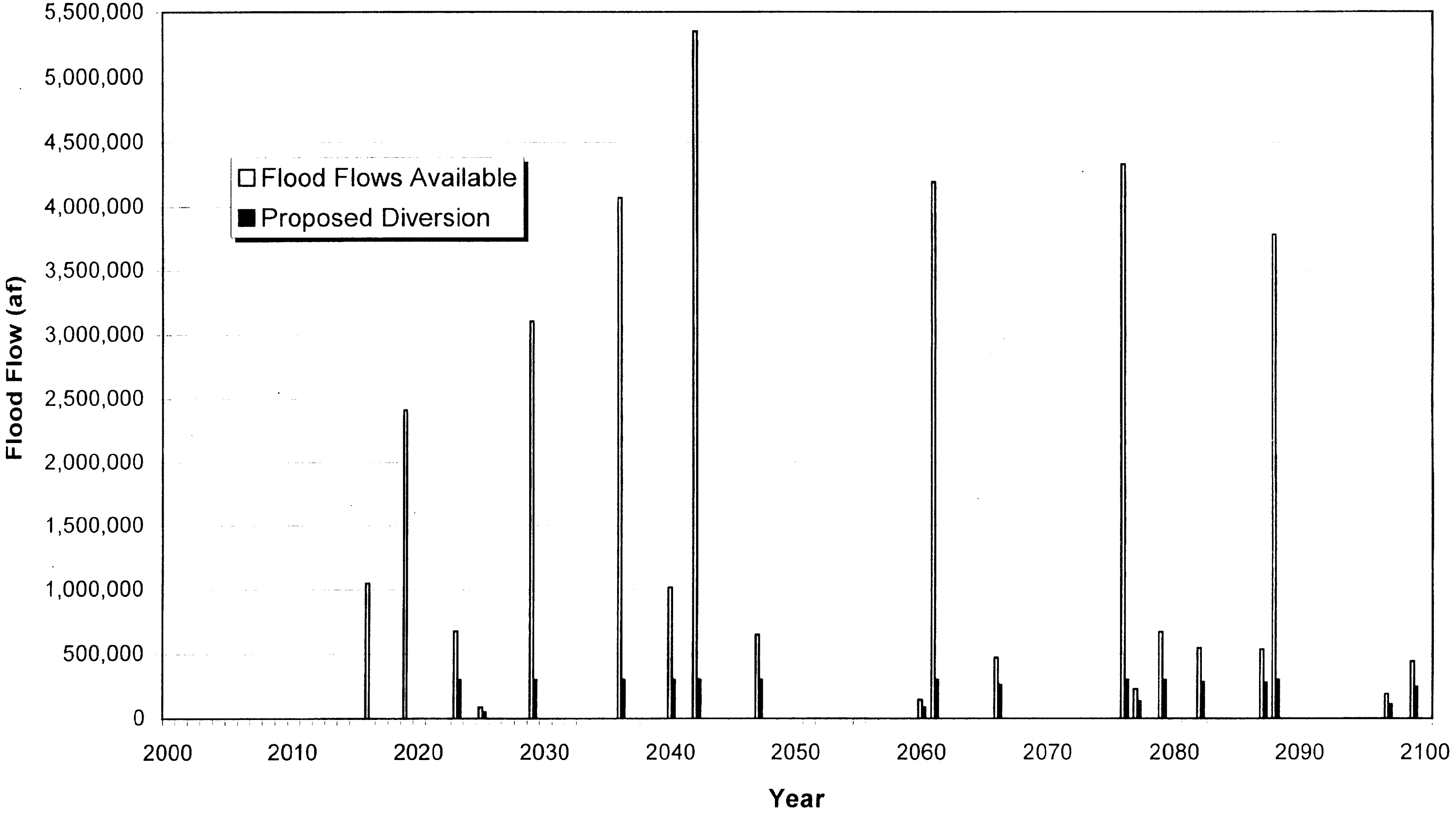
exceeded. Under the conditions expected to exist in 2010, Figure 3.1-7 indicates that the probability that flood flows will occur in any one year is about 23 percent. Stated a little differently, there is a 77 percent chance that flood flows would not occur at all (i.e., that flood flows would be less than zero).

Figure 3.1-7 also shows that larger flood flows have a lower probability of occurring. For example, there is a little more than a ten percent chance, under 2010 conditions, that flood flows would exceed 3 million acre-feet in a year. In general, the lines on the graph representing conditions further ahead in the future tend to be shifted to the left, toward lower probability. This is because use of Colorado River flows in the United States is expected to increase in the future. This additional water use will reduce the amount of flood flows. Thus, by 2040, it is expected that flood flows of 3 million acre-feet will have a little more than five percent chance of occurring in any given year.

Figure 3.1-8 shows an example of possible future flood flows based on the predictions of the Salton Sea Accounting Model. To arrive at the distribution of flows shown in Figure 3.1-8, the model randomly selected flood flows for each year. The size of the flood flows were based on the probability functions shown in Figure 3.1-7. The sequence of flood flows shown in Figure 3.1-8 is just one possible outcome, but it illustrates some important features of a randomly distributed pattern of flood flows that must be considered when evaluating the downstream impacts. For example, Figure 3.1-8 shows that there may be no flood flows available for long periods of time, and that flood flows may be clustered together. Figure 3.1-8 shows that it is not unusual to experience 5- to 15-year periods with negligible or no flood flows. Figure 3.1-8 also illustrates that flood flows range widely in magnitude.

Figure 3.1-9 illustrates the expected distribution of flows during an average year. The variation in the distribution of the flows throughout the year results from factors such as the timing of runoff and the capacities of storage and conveyance facilities. The capacities of storage and conveyance facilities are based on factors such as the demand for water, hydrologic forecasts, return flows from irrigation, and the operating rules of storage and conveyance facilities. The months of September through December are shown as having flood flows that are potentially divertable into the Salton Sea. This corresponds to months when carriage capacity might be available to transport flood flows to the Salton Sea through the All American and Coachella Canals.

Figure 3.1-8 Sample Stochastic Trace of Future Colorado River Flood Flows Delivered to Mexico[1] and Portion that would be Diverted to the Salton Sea



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[1] Total Available Flood Flows Beyond Requirement to Mexico

Figure 3.1-9 Average Monthly Divertable and Non-Divertable Flood Flows as Percentage of Total Flood Flows