2-25-1994

Study of existing information concerning water quality within Lake Mead

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Southern Nevada Water Authority

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INTRODUCTION

The purpose of Task 010A15M of the Southern Nevada Water Authority (SNWA) Treatment and Transmission Facility (TTF) contract is to conduct a study of existing information concerning water quality within Lake Mead and identify additional water quality studies that are needed to supplement existing data.

The objective of this task is not to discuss treatability of the raw water source; this is addressed by Task 010A18M, "Define Water Treatment Requirements". In addition, a narrative on the effect of pending Safe Drinking Water Act amendments and a determination of treated water quality goals is included in Task 010A16M, "Review Safe Drinking Water Act (SDWA) Regulatory Impacts".

Lake Mead has the largest surface area of any reservoir in the Northern Hemisphere. Bordered by Arizona and Nevada, the lake was created by the impoundment of the Colorado River behind Hoover Dam. The dam was constructed in 1935 to control flooding and provide a dependable water source, which now supplies about 20 million people in the desert Southwest and Los Angeles metropolitan area. The Bureau of Reclamation manages the water resources of the reservoir, and the National Park Service administers the recreation facilities at the reservoir.

SUMMARY

A considerable body of water quality data have been collected in Lake Mead at or near the alternative intake sites for the SNWA TTF. The sites include Callville Bay, Water Barge Cove, Black Island, Government Wash (Las Vegas Bay), Saddle Island (SNWS intake), Hemenway Wall (Promontory Point), and Hoover Dam. The major sources of Lake Mead water quality data include the Southern Nevada Water System (SNWS), the U.S. Bureau of Reclamation, the National Park Service, and the City of Las Vegas/Clark County Sanitation District joint Water Quality Study.

With respect to water quality data that would be used to evaluate and select treatment processes, data is available at most intake sites for turbidity, alkalinity, coliforms, dissolved oxygen, TDS, odor and temperature. However, there is little or no data on arsenic, total organic carbon, and trihalomethane formation potential. Several years of data is available at the SNWS intake (Saddle
Island site) and at the Colorado River below Hoover Dam. Minimal data was found for Water Barge Cove. There is a preponderance of data within the Las Vegas Bay from the confluence with the Las Vegas Wash to Black Island; however, the data was predominately collected to collaborate water quality standards set for the wastewater treatment plants (nitrogen: ammonia, nitrate, nitrite and dissolved oxygen, chlorophyll, coliforms).

This activity has focused on identifying additional tasks for data collection and analysis rather than evaluation. However, preliminary review of the data suggests:

- Las Vegas Bay, influenced by wastewater discharge and stormwater runoff conveyed through the Las Vegas Wash, has higher concentration of microorganisms than other sites. Because of this risk of contamination from pathogens in the wash discharge and because of the shallower depth, an intake in the Las Vegas Bay should be eliminated from further consideration by this initial screening.

- Based on depth sampling conducted by the SNWS and others, it appears that some water quality parameters vary with depth. This has been demonstrated in samples taken at the SNWS intake from 0 to 54 meters for dissolved oxygen, temperature and odor, occurring predominately during the summer months. Multiple intake depths should be considered.

A preliminary evaluation of data indicates that alternate intake sites (other than the Las Vegas Bay/Government Wash site) are similar in terms of water quality.

**TASK SCOPE**

The scope for Task 010A15M is as follows:

- Conduct a study of existing information concerning water quality within Lake Mead and at different elevations.
  - Identify relevant materials regarding water in Lake Mead to (1) assist in selecting alternative intake sites and depths and (2) assist in defining treatment requirements.
  - Obtain data from existing Southern Nevada Water System and U.S. Fish and Wildlife Service sources.
  - Review and summarize existing water quality data.
  - Determine relationships between water quality, treatment selection, and intake location.
- Identify additional water quality studies that are needed to supplement existing data.
ALTERNATIVE INTAKE LOCATIONS

Available Lake Mead water quality data was collected for seven alternate intake locations:

- Callville Bay
- Water Barge Cove
- Box Car Cove
- Government Wash
- Saddle Island
- Hemenway Wall
- Hoover Dam

These intake sites are shown on Figure 15-1. Intake elevations could vary from as low as elevation 895 MSL, the worst-case drought elevation, to as high as elevation 1050 MSL which is the minimum power pool at Hoover Dam. The existing SNWS intake is set at elevation 1013 MSL. The maximum gage height for Lake Mead was recorded at 1225.85 ft (July 24, 1983) and the minimum recorded gage height is 1083.21 ft (April 26, 1956).

WATER QUALITY FACTORS AFFECTING TREATMENT

The principal objective of a water treatment facility is to provide water to consumers which satisfies regulatory requirements and other water quality objectives such as color, odor, hardness, etc. Undesirable constituents in the source water must either be removed or rendered innocuous through appropriate physical and chemical processes.

Table 15-1 shows a list of constituents which affect water treatment process selection.
FIGURE 15-1
ALTERNATIVE INTAKE SITES

1 Callville Bay
2 Water Barge Cove
3 Box Car Cove
4 Government Wash
5 Saddle Island
6 Hemenway Wall
7 Hoover Dam
Table 15-1

Source Water Quality Characteristics Impacting Treatment

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Processes Impacted by Characteristic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turbidity</td>
<td>Filtration technique (i.e., conventional, direct filtration)</td>
</tr>
<tr>
<td>Total Organic Carbon</td>
<td>Disinfection/DBP Rule (enhanced coagulation); DBP formation</td>
</tr>
<tr>
<td>Alkalinity</td>
<td>Disinfection Method/DBP Rule (enhanced coagulation)</td>
</tr>
<tr>
<td>Arsenic</td>
<td>Enhanced coagulation</td>
</tr>
<tr>
<td>Coliform Bacteria (Total &amp; Fecal)</td>
<td>Disinfectant choice and required inactivation</td>
</tr>
<tr>
<td>DBP (or THM) Form. Potential</td>
<td>Disinfectant choice and organics removal technology</td>
</tr>
<tr>
<td>Dissolved Oxygen</td>
<td>Oxidation, iron and manganese removal</td>
</tr>
<tr>
<td>Hardness</td>
<td>Softening, membrane technology</td>
</tr>
<tr>
<td>Taste and Odor or Algae Counts/ Chlorophyll a</td>
<td>Oxidation, PAC, GAC, etc.</td>
</tr>
<tr>
<td>Total Dissolved Solids</td>
<td>Membrane/softening</td>
</tr>
<tr>
<td>Temperature</td>
<td>Flocculation/sedimentation; disinfection</td>
</tr>
</tbody>
</table>

Process engineering must select the appropriate technology to provide cost effective treatment to meet the water quality standards. In order to adequately evaluate individual units in the process train, and to find the best source water quality, a reconnaissance was performed for the availability of these data in numerous areas in Lake Mead.

EXISTING WATER QUALITY DATA AND STUDIES

Over one hundred studies have been prepared and published on water quality in Lake Mead. Appendix 15-1, entitled "Chronological Summary of Water Quality and Limnological Studies in Lake Mead During 1936 - 1993" includes the title, study period, stations sampled and constituents/measure-ments analyzed for each study.
Several agencies were contacted to discuss ongoing water sampling and monitoring programs being conducted in Lake Mead. The following briefly discusses current sampling locations and the constituents for which analyses are performed.

Southern Nevada Water System

The Southern Nevada Water System (SNWS) has been taking raw water samples in Lake Mead for over 10 years. The various sampling locations are shown in Figure 15-2. All samples are taken from a boat. Sample location and frequency are summarized below. Data is reported on forms by hand; at this time it is not stored in a database. Representative report forms are included in Appendix 15-2. Although the data discussed below does not include total organic carbon, the SNWS is purchasing a TOC analyzer and will begin this analysis by July 1994.

Form 105N - Routine Physical & Chemical Analysis.

<table>
<thead>
<tr>
<th>Sampling Interval:</th>
<th>Monthly</th>
</tr>
</thead>
<tbody>
<tr>
<td>Locations Sampled:</td>
<td>SNWS Intake (surface)</td>
</tr>
<tr>
<td></td>
<td>SNWS Intake (24 m)</td>
</tr>
<tr>
<td></td>
<td>LV Bay (surface)</td>
</tr>
<tr>
<td></td>
<td>LV Bay (24 m)</td>
</tr>
<tr>
<td></td>
<td>LV Wash (surface)</td>
</tr>
<tr>
<td></td>
<td>Black Island (surface)</td>
</tr>
<tr>
<td></td>
<td>Black Island (24 m)</td>
</tr>
<tr>
<td></td>
<td>Callville Bay (surface)</td>
</tr>
<tr>
<td></td>
<td>Callville Bay (24 m)</td>
</tr>
<tr>
<td></td>
<td>Promontory Point (surface)</td>
</tr>
<tr>
<td></td>
<td>Promontory Point (24 m)</td>
</tr>
<tr>
<td>Constituents Tested:</td>
<td>Alkalinity (Carbonate and Bicarbonate)</td>
</tr>
<tr>
<td></td>
<td>Ammonia, Nitrogen</td>
</tr>
<tr>
<td></td>
<td>Color</td>
</tr>
<tr>
<td></td>
<td>Conductivity</td>
</tr>
<tr>
<td></td>
<td>Nitrate</td>
</tr>
<tr>
<td></td>
<td>Odor</td>
</tr>
<tr>
<td></td>
<td>Dissolved Oxygen</td>
</tr>
<tr>
<td></td>
<td>pH</td>
</tr>
<tr>
<td></td>
<td>Phosphate</td>
</tr>
<tr>
<td></td>
<td>Temperature</td>
</tr>
<tr>
<td></td>
<td>Turbidity</td>
</tr>
<tr>
<td></td>
<td>Particle Count</td>
</tr>
<tr>
<td></td>
<td>Secchi Disk Reading</td>
</tr>
</tbody>
</table>

FIGURE 15-2
SOUTHERN NEVADA WATER SYSTEM
SAMPLING LOCATIONS

1. SNWS Intake
2. Black Island
3. Fish Hatchery
4. Sand Island
5. Las Vegas Bay
6. LV Wash Outlet
7. Saddle Island
8. Promontory Point
9. Callville Bay
Form 478F - Lake Chlorophyll.

Sampling Interval: Monthly

Locations Sampled:
- SNWS Intake (0-6 m)
- SNWS Intake (9 m)
- SNWS Intake (12 m)
- SNWS Intake (15 m)
- SNWS Intake (18 m)
- SNWS Intake (21 m)
- SNWS Intake (24 m)
- Saddle Island (0-6 m)
- Pish Hatchery (0-6 m)
- Sand Island (0-6 m)
- LV Bay (0-6 m)
- LV Wash Outlet (0-2 m)

Constituents Tested:
- Temperature
- Transparency
- pH
- Dissolved Oxygen
- Conductivity
- Chlorophyll

Form 108L - Lake Profile.

Sampling Interval: Weekly/Twice Weekly

Locations Sampled:
- SNWS Intake (surface)
- SNWS Intake (3 m)
- SNWS Intake (6 m)
- SNWS Intake (12 m)
- SNWS Intake (18 m)
- SNWS Intake (24 m)
- SNWS Intake (24 m)
- SNWS Intake (30 m)
- SNWS Intake (36 m)
- SNWS Intake (42 m)
- SNWS Intake (48 m)
- SNWS Intake (54 m)

Constituents Tested:
- Temperature
- Threshold Odor Number
- pH
Memo to: Douglas A. Selby  
Activity 010A15M  
February 25, 1994

Dissolved Oxygen  
Orthophosphate  
Nitrate  
Nitrite  
Ammonia  
Particle Count  
Turbidity  
Conductivity  
True Color

**Form 101N - Phytoplankton Record.**

**Sampling Interval:** Weekly

**Locations Sampled:**  
SNWS Intake (0-6 m)  
SNWS Intake (12 m)  
SNWS Intake (24 m)  
SNWS Intake (42 m)  
Raw Water  
Finished Water

**Species Generally Present:**  
*Oscillatoria* (Filamentous blue-green alga)  
*Aphanothece*  
*Gamphosphaeria*  
*Phormidium*  
*Merismopedia*  
*Sphaerocystis*  
*Ochromonas*  
*Chlamydomonas* (Green alga)  
*Oocystis*  
*Trachelomonas*  
*Quadrigula Lagerheimia*  
*Scenesdesmus* (Coccoid Nonmotile green alga)  
*Cyclotella* (Centric Diatom)  
*Melosira* (Centric Diatom)

**Form 257B - Trihalomethanes.** These data have only been collected for the last 18 months and is the result of pilot plant work conducted on raw water.

**Sampling Interval:** Daily/Weekly

**Locations Sampled:** SNWS Intake
THMs Tested: Chloroform
Bromodichloromethane
Chlorodibromomethane
Bromoform
Total THMs

Microbiological Data.

Sampling Interval: Intermittent

Locations Sampled:
SNWS Intake
Callville Bay
Black Island
Saddle Island
Promontory Point
Fish Hatchery (0-6 m)
Sand Island (0-6 m)
LV Bay (0-6 m)
LV Wash Outlet (0-2 m)

Pathogens Tested:
Fecal Coliform
Fecal Streptococci
Vibrio sp.
Salmonella sp.
Shigella
Campylobacter
Yersinia
Legionella
Listeria

National Park Service

The National Park Service (NPS) operates five water treatment plants in Nevada to serve visitors to the Lake Mead National Recreation Area. Intakes for the treatment plants are located at Overton Beach, Echo Bay, Callville Bay, Las Vegas Bay and Boulder Beach. Total coliform is tested twice per month and turbidity is measured daily at each of these sites.

Lake Mead National Recreation Area recently retained the University of Nevada Las Vegas (UNLV) to prepare a report on the "Determination of Fecal Coliform Levels and Heterotrophic Plate Counts in the Las Vegas Wash Waterway", October 1993. Sampling locations in Lake Mead included the delta, the beach outcrop below the campground, and the dropoff area (where the greatest depth occurs) at Las Vegas Bay (reference Figure 15-3).

Constituents Tested:  
pH  
TDS  
Conductivity  
Temperature  
Fecal Coliform  
Heterotrophic Plate Count  
Chemical Analyses (currently unpublished)

The NFS is currently conducting a Carrying Capacity Study on Lake Mead and Lake Mohave to determine public health risk at the most heavily used recreational sites and "background" sites to represent "pristine" lake conditions. There are 24 zones, two sample sites per zone. Sites 1 through 9 are on Lake Mohave; Sites 10 through 24 are on Lake Mead. The NFS is analyzing for the presence of pathogens in the water and the sediments of these zones.

Sampling Interval:  
Weekly to Bi-weekly from June 2 to September 29, 1993.

Constituents Tested:  
Temperature  
Fecal Coliform  
Fecal Streptococci

U.S. Bureau of Reclamation

The Bureau of Reclamation (Reclamation) has prepared several reports and collected numerous data within Lake Mead and below Hoover Dam since 1941. The reports are listed in Appendix 15-1. Reclamation has recently completed a remote sensing study in Las Vegas Bay as part of the effort in preparing a report entitled "Monitoring Impacts on Inland Fisheries Using Hydroacoustics", which includes landsat images for recording chlorophyll a concentrations in Las Vegas Bay and surface temperature in the lake. These images are presented in Figure 15-4 and Figure 15-5. Reclamation monitors water quality at Hoover and Davis Dams as well; this information is reported by the U.S. Geological Survey (USGS) in the annual publication "Water Resources Data for Arizona".

Water Resources Data for Arizona (USGS)

Sampling Interval:  
Varies by parameter

Locations Sampled:  
Colorado River below Hoover Dam, Arizona-Nevada  
Lake Mohave at Davis Dam, Arizona-Nevada

Constituents Tested:  
Streamflow  
Specific Conductance  
pH  
Temperature
FIGURE 15-3
NATIONAL PARK SERVICE
BACTERIOLOGICAL SAMPLING SITES
Figure 15-4 - Water surface temperatures measured by Landsat satellite imagery for Lake Mead, Nevada, August 9, 1992.
Figure 15-5 - Surface chlorophyll-a concentrations measured by Landsat satellite imagery of Las Vegas Bay, Lake Mead, Nevada, August 9, 1992.
Turbidity
Dissolved Oxygen
Fecal Coliform
Fecal Streptococci
Hardness
Calcium
Magnesium
Sodium Adsorption Ratio
Potassium
Bicarbonate
Alkalinity
Sulfate
Chloride
Flouride
Silica
Solids Residue @ 180° C., Dissolved (mg/l)
Solids, Sum of Constituents, Dissolved (mg/l)
Solids, Dissolved (tons per acre foot)
Nitrite
Nitrite + Nitrate
Ammonia
Nitrogen - Organic
Nitrogen - Organic + Ammonia
Total Nitrogen
Total Phosphate
Total Orthophosphate

Aluminum (Reported Quarterly)
Arsenic (Reported Quarterly)
Barium (Reported Quarterly)
Barylium (Reported Quarterly)
Cadmium (Reported Quarterly)
Chromium (Reported Quarterly)
Cobalt (Reported Quarterly)
Copper (Reported Quarterly)
Iron (Reported Quarterly)
Lead (Reported Quarterly)
Lithium (Reported Quarterly)
Manganese (Reported Quarterly)
Mercury (Reported Quarterly)
Molybdenum (Reported Quarterly)
Nickel (Reported Quarterly)
Selenium (Reported Quarterly)
Silver (Reported Quarterly)
Memo to: Douglas A. Selby  
Activity 010A15M  

Strontium (Reported Quarterly)  
Vanadium (Reported Quarterly)  
Zinc (Reported Quarterly)  
Sediment Suspended (Report for 9 Months)  
Sediment, Discharge, Suspended (Reported for 9 Months)  
Sediment, Suspended (Reported Quarterly)  
Sieve Dia.1 Finer than 0.062 MM  

Las Vegas Bay Remote Sensing Study  

Sampling Interval:  Almost monthly from January 1990 through 1992 and has continued intermittently since  

Locations Sampled:  14 stations and 6 coves beginning at LV Wash mouth of bay across from Saddle Island following the buoyline  

Constituents Tested:  Chlorophyll a (Surface)  
Temperature (Surface)  
Phosphate (0 m, 1 m, 3 m, and 0-5 m composite)  
Nitrate  
Zooplankton  
Dissolved Oxygen  
Specific Conductance  
pH  

The Lower Colorado Region office of Reclamation began water quality monitoring from Temple Basin up to the Grand Wash Cliffs; which lies west and north of Boulder Basin.  

Sampling Interval:  Quarterly since June 1993  

Constituents Tested:  Ammonia  
Phosphate  
Nitrate  
Zooplankton  
Temperature  
Dissolved Oxygen  
Conductivity  
pH  

City of Las Vegas/Clark County Sanitation District  

The City of Las Vegas (CLV) Water Pollution Control Facility has been gathering water quality samples in Lake Mead for over 4 years. The Lake Mead sampling was conducted at a total of 10 stations: six locations in the inner Las Vegas Bay; two in the middle Las Vegas Bay (Stations 4 &
The Clark County Sanitation District laboratory analyzes the samples. Some zooplankton analyses is done by the CLV laboratory as well.

**Sampling Interval:**
- Biweekly from March through October
- Monthly from November through February
- LM 9 bimonthly
- Total Organic Carbon (last 6 to 8 months)

**Constituents Tested:**
- Chlorophyll-a
- Fecal Coliform
- Total Phosphorus
- Dissolved Orthophosphate
- Ammonia
- TKN
- Nitrate
- Nitrite
- Nitrate + Nitrite
- Temperature
- Dissolved Oxygen
- Conductance
- pH

**Metropolitan Water District of Southern California**

The Metropolitan Water District of Southern California (MWD) has numerous years of Colorado River water quality data from Lake Havasu near the Whitsett Intake Pumping Plant. MWD diverts water for the Los Angeles Basin from Lake Havasu which is used to supply drinking water to millions of people in the Southern California area.

**Location Tested:**
- Lake Havasu near Whitsett Intake

**Constituents Tested:**
- Aluminium
- Arsenic
- Barium
- Cadmium
- Chromium
- Copper
- Iron
- Lead
- Lithium
- Manganese
- Mercury
- Molybdenum
Key:
*+ Water Quality Sampling Locations
Ø Current Monitoring
+ Meteorological Data

FIGURE 15-6
CITY OF LAS VEGAS/CLARK COUNTY SANITATION DISTRICT
WQS SAMPLING PROGRAM
Selenium
Silver
Strontium
Zinc
Silica
Calcium
Magnesium
Sodium
Potassium
Carbonate
Bicarbonate
Sulfate
Chloride
Nitrate
Flouride
Boron
Total Dissolved Solids
Total Hardness as CaCO₃
Total Alkalinity as CaCO₃
Free Carbon Dioxide
H⁺ Concentration
Specific Conductance
Turbidity
Temperature

EXISTING PHYSICAL DATA AND STUDIES

Lake Mead is a complex body of water which varies in structure throughout the year. An understanding of the hydrodynamics of the Lake will assist in selecting the intake location, depth and type. Measurements of the currents within Lake Mead are rather limited; however two studies have been conducted which include current profiles for the lake.

U.S. Bureau of Reclamation Study from 1971

A study entitled "Measurements of Currents in Lake Mead with the Deep Water Isotopic Current Analyzer (DWICA)" was performed in 1971 by J.J. Sartoris and D.A. Hoffman for the U.S. Bureau of Reclamation.

Study Period: November 10 - 17, 1967

Locations Monitored:

Station 1: Promontory Point about 1 mile above Hoover Dam at a depth of 410 feet.
Station 2: Mouth of Las Vegas Bay about 1 mile north of Saddle Island at a depth of 285 feet.

Station 3: Boulder Basin 0.6 miles southwest of Sentinel Island at a depth of 358 feet.

Summary of Findings:

Station 1. "A comparison of current profiles obtained at Station 1 indicates a strong current in the direction of Hoover Dam and approximately centered on the elevation of the outlet. Measurements obtained during the peaking cycle indicate that this current is closely related to discharges through the dam. ...Strong bottom currents in the direction of the dam were observed on the 11th and 16th [of November]. These may be density currents and could be caused by sediment load, salinity, and cold inflow."

Station 2. "The current profiles at this station agree rather closely in indicating a strong current at the surface flowing into Las Vegas Bay out of Boulder Basin. Below this current and centered at about the 100 foot depth is a slightly stronger current flowing in the opposite direction. This current, flowing out of Las Vegas Bay into Boulder Basin, coincides with the top of the thermocline. ... These profiles indicate a major component current in the direction of the water pipe [at Saddle Island] intake between depths of 50 and 110 feet."

Station 3. Data were inconclusive for this station.

City of Las Vegas/CCSD/ECO-Systems Study from 1989

A draft of a two volume study entitled "Physical/Chemical Measurements in Lake Mead, Nevada From August 1 to October 11, 1989" was prepared by ECO-Systems Management Associates for the City of Las Vegas and Clark County Sanitation District. This information was used in the Lake Mead Eutrophication Model, prepared to develop an understanding of the extent to which wastewater discharges affect water quality in Lake Mead. Although the focus of this study was Las Vegas Bay, several data collection sites were chosen in order to determine the characteristics and the correlation of currents in Lake Mead.

Study Period: April 20 to May 22, 1989
August 1 to October 11, 1989

Locations Monitored: Four sites within Las Vegas Bay
Off Saddle Island near the SNWS intake
The Narrows between Boulder and Virgin Basins
Figures 15-7 and 15-8 represent the flow distribution for the model. The report entitled "Development and Calibration of the Lake Mead Eutrophication Model", April 1991 states that "The 1988-89 model calibration and preliminary modeling of 1979-80 conditions found that the Lake stratifies rapidly during the end of March and mid-April. Recurring periods of high vertical mixing appear in June of the three years where the measurements have been studied. This event appears to bring large quantities of inorganic nutrients to the surface just as water temperatures begin to approach annual maximums, so it is an important influence on chlorophyll production."

In Las Vegas Bay, the ECO-Systems study reports the presence of currents moving in a southwesterly direction at a depth of 5 m and currents moving in a northerly direction at a depth of 25 m. Further, the study reports a current moving in a southwesterly direction at about 5 Km/month near Black Island. All currents in the vicinity of the SNWS Intake are reported to be moving parallel to the Saddle Island shoreline. The study noted that current velocities and directions were similar for both summer and fall monitoring periods.

SUMMARY OF WATER QUALITY DATA

In general, water quality in Lake Mead is very consistent as a result of the numerous dams on the Colorado River that regulate the flow and tend to equalize the water quality. The water quality parameters that can be most affected by local conditions are turbidity and biological parameters. Trace metals and minerals are not expected to change significantly in Lake Mead. Turbidity may change due to modification in operation of the reservoir and changing lake levels. Biological parameters (e.g., coliforms and HPCs) vary by proposed intake site due to discharges from wastewater treatment plants and stormwater discharge (i.e., nonpoint sources). This is particularly noticeable in the samples taken from the Las Vegas Bay which receives wastewater from the treatment plants discharging to the Las Vegas Wash as well as urban stormwater runoff. This observation is elaborated by Figure 15-10 and Figure 15-11.

Mineral, Physical and Biological Parameters

Table 15-2 presents mineral, physical and biological information collected from the SNWS, MWD and Reclamation. Of those constituents which are covered by a Primary Drinking Water Standard (i.e., MCL) only turbidity and coliforms are exceeded. Of those constituents covered by the Secondary Drinking Water Standards, only total dissolved solids (TDS) is exceeded.

TDS and Hardness. Figure 15-9 is a plot of Colorado River water TDS and hardness for a 15-year period. This information was prepared by MWD for Lake Havasu water. In addition, the annual summary of TDS for the Colorado River below Hoover Dam was analyzed from 1941 to the present. In general, raw water TDS can be expected to vary between 500 to 700 mg/l (an annual high TDS concentration of 833 mg/l was recorded in 1956, a drought year when the lake reached a record low level). However, TDS concentrations will increase if an extended drought occurs. Figure 15-12 is a plot of conductivity values for a two-year period (1992-1993) from the SNWS intake at depths from 0 to 54 meters. Based on the secondary standards, it would be
FLOW ROUTING IN LAS VEGAS BAY AND BOULDER BASIN

FIGURE 15-7
FIGURE 15-8
COLORADO RIVER FLOW ROUTING
CHEMICAL QUALITY OF COLORADO RIVER WATER AT WITSETT INTAKE PUMPING PLANT

Figure 15-9

TDS AND HARDNESS DATA FROM MWDSC
UNLV Study of Las Vegas Wash

### Fecal Coliform Concentrations (/100 ml) 1993

<table>
<thead>
<tr>
<th>Date</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>27-Jul</td>
<td>110</td>
</tr>
<tr>
<td>3-Aug</td>
<td>30</td>
</tr>
<tr>
<td>10-Aug</td>
<td>9</td>
</tr>
<tr>
<td>17-Aug</td>
<td>130</td>
</tr>
<tr>
<td>24-Aug</td>
<td>9</td>
</tr>
<tr>
<td>31-Aug</td>
<td>130</td>
</tr>
<tr>
<td>7-Sep</td>
<td>&lt;2*</td>
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<tr>
<td>14-Sep</td>
<td>&lt;2*</td>
</tr>
<tr>
<td>Min</td>
<td>9</td>
</tr>
<tr>
<td>Max</td>
<td>130</td>
</tr>
<tr>
<td>Avg</td>
<td>69.5</td>
</tr>
</tbody>
</table>

* These values are not included in Min, Max, Avg calculations.

### Heterotrophic Plate Count (/1 ml) 1993

<table>
<thead>
<tr>
<th>Date</th>
<th>Plate Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>27-Jul</td>
<td>7.20E+04</td>
</tr>
<tr>
<td>3-Aug</td>
<td>1.80E+05</td>
</tr>
<tr>
<td>10-Aug</td>
<td></td>
</tr>
<tr>
<td>17-Aug</td>
<td>1.30E+05</td>
</tr>
<tr>
<td>24-Aug</td>
<td>2.40E+05</td>
</tr>
<tr>
<td>31-Aug</td>
<td>1.40E+05</td>
</tr>
<tr>
<td>7-Sep</td>
<td>6.00E+04</td>
</tr>
<tr>
<td>14-Sep</td>
<td>6.80E+04</td>
</tr>
<tr>
<td>Min</td>
<td>6.00E+04</td>
</tr>
<tr>
<td>Max</td>
<td>2.40E+05</td>
</tr>
<tr>
<td>Avg</td>
<td>1.34E+05</td>
</tr>
</tbody>
</table>

Figure 15-10
Table 15-2
Mineral, Physical, and Biological Analyses
(Results in mg/l, except where noted)

<table>
<thead>
<tr>
<th>SNWS Data for Lake Mead (1992/1993)</th>
<th>MWD Data for Lake Havasu Near the Whitsett Intake 1987 to 1989</th>
<th>Colorado River below Davis Dam Big Bend Water District</th>
<th>Proposed or Existing MCL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg</td>
<td>Max</td>
<td>Min</td>
<td>Max</td>
</tr>
<tr>
<td>Silica</td>
<td>9.14</td>
<td>9.50</td>
<td>8.6</td>
</tr>
<tr>
<td>Calcium</td>
<td>77.15</td>
<td>77.90</td>
<td>61</td>
</tr>
<tr>
<td>Magnesium</td>
<td>30.80</td>
<td>32.40</td>
<td>25</td>
</tr>
<tr>
<td>Sodium</td>
<td>98.97</td>
<td>107.00</td>
<td>72</td>
</tr>
<tr>
<td>Potassium</td>
<td>5.00</td>
<td>5.70</td>
<td>3.7</td>
</tr>
<tr>
<td>Carbonate</td>
<td>--</td>
<td>--</td>
<td>0</td>
</tr>
<tr>
<td>Bicarbonate</td>
<td>--</td>
<td>--</td>
<td>148</td>
</tr>
<tr>
<td>Sulfate</td>
<td>281.28</td>
<td>310.00</td>
<td>208</td>
</tr>
<tr>
<td>Chloride</td>
<td>87.38</td>
<td>95.00</td>
<td>55</td>
</tr>
<tr>
<td>Nitrate</td>
<td>0.50</td>
<td>0.58</td>
<td>0.4</td>
</tr>
<tr>
<td>Fluoride</td>
<td>0.34</td>
<td>0.38</td>
<td>0.26</td>
</tr>
<tr>
<td>Total Dissolved Solids</td>
<td>--</td>
<td>--</td>
<td>513</td>
</tr>
<tr>
<td>Total Hardness</td>
<td>329</td>
<td>344.00</td>
<td>255</td>
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<tr>
<td>Total Alkalinity</td>
<td>124.7</td>
<td>132.00</td>
<td>119</td>
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<tr>
<td>Free Carbon Dioxide</td>
<td>4.55</td>
<td>6.53</td>
<td>0.7</td>
</tr>
<tr>
<td>pH (Standard Unit)</td>
<td>7.69</td>
<td>7.99</td>
<td>8.11</td>
</tr>
<tr>
<td>Specific Conductivity (umho/cm)</td>
<td>1062</td>
<td>1107</td>
<td>808</td>
</tr>
<tr>
<td>Turbidity (NTU)</td>
<td>0.28</td>
<td>0.78</td>
<td>0.34</td>
</tr>
<tr>
<td>Temperature (°C)</td>
<td>18.87</td>
<td>20.50</td>
<td>9</td>
</tr>
<tr>
<td>Color (cu)</td>
<td>4.17</td>
<td>5.00</td>
<td>&lt;2</td>
</tr>
<tr>
<td>Total Coliform (C/100 ml)</td>
<td>--</td>
<td>--</td>
<td>1,000</td>
</tr>
<tr>
<td>HPC Bacteria (C/ml)</td>
<td>--</td>
<td>--</td>
<td>2</td>
</tr>
</tbody>
</table>

*Secondary Drinking Water Standard.
*Primary Drinking Water Standard
Figure 15 - 12
Conductivity - SNWS Intake, 1992 - 93
desirable to have a water source with less TDS or possibly reduce TDS through advanced treatment processes; however, it is not mandatory.

**Turbidity.** As shown in Table 15-2, turbidity values from raw water at SNWS for a two-year period (1992 and 1993) averaged 0.28 NTU with a maximum of 0.78 NTU. SNWS turbidity lake profile data is plotted in Figure 15-13.

**Dissolved Oxygen and Temperature.** Dissolved oxygen concentrations in Lake Mead vary considerably with depth during periods of thermal stratification (Figure 15-14). As depicted in Figure 15-15, thermal stratification begins to develop by late-April and early-May. The reservoir is well stratified by early June, with the thermocline located at about 10 - 15 m. By late summer, the thermocline drops to 15 - 20 m. Thermal stratification persists well into the fall. The lake does not mix completely until late-November or early-December.

Lake Mead is characterized by a negative heterograde oxygen profile during periods of thermal stratification. A negative heterograde oxygen profile points to a decrease in Dissolved Oxygen (DO) concentrations with depth until a minimum DO concentration is reached. Beyond this depth the DO concentrations increase as a function of depth. In general, acute DO depletions in the metalimnion are attributed to this condition. A plausible explanation for this anomalous DO profile is reported by Paulson, L.J., Baker, J.R., Deacon, J.E. (1980) to be a metalimnetic biological and/or chemical oxygen demand. The thermocline is theorized to represent a sharp density gradient. This facilitates the agglomeration of settling organic matter in the metalimnion, which in turn creates an oxygen demand in this depth zone. Mineralization of this organic matter in the metalimnion reduces oxygen demand in the hypolimnion, thereby sustaining relatively higher DO concentrations in the hypolimnion. DO concentrations typically run about 8 ppm in the epilimnion during summer. Oxygen depletion occurs in the metalimnion between depths of 10 - 20 m. At the thermocline, DO often drops to less than 1 ppm in Las Vegas Bay and down to about 3 - 4 ppm in Boulder Basin. In the hypolimnion, DO concentrations rarely drop below 5 ppm in Boulder Basin. However, in Las Vegas Bay, hypolimnetic DO concentrations often drop to less than 1 ppm during late summer.

Oxygen concentrations are replenished in the metalimnion and hypolimnion during fall mixing. The lake is completely mixed during winter and early spring, and DO concentrations run about 10 ppm throughout the water column.

SNWS chlorophyll data were reviewed for the past two years at the six sampling locations. Figure 15-16 illustrates the temporal variation of chlorophyll a concentrations at the sampled locations. Chlorophyll a concentrations at the SNWS intake show that during summer months, when greater photosynthesis occurs, the chlorophyll a depth profile increases, peaking at depths of approximately 15 to 20 meters. Chlorophyll a concentrations increased dramatically at the SNWS intake between 1992 and 1993. Marked increases in chlorophyll a levels have occurred in the Las Vegas Bay over the last ten years. Data collected by Reclamation indicate that there are greater blooms in the Las Vegas Bay and that the temperature in the Bay has increased during this time.
Figure 15-13
Turbidity - SNWS Intake, 1992-93
Figure 15-14
Dissolved Oxygen Concentrations - SNWS Intake, 1992-93

Concentration vs. Time graph showing dissolved oxygen concentrations at various depths from the surface to 54 meters, with data collected from January 1992 to December 1993.
Figure 15-15
Temperature - SNWS Intake, 1992 - 93

The diagram shows the temperature (C) over time from January 1992 to January 1994. The temperature varies significantly throughout the year, with peaks and troughs at different depths (3 m, 12 m, 24 m, 36 m, 42 m, 54 m). The temperature at the surface varies the most, while the temperature at 54 m remains relatively stable.
Figure 15-16
Chlorophyl "a" Concentrations

- SNWS
- Saddle Is.
- Fish Hat.
- L.V. Bay
- L.V. Wash
- Sand Is.
- SNWS - 24m

Las Vegas Wash
Las Vegas Bay
Trace Metals

Table 15-3 presents trace metals information collected from SNWS and MWD at Lake Havasu. As with the mineral, physical and biological data presented above, the water quality data at both locations is similar. All of the trace metals comply with the existing water quality standards (i.e., MCLs or secondary standards). However, there are questions regarding future standards for arsenic which will be addressed in Task 010A18M, Water Treatment.

The current MCL for arsenic is 50 ug/L (micrograms/liter); the proposed standard could be as low as 2 ug/L. Arsenic data received from MWD at Lake Havasu indicate arsenic levels ranging from 2 to 3 ug/L (in four samples taken in April and October of 1992 and 1993). SNWS data in two raw water samples indicate an arsenic level of 3 ug/L (samples taken in March and June 1993).

Trace Organics

Water quality data from the SNWS and BBWD indicate there are no trace organics present in treated Colorado River water except the THM compounds. Preliminary data from MWD shows concentrations of Haloacetic Acids (HAA) to be 40 to 60 percent of the total THMs in Colorado River water. Total organic carbon (TOC) analysis performed by the University of Arizona for Colorado River water show that TOC is between 1 and 3 mg/L. These results suggest that there is not a problem with either volatile organic compounds (VOCs) or synthetic organic compounds (SOCs) in the river water and that the TOC is relatively low.

The City of Las Vegas and Clark County Sanitation District have begun collecting TOC data at their Lake Mead stations 2 through 9 (reference Figure 15-6). The Clark County Sanitation District estimates that these data will be available for review by April 1994. These data should be reviewed for treatment impacts due to TOC concentration in the lake.

RECOMMENDATIONS FOR ADDITIONAL INFORMATION

Table 15-4 shows available water quality data at each alternative intake site. It is recommended that several years of data be reviewed at the specific intake sites including available data at depth to assist in intake siting and selection.

With respect to the water quality data used to evaluate treatment processes, the following is available at or in the general vicinity of most intake sites:

- Turbidity
- Alkalinity
- Coliform Bacteria
- DO
- TDS or Conductivity
- Odor
- Temperature
Table 15-3
Trace Metals Analyses
(Results in ug/l)

<table>
<thead>
<tr>
<th></th>
<th>Detection Limit</th>
<th>Proposed or Existing MCL</th>
<th>SNWS Data for Raw Lake Mead Water</th>
<th>MWD Data for Lake Havasu Near the Whitsett Intake</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Maximum</td>
<td>Average</td>
</tr>
<tr>
<td>Aluminum</td>
<td>5</td>
<td>50^a</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Arsenic</td>
<td>1</td>
<td>50</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Barium</td>
<td>5</td>
<td>- 1,000</td>
<td>220</td>
<td>190</td>
</tr>
<tr>
<td>Cadmium</td>
<td>0.5</td>
<td>5</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Chromium</td>
<td>2</td>
<td>50</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Copper</td>
<td>10</td>
<td>1,300</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Iron</td>
<td>20</td>
<td>300</td>
<td>&lt;10</td>
<td>&lt;10</td>
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<td>Lead</td>
<td>2</td>
<td>50</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Manganese</td>
<td>2</td>
<td>50^a</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Mercury</td>
<td>0.2</td>
<td>2</td>
<td>&lt;1</td>
<td>&lt;1</td>
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<tr>
<td>Selenium</td>
<td>1</td>
<td>10</td>
<td>3</td>
<td>3</td>
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<tr>
<td>Silver</td>
<td>2</td>
<td>50</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Strontium</td>
<td>20</td>
<td>-</td>
<td>1220</td>
<td>1205</td>
</tr>
<tr>
<td>Zinc</td>
<td>20</td>
<td>5,000^a</td>
<td>&lt;20</td>
<td>&lt;20</td>
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</table>

^aSecondary Drinking Water Standards
<table>
<thead>
<tr>
<th>Site</th>
<th>Turbidity</th>
<th>TOC</th>
<th>Alkalinity</th>
<th>Arsenic</th>
<th>Coliform Bacteria</th>
<th>THMFP</th>
<th>Dissolved Oxygen</th>
<th>Hardness</th>
<th>Odor</th>
<th>Algae</th>
<th>Conductivity or TDS</th>
<th>Temp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calville Bay</td>
<td>SNWS</td>
<td>SNWS (0 &amp; 24M)</td>
<td>SNWS</td>
<td>SNWS</td>
<td>SNWS (0 &amp; 24M)</td>
<td>SNWS (0 &amp; 24M)</td>
<td>SNWS (0 &amp; 24M)</td>
<td>SNWS (0 &amp; 24M)</td>
<td>SNWS (0 &amp; 24M)</td>
<td>UNLV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water Barge Cove</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Box Car Cove (Black Island)</td>
<td>SNWS</td>
<td>CCSD</td>
<td>SNWS (0 &amp; 24M)</td>
<td>SNWS</td>
<td>UNLV</td>
<td>SNWS (0 &amp; 24M)</td>
<td>SNWS (0 &amp; 24M)</td>
<td>UNLV</td>
<td>UNLV</td>
<td>UNLV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Government Wash (Las Vegas Bay)</td>
<td>SNWS</td>
<td>CCSD</td>
<td>SNWS (0 &amp; 24M)</td>
<td>SNWS</td>
<td>CCSD</td>
<td>SNWS (0 &amp; 24M)</td>
<td>SNWS (0 &amp; 24M)</td>
<td>USBR</td>
<td>USBR</td>
<td>CCSD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Saddle Island (SNWS Intake)</td>
<td>SNWS</td>
<td>CCSD</td>
<td>SNWS (0 &amp; 54M)</td>
<td>SNWS</td>
<td></td>
<td>UNLV</td>
<td>SNWS (0 &amp; 54M)</td>
<td>SNWS (0 &amp; 54M)</td>
<td>UNLV</td>
<td>SNWS</td>
<td>(0 &amp; 54M)</td>
<td></td>
</tr>
<tr>
<td>Hemenway Wall (Promontory Point)</td>
<td>SNWS</td>
<td>SNWS (0 &amp; 24M)</td>
<td>SNWS</td>
<td>SNWS</td>
<td>SNWS (0 &amp; 24M)</td>
<td>UNLV</td>
<td>SNWS (0 &amp; 24M)</td>
<td>UNLV</td>
<td>SNWS</td>
<td>(0 &amp; 24M)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hoover Dam</td>
<td>USBR</td>
<td>CCSD</td>
<td>USBR</td>
<td>USBR</td>
<td>USBR CCSD</td>
<td>UNLV</td>
<td>USBR CCSD</td>
<td>USBR</td>
<td>UNLV</td>
<td>USBR</td>
<td>CCSD</td>
<td>USBR CCSD</td>
</tr>
</tbody>
</table>

SNWS - Southern Nevada Water System
NPS - National Park Service
CCSD - City Las Vegas & Clark County Sanitation District WQS
USBR - U.S. Bureau of Reclamation
UNLV - University of Nevada, Las Vegas
There is little or no data on

- Arsenic
- TOC
- THM Formation Potential

In addition, there are several years worth of data at Saddle Island (SNWS intake), Colorado River below Hoover Dam (Reclamation) and Las Vegas Bay. Minimal data was found for Water Barge Cove.

Additional data would be useful in assessing disinfection by-product formation (TOC data), enhanced coagulation needs (low-level arsenic data). Task 010A18M addresses these issues in further detail along with recommendations for pilot- or bench-scale testing.
APPENDIX 15-1

CHRONOLOGICAL SUMMARY OF WATER QUALITY AND LIMNOLOGICAL STUDIES IN LAKE MEAD DURING 1936-1993
Chronological Summary of Water Quality and Limnological Studies in Lake Mead during 1936-1993

Prepared for:
Montgomery Watson Engineers

Compiled by:
Larry J. Paulson, Ph.D.
West Lakes

February 24, 1994


Study Period: Twelve Survey Cruises from 25 February, 1948 to 11 February, 1949

Stations Sampled: 68 Stations Lake-wide

Constituents/ Measurements: Temperature Salinity Secchi Depth


**Study Period:** April-May 1964  
**Stations Sampled:** 16 Stations in Las Vegas Bay/Boulder Basin

**Constituents/Measurements:**  
- pH  
- Dissolved Carbon Dioxide  
- Dissolved Oxygen  
- Conductance  
- Temperature  
- TDS (select stations)  
- Anions/Cations (select stations)  
- Nitrate (select stations)


**Study Period:** June 4-8, 1965  
**Stations Sampled:** 50 Stations in Las Vegas Bay/Boulder Basin

**Constituents/Measurements:**  
- Total Phosphorus  
- Soluble Phosphorus  
- Nitrate-Nitrogen  
- Ammonia-Nitrogen  
- Organic Nitrogen  
- Phytoplankton Species/Counts


**Study Period:** May 19-31, 1966  
**Stations Sampled:** 14 Stations in Las Vegas Wash  
8 Stations in Las Vegas Bay  
7 Stations along Boulder Beach
Constituents/Measurements: Total Phosphorus
Nitrate-Nitrogen
Ammonia-Nitrogen
Organic Nitrogen
Total/Fecal Coliforms
Salmonella
Biological Oxygen Demand
Phytoplankton Species/Counts
Metals
Pesticides


Study Period: April 23-May 8, 1964
May 11-24, 1965
November 1-11, 1965
April 14-20, 1966
November 1-9, 1966

Stations Sampled: 28 Stations Lake-wide
16 Stations in Las Vegas Bay/Boulder Basin

Constituents/Measurements: pH
Dissolved Carbon Dioxide
Dissolved Oxygen
Conductance
Temperature
Secchi Depth
Alkalinity
TDS (select stations)
Anions/Cations (select stations)
Nitrate (select stations)


Study Period: April 1966

Stations Sampled: Selected Reaches of the Colorado River.
One Station in Las Vegas Bay
Constituents/Measurements: Phytoplankton Species/Counts
Invertebrate Identifications/Counts

Blackman, W.C., Jr. 1968. *Pollution of Las Vegas Wash and Lake Mead and Recommendations for Necessary Studies*. Memorandum to Director, SW Region, Federal Water Pollution Control Administration and Project Director, Colorado River Basin Water Quality Control Program. February 23, 1968. 16 p., plus appendices of raw data.


Study Period: January 25-26, 1970
February 16-17, 1970
March 1-4, 1970

Stations Sampled: 7 Stations in Las Vegas Bay/ Boulder Basin
3 Stations Downstream of Hoover Dam
5 Ground Water Stations in Las Vegas Wash

Constituents/Measurements: Temperature
Conductance
Total Phosphorus
Ortho Phosphorus
Nitrate-Nitrogen
Nitrite- Nitrogen
Ammonia-Nitrogen
Total Organic Nitrogen
Total Kjeldahl Nitrogen
Algal Bioassays
Chlorophyll-a


Summarizes results of lake wide sediment survey conducted to re-evaluate the 1948-49 area, capacity and sediment volume tables for the lake.

Study Period: January 25-26, 1970  
February 16-17, 1970  
March 1-4, 1970  
August 13-14, 1970

Stations Sampled: 7 Stations in Las Vegas Bay/Boulder Basin  
3 Stations Downstream of Hoover Dam  
5 Ground Water Stations in Las Vegas Wash

Constituents/Measurements: Temperature  
Conductance  
Total Phosphorus  
Ortho Phosphorus  
Nitrate-Nitrogen  
Nitrite- Nitrogen  
Ammonia-Nitrogen  
Total Organic Nitrogen  
Total Kjeldahl Nitrogen  
Algal Bioassays  
Chlorophyll-a


Study Period: March 2-11, 1968  
May 22-27, 1968  
August 21-27, 1968  
November 15-19, 1968

Stations Sampled: 4 Stations in Las Vegas Bay/Boulder Basin  
3 Stations in Las Vegas Wash

Constituents/Measurements: pH  
Dissolved Oxygen  
Conductance  
Temperature  
Secchi Depth
Dissolved Carbon Dioxide
Alkalinity
Chlorophyll-a
Total Phosphorus
Ortho Phosphorus
Nitrate-Nitrogen
Ammonia-Nitrogen
Organic-Nitrogen
TDS (wash stations)
Anions/Cations (wash stations)
Current Velocity (wash stations)


Study Period: November 10-17, 1967

Stations Sampled: 3 Stations in Boulder Basin

Constituents/
Measurements: Current Velocity and Direction


Study Period: January 25-26, 1970
February 16-17, 1970
March 1-4, 1970
August 13-14, 1970

Stations Sampled: 9 Stations in Las Vegas Bay/Boulder Basin
3 Stations Downstream of Hoover Dam
5 Ground Water Stations in Las Vegas Wash
11 Surface Water Stations in Las Vegas Wash

Constituents/
Measurements: Temperature
Conductance
Secchi Depth
Total Phosphorus
Ortho Phosphorus
Nitrate-Nitrogen
Nitrite-Nitrogen
Ammonia-Nitrogen
Total Organic Nitrogen
Total Kjeldahl Nitrogen
Algal Bioassays
Chlorophyll-a


Summarizes previous water quality studies in Las Vegas Wash and water quality standards for the Colorado River and Las Vegas Wash.


Study Period: September 4-11, 1970
November 24-29, 1970
January 23-29, 1971
February 25-28, 1971
April 3-9, 1971
June 4-9, 1971

Stations Sampled: 8 Stations Lake-wide, 3 in Las Vegas Bay/Boulder Basin

Constituents/Measurements: pH
Dissolved Oxygen
Conductance
Temperature
Light Intensity
Alkalinity
Ortho Phosphorus
Nitrate-Nitrogen
TDS
Anions/Cations
Iron
Manganese
Zinc
Copper
Zooplankton Species/Counts
Primary Productivity (Carbon-14 Method)
Study Period:

- September 4-11, 1970
- November 24-29, 1970
- January 23-29, 1971
- February 25-28, 1971
- April 3-9, 1971
- June 4-9, 1971

Stations Sampled:

- 8 Stations Lake-wide, 3 in Las Vegas Bay/Boulder Basin

Constituents/
Measurements:

- pH
- Dissolved Oxygen
- Conductance
- Temperature
- Light Intensity
- Alkalinity
- Ortho Phosphorus
- Nitrate-Nitrogen
- TDS
- Anions/Cations
- Iron
- Manganese
- Zinc
- Copper
- Zooplankton Species/Counts
- Primary Productivity (Carbon-14 Method)
Constituents/Measurements:

- pH
- Dissolved Oxygen
- Conductance
- Temperature
- Secchi Depth
- Chlorophyll-a
- Ortho Phosphorus
- Nitrate+Nitrite-Nitrogen (select stations)
- Alkalinity (select stations)
- TDS (select stations)
- Anions/Cations (select stations)
- Silica (select stations)
- Fecal Coliforms (select stations)
- Phytoplankton Species/Counts
- Fish Distribution


Study Period: February 1974 - December 1974

Stations Sampled: 7 Stations in Las Vegas Bay/Boulder Basin
1 Station in Las Vegas Wash

Constituents/Measurements:

- pH
- Dissolved Oxygen
- Conductance
- Temperature
- Light Intensity
- Chlorophyll-a
- Biological Oxygen Demand (wash station)
- MBAS (wash station)
- Chemical Oxygen Demand (wash station)
- TSS (wash station)
- Turbidity (wash station)
- Total Phosphorus (select stations)
Dissolved Phosphorus (select stations)
Ammonia-Nitrogen (select stations)
Nitrate+Nitrite-Nitrogen (select stations)
Total Kjeldahl Nitrogen (select stations)
Alkalinity (select stations)
Fecal Coliform Bacteria (select stations)
Phytoplankton Species/Counts
Algal Bioassays
Fish Distribution


Study Period: April 1975 - February 1976

Stations Sampled: 6 Stations in Las Vegas Bay/Boulder Basin
1 Station in Las Vegas Wash

Constituents/Measurements:
- pH
- Dissolved Oxygen
- Conductance
- Temperature
- Light Intensity
- Chlorophyll-a
- Biological Oxygen Demand (wash station)
- MBAS (wash station)
- Chemical Oxygen Demand (wash station)
- TSS (wash station)
- Turbidity (wash station)
- Total Phosphorus (select stations)
- Dissolved Phosphorus (select stations)
- Ammonia-Nitrogen (select stations)
- Nitrate+Nitrite-Nitrogen (select stations)
- Total Kjeldahl Nitrogen (select stations)
- Alkalinity (select stations)
- Fecal Coliform Bacteria (select stations)
Phytoplankton Species/Counts  
Primary Productivity (Carbon-14 Method)  
Zooplankton Species/Counts


Critical review of the Lake Mead Monitoring Program with recommendations for water quality standards and pollution abatement in Las Vegas Bay.


Review of controversy regarding water quality standards for Las Vegas Wash.


Study Period: August 1976 - June 1977

Stations Sampled: 6 Stations in Las Vegas Bay/Boulder Basin  
1 Station in Las Vegas Wash

Constituents/Measurements:  
pH  
Dissolved Oxygen  
Conductance  
Temperature  
Light Intensity  
Chlorophyll-a

Summarizes UNLV Lake Mead Monitoring Program results for 1975-1976.


**Study Period:**
- February 24, 1975
- June 11, 1975
- November 20, 1975
- December 01, 1975

**Stations Sampled:**
- 15 NES Stations Lake-wide
- 22 Special Stations in Las Vegas Bay/Boulder Basin
- 4 Tributary Stations

**Constituents/Measurements:**
- pH
- Dissolved Oxygen
- Conductance
- Temperature
- Secchi Depth
- Total Phosphorus
- Dissolved Phosphorus
- Ammonia-Nitrogen
Nitrate+Nitrite-Nitrogen
Total Kjeldahl Nitrogen
Alkalinity
Phytoplankton Species/Counts
Algal Bioassays


Summarizes historical water quality data for Las Vegas Wash, Las Vegas Bay and Boulder Basin with recommended water quality standards for Las Vegas Wash.


Summarizes historical water quality data, evaluates water quality problems, and presents proposals for further studies.


Study Period: October 1977 - September 1978

Stations Sampled:
13 Stations Lake-wide
  5 Stations in Las Vegas Bay/Boulder Basin
  4 Tributary Stations

Constituents/Measurements:
P pH
Dissolved Oxygen
Conductance
Temperature
Light Intensity
Secchi Depth
Chlorophyll-a
Total Phosphorus
Ortho Phosphorus
Ammonia-Nitrogen
Nitrate+Nitrite-Nitrogen
Phytoplankton Species/Counts
Primary Productivity (Carbon-14 Method)
Zooplankton Species/Counts


Study Period: October 1979
Stations Sampled: 6 Stations Lake-wide
Constituents/Measurements: Sediment Cesium-137
Sediment CaCO$_3$
Sediment Bulk Density
Sediment Organic Carbon
Sediment Organic Nitrogen
Sediment Total Phosphorus
Sediment Extractable Phosphorus
Sediment Organic Content
Sediment Water Of Hydration
Sediment Pore Water for Ammonia, Nitrate, Phosphate


Summarizes results of sediment study conducted for the Las Vegas Valley Water Quality Program, Water Quality Standards Study.


Study Period: March 1979-December 1981

Stations Sampled:
- 8 Stations in Las Vegas Bay/Boulder Basin
- 1 Station in Virgin Basin
- 2 Stations in Bonelli Bay
- 5 Stations in Las Vegas Wash

Constituents/
Measurements:
- pH
- Dissolved Oxygen
- Conductance
- Temperature
- Light Intensity
- Color
- Secchi Depth
- Chlorophyll-a
- Biological Oxygen Demand (wash stations)
- Carbonaceous BOD (wash stations)
- Nitrogenous BOD (wash stations)
- Total Coliforms (wash and select lake stations)
- Fecal Coliforms (wash and select lake stations)
- Fecal Streptococci (wash stations)
- TSS
- Volatile Suspended Solids
- Total Phosphorus
- Dissolved Phosphorus
- Ortho Phosphorus
- Extractable Phosphorus
- Alkaline Phosphatase Activity
- Nitrogen Fixation
- Ammonia-Nitrogen
- Nitrate+Nitrite-Nitrogen
- Nitrite-Nitrogen
- Total Nitrogen
- Total Kjeldahl Nitrogen
- Alkalinity
- Anions/Cations
- Heavy Metals
- Soluble Iron
- Silica
- Phytoplankton Species/Counts
- Primary Productivity (Carbon-14 Method)
- Periphyton Species/Biomass
- Zooplankton Species/Counts
- Algal Bioassays
- Fish Distribution
Dye Tracing of Currents
Sediment Characteristics


Appendix A. University of Nevada, Las Vegas Limnological Procedures Manual

Appendix B. Other University of Nevada, Las Vegas Technical Reports

Appendix C. Algal Bioassay Reports from Ecological Research Associates and EPA


Appendix D. University of Washington Sediment Report

Appendix E. Supporting Limnological Data and Data Handling Procedures

Appendix F. Hydraulic Study Report


Study Period: January 1981 - December 1982
Stations Sampled: 17 Stations Lake-wide
7 Stations in Las Vegas Bay/Boulder Basin
4 Tributary Stations

Constituents/
Measurements: pH
Dissolved Oxygen
Conductance
Temperature
Light Intensity
Secchi Depth
Chlorophyll-a
Total Phosphorus
Ortho Phosphorus
Ammonia-Nitrogen
Nitrate+Nitrite-Nitrogen
Total Nitrogen
Phytoplankton Species/Counts
Primary Productivity (Carbon-14 Method)
Zooplankton Species/Counts
Fish Distribution


Study Period: January 1981 - December 1982

Stations Sampled: Lake Powell, Lake Mead, Lake Mohave, Lake Havasu
17 Stations Lake-wide in Lake Mead
7 Stations in Las Vegas Bay/Boulder Basin
4 Tributary Stations, and Hoover Dam outflow

Constituents/
Measurements: pH
Dissolved Oxygen
Conductance
Temperature
Light Intensity
Secchi Depth
Chlorophyll-a
Total Phosphorus
Ortho Phosphorus
Ammonia-Nitrogen
Nitrate+Nitrite-Nitrogen
Total Nitrogen
Phytoplankton Species/Counts
Primary Productivity (Carbon-14 Method)
Zooplankton Species/Counts
Fish Distribution


Stations Sampled: 5 Stations in Las Vegas Bay/Boulder Basin
Constituents/
Measurements: pH
Dissolved Oxygen
Conductance
Temperature
Light Intensity
Secchi Depth
Chlorophyll-a
Total Phosphorus
Ortho Phosphorus
Ammonia-Nitrogen
Nitrate+Nitrite-Nitrogen
Total Nitrogen


Study Period: January 1985 - November 1985

Stations Sampled: 5 Stations in Las Vegas Bay/Boulder Basin

Constituents/Measurements:
- pH
- Dissolved Oxygen
- Conductance
- Temperature
- Light Intensity
- Secchi Depth
- Chlorophyll-a
- Total Phosphorus
- Ortho Phosphorus
- Ammonia-Nitrogen
- Nitrate+Nitrite-Nitrogen
- Total Nitrogen


Study Period: April 1986 - December 1987

Stations Sampled: 15 Stations Lake-wide
- 5 Stations in Las Vegas Bay/Boulder Basin

Constituents/Measurements:
- pH
- Dissolved Oxygen
- Conductance
- Temperature
- Light Intensity
- Secchi Depth
- Chlorophyll-a
- Total Phosphorus
- Ortho Phosphorus
- Ammonia-Nitrogen
- Nitrate+Nitrite-Nitrogen
- Total Nitrogen
- TDS
- Anions/Cations
- Current Velocity
Zooplankton Species/Counts
Fish Distribution


City of Las Vegas. 1987. *Analysis of the Water-Quality Standards Proposed by the Nevada Division of Environmental Protection.* 154 p., plus appendices.


Study Period: March 1986 - December 1986
Stations Sampled: 5 Stations in Las Vegas Bay/Boulder Basin
Constituents/Measurements: pH
Dissolved Oxygen
Conductance
Temperature
Light Intensity
Secchi Depth
Chlorophyll-a
Total Phosphorus
Ortho Phosphorus
Ammonia-Nitrogen
Nitrate+Nitrite-Nitrogen
Total Nitrogen


Mead. Lake Mead Limnological Research Center, Tech. Rept. No. 19, University of Nevada, Las Vegas, 113 p.


Study Period: April 1987 - December 1987

Stations Sampled: 5 Stations in Las Vegas Bay/Boulder Basin

Constituents/Measurements:
- pH
- Dissolved Oxygen
- Conductance
- Temperature
- Light Intensity
- Secchi Depth
- Chlorophyll-a
- Total Phosphorus
- Ortho Phosphorus
Ammonia-Nitrogen
Nitrate+Nitrite-Nitrogen
Total Nitrogen


Clark County Sanitation District No. 1. 1988. *Lake Mead Water Quality Standards Study.* Data collection program run by the Lake Mead Limnological Research Center, no formal report prepared for the project. Data were used for development of water quality model by Dan Szumski and Richard French.

**Study Period:**
August 1988 - November 1989

**Stations Sampled:**
13 Stations in Las Vegas Bay/Boulder Basin

**Constituents/Measurements:**
- pH
- Dissolved Oxygen
- Conductance
- Temperature
- Light Intensity
- Secchi Depth
- Chlorophyll-a
- Total Phosphorus
- Dissolved Phosphorus
- Ortho Phosphorus
- Ammonia-Nitrogen
- Nitrate+Nitrite-Nitrogen
- Total Kjeldahl Nitrogen
- Primary Productivity (Carbon-14 Method)
- Phytoplankton Species/Counts
- Algal Bioassays
- Zooplankton Species/Counts
- Fish Distribution


Study Period: April 1988 - December 1988

Stations Sampled: 5 Stations in Las Vegas Bay/Boulder Basin

Constituents/Measurements:
- pH
- Dissolved Oxygen
- Conductance
- Temperature
- Light Intensity
- Secchi Depth
- Chlorophyll-a
- Total Phosphorus
- Ortho Phosphorus
- Ammonia-Nitrogen
- Nitrate+Nitrite-Nitrogen
- Total Nitrogen


Study Period: July 8, 1990

Stations Sampled: 27 Stations in Las Vegas Bay

Constituents/Measurements: Sediment Total Phosphorus
Sediment Total Nitrogen
Sediment Total Organic Carbon
Sediment Organic Matter
Sediment Texture


Study Period: October 1990 - December 1990

Stations Sampled: 10 Stations in Las Vegas Bay/Boulder Basin
3 Stations in Las Vegas Wash

Constituents/Measurements: pH
Dissolved Oxygen
Conductance
Temperature
Light Intensity
Secchi Depth
Chlorophyll-a
Chloride
TSS (wash stations)
TDS (wash stations)
Total Phosphorus
Ortho Phosphorus
Ammonia-Nitrogen
Nitrate+Nitrite-Nitrogen
Nitrite-Nitrogen
Total Kjeldahl Nitrogen
Zooplankton Species/Counts


Study Period: December 9 - December 30, 1990

Stations Sampled: 6 Stations in Las Vegas Bay

Constituents/
Measurements: Measurements on Sediments
Total Phosphorus
Total Nitrogen
Total Organic Carbon
Organic Matter
Texture

Measurements on Sediment Water
Temperature
pH
Dissolved Oxygen


APPENDIX 15-2

SNWA DATA
REPRESENTATIVE FORMS
## Routine Physical & Chemical Analysis

### Date Collected: 10-28-93  
Received by: 
Collected by: 

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<thead>
<tr>
<th>Characteristic</th>
<th>Sample, Sample #, Time Collected</th>
<th>Date, Time, Analyst</th>
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<td>Hydroxide</td>
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<td>Carbonate</td>
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<td>Bicarbonate</td>
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<td>Secci Disk Reading</td>
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<td>mg/L</td>
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### Remarks:

Cloudy, light barrier from west, 62° NO color, fine H2O
# Routine Physical & Chemical Analysis

**Certification:** SOUTHERN NEVADA WATER SYSTEM  
**Lab I.D. #5** ROUTINE PHYSICAL & CHEMICAL ANALYSIS  
**LAKE**

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<tr>
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<td>/100mL</td>
<td>/100mL</td>
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<td>/100mL</td>
<td>/100mL</td>
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<td>m</td>
<td>4.5 m</td>
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**Remarks:** Partly Cloudy, Light breeze from west, 64°. No odor.

**Lab Mgr.:**  
**Treat. Mgr.:**  
**Director:**  
**Lab Supt./Supr.:**  
**Chem. Supr.:**  
**Microbio. Supr.:**
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<td>mg/L</td>
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Remarks: Mostly sunny. Light breeze. From WNW. 65° - Ng. 100% tree H2O.

Lab Mgr.: DAD Date: 11-10-93  Lab Supt. Supr.: DAD Date: 11-9-93
Tre:Mgr.: DAD Date: 11-10-93  Chem. Supr.: SK Date: 11-9-93
Director: DAD Date: 11-10-93  Microbio. Supr.: DAD Date: 11-10-93
**SOUTHERN NEVADA WATER SYSTEM**

**Routine Physical & Chemical Analysis**

**Lake**

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**Remarks:** Partly Sunken, Calm, Clear - No odor, free water

**Certification:**

Lab I.D. #5

**Date Collected:** 10-28-93

**Date Received:** 10-28-93

**Date Analyzed:** 11-2-93

**Date Reported:** 11-6-93

**Characteristics:**

- **Alkalinity:**
  - Hydroxide
  - Carbonate
  - Bicarbonate

- **Ammonia, Nitrogen:** <0.05 mg/L

- **Ammonia, Unionized:**

- **BOD:**

- **Calcium:**

- **Carbon Dioxide:**

- **Chloride:**

- **Coliform, Total:** /100mL

- **Coliform, Fecal:** /100mL

- **Color:** 8 units

- **Conductivity:** 1120 us/cm

- **Fecal Streptococcal:** /100mL

- **Fluoride:**

- **Hardness:**

- **Iron:**

- **Magnesium:**

- **Manganese:**

- **Nitrate:** 0.21 mg/L

- **Odor:** N/A

- **Oxygen Dissolved:** 7.68 mg/L

- **pH:** 8.32

- **Phosphate:** <0.01 mg/L

- **Residue (filtrable):**

- **Sulfate:**

- **Suspension Solids:**

- **Temperature:** 21.1° C

- **Turbidity:** 0.3 NTU

- **Particle Count:** 699 /mL

- **Plankton Biomass:**

- **Secci Disk Reading:** 11.0 m

**Date & Signature:**

Lab Mgr.: [Signature] Date: 11-1-93

Lab Supt. Supr.: [Signature] Date: 11-2-93

Treat. Mgr.: [Signature] Date: 11-1-93

Chem. Supr.: [Signature] Date: 11-2-93

Director: [Signature] Date: 11-1-93

Microbio. Supr.: [Signature] Date: 11-2-93
**Routine Physical & Chemical Analysis**

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</table>

**Remarks:** ParthydroxylicCalc.69°-No odor Free +H2O

**Certification:** SOUTHERN NEVADA WATER SYSTEM

**Lab I.D. #5** ROUTINE PHYSICAL & CHEMICAL ANALYSIS

**Date Collected:** 10-28-93  **Date Received:** 10-28-93

**Date Analyzed:** 11-2-93  **Date Reported:** 11-2-93

**Sample, Sample #, Time Collected:**

- **Date:** 10-28-93
- **Time:** 12:15
- **Received by:**
  - **Lab Mgr.:** Date: 11-10-93
  - **Treat. Mgr.:** Date: 11-10
  - **Director:** Date: 11-10-93
  - **Lab Supc.Supr.:** Date: 11-9-93
  - **Chem. Supr.:** Date: 11-3-93
  - **Microbio. Supr.:** Date: 11-10-93
## Monthly Lake Chlorophyll

### Location

<table>
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<tr>
<th>Location</th>
<th>Field Analyst</th>
<th>Time Collected</th>
<th>Temp (°C)</th>
<th>Transparency (m)</th>
<th>pH (Units)</th>
<th>Dissolved Oxygen (mg/L)</th>
<th>Conductivity (us/cm)</th>
<th>Sample Volume (mL)</th>
<th>Chlorophyll ug/L</th>
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### Comments:

*Calculated using monochromator equation*
# SOUTHERN NEVADA WATER SYSTEM

## LAKE PROFILE

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<th>Source</th>
<th>Date Collected</th>
<th>Time Collected</th>
<th>Location</th>
<th>SNWS Julian</th>
<th>Dissolved Oxygen (mg/L)</th>
<th>Temp. (°C)</th>
<th>pH (value)</th>
<th>Ortho-phosphate (mg/L)</th>
<th>Nitrato (mg/L)</th>
<th>Ammonia (mg/L)</th>
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### REMARKS:
- Turbidimeter wasn't working right took back to Lab.
- Lab Supt. Supv.: [Signature]
- Chemistry Supv.: [Signature]
- Microbio. Supv.: [Signature]
- Lab Manager: [Signature]
- Treat. Supv.: [Signature]
- Treat. Manager: [Signature]

Date: 1-27-94

**Secchi Disk Reading (m)**

- 1: 14.5

**Lake Mead Elevation (m)**

- 362.7

**SNWS Intake (Elev. 318 m) (m)**

- 44.7

**Instantaneous CI2 surface TON**

- Date: 1-27-94

**4-Hour CI2 Surface TON**

- Date: 1-27-94
**PHYTOPLANKTON RECORD**

**Collection Date:** 9-7-95

<table>
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<th>Species</th>
<th>Size (μm)</th>
<th>Counts</th>
<th>B. Strip 1</th>
<th>C. Strip 2</th>
<th>B + C</th>
<th>D. (B + C)</th>
<th>E. Cells/mL (DxA)</th>
<th>F. Biomass mg/m³ (ExF x 10⁻³)</th>
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**Sample Depth (m):** Raw 1.0

**Location:** Raw-01's Tap

**Source:** Lake Mead

**Date Collected:** 9-7-93

**Date Analyzed:** 11/12/93

**pH:**

**Dissolved Oxygen:**

**Nitrite (NO₂⁻ N):**

**Nitrate (NO₃⁻ N):**

**Ammonia (NH₃⁻ N):**

**Total Phosphate (as P):**

**Volume Settled (Vs):** 0.50 ml

**Conversion Factor (a):** 1.11

**Magnification:**

**Strip width (mm):** 0.4, 0.2, <0.1

**Strip length (mm):** 25.5, 10

**Number of Strips:** 1 (2) 3 4 Entire

**Total Cells/mL (T):** 978

**Total Biomass mg/m³ (T):** 5119

**% Blue-Green Algae Biomass:** 3.22

**Time Req'd for Anal.:** 29 h

**Remarks:**

**Treat. Sup.:**

**Treat Mgr.:**

**Director:**
**SOUTHERN NEVADA WATER SYSTEM**

**PHYTOPLANKTON RECORD**

Collection Date: **9-7-95**

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<thead>
<tr>
<th>Species (μm)</th>
<th>Size</th>
<th>Counts</th>
<th>D. Total (B + C)</th>
<th>E. Cells/mL (ExFx10^-3)</th>
<th>G. Biomass mg/m³</th>
<th>Sample Depth(m)</th>
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**Removals:**
- Lab Sup.
- Lab Mgr.
- Treat. Sup.
- Treat Mgr.
- Director
<table>
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<th>Species</th>
<th>Size (μm)</th>
<th>Counts B. Strip 1</th>
<th>Counts C. Strip 2</th>
<th>Total (B+C)</th>
<th>E. Total Cells/mL (DxA)</th>
<th>G. Biomass mg/m3 (ExFx10^-3)</th>
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**Sample Depth (m):**

- Raw H2O

**Location:**

- Raw H2O Op's Temp

**Source:**

- Lake Mead

**Date Collected:**

- 9-7-93

**Date Analyzed:**

- 11-17-93

**pH:**

- 7.2

**Dissolved Oxygen:**

- 5.5

**Nitrite (NO2 - N):**

- 0.03

**Nitrate (NO3 - N):**

- 0.03

**Ammonia (NH3 - N):**

- 0.03

**Total Phosphate (as P):**

- 0.03

**Volume Settled (Vs):**

- 50 mL

**Conversion Factor (a):**

- 0.52

**Magnification:**

- 100x 200x 400x 1000x

**Strip width (mm):**

- 0.4 0.2 0.1 0.04

**Strip length (mm):**

- (25.5) 10

**Number of Strips:**

- 1 2 3 4 Entire

**Total Cells/mL (IE):**

- 772

**Total Biomass mg/m3 (ΣG):**

- 51.19

**% Blue-Green Algae Biomass:**

- 3.27

**Time Req'd for Anal.:**

- 2.9 h

**Remarks:**

- Lab Sup.
- Lab Mgr.
- Treat. Sup.
- Treat Mgr.
- Director
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<th>Chloroform CHCl₃ (ug/L)</th>
<th>Bromo-Dichloro-Methane CHCl₂Br (ug/L)</th>
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Remarks:

\[ x : 56.8 \]

\[ s : 6.8 \]
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<th>Sample No.</th>
<th>Time Date Taken</th>
<th>Rec’d Date</th>
<th>Time Date Setup</th>
<th>Time Date Count’d</th>
<th>Count’d By</th>
<th>Refrig.</th>
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<th>mL Used</th>
<th>Membrane Technique</th>
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Remarks:

\[ \log_{10} \frac{10}{10^{0.90}} = 0.1 \leq 0.15 \text{ mL} \text{ Data Acceptable} \]

Medium Batch: M. Enterot #33-3

Rinses #32-24

Samp. Supr.