3.5 WATER QUALITY

3.5.1 INTRODUCTION

This section addresses the salinity of the Colorado River and mainstream reservoirs, and the quality of Lake Mead water available for municipal and industrial purposes. The potential changes in the operation of the Colorado River system downstream from Lake Powell under interim surplus criteria alternatives could temporarily affect the salinity of Colorado River water, which affects municipal and industrial uses in the Lower Basin. In addition, changes in Lake Mead water levels could affect the quality of water arriving at the SNWS pump intakes in the Boulder Basin of Lake Mead, and thereby affect the quality of the water supply for the Las Vegas Valley.

3.5.2 COLORADO RIVER SALINITY

This section discusses potential effects that could result from the implementation of the interim surplus criteria alternatives under consideration. Salinity has long been recognized as one of the major problems of the Colorado River. "Salinity" or "total dissolved solids" (TDS) include all of the soluble constituents dissolved in a river and the two terms are used interchangeably in this document. This section considers potential changes in salinity concentrations from Lake Mead to Imperial Dam. The section also presents a general discussion of the adverse effects of increased salinity concentrations on municipal and industrial systems.

3.5.2.1 METHODOLOGY

Reclamation's model for salinity is used to create salinity reduction targets for the Colorado River Basin Salinity Control Program (SCP). To do this, the model simulates the effects of scheduled water development projects to predict future salinity levels. This data is then used to compute the amount of new salinity control projects required to reduce the river's salinity to meet the standards at some point in the future (2015). The model itself does not include future salinity controls because implementation schedules for future salinity control projects are not fixed and vary considerably. The salinity control standards are purposefully designed to be long-term (nondegradation) goals, rather than exceedence standards used for industry or drinking water.

By definition, the SCP is designed to be flexible enough to adjust for any changes caused by the various alternatives being considered. Therefore, it could be concluded that there would be no change in compliance with the standards caused by selecting any one of the alternatives. However, for the purposes of this analysis, each alternative has been evaluated using fixed (existing) levels of salinity controls to identify the differences between alternatives and the baseline conditions.

General effects of salinity were determined from review of records of historic river flow and salinity data available and economic impacts presented in *Quality of Water Colorado River Basin – Progress Report No. 19*, 1999, U.S. Department of the Interior; *Water Quality Standards for Salinity Colorado River System, 1999 Review*, June 1999, Colorado River Basin Salinity Control Forum and *Salinity Management Study*, Technical Appendices, June 1999, Bookman-Edmonston Engineering, Inc.

The salinity program as set forth in the Forum's 1999 Annual Review enables the numeric criteria to be met through the year 2015. Therefore, it was presumed that the criteria would be maintained through 2015. Although the 1999 Review considers only the period to 2015, it was presumed that future additions to the salinity control program will be sufficient to maintain the criteria through 2050.

3.5.2.2 AFFECTED ENVIRONMENT

3.5.2.2.1 Historical Data

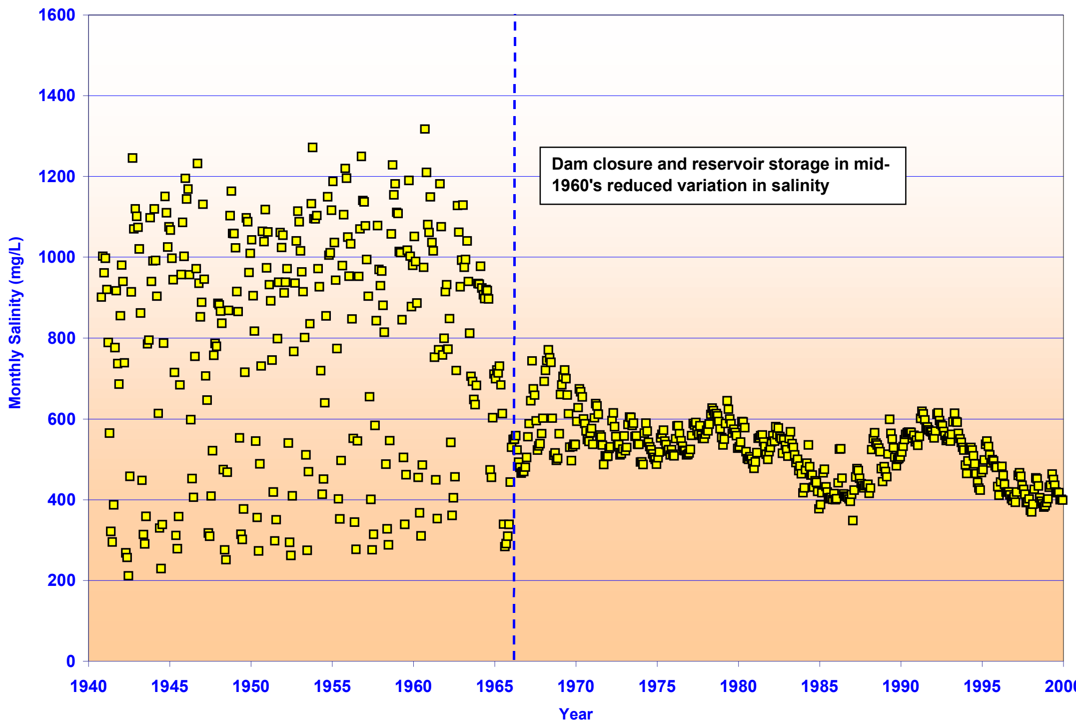
The Colorado River increases in salinity from its headwaters to its mouth, carrying an average salt load of nine million tons annually past Hoover Dam. Approximately half (47 percent) of the salinity concentration is naturally caused and 53 percent of the concentration results from human activities including agricultural runoff, evaporation and municipal and industrial sources (Forum, 1999).

Salinity of the river has fluctuated significantly over the period of record 1941 through 1997. Below Hoover Dam, annual salinity concentrations have ranged from 833 milligrams per liter (mg/l) in 1956 to 517 mg/l in 1986. However, the maximum monthly fluctuation in any year is approximately 50 mg/l. Salinity of the river is influenced by numerous factors including reservoir storage, water resource development (and associated return flows), salinity control, climatic conditions and natural runoff.

The impact of reservoir storage has all but eliminated seasonal fluctuations in salinity. Annual variations in salinity are primarily driven by natural, climatic variations in precipitation and snowmelt runoff. These hydrologic variations cause differences in both flow and salinity.

As shown in Figure 3.5-1, the salinity of the river varied by as much as 1000 mg/l prior to the construction of Glen Canyon Dam in 1961. By the 1980s, that variation was reduced to about 200 mg/l due to the mixing and dampening effect of the large volume of storage in Lake Powell. Figures 3.5-2 and 3.5-3 show the comparison between mainstream flows and salinity. Figure 3.5-2 shows the outflow from Glen Canyon and Imperial Dams. Figure 3.5-3 shows the salinity at Imperial, Hoover and Glen Canyon dams.

Figure 3.5-1
Historical Monthly Salinity Concentrations Below Glen Canyon Dam (1940-1995)



3.5.2.2.2 Regulatory Requirements and Salinity Control Programs

In 1972, the EPA promulgated regulations requiring water quality standards for salinity, numeric criteria and a plan of implementation for salinity control. The Seven Colorado River Basin States, acting through the Forum, adopted numeric criteria for flow-weighted average annual salinity, at three points on the river as shown below:

Below Hoover Dam	723 mg/l
Below Parker Dam	747 mg/l
At Imperial Dam	879 mg/l

Figure 3.5-2
Historical Glen Canyon Dam and Imperial Dam Releases

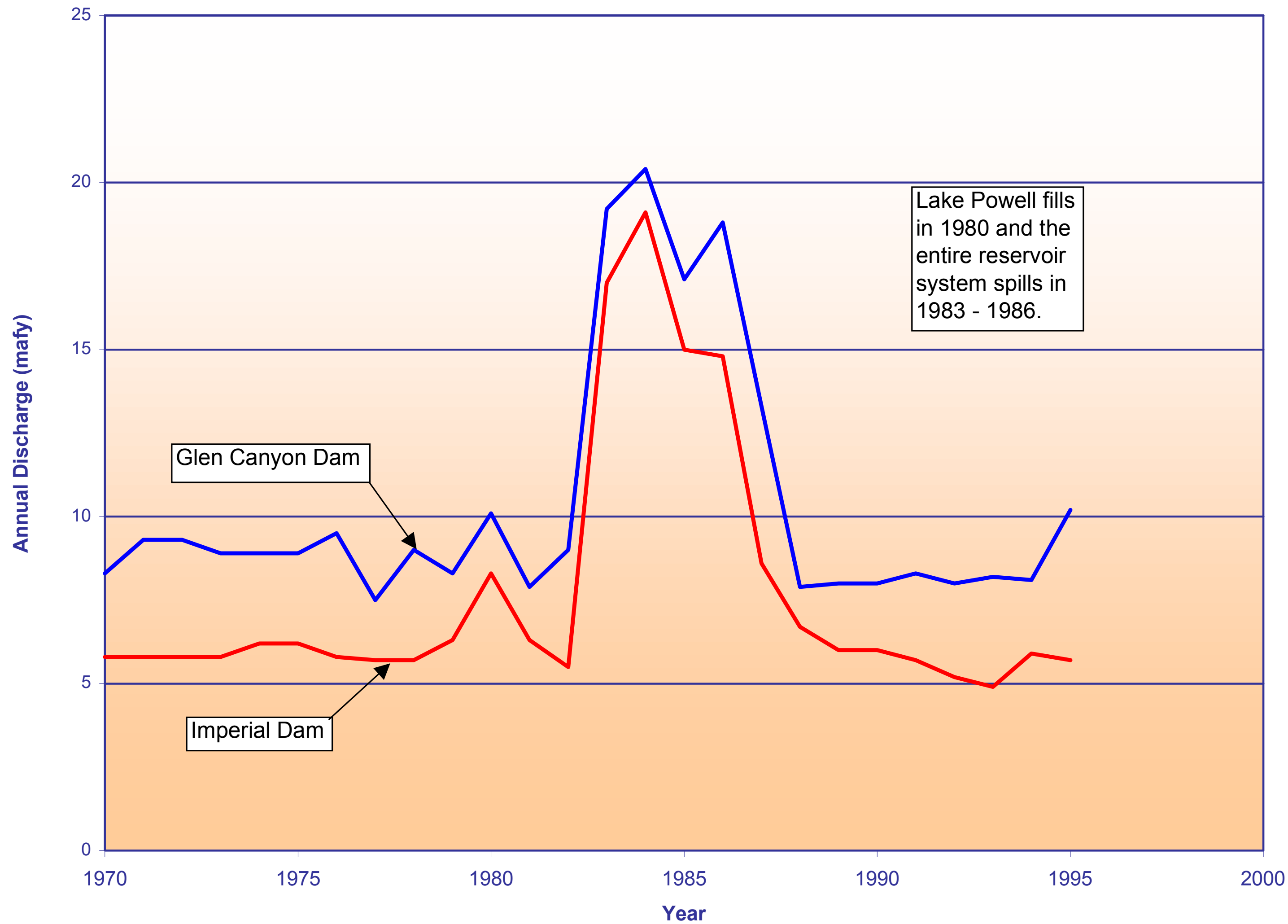
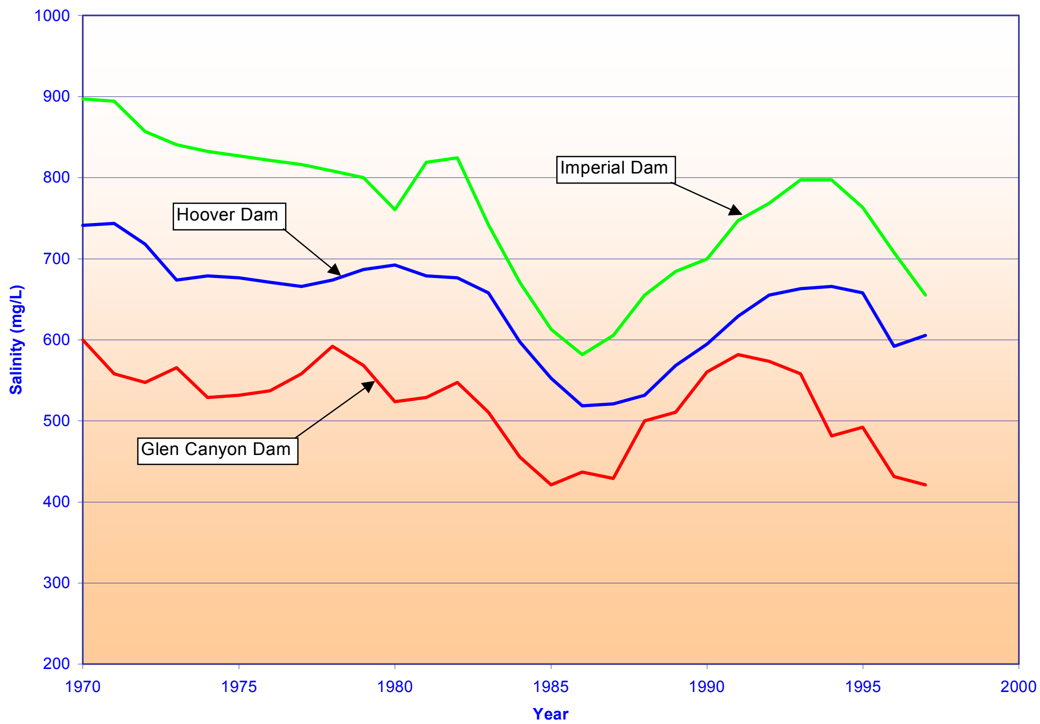


Figure 3.5-3
Historical Salinity Concentrations of Releases from Glen Canyon, Hoover, and Imperial Dams



These criteria applied only to the lower portion of the Colorado River from Hoover Dam to Imperial Dam. Below Imperial Dam, salinity control is a federal responsibility to meet the terms of Minute 242 to the U.S.-Mexico Water Treaty of 1944. Minute 242 requires that salinity concentrations upstream of Mexico's diversion be no more than 115 mg/l $\pm$ 30 mg/l TDS higher than the average salinity of water arriving at Imperial Dam.

In 1974, the Colorado River Basin Salinity Control Act (P.L. 93-320) was enacted. The Act contains two Titles: 1) Title I provides the means for the United States to meet its commitment to Mexico; and 2) Title II creates a salinity control program within the Colorado River Basin in order that the numeric criteria will be maintained while the Basin States continue to develop their apportionment of Colorado River water.

The federal/state salinity control program is designed to maintain the flow-weighted average annual salinity at or below the numeric criteria. The program is not intended to counteract short-term salinity variations resulting from short-term water supply. Federal regulations provide for temporary increases above the criteria due to natural variations in flows.

The seven Basin States acting through the Forum reviews the numeric criteria and plan of implementation every three years and makes changes in the plan of implementation to accommodate changes occurring in the Basin States. The latest review was in 1999. The review is currently undergoing adoption by the Basin States and approval by EPA.

At each triennial review, the current and future water uses are analyzed for their impact on the salinity of the Colorado River. If needed, additional salinity control projects are added to the plan to assure compliance with the standards.

The need for one or more additional salinity control projects is determined by monitoring the salinity of the river and making near-term projections of changes in diversions from and return flows to the river system. When an additional project is needed, it is selected from a list of potential projects that have undergone feasibility investigation. A proposal to implement the project is made through coordination with the Basin States. In selecting a project, considerable weight is given to the relative cost-effectiveness of the project. Cost-effectiveness is a measure of the cost per ton of salt removed from the river system or prevented from entering the river system. Other factors are also considered, including environmental feasibility and institutional acceptability.

It is estimated that 1,478,000 tons of salt will need to be removed or prevented from entering the Colorado River system to maintain the salinity concentration at or below the criteria through 2015. To date, over 720,000 tons have been controlled and an additional 756,000 tons will need to be controlled through 2015.

3.5.1.1.3 General Municipal, Industrial, and Agricultural Effects of Increased Salinity Concentrations

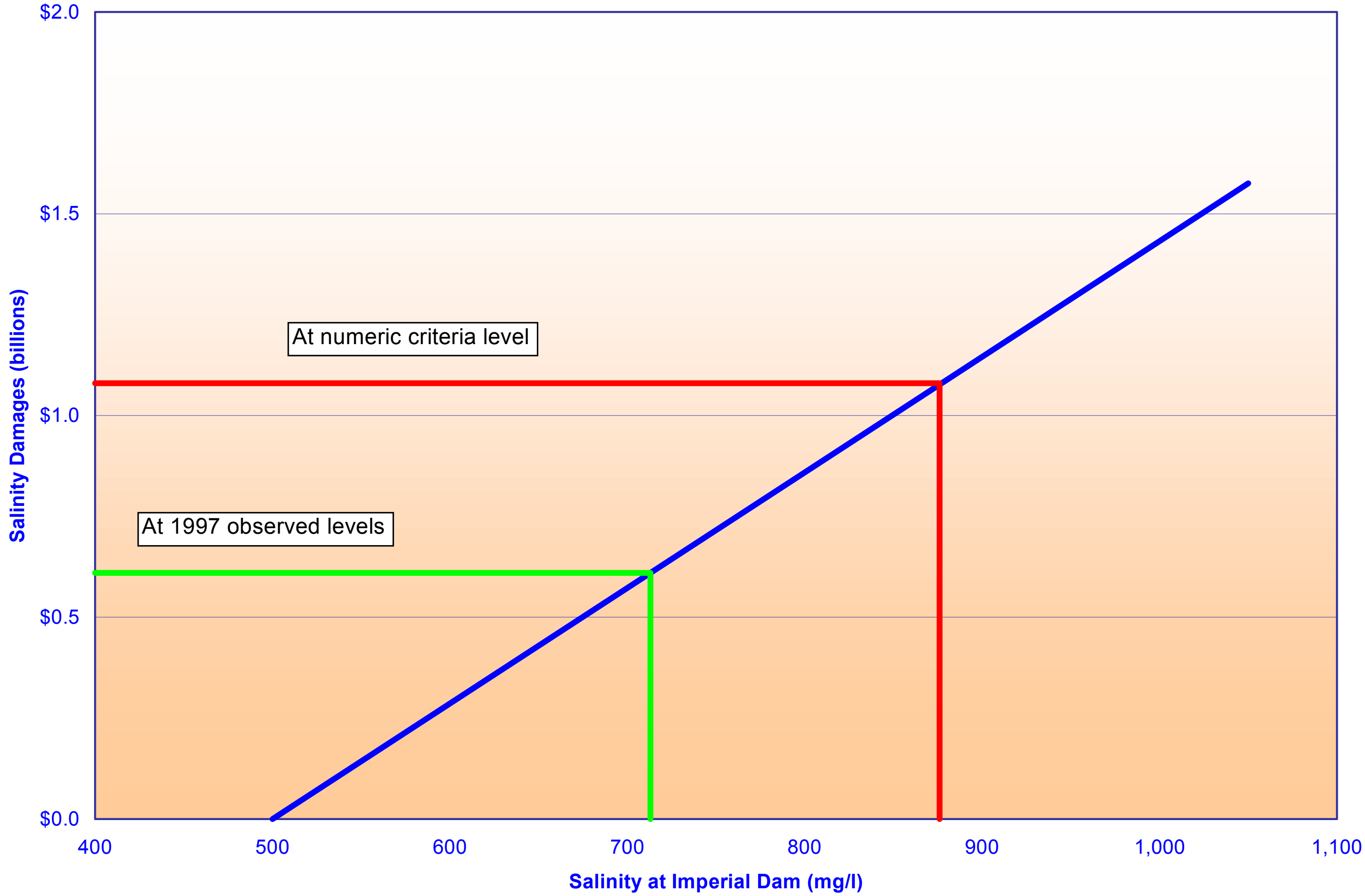
High salinity concentrations can cause corrosion of plumbing, reduce the life of water-using appliances, and require greater use of cleaning products. Industrial users incur extra water treatment costs. Increased salinity in drinking water can create unpleasant taste, often resulting in the purchase of bottled water or water treatment devices. Agriculture experiences economic losses from high salinity through reduced crop productivity and the need to change from less salt-tolerant high value crops, to more salt-tolerant low value crops. Increased salinity can also require more extensive agricultural drainage systems.

High salinity is a significant constraint to water recycling and groundwater replenishment programs. Compliance with regulatory requirements imposed by local water quality management programs to protect groundwater supplies can add significantly to the economic impacts. Restrictions have been placed on reuse or recharge of waters that exceed specific salinity levels. Such restrictions significantly constrain groundwater replenishment programs and wastewater reuse programs. Should salinity of the Colorado River increase, these regulatory actions could create a need for more expensive water treatment processes, such as reverse osmosis, prior to disposal or reuse. If disposal is selected, additional water supplies would need to be developed to meet demands that could have been met by water reuse.

Reclamation has determined that the economic damages from Colorado River salinity in the three Lower Division states served by Colorado River water amount to $2.5 million per mg/l. Figure 3.5-4 shows the relationship between costs of damages and salinity concentrations.

Therefore it is assumed for this analysis that the baseline conditions will reflect the numeric criteria at each station of interest (below Hoover Dam, below Parker Dam, and at Imperial Dam).

Figure 3.5-4
Estimated Cost of Damages Associated with Increased Salinity Concentrations



3.5.1.3 ENVIRONMENTAL CONSEQUENCES

The effects of the alternatives on the salinity of Colorado River water focus on their differences from baseline conditions. Since the current model configuration does not include any salinity control projects beyond those currently in place, modeling of baseline conditions indicates increases in salinity due to projected increased water consumption in the Upper Basin. However, in practice, these increases would be offset by salinity control projects that would continue to be implemented.

Tables 3.5-1 and 3.5-2 present these differences for years 2016 and 2050, respectively. The TDS values represent the mean values for the flow-weighted annual averages for the given year. The first column under each monitoring station heading in the tables presents the model projected TDS concentrations under the five alternatives calculated by applying the difference to the baseline TDS level. The second column presents the difference between the values for each alternative compared with baseline conditions.

As shown in Table 3.5-1, there is, in general, very little effect on TDS (less than one percent) due to interim surplus criteria in the year 2016. The exception is the decrease at Imperial Dam for the California Alternative of 19 mg/l (about 2.2 percent). This is due to the assumption in the model of an additional transfer from PVID to MWD of 100,000 af during normal and Tier 3 surplus conditions, which reduces the salt pickup in the return flows.

In general, the surplus alternatives tend to decrease TDS values slightly. These decreases are due to increased equalization releases from Lake Powell relative to baseline.

As shown in Table 3.5-2, interim surplus criteria have no effect on TDS values by the year 2050, with the exception of the PVID to MWD transfer assumed in the California Alternative.

3.5.3 LAKE MEAD WATER QUALITY AND LAS VEGAS WATER SUPPLY

This analysis addresses potential impacts of interim surplus criteria alternatives on water quality in Lake Mead, and potential changes to water quality and levels of contaminants at the SNWA intakes. This is a qualitative analysis based on system modeling and existing limnological studies.

3.5.3.1 METHODOLOGY

Evaluation of the environmental consequences of each operational alternative to Lake Mead water quality and Las Vegas water supply are based on a qualitative assessment of existing limnological and hydrodynamic data, and hydrologic modeling as discussed in Section 3.3. Each interim surplus criteria alternative was modeled for comparison to baseline projections. Modeling focused on the probability of decreased Lake Mead

Table 3.5-1
Estimated Colorado River Salinity in 2016
Unit: Total Dissolved Solids (mg/l)

Alternative	Below Hoover Dam		Below Parker Dam		At Imperial Dam	
	Value	Departure from Baseline	Value	Departure from Baseline	Value	Departure from Baseline
Baseline Conditions[1]	723	NA	747	NA	879	NA
Basin States	719	-2	737	-2	879	0
Flood Control	723	0	745	-0	879	0
Six States	719	-2	738	-2	881	0
California	712	-5	734	-5	853	-19
Shortage Protection	715	-4	736	-4	872	-3

1 Baseline conditions assume compliance with the numeric criteria at the locations cited.

Table 3.5-2
Estimated Colorado River Salinity in 2050
Unit: Total Dissolved Solids (mg/l)

Alternative	Below Hoover Dam		Below Parker Dam		At Imperial Dam	
	Value	Departure from Baseline	Value	Departure from Baseline	Value	Departure from Baseline
Baseline Conditions[1]	723	NA	747	NA	879	NA
Basin States	723	0	747	0	877	0
Flood Control	723	0	747	0	879	0
Six States	723	0	747	0	878	0
California	722	-1	745	0	857	-24
Shortage Protection	722	-1	747	0	876	0

1 Baseline conditions assume compliance with the numeric criteria at the locations cited.

surface elevations, which could exacerbate effects of discharge of Las Vegas Wash water into Boulder Basin.

Assessment of potential effects on water quality of Lake Mead, including consideration of Las Vegas Wash inflow on the SNWA intake, relied primarily on system modeling information associated with the probability of future Lake Mead surface elevations. Previous studies of Lake Mead were also an important source of information, particularly those focusing on Boulder Basin, Las Vegas Wash, and hydrodynamics potentially affecting intake water quality.

As discussed in Section 3.3, modeling identified probabilities associated with surface water elevations under baseline conditions as well as projections associated with implementation of the interim surplus criteria alternatives over a 50-year period. As discussed previously, model output utilized for this water quality analysis assumes shortage determinations would occur, if necessary, to protect a surface elevation of 1083 feet msl, which is the Lake Mead minimum power pool elevation. The primary SNWA intake at Saddle Island is at 1050 feet msl, and the secondary intake is at 1000 feet msl. Thus, assuming a strategy to protect 1083 feet msl also provides a level of protection to SNWA's intake water quality.

As discussed below, contaminant dilution and lake water quality are directly proportional to lake volume. As such, a critical element in this assessment is a comparison of projected Lake Mead volumes under the five action alternatives relative to baseline conditions. Using hydrologic modeling output, median Lake Mead volumes and surface areas were identified for each of the alternatives associated with projected reservoir elevations under the median modeled probabilities. Modeling results indicating these parameters were then developed for the years 2016, 2026, 2036, and 2050. Separate comparisons were then made of the volume and surface area for each alternative as compared to baseline conditions.

3.5.3.2 AFFECTED ENVIRONMENT

The focus of this section is a description of the affected environment related to Lake Mead water quality and the SNWA intake locations, with specific consideration of hydrodynamics of the Colorado River Basin, limnology and water quality (factors that may be influenced by implementation of interim surplus criteria alternatives).

3.5.3.2.1 General Description

Lake Mead is a large mainstream Colorado River reservoir in the Mohave Desert, within the States of Arizona and Nevada as shown on Map 3.2-1. Lake Mead, formed in 1935 following the construction of Hoover Dam, is the largest reservoir in the United States by volume (26 maf active storage). At full pool (reservoir elevation 1221 feet msl), Lake Mead extends 108 miles from Black Canyon (Hoover Dam) to Separation Canyon at the upstream end. Lake Mead has four large sub-basins including Boulder, Virgin, Temple and Gregg. Between these basins are four narrow canyons: Black, Boulder, Virgin and Iceberg. Over 170,000 square miles of the Colorado River Basin watershed are located above Hoover Dam. Boulder Basin, SNWA intake locations and the Las Vegas Wash are shown on Map 3.5-1.

The Muddy and South Virgin mountains border the reservoir on the north, and the Virgin and Black mountains and various desert hills border the reservoir on the south. The shoreline is extremely irregular with a Shoreline Development Value (SLD) of 9.7 (Paulson and Baker, 1981). SLD is the ratio of the length of the shoreline of a lake or reservoir to the length of the circumference of a circle with an area equal to that of the lake (Wetzel, 1975). The shoreline includes several large bays, including Las Vegas and Bonelli, and numerous coves. The principal morphometric characteristics of Lake Mead are summarized below in Table 3.5-3.

Table 3.5-3
Morphometric Characteristics of Lake Mead

Parameter	Units	Value
Normal operating level (spillway crest)	feet	1,205
Maximum depth	feet	590
Mean depth	feet	180
Surface area	square miles	231
Volume (including dead storage)	maf	30
Maximum length	miles	108
Maximum width	miles	17
Shoreline development	Index Value	9.7
Discharge depth	feet	310
Annual discharge (approximate)	maf	10
Replacement time at maximum operating level	years	3.9

Derived from Interior (1966), Lara and Sanders (1970), Hoffman and Jonez (1973)

LaBounty and Horn (1997) conducted a study of the influence of drainage from the Las Vegas Valley on the limnology of Boulder Basin that is highly relevant to the issue addressed in this section. Unless otherwise noted, the descriptions of reservoir characteristics, hydrodynamics, and general limnology of Lake Mead are drawn from this study.

The Colorado River contributes about 98 percent of the annual inflow to Lake Mead; the Virgin and Muddy rivers and Las Vegas Wash provide the remainder. Annual flows from Las Vegas Wash are approximately 155,000 af, providing the second highest inflow into Lake Mead. Discharge from Hoover Dam is hypolimnetic and occurs 285 feet below the normal operating shown above (1205 feet msl). Average annual discharge is approximately 10 maf.

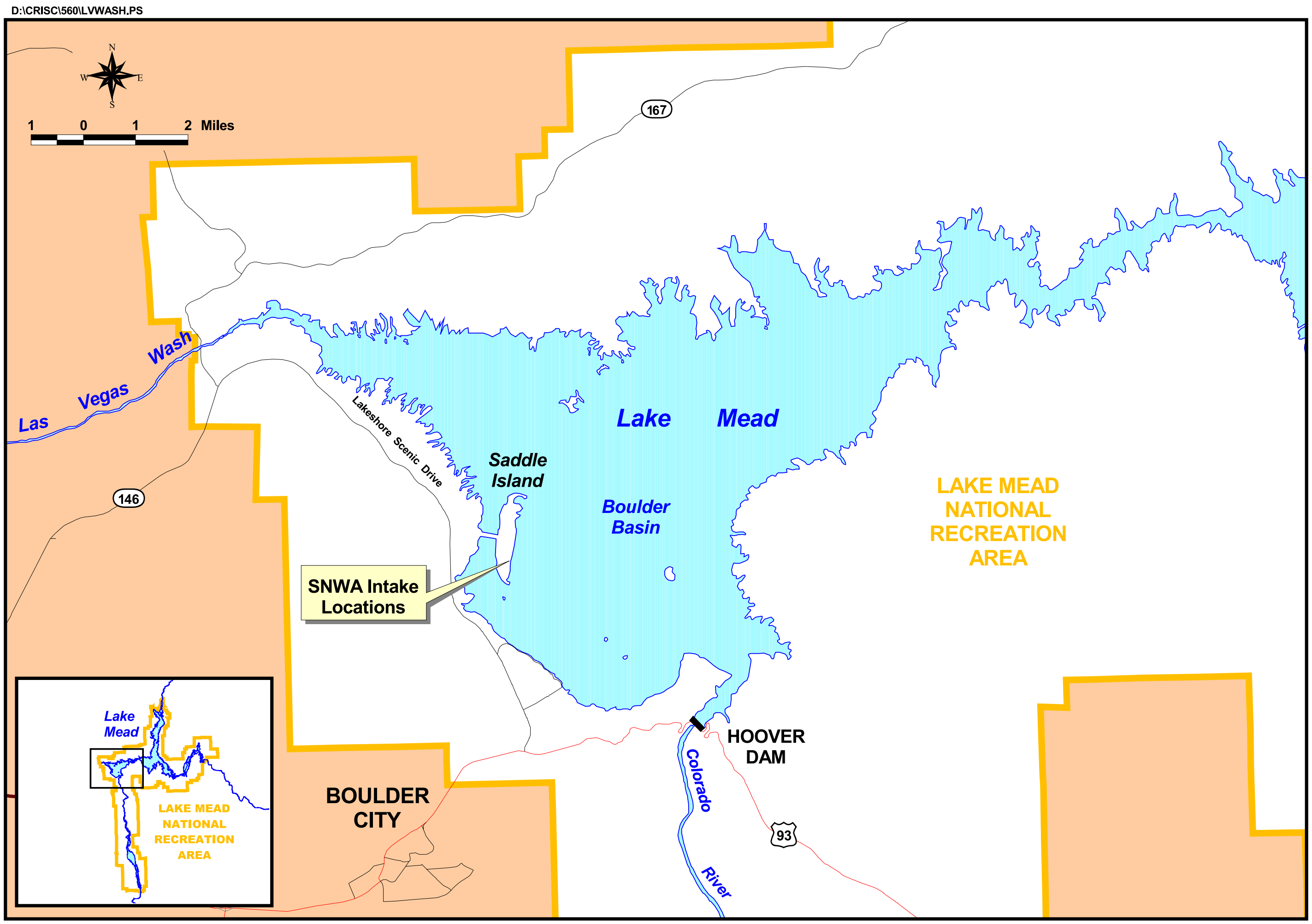
Boulder Basin, the lowermost basin of Lake Mead, receives all nonpoint surface and groundwater discharges and treated effluent from the Las Vegas Valley and municipal wastewater treatment facilities via drainage from Las Vegas Wash into Las Vegas Bay. Boulder Basin is 9.3 miles wide from Boulder Canyon to Hoover Dam (Black Canyon), and the distance from the confluence of Las Vegas Wash to Hoover Dam is approximately 9.9 miles. The historical Colorado River channel lies along the eastern side of Boulder Basin.

Due to effects of urban runoff and treatment plant effluents on the discharge through Las Vegas Wash (discussed later in this section), Boulder Basin has the highest nutrient concentrations in the Lake Mead system (Paulson and Baker, 1981; Prentki and Paulson, 1983). This is in contrast to the normal upstream-downstream decrease in the pattern of productivity more typical of reservoirs, and results in several limnological features within Boulder Basin that are normally associated with upstream reaches (Kimmel et al., 1990).

Overall, Lake Mead is mildly mesotrophic based on several classification indices (Vollenweider 1970; Carlson 1977), including chlorophyll *a* concentration and secchi transparency measurements. Chlorophyll concentration is a measure of algal biomass and can, therefore, be interpreted as an index of lake productivity. Secchi disk measurements are used to determine the depth to which light penetrates lake water and help to establish the euphotic zone which marks that area of a lake where primary productivity (energy production by photosynthesis) occurs.

Due to abundant nutrient input into Las Vegas Bay, chlorophyll concentrations have been measured greater than 100 milligrams per cubic meter (mg/m^3). Secchi transparency readings of less than two feet have been measured in the inner bay (LaBounty and Horn, 1997). However, secchi transparency increases to over 16 feet, and chlorophyll *a* is reduced by 90 percent within the first 2.6 miles from the Las Vegas Wash inflow. These findings suggest that Boulder Basin is a relatively isolated embayment and that it is much more productive than the lake as a whole.

Map 3.5-1
Las Vegas Wash and SNWA Lake Mead Intake Facilities at Saddle Island



The Federal Water Pollution Control Act (Clean Water Act) Amendments of 1972 and 1977 require the control of all sources of water pollution in meeting the goals of the Act. Section 208 of the Act requires that all activities associated with water pollution problems are planned and managed through an integrated area-wide water quality management program. It also defines the schedule and scope of area-wide wastewater treatment management plans. The 1997 Las Vegas Valley 208 Water Quality Management Plan Amendment certified by the State of Nevada and EPA, is a 20-year plan that comprehensively addresses the quality and quantity of the Valley's point source (discharges from wastewater treatment facilities) and non-point sources (groundwater, stormwater issues, Las Vegas Wash, agricultural diffuse sources), and revisions of water quality standards.

The water quality requirements currently being met by the wastewater discharges of the Las Vegas Valley have a long history. Beginning in the 1950s with requirements for secondary treatment, through the 1970s and the promulgation of the Clean Water Act, and into the 1990s with more advanced nutrient removal requirement, the quality and volume of treated wastewater discharged to Lake Mead has continued to increase and will continue to meet standards into the future through the Section 208 process (Clark County, 1997).

The Lake Mead Water Quality Forum, established by the Nevada Division of Environmental Protection (NDEP), has been identified in the Plan as an avenue for coordinated research opportunities and solutions to the water quality issues that face Las Vegas Valley and Lake Mead in the future. The forum is comprised of federal, state and local agencies with a vested interest in Lake Mead's water quality. The Lake Mead Water Quality forum is responsible for issue identification, coordination and defining the process approach in identifying issues regarding water quality and potential impacts to the water supply. The Las Vegas Wash Coordination Committee (LVWCC) is comprised of more than two dozen members of local, state, and federal agencies, business owners and members of the public. The LVWCC was tasked with the support, development and implementation of the Las Vegas Wash Comprehensive Adaptive Management Plan (LVWCAMP). The planning phase of the LVCAMP is now complete, and various actions presented in the plan are currently in progress to restore the wash, its wetlands, and its ability to improve the quality of return flows into Lake Mead. Reclamation is an active member of both of these groups and has been independently funding research on Lake Mead water quality prior to their formation and is now a funding partner with other agencies for ongoing studies on the Wash and Lake Mead. Water quality in Lake Mead and Las Vegas Wash are the subject of numerous articles and the chemical and physical analyses of raw and treated Lake Mead source water is published on SNWA's website (http://www.snwa.com).

3.5.3.2.2 Lake Mead Water Quality and Limnology

Water quality of Lake Mead and the Colorado River is alkaline with a pH of 8.3 and an average concentration of TDS of approximately 700 mg/l. Chemical characteristics of the river at the inflow to Lake Mead, near the outflow at Hoover Dam, and at Lake Mohave are shown below in Table 3.5-4.

Table 3.5-4
Chemical Characteristics of Colorado River

Parameter	Units	Gage Station Location[1]		
		Grand Canyon	Hoover Dam	Davis Dam
pH		8.0	7.7	8.0
Conductivity	umho/cm^2	945	1086	1089
Total Dissolved Solids	mg/l	617	705	714
Calcium	mg/l	74	86	84
Magnesium	mg/l	26	28	29
Potassium	mg/l	4.1	4.9	5.0
Bicarbonate	mg/l	170	163	157
Sulfate	mg/l	228	283	293
Chloride	mg/l	79	85	87
Silica	mg/l	7.0	8.3	7.8
Nitrate	mg/l	.50	.41	.28
Phosphate	mg/l	.010	.013	--

[1]USGA data, average for October 1975 – September 1976

The principal constituents of TDS are the anions of sulfate, carbonate and chloride and the cations of sodium, calcium, magnesium and potassium. Nitrate concentrations are moderate (0.28 to 0.50 mg/l), but phosphorus is extremely low (0.01 to 0.03 mg/l). Silica is present in very high concentrations (7.0 to 8.3 mg/l).

Limnological investigations of Lake Mead have found that 80 percent of the inorganic nitrogen within the lake is provided by the Colorado River, and that Las Vegas Wash contributes 70 percent of the inorganic phosphorus (Paulson, Baker, Deacon, 1980). The Upper Basin of Lake Mead was found to be phosphorus-limited, and the Lower Basin nitrogen-limited during the summer. Equal proportions of nitrogen and phosphorous were retained in the Upper Basin of Lake Mead, but nitrogen retention decreased to seven percent, and phosphorus to 33 percent in the Lower Basin. Additionally, the high nitrate loss from Hoover Dam greatly reduced nitrogen retention in the Lower Basin of Lake Mead.

In 1978 the EPA estimated that Lake Mead retained 93 percent of the total phosphorus input versus 52 percent of total nitrogen (EPA, 1978). Phosphorus concentrations are low in the Upper Basin of the lake due to the low input from the Colorado River, a result of sediment trapping that occurs upstream within Lake Powell.

As recently as 1998, new contaminants to Lake Mead have been discovered as a part of the nonpoint pollutant load of Las Vegas Wash (EPA, 2000). Perchlorate has been detected in the water of the Colorado River and Lake Mead. Ammonium perchlorate is manufactured as an oxygen-adding compound in solid rocket fuel propellant, missiles and fireworks. The EPA identified two facilities that manufactured ammonium perchlorate in Henderson, Nevada, that were found to have released perchlorate to groundwater, resulting in four to 16 parts per billion (ppb) concentrations in Lake Mead and the Colorado River (EPA, 2000).

The NDEP and the SNWA have initiated a collective investigation to locate and clean up perchlorate in the Colorado River system in coordination with the EPA. The primary objectives are to locate the source, the groundwater discharge sources, clean it up, and prevent it from becoming a problem in the future. The EPA has not established concentration levels of perchlorate because it is not considered a water contaminant. However, California's Department of Health Services and NDEP have established an interim action level of 18 ppb for drinking water. Concentrations lower than 18 ppb are not considered to pose a health concern for the public, including children and pregnant women. All SNWA drinking water has tested at 11 ppb or lower for perchlorate. Average perchlorate values for water samples collected at their intake were 9.5 ppb between June 1999 and August 2000. Perchlorate is not regulated under the Federal Safe Drinking Water Act and thus information is limited regarding its potential health risks but it is known to affect how the thyroid processes iodine and is used to treat Graves Disease. In March 1998, perchlorate was added to the Contaminant Candidate List as part of the Safe Drinking Water Act due to the concern over potential public health impact, need for additional research in areas of health effects, treatment technologies, analytical methods, and more complete occurrence data.

The SNWA identified a major surface flow of perchlorate-laden water from a groundwater discharge point along Las Vegas Wash in late 1999. Other discharge points are being investigated. Kerr-McGee Chemical Company, with the NDEP, and Reclamation as the land management agency, worked together to begin intercepting that surface flow for treatment. This program is now underway and has significantly reduced the amount of perchlorate entering the Las Vegas Wash, Lake Mead, and the Colorado River. This remediation program will continue into the future and will continue to reduce perchlorate contamination in groundwater and Colorado River water in Lake Mead and downstream.

In a soon to be published article on contaminants found in Lake Mead fish by Dr. Jim Cizdziel, University Nevada Las Vegas, only one fish sampled of approximately 300 fish tissues sampled for mercury indicated results above the Federal Department of Agriculture's 1.0 ppm level of concern. During this 1998-1999 investigation for metals found in Lake Mead fish tissue, most fish sampled for mercury were less than 0.5 ppm (Pollard, 1999). After reviewing this work, the State of Nevada has decided not to issue any fish consumption advisories for any contaminates for Lake Mead fish (Pohlmann, 1999).

The rate and volume of inflow from the Colorado River are major determinants of the limnology of Lake Mead, with minor contributions to volume coming from the Virgin and Muddy rivers and the Las Vegas Wash (see Table 3.5-5). Due to its lower conductivity within Lake Mead, Colorado River flows can be identified through the reservoir. Flows into Lake Mead average approximately 17,900 to 21,400 cfs. During a seven-day controlled flood in 1996, inflows of 44,600 cfs resulted in a three-foot rise in surface elevation. Flows of this magnitude influence reservoir limnology of Lake Mead well into Boulder Basin (LaBounty and Horn, 1997).

Table 3.5-5
Hydraulic Inputs for Lake Mead

Input	Flow (af)	% of Total
Colorado River	8,800,000	98
Virgin River	92,000	1
Las Vegas Valley Wash	59,000	0.60
Muddy River	29,000	0.34
TOTAL INPUT	**9,000,000**	**100**

Derived from USGS data from October 1975 – September 1976

The two major outflows from Lake Mead are both in Boulder Basin: Hoover Dam and the SNWA intake. Hoover Dam is operated for flood control, river regulation and power production purposes. The operating elevation for Hoover Dam powerplant ranges from 1083 feet to a maximum elevation of 1221 feet msl. The dam's four intake towers draw water from the reservoir at approximate elevations 1050 and/or 900 feet msl to drive the generators within the dam's powerplant. SNWA pumps water from two adjacent intakes located at Saddle Island that operate down to elevations of 1050 feet and 1000 feet msl. Hoover Dam outflows vary on a daily basis from approximately 2000 cfs to 50,700 cfs. Capacity of the SNWA intake is 600 cfs. Despite its much smaller volume, the SNWA intake has been shown to influence deep water currents near the entrance to Las Vegas Bay (Sartoris and Hoffman, 1971).

LaBounty and Horn (1997) cite the rarity of complete turnover in Lake Mead due to the great depth (590 feet), and relatively constant temperature gradient. The thermal regime over the period of 1990 through 1996 was characterized by surface temperatures of 14 degrees Celsius (°C) in December and January to over 30°C in August. Seasonal thermoclines range from 50 feet in early summer to 100 feet in late summer. Hypolimnetic temperatures remain near 12°C year-round. Though full reservoir turnover seldom occurs, turnover occurs to a depth of approximately 200 to 230 feet in January and February, a sufficient depth for complete mixing in Las Vegas Bay.

As with other reservoirs, dam operation exerts a great influence on the water quality and ecology of the system (Thornton, 1990). The hydrodynamics of this large reservoir are complex and not completely understood. Each basin within Lake Mead is ecologically unique, and therefore responds differently to the inflow-outflow regime. Furthermore, the different sources of water entering Lake Mead often retain their identity for substantial distances into the reservoir and do not necessarily mix completely with the rest of the water column (Ford, 1990). This spatial heterogeneity can lead to significant underestimates of actual water retention time, conveyance and fate of materials transported into the reservoir.

3.5.3.2.3 Hydrodynamics of Lake Mead and Boulder Basin

The Colorado River, Virgin and Muddy rivers and Las Vegas Wash all form density currents in Lake Mead (Anderson and Pritchard, 1951; Deacon and Tew, 1973; Deacon 1975, 1976, 1977; Baker et al., 1977; Baker and Paulson, 1978). Anderson and Pritchard (1951) conducted a detailed investigation of density currents in 1948-1949 using temperature and TDS relationships to trace the river inflows. They found that the Colorado River flowed along the bottom of the old river channel in winter (January-March). The underflow was detectable well into the Virgin Basin and at times extended to Boulder Basin. The underflow created a strong convergence at the point where river water flowed beneath lake water. Up-lake flow of surface water occurred due to frictionally induced, parallel flow of lake water (entrainment) along the boundary of the cold river inflow. This produced a large circulation cell in the Upper Basin of Lake Mead, as surface water was pulled up-lake to replace that entrained by the underflow.

Hydrodynamics within Las Vegas Bay have also been the subject of research and are particularly important from the standpoint of potential interactions between Las Vegas Wash water and intake water quality. LaBounty and Horn (1997) provide an excellent discussion of flow patterns in this area of Lake Mead. These authors cite unique signatures of both Colorado River water and Las Vegas Wash water that allow mapping of higher conductivity intrusions from Las Vegas Wash into Boulder Basin. Depending on conditions, the intrusion can be measured for over five miles into Lake Mead. Seasonally, the Las Vegas Wash intrusion is deepest in January and February (130 to 200 feet) and shallowest in early spring (33 to 50 feet).

Water quality in Las Vegas Wash, and ultimately in Boulder Basin, is heavily influenced by urban runoff, as well as the treated effluent from three major sewage treatment facilities upstream. Historically, flows in this basin drained wetlands, which allowed for natural cooling and nutrient removal. Flows today are warmer and have doubled in volume over the last 15 years, from 110 cfs to 215 cfs (LaBounty and Horn, 1997). These factors have tended to force the intrusion higher in the water column of Las Vegas Bay.

The existence of contaminants in sediments and fish tissue in Las Vegas Bay, and poor water quality has been well documented (LaBounty and Horn, 1996; Roefer et al., 1996; Bevans et al., 1996). LaBounty and Horn (1997) cite the relatively close proximity of the SNWA intake at Saddle Island to potential intrusions of the Las Vegas Wash, and conclude that changes in hydrodynamics of the basin (i.e., due to drought or management actions) are critical considerations in assessing effects of the Las Vegas Wash on drinking water quality.

3.5.3.3 ENVIRONMENTAL CONSEQUENCES

3.5.3.3.1 General Effects of Reduced Lake Levels

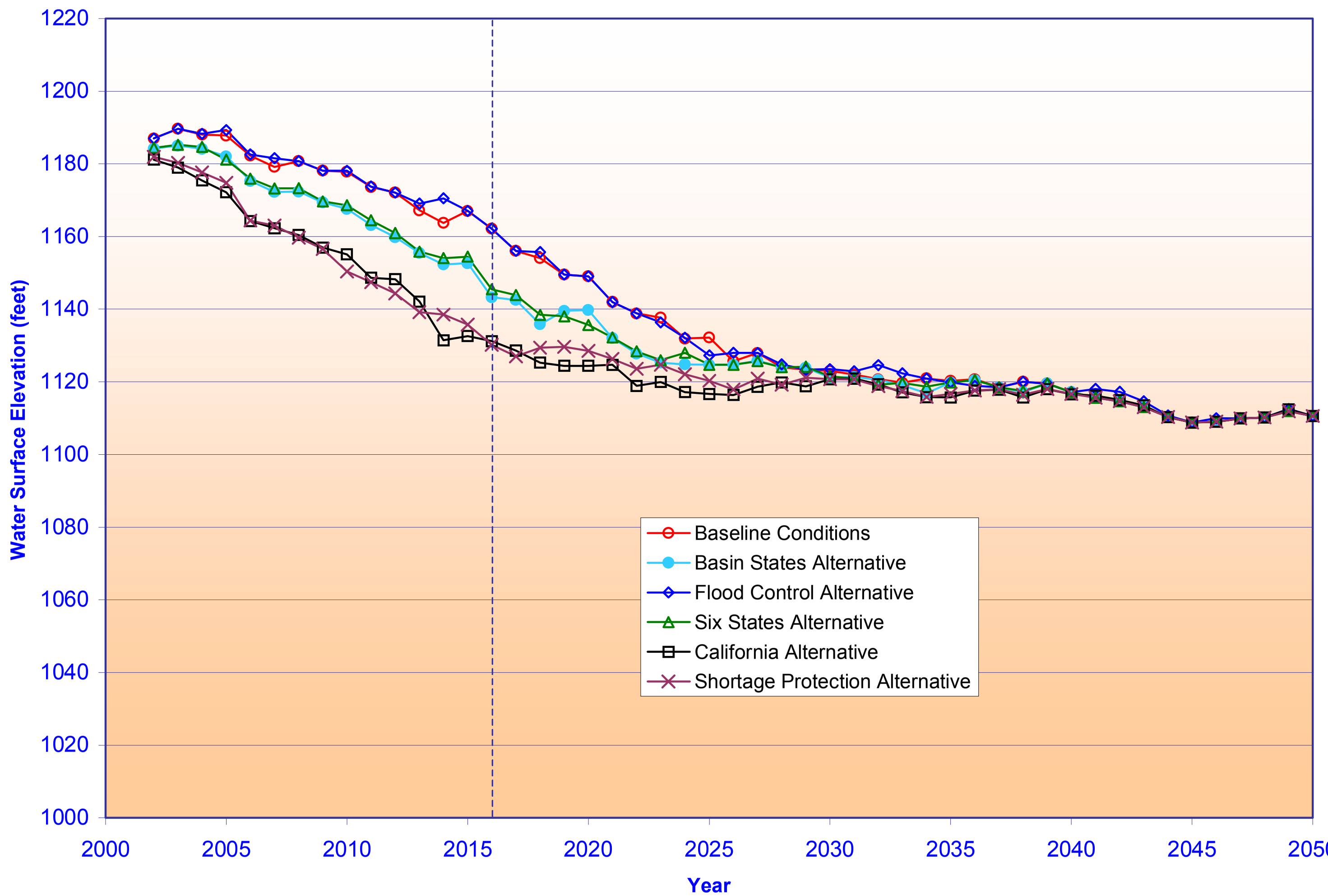
This section presents potential water quality changes in Lake Mead associated with reductions in lake levels, and potential effects of these changes on the concentration of Las Vegas Wash water at SNWA water supply intakes. In addition, this section addresses general limnological changes in Lake Mead that may occur under each alternative.

It is important to note that estimates of potential changes in Lake Mead surface elevations are based on system modeling discussed in Section 3.3. Water quality modeling has not been conducted as a part of this investigation; however, literature review and assumptions with regard to Las Vegas Wash mixing in the Boulder Basin under various Lake Mead elevations have been used to estimate potential future water quality conditions.

Results of model runs conducted for this analysis indicate that projections of baseline conditions and each of the interim surplus criteria alternatives indicate increased potential over time for the occurrence of declining Lake Mead surface elevations within and beyond the interim 15-year period, as indicated by the plots of median elevations on Figure 3.5-5.

The potential degradation of SNWA intake water is not demonstrated quantitatively in this FEIS, rather the expectation of degradation is based on the assumption that decreasing lake levels, and therefore lake volume and surface area, could result in decreased water quality and, more specifically, increased concentration of Las Vegas Wash inflow at the intake locations. The potential effects associated with Lake Mead elevation declines are described below, and are followed by a tabular comparison of the projected Lake Mead volume and surface area changes under the alternatives and baseline conditions.

Figure 3.5-5
Lake Mead End-of-Year Water Elevations
Comparison of Surplus Alternatives to Baseline Conditions
50th Percentile Values



3.5.3.3.1.1 Volume Reduction

Reduction in the volume of Lake Mead would likely have effects on lake water quality and, potentially, on water quality withdrawn by SNWA. These effects occur as a result of changes in mixing patterns in Boulder Basin. Given the hydrodynamics of Boulder Basin associated with the relatively confined nature of the embayment, effects of reduction in volume of Lake Mead would likely be disproportionately greater in Boulder Basin than in the lake as a whole. LaBounty and Horn (1997) cite the importance of salinity and thermal gradients in determining the extent of intrusion of the Las Vegas Wash into Boulder Basin. Lower lake volumes could increase the overall salinity of the Boulder Basin, thereby lowering the differential between lake water and inflows of the Las Vegas Wash. This in turn may act to disperse the intrusion, causing a more diffuse flow from Las Vegas Wash, a greater concentration of nutrients and contaminants throughout Boulder Basin, and greater availability of nonpoint contaminants in the vicinity of the SNWA intakes. Clark County's 208 Water Quality Plan certified by EPA and NDEP, regulates the quality and quantity of discharges from wastewater treatment facilities that flow into Lake Mead. These discharges currently meet standards and will do so into the future (Clark County, 1997). The SNWA is in the process of upgrading its raw water treatment facilities and these state of the art facilities will be able to meet any treatment challenges from reduced reservoir levels caused by drought or declines from interim surplus alternatives.

3.5.3.3.1.2 Tributary Water Quality

Lower water surface elevations in Lake Mead could also impact the quality of tributary flows from the Las Vegas Wash, Virgin and Muddy rivers. These effects would be a result of longer channels, and thus, longer travel times for influent streams. Potential effects on Lake Mead could include increased temperature due to warmer tributary flows. Higher evaporative losses and greater concentration of salts and contaminants may also occur in tributaries due to longer channels, leading to higher concentrations of pollutants in the Las Vegas Wash, and potentially greater concentrations of contaminants near the SNWA intakes. However, new riparian habitat development near the mouths and in these tributaries would likely develop and would be expected to offset impacts to tributary water quality. Restoration of the Las Vegas Wash wetlands will trap surface and groundwater contaminants, cool return flows and further improve the quality of return flows before it reaches Lake Mead.

3.5.3.3.2 Comparison of Baseline Conditions and Alternatives

Section 3.5.3.3.1, above, discussed the general water quality effects that may be expected given reduced Lake Mead surface elevations and volumes. The following sections compare predicted surface elevations, volume, and surface area of Lake Mead under baseline and alternative conditions. This analysis is based on system modeling results; specifically the 50 percent (median) probability elevations, as shown on Figure 3.5-5.

Characteristics of Lake Mead (elevation, volume, surface area) under baseline and alternative conditions are shown below for four selected years (i.e., years 2016, 2026, 2036 and 2050) within the modeled period, as shown in Table 3.5-6. A comparison of the percentage difference between the alternatives and baseline conditions is shown in Table 3.5-7. It should be noted that median elevations converge with the baseline condition towards the end of the period of analysis, resulting in minimal differences among the alternatives and baseline conditions in the year 2050.

3.5.3.3.2.1 Baseline Conditions

Baseline projections indicate a general trend of decreasing Lake Mead surface elevations, volume and surface area over the period of analysis, as shown above on Figure 3.5-5 and in Table 3.5-4. At the end of the interim surplus criteria period, 2016, the median elevation for Lake Mead is 1162 feet msl, a reduction of 15 feet from the surface elevation in 2002. The median baseline elevation in 2050 is 1111 feet msl for a total reduction in the median elevation of 76 feet over the entire period of analysis. This increased potential for lake level reductions would be expected to result in an increased potential for declining water quality of Lake Mead and associated effects on the SNWA intake (discussed in Section 3.5.3.3.1, above) over time under baseline conditions.

3.5.3.3.2.2 Basin States Alternative

Modeling of the Basin States Alternative indicates intermediate reductions in surface elevations, surface area and volume compared with baseline conditions in the year 2016 (when the largest differences among the alternatives are seen). The median elevation in year 2016 under the Basin States Alternative is 1143 feet msl, or 1.6 percent lower than baseline conditions in the same year, with reservoir volume approximate 12 percent lower than baseline conditions and volume becoming slightly greater than baseline by the year 2026 and slightly less than baseline in 2036. By the year 2050 no differences between this alternative and baseline conditions are present.

Table 3.5-6
Modeled Characteristics of Lake Mead Under Baseline and Alternative Conditions

Alternative	Elevation[1] (feet above msl)				Volume (maf)				Surface Area (x 1000 acres)			
	2016	**2026**	**2036**	**2050**	**2016**	**2026**	**2036**	**2050**	**2016**	**2026**	**2036**	**2050**
Baseline Conditions	1162.1	1125.7	1120.7	1110.6	17.9	13.9	13.4	12.5	120.2	99.8	97.6	93.6
Basin States	1143.3	1124.7	1120.4	1110.6	15.8	13.8	13.4	12.5	108.1	99.3	97.4	93.6
Flood Control	1162.1	1128.0	1118.9	1110.6	17.9	14.1	13.2	12.5	120.2	100.7	96.8	93.6
Six States	1145.5	1124.7	1120.5	1110.6	16.0	13.8	13.4	12.5	109.4	99.3	97.5	93.6
California	1131.2	1116.4	1117.6	1110.6	14.5	13.0	13.1	12.5	102.1	95.9	96.3	93.6
Shortage Protection	1130.2	1117.9	1117.6	1110.6	14.4	13.2	13.1	12.5	101.7	96.5	96.3	93.6

[1] Values shown are median elevations (50th percentile) for each year group.

Table 3.5-7
Modeled Comparisons of Alternatives to Baseline Conditions

Alternative	Elevation Change				Volume Change				Surface Area Change			
	2016	**2026**	**2036**	**2050**	**2016**	**2026**	**2036**	**2050**	**2016**	**2026**	**2036**	**2050**
Basin States	-1.6%	-0.1%	0.00%	0.00%	-11.7%	-0.7%	0.00%	0.00%	-10.1	-0.5	-0.2	0.00%
Flood Control	0.00%	0.2%	-0.2%	0.00%	0.00%	1.4%	-1.5%	0.00%	0.00%	0.9%	-0.8%	0.00%
Six States	-1.4%	-0.1%	0.00%	0.00%	-10.6%	-0.7%	0.00%	0.00%	-9.0%	-0.5%	-0.2%	0.00%
California	-2.7%	-0.8%	-0.3%	0.00%	-19.0%	-6.5%	-2.2%	0.00%	-15.1%	-3.9%	-1.3%	0.00%
Shortage Protection	-2.7%	-0.7%	-0.3%	0.00%	-19.6%	-5.0%	-2.2%	0.00%	-15.4%	-3.3%	-1.3%	0.00%

3.5.3.3.2.3 Baseline Conditions

Baseline projections indicate a general trend of decreasing Lake Mead surface elevations, volume and surface area over the period of analysis, as shown above on Figure 3.5-5 and in Table 3.5-4. At the end of the interim surplus criteria period, 2016, the median elevation for Lake Mead is 1162 feet msl, a reduction of 15 feet from the surface elevation in 2002. The median baseline elevation in 2050 is 1111 feet msl for a total reduction in the median elevation of 76 feet over the entire period of analysis. This increased potential for lake level reductions would be expected to result in an increased potential for declining water quality of Lake Mead and associated effects on the SNWA intake (discussed in Section 3.5.3.3.1, above) over time under baseline conditions.

3.5.3.3.2.4 Basin States Alternative

Modeling of the Basin States Alternative indicates intermediate reductions in surface elevations, surface area and volume compared with baseline conditions in the year 2016 (when the largest differences among the alternatives are seen). The median elevation in year 2016 under the Basin States Alternative is 1143 feet msl, or 1.6 percent lower than baseline conditions in the same year, with reservoir volume approximate 12 percent lower than baseline conditions and volume becoming slightly greater than baseline by the year 2026 and slightly less than baseline in 2036. By the year 2050 no differences between this alternative and baseline conditions are present.

3.5.3.3.2.5 Flood Control Alternative

Modeling of the Flood Control Alternative produces similar surface elevations, surface area, and volume compared with baseline conditions in the year 2016, with the elevation, surface area and volume becoming slightly greater then baseline by the year 2026 and slightly less than baseline in 2036. By the year 2050 no differences between this alternative and baseline conditions are present.

3.5.3.3.2.6 Six States Alternative

Modeling of the Six States Alternative indicates a Lake Mead surface elevation 1.4 percent lower and a volume 10.6 percent lower than baseline conditions in 2016. By the year 2026 and for the remaining period of analysis, differences between baseline conditions and this alternative are within one percent.

3.5.3.3.2.7 California Alternative

Modeling of the California Alternative indicates a volume of Lake Mead in the year 2016 that is 19 percent lower than baseline conditions, with the difference decreasing to 6.5 percent and 2.2 percent in the years 2026 and 2036, respectively.

3.5.3.3.2.8 Shortage Protection Alternative

Modeling of the Shortage Protection Alternative indicates similar changes in volume reduction as the California Alternative throughout the period of analysis, with volume 19.6 percent lower than baseline conditions in 2016, 6.5 percent lower in 2026 and 2.2 percent lower in 2036.

3.5.3.3.2.9 Summary of Changes in Lake Mead Volume and Elevation

Tables 3.5-6 and 3.5-7 summarize modeled changes in Lake Mead surface elevation, area, and volume under each of the alternatives as compared with baseline conditions. With the exception of the Flood Control Alternative, each of the alternatives indicate an increase potential for lower surface elevations, surface area and lake volume. These difference are most pronounced in year 2016, the end of the interim surplus criteria period. The greatest differences compared with baseline conditions are associated with the California and Shortage Protection alternatives, with intermediate differences indicated by the Basin States and Six States alternatives.

3.5.4 WATER QUALITY BETWEEN HOOVER DAM AND SOUTHERLY INTERNATIONAL BOUNDARY

There have been concerns from the EPA and others about contaminants in the Lower Colorado River between Hoover Dam and the SIB. However, there is little site specific data from this segment of the river. A USGS (1995) study of mercury and other contaminants found in fish and wildlife located in the Yuma Valley area concluded that mercury is not a problem.

The above study also indicates that selenium is also not a problem for fish and wildlife. Selenium in Colorado River water in the Yuma Valley had a median value of less than one micrograms per liter (µg/l). This research also confirms what other previous selenium studies have concluded: selenium in the LCR and its biota remains below the DOI level of concern of five µg/l. A 1986-1987 study by the USGS indicated a finding of 3.4 µg/l or less for dissolved selenium at several sites in the Lower Colorado River (USGS, 1988). Department of Interior's Pre-reconnaissance Investigation Guides (1992) reported similar findings of less than 3.4 µg/l in Colorado River water at Pilot Knob. In the 1995 USGS study of the Yuma area, measured selenium in 18 water samples averaged 1.72 µg/l, with a maximum of 8.0 µg/l and a minimum of less than 1.0 µg/l. Nine of the 18 measurement results were reported to be less than 1.0 µg/l. Currently there are no state fish consumption advisories for mercury, selenium or any other contaminants on the Lower Colorado River (Ketinger, 2000). Water quality studies will continue in this segment of the river during the 15-year period of proposed interim surplus criteria. None of the action alternatives are anticipated to increase concentrations of contaminants beyond the noted limits.