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## Las Vegas Wash and Lake Mead proposed water quality standards: Revisions and rationale

State of Nevada: Division of Environmental Protection

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# STATE OF NEVADA

DIVISION OF ENVIRONMENTAL PROTECTION

LAS VEGAS WASH AND LAKE MEAD

PROPOSED WATER QUALITY STANDARDS

REVISIONS AND RATIONALE



201 S. Fall Street  
Carson City, Nevada 89710

LAS VEGAS WASH AND LAKE MEAD PROPOSED WATER QUALITY STANDARDS

REVISIONS AND RATIONALE

MAY 1987

DIVISION OF ENVIRONMENTAL PROTECTION  
201 S. FALL STREET  
CARSON CITY, NEVADA 89710

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Rationale of review and for proposed changes to the Nevada Pollution Control Regulations (NAC 445.1354, 445.1355, 445.1356, 445.1367, 445.1352, 445.1353, 445.1350, 445.1351) before the State Environmental Commission on June 23 and 24, 1987.

#### REACHES

The reaches under review are:

- 1) Las Vegas Wash from Pabco Road to the city and county sewage treatment plants.
- 2) Las Vegas Wash from Pabco Road to Lake Mead.
- 3) Lake Mead from western boundary of Las Vegas Marina Campground to confluence of Las Vegas Wash.
- 4) Lake Mead excluding area covered in 3 above.

#### BENEFICIAL USES

The specific wording of each beneficial use has been changed to be consistent with wording adopted by the SEC at earlier hearings. The wording of the beneficial use description for all the proposed tables has been modified as follows:

- a. Agricultural use has been separated into two uses, "irrigation" and "watering of livestock."
- b. Aquatic life has been changed to "propagation of aquatic life", and includes coldwater species for group 1 streams and warmwater species for groups 2 and 3.
- c. Bathing and water contact sports was changed to read "recreation involving contact with the water."

- d. Noncontact sports and esthetics is now "recreation not involving contact with the water."
- e. Drinking water supply is now referred to as "municipal or domestic supply, or both".
- f. Industrial supply remains unchanged.
- g. Wildlife propagation has been changed to "propagation of wildlife."

Although there is not any change in the actual beneficial uses which were adopted by the SEC in 1982 after extensive testimony and discussion, it may appear to some that by changing "aquatic life" to "propagation of aquatic life" that a change was made. The definition of "aquatic life" in NAC 445.133 states, "The water must be suitable as a habitat for fish and other aquatic life existing in a body of water. This does not preclude the reestablishment of other fish or aquatic life." Propagation of aquatic life means a multiplying or reproduction of aquatic life.

The specific beneficial uses that apply to the previously identified reaches are as follows:

Las Vegas Wash (Both Reaches)

- 1. Propagation of aquatic life excluding fish;
- 2. Propagation of wildlife;
- 3) Irrigation;
- 4) Watering of livestock;
- 5) Freshwater marsh maintenance; and
- 6) Recreation not involving contact with the water.

Lake Mead from western boundary of Las Vegas Marina Campground to confluence of Las Vegas Wash

- 1) Industrial supply;
- 2) Propagation of aquatic life;
- 3) Propagation of wildlife;
- 4) Irrigation;
- 5) Watering of livestock; and
- 6) Recreation not involving contact with the water.

Lake Mead not covered by above

- 1) Municipal or domestic supply, or both;
- 2) Industrial supply;
- 3) Propagation of aquatic life;
- 4) Propagation of wildlife;
- 5) Irrigation;
- 6) Watering of livestock;
- 7) Recreation involving contact with the water; and
- 8) Recreation not involving contact with the water.

Method of Determining The Requirements to Maintain Existing Higher Quality (RMHQs)

To compute the annual average and single value requirements to maintain existing higher quality (RMHQ) for the evaluated streams, analyses were conducted both for the period of record and the three year period from 1984 through 1986. All available Nevada Division of Environmental Protection (DEP), U.S. Environmental Protection Agency (EPA), U.S. Bureau of Reclamation (BOR), U.S. Geological Survey (USGS), University of Nevada at Las Vegas (UNLV), and Clark County Sanitation District (CCSD) data were utilized.

The procedures used to establish the RMHQs are as follows:

1. The percent violations of the existing standards for the period of record are determined. If greater than 5 percent, the existing standard is compared with the BUS and if more stringent, the existing standard is proposed for the RMHQ.

However, this procedure does not apply to those parameters for which no RMHQ's are proposed. Further explanation for not proposing RMHQ's in some circumstances is given for individual parameters later in the rationale.

2. In situations where the percent violations of existing standards are less than five percent, more complex procedures are followed.
  - a. First the data for parameters to be considered are averaged and the range of values are determined for both period of record and the preceding three year period.



- b. 95th percentiles are then determined for the period of record and most recent three year period for each parameter. The 95th percentile is defined as the 95th ranked value of the sample population distributed into one hundred evenly divided increments. In performing the analysis on the data, the 95th percentile values were determined and used to help determine RMHQ's.

No annual average 95th percentiles are calculated for temperature, heavy metals and pesticides since neither the existing standards nor the BUS address annual averages for these parameters. For fecal coliform, annual geometric means are calculated. The 95th percentile for the geometric mean is then determined.

- c. A comparison is made among the average and single value existing standards and the corresponding period of record high (or low) ranges and 95th percentiles. The most stringent value resulting from this comparison is then proposed as the RMHQ, if it is more stringent than the BUS. If none of the values compared proves to be more stringent than the proposed BUS, then no RMHQ is proposed.
- d. Specific procedures were followed in the chlorophyll a and un-ionized ammonia rationale as described in a later section of the rationale.

#### Heavy Metals and Organics

The control of heavy metals and organics is covered by NAC 445.119 (narrative standards applicable to all waters). Future revisions of the standards should include numerical standards for specific parameters.

#### Las Vegas Wash

All data and standards for Las Vegas Wash were reviewed and no changes or revisions to the existing standards are proposed. Refer to the water quality analysis summary tables for Pabco Road and North Shore Road for a review of the data and existing standards.

#### Lake Mead

All data and standards for Lake Mead were reviewed and revisions or additions of the following parameters are proposed; pH, total phosphorus, chlorophyll a and un-ionized ammonia.

WATER QUALITY ANALYSIS SUMMARY \*

Control Point: Pabco Road

REACH: Las Vegas Wash from Pabco Road to City/County Sewage Treatment Plants

PARAMETER	# YRS	# SAMPLES	AVERAGE FOR PERIOD OF RECORD	95th PERCENTILE	RANGE FOR PERIOD OF RECORD	EXISTING RMHQ	EXISTING BUS
Temperature °C	-/-	189/91	S.V. SUM:22.6/25.0	29.1/30.2	9.5-31.4/ 18.0/31.4	Single Value T = 0°C	----
Max. Increase above receiving water	-/-	163/70	S.V. WIN:14.1/16.7	21.0/22.2	2.0-27.0/ 10.5-27.0		
pH - Standard Units	15/3	261/137	Ann.Avg: 7.4/7.5	7.4-7.6/7.4-7.5	7.2-7.65/ 7.36-7.55	S.V. in 90% of samples 6.5-7.8	S.V. in 90% of samples 6.5-9.0
Total Phosphates (P) - mg/l	15/3	261/137	S.Value:7.47/7.47	6.83-8.0/ 6.64-8.13	6.2-8.56/ 6.18/8.56	----	----
	14/3	264/132	Ann.Avg: 3.6/1.4	7.2/2.4	0.54-7.57/ .74-2.71		
Ortho Phosphates (P) - mg/l	14/3	264/132	S.Value:2.75/1.62	6.9/1.34	0.0-98.0/.13-98.0	----	----
	3/3	106/106	Ann.Avg:.76/.76	.82/.82	.72-.83/.72-.83		
Nitrogen Species: Total Nitrogen (N) - mg/l	3/3	106/106	S.Value:.77/.77	1.06/1.06	.39-1.33/ .39/1.33	----	----
	11/2	110/35	Ann.Avg:16.0/17.0	19.4/17.1	10.8-20.2/ 16.9-17.2		
Total Nitrate (N) - mg/l	11/2	110/35	S.Value:16.4/17.1	20.5/19.0	5.4-27.1/ 13.3-20.9	----	S.V. in 90% of samples <100
	9/-	121/-	Ann.Avg:.29/-	.62/-	.01-.62/-		
Total Nitrite (N) - mg/l	9/1	121/1	S.Value:.23/.03	.89/.03	0-2.70/.03-.03	----	S.V. in 90% of samples <10
	13/3	181/53	Ann.Avg:.29/.20	.72/.30	.04-.92/.11-.33		
Total Kjeldahl Nitrogen (N)- mg/l	13/3	181/53	S.Value:.23/.18	.62/.51	0-4.20/0-.71	----	S.V. in 90% of samples <10
	13/3	214/132	Ann.Avg:13.3/14.1	19.0/15.7	3.6-19.7/ 11.5-15.9		
Ammonia (Un-ionized)- mg/l	13/3	214/132	S.Value:14.4/14.4	19.0/17.9	0-26.0/0.4-20.2	----	----
	11/3	180/117	Ann.Avg:.14/.26	.32/.34	.04-.36/.15-.36		
Total Inorganic Nitrogen (TIN) - mg/l	11/3	180/117	S.Value:.24/.29	.53/.61	0-3.18/.003-3.18	S.V. in 90% of samples <20	----
	13/3	272/149	Ann.Avg: 12.0/13.6	16.3/15.1	5.4-16.3/ 10.9-15.2		
	13/3	272/149	S.Value: 13.0/13.5	18.1/17.4	0.03-21.02/ 1.4-19.2		

\* Period of record data / 1984 - 1986 data.

WATER QUALITY ANALYSIS SUMMARY \*

Control Point: Pabco Road

REACH: Las Vegas Wash from Pabco Road to City/County Sewage Treatment Plants

PARAMETER	# YRS <sup>e</sup>	# SAMPLES	AVERAGE FOR PERIOD OF RECORD	95th PERCENTILE	RANGE FOR PERIOD OF RECORD	EXISTING RMHQ	EXISTING BUS
Dissolved Oxygen - mg/l	10/3	197/129	Ann.Avg:4.0/6.3	.25/5.65	0.25-6.93/	--	Footnote b in NAC 445.1355
	10/3	197/129	S.Value: 5.0/6.2	.30/2.55	5.65-6.93 0.10-10.7/ 2.1-10.7		
BOD <sub>5</sub>	4/3	121/103	Ann.Avg:8.4/8.47	9.40/9.43	7.69-9.67/	--	--
	4/3	121/103	S.Value:8.6/8.67	14.0/14.0	7.69-9.67 3.0-18.0/ 3.00-17.0		
Suspended Solids mg/l	5/3	125/105	Ann.Avg:63.4/102.2	141.0/149.9	3.75-163.21/	--	--
	5/3	125/105	S.Value:93.5/110.1	314.5/336.0	69-163.21 1.0-433.0/ 12.0-433.0		
Turbidity - NTU	1/1	5/5	Ann.Avg:110.7/	110.7/110.7	110.7-110.7/	--	--
	1/1	5/5	S.Value:174.0/	432.5/432.5	110.7-110.7 32.0-500.0/ 32.0-500		
Total Dissolved Solids - mg/l xx	11/3	179/117	Ann.Avg:1920/1717	2538/1887	1546-2554/	S.V. in 90% of samples <2300	S.V. in 90% of samples <3000
	11/3	179/117	S.Value:1810/1676	2503/2017	1546-1922 1241-3330/ 1241-2870		
Chlorides - mg/l	17/3	149/80	Ann.Avg:348/282	435.8/305.9	247-502/	--	--
	17/3	149/80	S.Value:325/282	465.5/357.0	247-309 24.6-840/ 24.6-450		
Sulfate - mg/l	16/2	80/12	Ann.Avg:754/871	926/906	615-973/828-914	--	--
	16/2	80/12	S.Value:782/878	1050/1220	530-1400/580-1400		
Sodium - SAR	13/-	66/-	Ann.Avg:4.70/-	5.3/-	4.0-5.4/-	--	--
Sodium - Percent	13/-	66/-	S.Value: 4.75/-	5.9/-	3.4-7.6/-	--	--
Total Alkalinity mg/l as CaCO <sub>3</sub>	15/3	185/102	Ann.Avg:211/158	137/137	137-243/137-189	--	--
	15/3	185/102	S.Value:190/160	120.6/115.7	13.7-1598/ 13.7-1598		
Fecal Coliform No./100 ml	-/-	-/-	A.G.M: -/-	-/-	-/-	--	Footnote C in NAC 445.1355
	-/-	-/-	S.Value: -/-	-/-	-/-		

\* Period of record data / 1984 - 1986 data.

xx Also known as filterable residue.

WATER QUALITY ANALYSIS SUMMARY \*

Control Point: North Shore Road

REACH: Las Vegas Wash from Confluence of Las Vegas Wash with Lake Mead to Pabco Road

PARAMETER	# YRS	# SAMPLES	AVERAGE FOR PERIOD OF RECORD	95th PERCENTILE	RANGE FOR PERIOD OF RECORD	EXISTING RMHQ	EXISTING BUS
Temperature °C	-/-	324/870	S.V. SUM:22.0/26.3	29.4/33.2	9.5-36.6/	Single Value T = 0°C	----
Max. Increase above receiving water	-/-	253/65 (w)	S.V. WIN:13.2/17.8	21.0/25.8	17.5/36.6 3.0-27.2/ 11.0-27.2		
pH - Standard Units	18/3	375/131	Ann.Avg:7.84/7.67	7.14-8.10/	7.14-8.10/	S.V. in 90% of samples 7.2-8.7	S.V. in 90% of samples 7.9-9.0
	18/3	375/131	S.Value:7.83/7.69	7.54-7.74 7.18-8.20/ 7.06-8.10	7.54-7.74 0-8.70/ 6.22/8.44		
Total Phosphates (P) - mg/l	14/3	435/157	Ann.Avg:3.06/1.22	5.22/1.53	.76-6.04/	----	----
	14/3	435/157	S.Value:2.53/1.23	5.10/2.62	0.09-1.60 0.0-69.0/ 0.0-13.94		
Ortho Phosphates (P) - mg/l	3/3	134/134	Ann.Avg:1.03/1.03	1.31/1.31	.70-1.36/.70-1.36	----	----
	3/3	134/134	S.Value:1.01/1.01	2.57/2.57	.33-6.15/ 0.33-6.15		
Nitrogen Species:							
Total Nitrogen (N) - mg/l	13/2	268/32	Ann.Avg:11.02/16.08	15.95/16.69	7.36-16.8/	----	----
	13/2	268/32	S.Value:11.36/15.79	17.02/18.18	15.32-16.84 4.07-27.0/ 9.22-20.78		
Total Nitrate (N) - mg/l	9/-	233/-	Ann.Avg:1.12/-	1.90/-	.51-1.91/-	----	S.V. in 90% of samples <100
	9/-	233/-	S.Value:0.97/-	2.47/-	.09-2.70/-		
Total Nitrite (N) - mg/l	13/3	263/49	Ann.Avg:0.68/0.74	1.26/1.03	0.08-1.30/	----	S.V. in 90% of samples <10
	13/3	263/49	S.Value:0.75/0.91	2.10/1.98	.46-1.09 0.01-3.50/ 0.10-2.26		
Total Kjeldahl Nitrogen (N)- mg/l	14/3	380/156	Ann.Avg:6.29/11.25	12.50/12.83	0.79-12.92/	----	----
	14/3	380/156	S.Value:8.09/11.28	14.50/15.11	8.51-12.92 0.0-22.2/1.2-22.2		
Ammonia (Un-ionized)- mg/l	14/3	231/128	Ann.Avg:0.16/0.36	0.44/0.45	0.01-1.45/	----	----
	14/3	231/128	S.Value:0.29/0.39	0.73/0.82	0.19-0.45 0.0-1.88/0.01-1.88		
Total Inorganic Nitrogen (TIN) - mg/l	13/3	419/150	Ann.Avg:6.60/10.95	12.29/12.92	2.23-13.11/	S.V. in 90% of samples <17	----
	13/3	419/150	S.Value:7.87/10.91	13.98/14.92	7.88-13.11 0.71-20.13/ 2.92-16.69		

\* Period of record data / 1984 - 1986 data.

WATER QUALITY ANALYSIS SUMMARY \*

Control Point: North Shore Road

REACH: Las Vegas Wash from Confluence of Las Vegas Wash with Lake Mead to Pabco Road

PARAMETER	# YRS	# SAMPLES	AVERAGE FOR PERIOD OF RECORD	95th PERCENTILE	RANGE FOR PERIOD OF RECORD	EXISTING RMHQ	EXISTING BUS
Dissolved Oxygen - mg/l	17/3	357/152	Ann.Avg:8.87/7.51	7.27/7.27	7.27-11.6/7.27-7.65	--	Footnote b in NAC 445.1367
	17/3	357/152	S.Value:8.30/7.53	6.11/5.74	2.60-14.0/2.60-10.60	--	
BOD <sub>5</sub>	5/3	172/127	Ann.Avg:18.71/18.95	23.88/23.71	13.1-24.5/13.1-24.5	--	--
	5/3	172/127	S.Value:18.95/19.54	35.00/36.65	2.0-42.0/2.0-42.0	--	--
Suspended Solids mg/l	9/3	295/132	Ann.Avg:501.30/370.4	1032.7/563.8	155-1197/155-601	--	--
	9/3	295/132	S.Value:495.6/357.7	1414.5/1237.0	4-15500/4-4542	--	--
Turbidity - NTU	7/-	143/-	Ann.Avg:112.2/-	187.2/-	30-2003/-	--	--
	7/-	143/-	S.Value:119.7/-	318.5/-	9.0-1900/-	--	--
Total Dissolved Solids - mg/l xx	16/3	340/154	Ann.Avg:2847/2008	4291/2150	1896-4348/1896-2187	S.V. in 90% of samples <2600	S.V. in 90% of samples <3000
	16/3	340/154	S.Value:2446.4/2003.7	4230/2566	0-7897/723-7897		
Chlorides - mg/l			Ann.Avg:585.2/315.5	1057/334	291-1059/291-336	--	--
	18/3	185/103	S.Value:497.0/319.3	1058/372	29-1180/29-410	--	--
	18/3	185/103				--	--
Sulfate mg/l	17/2	90/8	Ann.Avg:1177/871	1512/944	780-1521/780-963	--	--
	17/2	90/8	S.Value:1253/871	1625/1052	580-2000/580-1100	--	--
Sodium - SAR	14/-	76/-	Ann.Avg:5.13/-	6.64/-	4.0-6.7/-	--	--
Sodium - Percent	14/-	76/-	S.Value:5.40/-	6.82/-	3.2-7.5/-	--	--
Total Alkalinity mg/l as CaCO <sub>3</sub>	16/3	246/121	Ann.Avg:197/173	141/141	141-218/141-189	--	--
	16/3	246/121	S.Value:189/171	117/114	13-1409/13-1409	--	--
Fecal Coliform No./100 ml	2/-	23/-	A.G.M: 69/-	71/-	65-72/-	--	Footnote c in NAC 445.1367
	2/-	23/-	S.Value:154/-	462/-	10-1400/-	--	

\* Period of record data / 1984 - 1986 data.

xx Also known as filterable residue.

## pH

Beneficial uses related to pH include wildlife propagation, aquatic life and water contact recreation. Wildlife propagation is the controlling beneficial use for the low pH beneficial use standard (BUS) of 7.0, while the high pH BUS's of 9.0 relate to aquatic life beneficial uses.

No RMHQ's are being recommended for the lower range since there is no evidence that standards more stringent than the recommended single value BUS ranges offer better protection of the beneficial uses.

However, as pH affects the speciation of ammonia, an upper value RMHQ based on the 95th percentile is recommended for the lake stations and are as follows:

<u>Station</u>	<u>pH</u>
Station 2	8.9
Lake-wide	8.8

## Total Phosphorus

When the total phosphorus standard was adopted in 1982, an in lake standard was not adopted. Instead a standard requiring an effluent limit of 1 mg/l for all point sources and application of Best Management Practices for non-point sources was adopted. This approach does not address the issue of loads and may be overly restrictive for small discharges which discharge to other areas of the Colorado River System.

The proposal is to eliminate the phosphorus standard including footnote c for both tables covering Lake Mead and replace with a chlorophyll a standard as discussed below and in Appendix C.

## Chlorophyll a

Beneficial uses related to the concentration of chlorophyll a include municipal or domestic supply, propagation of aquatic life, propagation of wildlife, watering of livestock, recreation involving contact with the water and recreation not involving contact with the water. The following water quality standard for chlorophyll a is recommended for the waters of Lake Mead:

### Station 3 (Las Vegas Bay)

- No more than one monthly mean shall exceed 45 ug/l in any calendar year.
- Mean summer (July-September) chlorophyll a shall not exceed 40 ug/l. The 4 year mean of summer means shall not exceed 30 ug/l.
- Mean is defined here as the average of at least two samples per month and the daily value to be used will consist of the average of at least three sights at the cross section of Station 3 which shall be representative of the top 5 meters of the cross section.
- Station 3 is that location in the center of the channel where the depth is 16 to 18 meters.

### Lake-wide

- Mean growing season (April-September) chlorophyll a shall not exceed 5 ug/l in the open waters of Boulder Basin, Virgin Basin, Gregg Basin, or Pierce Basin. No more than 10% of the samples (single value) shall exceed 10 ug/l.

See Appendix D for chlorophyll a rationale.

### Un-ionized Ammonia

Beneficial uses related to un-ionized ammonia include propagation of aquatic life. The following water quality standard for un-ionized ammonia is recommended for Lake Mead:

- The 4-day average concentration of un-ionized ammonia shall not exceed, more often than once every three years, 0.04 mg/l. The daily value to be used will consist of the average of at least three sites at the cross section of Station 2 which shall be representative of the top 2.5 meters of the cross section and take into account diurnal fluctuations. This is applicable to all of Lake Mead except between Station 2 and the confluence of Las Vegas Wash.

- The single value of un-ionized ammonia shall not exceed, more often than once every three years, 0.45 mg/l.
- When the temperature is greater than 20°C the standard will be adjusted according to accepted U.S. Environmental Protection Agency methods.
- Station 2 is that location in the center of the channel where the depth is 10 meters.

See Appendix E for un-ionized ammonia rationale.



APPENDIX A

INTRODUCTION TO LIMNOLOGY AND DEFINITION OF COMMONLY USED TERMS

## INTRODUCTION TO LIMNOLOGY AND DEFINITION

### OF COMMONLY USED TERMS

Limnology can be defined as the study of the physical, chemical, and biological relationships within a lake. The lakes and reservoirs of the United States are very diverse and occur in many shapes and sizes and in a variety of landscapes. The chemical composition of their waters range from very soft, comparable to rainwater (Lake Tahoe), to dense brines which are many times more concentrated than seawater (Great Salt Lake). Hydrology is quite variable: in some lakes the volume of water is replaced rapidly, every few days or so, but water replacement in some large, deep lakes takes centuries. In terms of biological condition, lakes range from nearly sterile environments to systems which produce massive quantities of biomass (plant and animal life).

Limnologists classify lakes according to their biological productivity as measured by physical, chemical, and biological parameters. The lakes with the lowest concentrations of plant nutrients, and hence with the lowest levels of biological productivity are called oligotrophic. In contrast, eutrophic lakes have high levels of plant nutrients, and as a result have high levels of biological productivity. Lakes with characteristics between oligotrophic and eutrophic are called mesotrophic. Over time oligotrophic lakes naturally become eutrophic (hundreds of thousands of years). The term eutrophication is used to describe this change in trophic state. It has also been found that lakes can undergo very rapid eutrophication in response to man-caused increases in nutrients and sediments. This rapid, man-caused change is often called cultural eutrophication.

The trophic state of a lake is determined by a large number of factors including latitude, altitude, climate, watershed characteristics, soil types, human activities, and lake morphometry. Three major factors seem to be most important; climate, nutrient supply, and lake depth. Lakes in cold climates tend to be less productive due to colder temperatures and a shorter growing season; other things being equal warmer climates promote more eutrophic conditions. Mean depth is an extremely important physical variable in determining trophic state. In general, the most oligotrophic lakes are also the deepest - Lake Superior and Lake Tahoe, for instance, and the very eutrophic lakes tend to

be quite shallow. While depth plays some role in holding down summer temperatures in the deepest lakes and thus reducing the rate of biological production, its greatest effect seems to be in reducing nutrient concentrations. Whether a given nutrient comes from surface runoff, point source pollution, or diffusion from bottom sediments, the greater the mean depth of a lake, the greater the nutrient dilution.

Many quantitative studies have confirmed that the amount of plant biomass in a lake during the summer peak is determined by the quantity of nutrients available. It has also been found that for most lakes phosphorus is the limiting nutrient. Experiments with pristine Canadian lakes have shown that an oligotrophic lake can be almost immediately changed into a eutrophic lake by adding inorganic phosphorus and nitrogen and that it rapidly reverts to the oligotrophic state if the fertilizer supply is cut off. This confirms other studies that a continuous supply of phosphorus and nitrogen is necessary to maintain the concentrations of those elements in the water column. Sediments release some nutrients, but in the long-term more materials move to the sediments than come out; the sediments thus serve as net nutrient traps rather than sources. An exception would be where nutrient input has significantly decreased. In this case there may be a net movement of nutrients back to the lake water, particularly shallow lakes or in lakes that had received heavy nutrient loading from sewage effluents for a long period of years.

Many lakes experience thermal stratification. In its simplest form, it consists of a layer of warm, relatively light water at the surface and a cold and dense layer on the bottom, separated from each other by a transition layer with a strong temperature gradient. Limnologists call the upper layer the epilimnion, the middle layer the metalimnion, and the bottom layer the hypolimnion. The density gradient in the metalimnion prevents the waters of the epilimnion from circulating any deeper, thus sealing off the hypolimnion from the lake surface.

In temperate regions many deep lakes are monomictic; these lakes do not freeze, have one long mixing period all through the winter, and thermally stratify during the summer and fall. In a typical cycle the lake is unstratified in the early spring, water temperatures are uniform from surface to bottom, and wind energy sufficient to completely mix the lake. Dissolved salts and gases are evenly distributed throughout the water column. As the season progresses, solar radiation causes the surface water to warm more rapidly than the

underlying water, and the resulting temperature gradient produces a density gradient that resists vertical mixing. A typical thermal stratification is produced, with a well-mixed epilimnion but a more or less stagnant metalimnion and hypolimnion.

With cooler weather in the fall, the lake begins to lose heat as surface temperatures drop. The wind is able to mix the lake progressively deeper and the density gradient weakens. Eventually the metalimnion "erodes" and the entire lake circulates in the fall turnover. The lake is completely mixed again.

The significance of stratification in eutrophic lakes is that no exchange of dissolved gases, such as oxygen and carbon dioxide, is possible between the hypolimnion and epilimnion. During the summer, organic material produced in the epilimnion settles into the hypolimnion and bottom sediments where it is decomposed by biological action. Dissolved oxygen is consumed in the decomposition process and cannot be replaced; light usually cannot penetrate sufficiently deep in a eutrophic lake to permit photosynthesis and accompanying release of oxygen to take place in the hypolimnion. It is not uncommon for complete hypolimnetic oxygen depletion to develop during summer stratification. When it does, it persists until fall turnover.

The biota of lakes are organized through two fundamental natural systems: the flow of energy from the sun through food chains, and the cycling of nutrient elements (e.g., carbon, nitrogen, phosphorus, iron, sulfur) that form organisms and organic matter. Algae (microscopic plants) absorb sunlight and convert the light energy into the chemical energy contained in the organic molecules that they manufacture through photosynthesis. Plants form the base of a complex web of food and energy transfers among groups of organisms labeled herbivores (plant feeders), omnivores (plant and animal feeders), carnivores (animal feeders), and detritivores (organisms that consume nonliving organic matter).

In the deep, open water of a lake, phytoplankton (planktonic algae) are the base of the food chain. Zooplankton (microscopic animals) and small fish graze on the algae, and in turn the zooplankton are grazed by fish. Death and settling of the remains of food web organisms into the bottom sediments act as a net loss of nutrients from the epilimnion.

It is now apparent that the physical, chemical, and biological characteristics of lakes are related so intimately that a change in one will surely lead to changes in the other two. For example, a chemical factor such as increased plant nutrients increases algal populations which in turn increases turbidity and reduces light penetration.

The worst problems associated with eutrophication (odors, fish kills, dense algal growths) usually occur during warm weather months. In cold weather, the most eutrophic lakes may resemble mesotrophic, or even oligotrophic water bodies, as low light intensities and low temperatures slow down biological processes.

During summer months the surface waters of highly eutrophic lakes are turbid and may smell of decaying organic matter. Algal mats or dense blooms of phytoplankton diminish or destroy the aesthetic value of lakes, but more important are numerous species that cause taste and odor problems in drinking water: certain blue-green algae impart a musty odor to water and others emit toxic substances that may kill other forms of aquatic life. Dense growths of algae can cause daily fluctuations in dissolved oxygen and pH. During daylight hours at the height of the growing season, surface water often become saturated and sometimes supersaturated with dissolved oxygen given off by the plants. At night when no oxygen is produced, respiration by aquatic plants and animals can deplete the supply sufficiently to cause a fish kill.

Low species diversity and high biomass are common features of eutrophic lakes. Poor water quality eliminates or greatly reduces many of the sensitive species. Energy becomes blocked in lower levels of the food chain instead of flowing smoothly through it, because many of the algae found in highly eutrophic lakes, such as blue-greens, are also the ones least favored by plant-eating animals.

Nutrient control is a very important element of any lake management program. For a program to be effective, the limiting nutrient - the one in the shortest supply - must be identified and controlled. Plants require 20 different elements for growth, but only two, nitrogen and phosphorus, are likely to be in short supply.

Phosphorus is usually the most important nutrient controlling lake productivity; therefore, total phosphorus (i.e., the phosphorus present in both inorganic and organic, dissolved and suspended forms) is an important measure of trophic state. Total phosphorus concentrations in lakes range from 1 part per billion in ultra-oligotrophic lakes to several parts per million in some hyper-eutrophic lakes. The dividing line between oligotrophic and mesotrophic lakes is usually regarded as about 10 ug/l (parts per billion) and eutrophic lakes as about 20 ug/l.

Nitrogen is an important plant nutrient, but limnologists have done little to develop quantitative trophic criteria for nitrogen concentrations. In part, this situation reflects the general attitude that phosphorus is the most common nutrient factor controlling trophic state, but it also attests to the considerably more complicated chemistry and biology associated with nitrogen, and the greater difficulty involved in controlling its sources.

Chlorophyll a, the principal photosynthetic pigment in plants, is generally considered to be a very useful indicator of algal biomass. There are some problems in relating chlorophyll a concentrations to the biomass of algae, but this parameter is more convenient and more easily quantified than other measures such as counting the number of algal cells per unit area. Average summer chlorophyll a concentrations of about 10 ug/l is generally considered the dividing line between oligotrophic and eutrophic lakes.

It should be pointed out that not all eutrophic lakes are impaired. From a fisheries standpoint, eutrophic lakes have higher rates of production than oligotrophic lakes though the species composition is different. Indeed, fertilizers have been used as a fisheries management tool to increase fish production.

Some general principles for lake management and for restoring water quality in degraded lakes can be derived from the preceding discussion. The productivity of a lake is controlled by a number of factors, only one of which is nutrient supply. To be effective, programs must be designed to overcome the causes of eutrophication rather than dealing simply with the symptoms.

Where possible, the best way of reducing nutrient inputs to lakes is through diversion. The next choice for reducing loading is through watershed management. Management involves many aspects, including: 1) controlling land-use practices; 2) developing programs to minimize loss of soil and fertilizer from agricultural

lands; 3) treating streams to remove nutrients (e.g., by passing them through wetlands); 4) installing sewage treatment systems to remove nutrients from waste water; and 5) developing laws and ordinances (e.g., to limit use of phosphate detergents, or to prohibit septic tanks in areas where soils have poor retention capacity for phosphorus).

APPENDIX B  
REVIEW OF PAST STUDIES



## Review of Past Studies

Numerous water quality studies have been conducted on the Las Vegas Wash-Las Vegas Bay-Lake Mead system. The following is a brief summary of the results of these investigations.

### U.S. Department of Health, Education, and Welfare. 1965

The study was conducted June 4-8, 1965. They found that Las Vegas Bay exhibited surface algal concentrations five times the surface algal concentrations observed in the main body of Lake Mead. However, these concentrations did not interfere with recreational use of the bay. Algal species were identified near the water supply intake structure that cause shortened water treatment filter runs and others that are responsible for taste and odor. Surface nutrient samples indicated that Lake Mead was phosphorus deficient. Total nitrogen was relatively high which indicated a large potential for the development of algal populations if sufficient phosphorus were added to the system. They warned that any increase in the amount of phosphorus discharged to the lake will increase algal populations.

### Department of Interior, Federal Water Pollution Control Federation. 1967

The study was conducted from May 19-31, 1966. Results of the study indicated that growth of algae in Las Vegas Bay was producing an objectionable aesthetic condition and if allowed to continue unabated, would eventually destroy the recreational use of the area. The study claimed that the algal growth resulted from the discharge of nutrients, particularly phosphorus, through the Las Vegas Wash from the Clark County Sewage Treatment Plant. They recommended that phosphorus concentrations in the bay should not exceed 0.005 mg/l; this level would require a 90 percent reduction in effluent phosphorus concentration.

Boyle Engineering. 1969

The study reviewed past water quality studies on Las Vegas Wash and Lake Mead and made recommendations on future management of water resources. The study predicted that Lake Mead water quality will deteriorate slightly in the future. They further predicted that increasing attention will be directed toward elimination of potential nutrient enrichment of Lake Mead and interrelated factors which promote or encourage eutrophication. They predicted that such considerations will almost surely lead to requirements for treatment of wastewater to the maximum degree practical by tertiary treatment before return to Lake Mead. They recommended that the Las Vegas Valley Water District be designated as the agency responsible for the management of water resources and water quality control.

Environmental Protection Agency, Technical Services Report. 1971

The study found substantial nuisance algal growths in Las Vegas Wash. They concluded that phosphorus and nitrogen may be limiting to algal growth during different seasons of the year. They recommended that both nitrogen and phosphorus be limited in the influent to Las Vegas Wash. Standards should be set such that the receiving water does not exceed .010 mg/l total phosphorus or more than 1 mg/l total nitrogen.

Deacon, J.E. and R.W. Tew. 1973

This study examined the "Interrelationships Between Chemical, Physical, and Biological Conditions of the Waters of Las Vegas Bay of Lake Mead". The study was conducted in 1971 and 1972. Their conclusions were that Las Vegas Bay appeared to be mesotrophic with the inner portion of the bay exhibiting eutrophic conditions. They were puzzled as to why Lake Mead did not show a greater predominance of troublesome blue-green algal blooms. Cessation of inflowing water from Las Vegas Wash would mediate the eutrophic character of the inner portion of Las Vegas Bay. Significant reduction of nutrients through improved treatment would also be reflected rapidly in lower algal populations. They recommended that maintaining nutrient loading of less than about 400 lbs/day of total phosphorus and 1617 lbs/day of total nitrogen would alleviate problems caused by algal abundance in Las Vegas Bay.

Sawyer, C.N. 1976

The report was prepared for the Clark County Board of County Commissioners dealing with wastewater disposal from the BMI complex, Henderson, City of Las Vegas and Clark County. He concluded that waters flowing into Lake Mead from Las Vegas Wash have a definite deteriorating effect upon the lake.

- 1) Nutrients stimulate extensive blooms of algae in the upper reaches of Las Vegas Bay which impairs use of its waters for recreational purposes.
- 2) The biological productivity of Boulder Basin is increased to the point where serious oxygen depletion occurs in the thermocline and further degradation will have serious consequences at the Southern Nevada Water System treatment plant.
- 3) The waters discharged to the lower Colorado River at Hoover Dam have an algal growth potential greater than surface waters in Boulder Basin.
- 4) Because Las Vegas Wash enters the bay as a density current, nutrients are distributed over a greater area of Lake Mead, thereby minimizing local effects.
- 5) If TDS in the wash decreases, the inflow can be expected to enter in a more normal manner and mix with the surface waters. This will cause extreme algal growth conditions unless upstream control of phosphorus and, possibly, nitrogen is practiced.
- 6) Las Vegas Wash, through the extensive vegetation it supports, is a valuable, natural purification device. It has undoubtedly been a big factor in maintaining the integrity of Lake Mead for many years.
- 7) Las Vegas Bay, Boulder Basin, and Lake Mohave are affected by cultural contributions of algal nutrients in Las Vegas Valley. The only solution is to bring these under control so as to prevent conditions now existing.

Goldman, C.R. 1976

Dr. Goldman wrote this report as an independent contractor for the Clark County Sanitation District to assess the adequacy of advanced wastewater treatment and critically evaluate validity of the numerical standards. Some of his more significant results are as follows:

- 1) Virtually all dissolved phosphorus occurs in inorganic form and in very low concentrations, indicating that biologically - available phosphorus is cycling extremely rapidly and the amount detectable may not be relevant for determining potential algal production.
- 2) Severely eutrophic conditions were not observed in Las Vegas Bay during the course of the study.
- 3) Calculated N:P ratios suggest that all Las Vegas Bay and Boulder Basin stations, except for the inner bay, are most limited by phosphorus.
- 4) AWT treatment of Las Vegas Wash wastewater cannot guarantee the eradication of problems in Las Vegas Bay. The correct application of predictive models show that AWT technology will not be sufficient to control algal growth in Las Vegas Bay.
- 5) Wastewater effluent currently enters the lake at the worst possible place for producing excessive algal growth problems. Regardless of the treatment strategy eventually employed, enrichment effects on Lake Mead could be minimized by diverting the effluent into Boulder Basin rather than continuing to discharge into Las Vegas Bay.
- 6) They were not convinced that AWT is the most appropriate solution to Lake Mead water quality problems. Secondary wastewater treatment combined with biological stripping of both nitrogen and phosphorus in ponds and an expanded Las Vegas Wash marsh would provide a more economical and ecologically-sound alternative than AWT.

Goldman, C.R. and J.E. Deacon. 1978

This report was prepared for the Nevada Environmental Commission for the City of Las Vegas as recommended water quality standards for Las Vegas Bay and Lake Mead. Significant recommendations were as follows:

- 1) Since the water quality problem has historically been related to algal concentrations, it is desirable to establish a level of algal concentration for the inner Las Vegas Bay that does not cause unacceptable conditions or interfere with beneficial uses.
- 2) Chlorophyll a is a good measure of algal concentrations because it is directly related to the quantity of algae and has been frequently monitored in inner Las Vegas Bay. In the late 1960's and early 1970's chlorophyll concentration in inner Las Vegas Bay reflected unacceptable quantities of algae. Chlorophyll concentrations in the outer Las Vegas Bay are low (5 ug/l) and have remained fairly constant since 1968. Nutrient discharge from Las Vegas Wash has little influence on algal concentration in the rest of Las Vegas Bay and Lake Mead.

The average daily total nitrogen load at North Shore Road be 3000 lbs from March-October not to exceed a maximum of 3500 lbs or 5300 lbs not to exceed 6300 lbs from November-February.

- 3) In order to maintain algal concentrations in inner Las Vegas Bay at the present, acceptable level, it will be necessary to establish appropriate maximum daily nutrient loads into inner Las Vegas Bay from Las Vegas Wash.
- 4) The existing information on nutrient limitation for the inner Las Vegas Bay provides substantial evidence that both phosphorus and nitrogen can control algal growth. However, nitrogen more than phosphorus is the principal factor. Therefore, it is necessary to establish permissible daily loads for these nutrients from Las Vegas Wash.
- 5) Since 1974 the total phosphorus load of North Shore Road has averaged 1841 lbs/day from November-February and 1620 lbs/day from March-October. Over the same periods, total nitrogen load has averaged 5252 lbs/day from November-February and 2933 lbs/day from March-October.
- 6) From the standpoint of algae, existing water quality supports the beneficial uses of fishing, swimming and boating under current nutrient loads. Therefore, we recommend that the average daily total phosphorus load at North Shore Road be 1600 lbs. from March-October not to exceed a maximum of 1700 lbs. or 1800 lbs. not to exceed a maximum of 2000 lbs. from November-February.

- 7) Las Vegas Wash also functions as a natural and effective means of nitrogen and phosphorus removal. Mechanisms for nutrient removal, acting singly or in combination, include uptake by plants, adsorption to clay and silt particles and loss to the atmosphere (denitrification). Once adequate erosion control and water distribution are implemented it is certain that these mechanisms can be expanded and improved for significant further reduction of both phosphorus and nitrogen. We recommend that a specifically designed nutrient removal management program be developed and implemented concurrently with the flow distribution and erosion control program necessary to maintain wetland wildlife habitat.

Brown and Caldwell, 1982

This study was called the Las Vegas Valley Water Quality Program and was the result of a Consent Decree in a litigation action filed by the cities of Las Vegas and North Las Vegas in July 1978. The suit was filed against the U.S. EPA, State of Nevada, and Clark County, and requested that water quality standards for Las Vegas Wash and Lake Mead be reevaluated. A summary of the algae and nutrients conclusions follow:

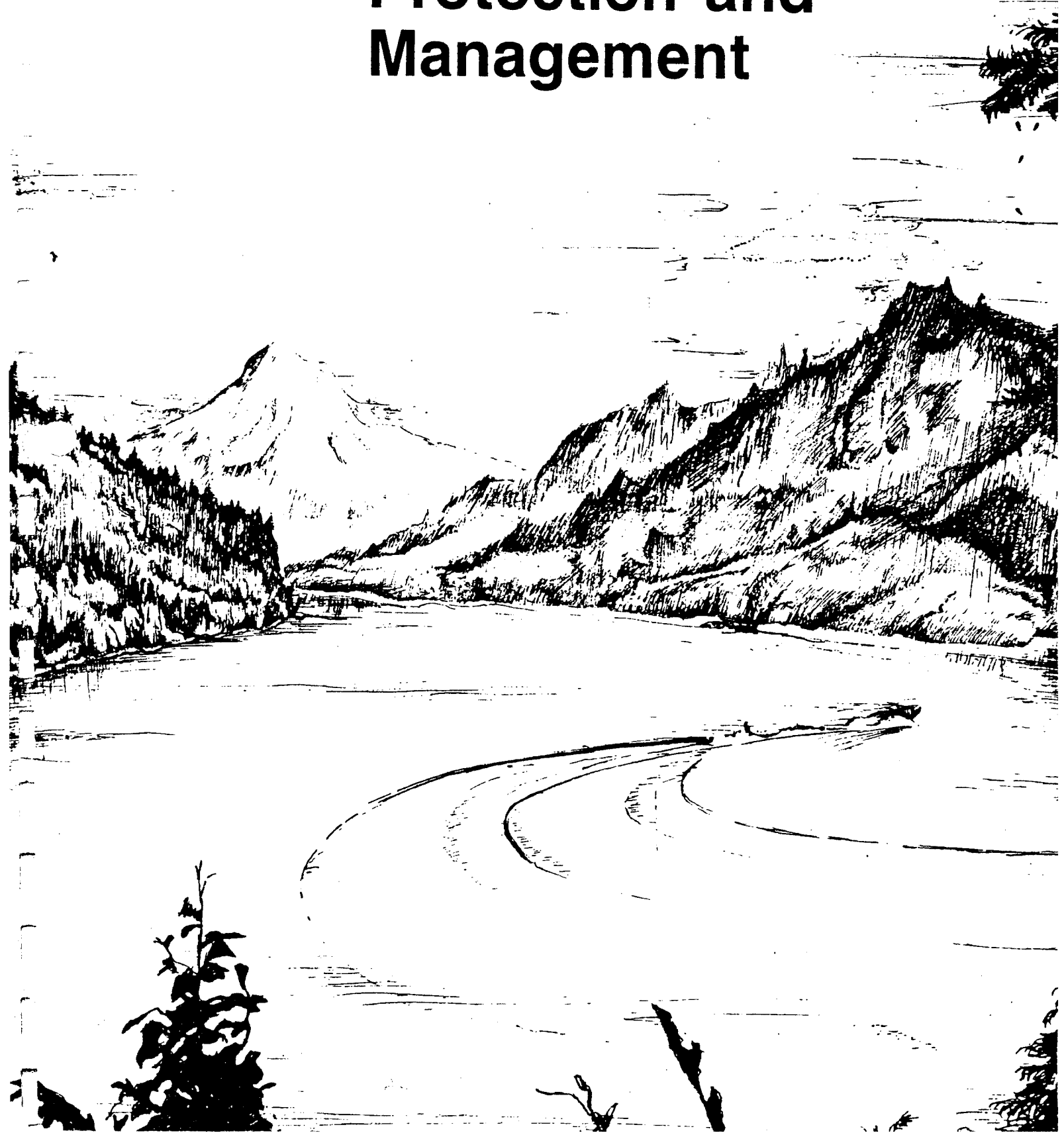
- 1) The chlorophyll concentration is the most significant water quality factor affecting transparency in Las Vegas Bay. Quantitative relationships were developed to predict transparency from chlorophyll in the bay.
- 2) Secchi depth (transparency) should be used as the basis for water quality criteria in the bay. A minimum Secchi depth of 1.2 m should be maintained in all areas of Lake Mead designated for swimming which should be met 90 percent of the time from May through September.
- 3) Transparency of the inner bay is expected to increase in proportion to reduction in phosphorus loading from Las Vegas Wash if the dissolved N/P ratio of the wash entering the bay is greater than 10.
- 4) A mixing zone, within which the proposed criteria would not apply, should be allowed extending from the mouth of Las Vegas Wash to station 2.

- 5) Improved transparency would have beneficial effects on swimming, aesthetics, and fishing uses in the inner bay. Nutrient reductions to improve transparency may have some adverse effects on the fishery due to decreased algal productivity.
- 6) For Nitrogen and phosphorus loading conditions during the 1979 and 1980 recreation seasons, Secchi depth inwards of station 3 did not meet the proposed criteria of 1.2 m more than 10 percent of the time.
- 7) The following TMDL's for total phosphorus are required to meet the recommended criterion for Secchi depth:
  - Spring (May to June) - 680 lbs/day
  - Summer (July to Sept) - 600 lbs/day
  - Winter (October to April) - No TMDL required
- 8) Nutrient removal in the Las Vegas Wash was remarkable considering travel times and channelization of flow. If the flow was slowed down by spreading the water throughout the marsh or impounding the water in a series of ponds, greater nutrient removal would be expected to occur.

Water



# Lake Restoration, Protection and Management





# EXPERIENCES IN DEVELOPING A CHLOROPHYLL A STANDARD IN THE SOUTHEAST TO PROTECT LAKES, RESERVOIRS, AND ESTUARIES

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## ABSTRACT

The adverse consequences associated with excessive growths of algae have been a problem of major concern for local, State, and Federal water pollution control agencies. The regulatory framework set forth by the Clean Water Act makes control of algae most logical through water quality standards-based effluent limitations. This paper documents the development of a chlorophyll a water quality standard by the State of North Carolina. The purpose of the standard was to provide regulations that could be used to limit both point and nonpoint source discharges of nutrients.

## INTRODUCTION

After passage of the Federal Water Pollution Control Act Amendment of 1972, State water pollution control agencies received unprecedented amounts of Federal funds to be used in water quality planning functions. The first round of planning concentrated on an inventory of pollutant sources, development of point source waste load allocations, and examination of water quality standards. These processes were documented, for the most part, in Section 303(e) Basin Plans.

The second round of planning continued those programs and greatly emphasized examining nonpoint sources of pollutants. The second round of planning culminated in the development of Section 208-financed Water Quality Management Plans. During the development of 208 plans, the Federal Water Pollution Control Act was amended in 1977 and 1981 and retitled the Federal Clean Water Act (the Act).

Starting with the 1972 amendments, the Act outlined a two-pronged approach for restoring and maintaining good quality in the Nation's waters. The Act set forth a plan to control water pollution by establishing technology-based minimum levels of treatment for point source discharges and

increased the levels of treatment through time. In addition, the Act proposed to control water pollution by establishing water quality standards. Once established, the water quality standards served as the basis for development of allowable waste loads for both point and nonpoint source discharges.

Except in rare cases, the development of technology-based minimum treatment levels did not limit nutrients such as phosphorus and nitrogen. For this reason, the regulatory framework made development of water quality standards the most logical approach for a statewide program to control excessive growths of algae.

## NORTH CAROLINA CASE

In the 303(e) Basin Planning Process, members of the State regulatory staff became acutely aware of the actual and potential water quality problems associated with excessive growths of algae. Also, in 1971 and 1972 the Chowan River, a freshwater estuary to the Albemarle Sound, experienced blooms of blue-green algae. These blooms made the estuary

unsuitable for water contact recreation, adversely affected both sport and commercial fisheries, and created industrial water supply problems. Other estuaries and lakes within the State had also encountered adverse consequences from excessive algal growth. The public reaction to these cases mandated that the State pollution control agency correct the problems.

In February 1975, the State held a public hearing on several proposed water quality standards revisions including a narrative standard for nutrient and algae control. That standard read as follows:

In impounded or slow-moving waters which are subjected to nutrient enrichment and in which excessive algae activity results in or is expected to result in interference with established water uses, the Department of Natural and Economic Resources is authorized to establish a stream nutrient standard appropriate to the body of water affected.

The proposed regulation was written using a State statute that gave the department general authority to control water pollution.

The language of the narrative standard appeared sufficient for the State to control nutrients; however, experience had shown that the State can be more effective with less resources when using numerical rather than narrative standards. For this reason, the State Division of Environmental Management staff was charged with responsibility to develop, if possible, numerical standards for controlling algae. In May of 1977, the State staff requested the assistance of the Water Resources Research Institute. The Institute is an organization that coordinates water research with the Universities. At the Division's request, the Institute organized a Water Quality Standards Advisory Group comprised of individuals from the Universities in North Carolina and other State agencies with technical expertise in algae. Members of the Advisory Group included:

Dr. James Stuart	-	Water Resources Research Institute, Raleigh
Dr. Peter Campbell	-	University of North Carolina, Chapel Hill
Dr. Charles Weiss	-	University of North Carolina, Chapel Hill
Mr. Terry Anderson	-	University of North Carolina, Chapel Hill
Dr. Donald Starley	-	University of North Carolina, Chapel Hill
Dr. Edward Kuezier	-	University of North Carolina, Chapel Hill
Dr. Gus Witherspoon	-	North Carolina State University, Raleigh
Dr. Donald Hayne	-	North Carolina State University, Raleigh
Dr. Mark Brinson	-	East Carolina University, Greenville
Mr. Scott Van Horn	-	North Carolina Wildlife Resources Commission, Raleigh
Mr. Cape Carnes	-	North Carolina Wildlife Resources Commission, Raleigh
Mr. Donald Tobaben	-	North Carolina Division of Inland Fisheries, Raleigh
Mr. Alan Peroutka	-	North Carolina Division of Environmental Management, Raleigh
Mr. David Park	-	North Carolina Division of Environmental Management, Raleigh
Mr. R. F. McGhee	-	North Carolina Division of Environmental Management, Raleigh

Prior to meeting with the Advisory Group, the Division of Environmental Management staff conducted a literature search and developed a proposed standard for discussion with the Advisory Group. The proposed standard read as follows:

Chlorophyll a shall not exceed 50  $\mu\text{g/l}$  in freshwater lakes and reservoirs, 20  $\mu\text{g/l}$  in lakes and reservoirs designated as Trout Waters, and 100  $\mu\text{g/l}$  in all sounds, estuaries, and other slow moving waters. The chlorophyll a concentration shall be that concentration determined at any one time and at a depth equal to one-half the Secchi depth.

The Advisory Group initially met June 10, 1977 and had a final meeting on July 7, 1977. The Group concluded that a chlorophyll a standard was a good method for controlling excessive cultural eutrophication. The Group also concluded that presently oligotrophic lakes should possibly be main-

tained at their current level. Further study on that issue was recommended. The Advisory Group also concluded that a statewide standard on phosphorus, nitrogen, or both would not be technically sound because other characteristics of the water bodies would not be taken into account.

Of utmost utility to the Advisory Group was a presentation of information by Dr. Charles M. Weiss (1976) from his recently completed report "Trophic State of North Carolina Lakes." His report included sampling of 69 lakes in North Carolina and a rigorous statistical analysis of the data. The report suggested classification of North Carolina lakes in the following manner:

Trophic State	Chlorophyll a mg/m <sup>3</sup>	Total Phosphorus mg/m <sup>3</sup>	Secchi Depth Meters
Oligotrophic	< 2	< 10	> 3.0
Oligo-mesotrophic	2-6	10-19	1.5-3.0
Mesotrophic	6-15	20-39	1.0-1.5
$\alpha$ - Eutrophic	15-40	40-79	0.5-1.0
$\theta$ - Eutrophic	40-100	80-150	0.1-0.5
Hypereutrophic	> 100	> 150	< 0.1

Dr Weiss advised that a standard of 40  $\mu\text{g/l}$  for warmwater lakes and 15  $\mu\text{g/l}$  for trout lakes seemed more reasonable than the values proposed by the Division of Environmental Management. The Advisory Group concurred with these values.

Dr. Stanley commented that chlorophyll a concentrations exceeded 100  $\mu\text{g/l}$  in the Pamlico estuary during the winter with no noticeable adverse effects. The final standard provided for this situation by being applicable only during the summer months.

In October 1977, the Division of Environmental Management obtained permission from the Environmental Management Commission to hold public meetings on the proposed chlorophyll a standard along with many other proposed standards revisions. The purpose of the meetings was to obtain public input into the formulation of all water quality standards revisions. Two public meetings were held in November 1977.

In May 1978, the Division of Environmental Management completed a set of proposed water quality standards that included the chlorophyll a standard. Also during this period the Division presented and obtained concurrence with proposed standards from both the 208 Technical Advisory Committee and the 208 Policy Advisory Committee. The Environmental Management Commission authorized public hearings, mandatory for rulemaking in North Carolina.

Public hearings were held at three locations in the State during July and August 1978. Very little concern or opposition was voiced over the chlorophyll a standards except for applying them to very small lakes such as farm ponds. The Environmental Management Commission members originally voiced concern over lake size and in response, size limitations were added to the standards.

During the summer of 1978 the Chowan River estuary experienced massive blooms of blue-green algae that greatly heightened the interest in establishing standards to control algae. The Chowan situation was so intense that another regulation called "Nutrient Sensitive Waters" was drafted by the Division of Environmental Management Staff: it prohibited, with some exceptions, the discharge of nitrogen and phosphorus above background levels in designated waters. This regulation proceeded simultaneously with the chlorophyll a standard.

After several delays, not related to the chlorophyll a standard, the Environmental Management Commission adopted the following standard on August 9, 1979:

Chlorophyll a: not greater than 40  $\mu\text{g/l}$  for lakes, sounds, estuaries, reservoirs, and other slow-moving waters not designated as trout waters, and not greater than 15  $\mu\text{g/l}$  for

lakes, reservoirs, and other slow-moving water designated as trout waters (not applicable during the months of December through March; not applicable to lakes and reservoirs less than 10 acres in surface area).

Also on that same date, the Chowan River Basin was designated by the commission as a Nutrient Sensitive Water. EPA approved the chlorophyll *a* standard on November 9, 1979, under the provisions of Sec. 303(c) of the Act.

**POST STANDARD ADOPTION**

At the time of adoption of the chlorophyll *a* standard, the State recognized that data and staff resources were not available to fully apply the standard statewide. However, the State has used the standard in making many water quality decisions. For the most part, the State has concentrated resources on the most severe nutrient problem areas, and also used the standard to formulate positions on a few pro-

posed waste treatment facilities and water resource projects such as dams (Westall, pers. comm.)

The State is pleased with the utility of the standard and plans to retain it until a more technically complete and usable alternative becomes available (Westall, pers. comm.)

**ACKNOWLEDGEMENTS:** The author expresses appreciation to the staff of the North Carolina Division of Environmental Management for their assistance in researching the water quality standards files.

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APPENDIX D

Chlorophyll a

Rationale for Las Vegas Bay - Lake Mead

## Introduction

### Lake Mead

Lake Mead was formed by impounding the Colorado River behind Hoover Dam in 1935. The reservoir is located in the Mohave Desert where maximum summer temperatures commonly exceed 40 C from June through September. Winds over 30 Km/hr are frequent. The lake has four major basins; Pierce Basin, Gregg Basin, Virgin Basin, and Boulder Basin (Figure 1) Moapa and Virgin rivers discharge into the Overton Arm of Virgin Basin and the Colorado River into the Pierce Basin. The Las Vegas Wash (LVW) discharges into a narrow inlet of Las Vegas Bay (LVB), a large arm of Boulder Basin (Figure 2).

Lake Mead is a deep, warm monomictic lake. Thermal stratification develops in May and June, and a classical thermocline develops between a depth of 10 and 15 m in July (Baker et al. 1977). Turnover begins in October and the lake is completely destratified by January.

The major portions of the lake have been declining in productivity (algal production) since completion of Glen Canyon Dam in 1963. Phosphorus laden silt particles in the Colorado River have been sedimenting out in Lake Powell significantly reducing the load to Lake Mead. The result has been a reclassification of the lake from oligo-mesotrophic to oligotrophic. This sharp decrease in phosphorus, decreased growth at all levels of the food chain and has detrimentally affected the sport fishery (Baker and Paulson 1983; Evans and Paulson 1983; Paulson and Baker 1983; Prentki et al. 1981). Experimental fertilization studies in 1986 confirmed initial feasibility of a larger fertilization study of a major portion of the Overton Arm to be conducted in Spring 1987.

Despite reduced nutrient loading to the major portions of Lake Mead, LVB has remained highly productive due to increased loading from LVW and the wastewater treatment plants. However, the level of productivity in major portions of LVB has surpassed that necessary to support a productive sport fishery (mesotrophy) and in 1986 eutrophic, poor water quality conditions detrimentally affected other beneficial uses of the bay.

### LAS VEGAS WASH

Las Vegas Wash is the terminus of the 1600 mi<sup>2</sup> Las Vegas Valley drainage system that discharges into Las Vegas Bay of Lake Mead. Both the City of Las Vegas Wastewater Treatment Plant and Clark County Sanitation District discharge

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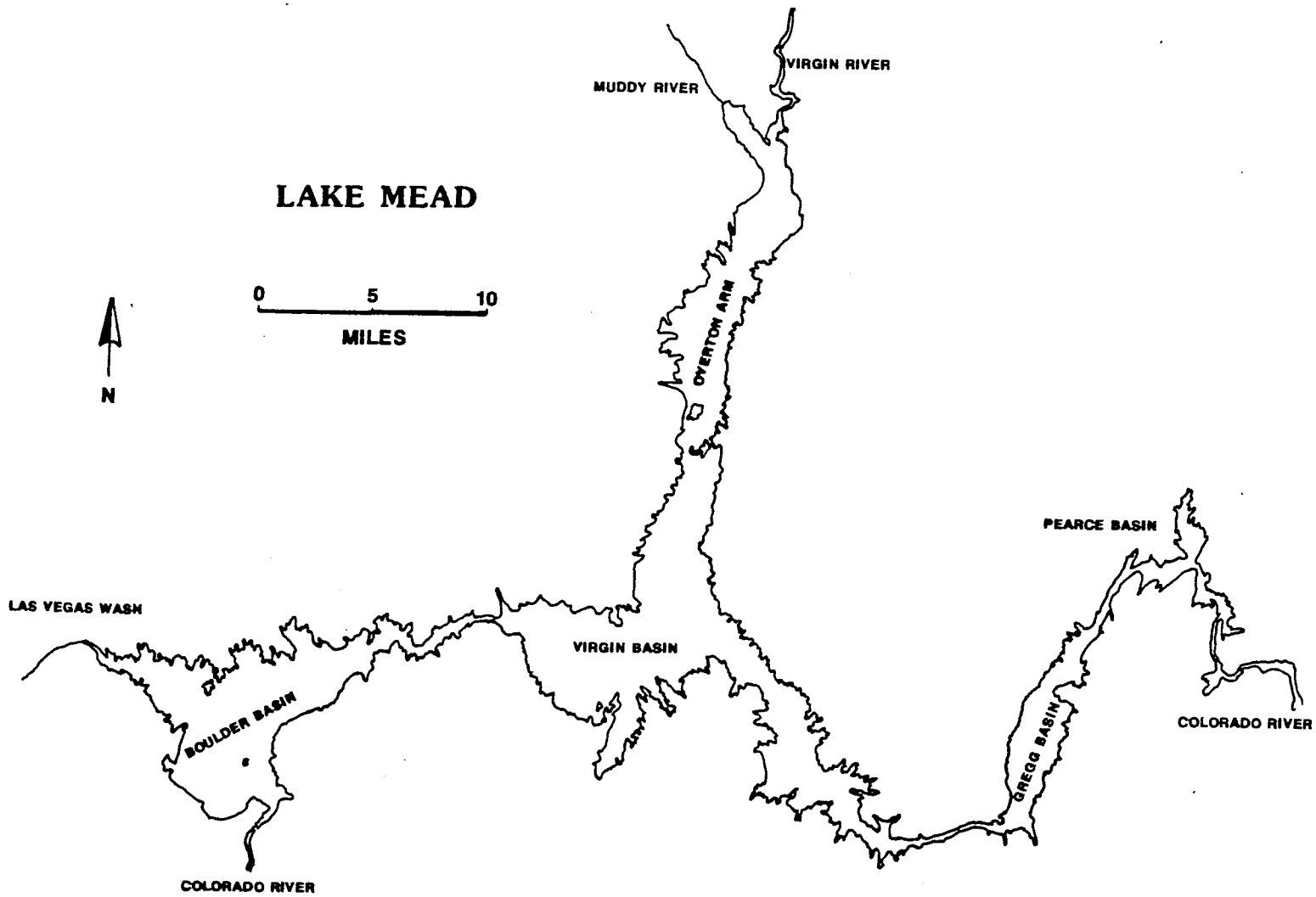


Figure 1. Map of Lake Mead showing major basins and tributaries.

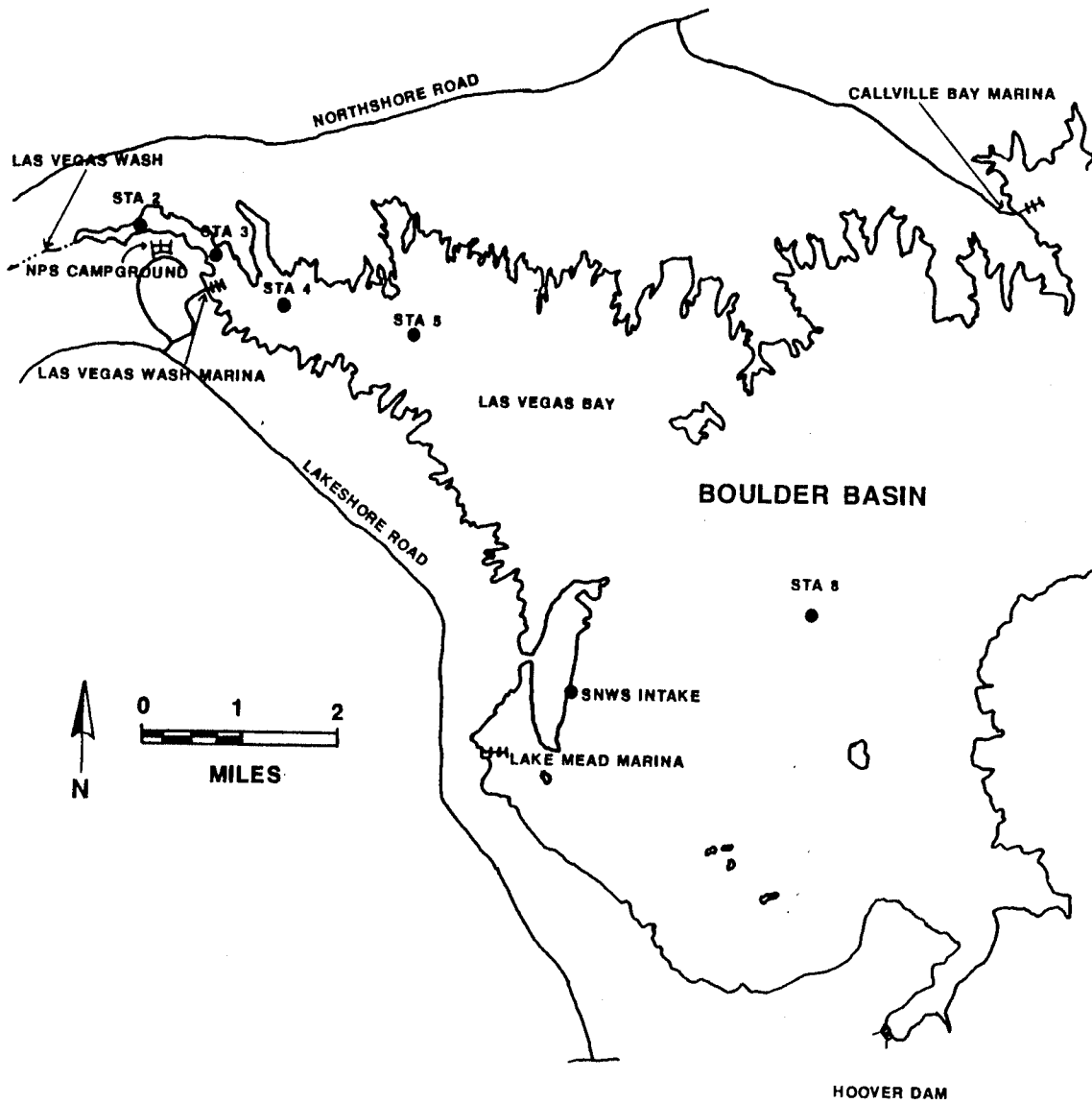


Figure 2. Map of Las Vegas Bay and Boulder Basin, Lake Mead.

into the wash about 11 miles upstream from the bay. An artificial wetlands has become established within the Las Vegas Wash downstream from the sewage treatment plants that is supported by the rich nutrient supply and long growing season. The wetland-marsh is dominated by cattail, Typha domengensis and common reed, Phragmites communis. Extensive growth of salt cedar, Tamarix petandra border the riparian zone.

The Las Vegas Wash and associated wetlands has historically acted as a buffer between the wastewater treatment facilities and the bay. Significant quantities of phosphorus and nitrogen were removed within the wetlands before discharging to the bay. Nitrification of ammonia to nitrate occurred seasonally in the wash and loading of ammonia to the bay was insignificant.

Goldman and Deacon (1978) reported a 90% reduction in ammonia loading as measured at Northshore Road while Morris and Paulson (1981) reported lower reductions (31%). Morris and Paulson (1981) also reported that total nitrogen was being reduced by 27% during summer 1980 and total phosphorus by roughly 33%.

Other studies conducted during this period document that the rate of nutrient removal in the wash appeared to be declining (URS 1978). The scientific recommendation at this time called for more intensive management of the wetland in order to maintain and enhance its nutrient removal capability. Brown and Caldwell (1982) recommended that consideration should be given to mechanisms that will prevent future loss of nutrient removal capacity in the wash. They suggested spreading the water over a larger area of the marsh or impounding water in a series of ponds to enhance nutrient removal.

Since about 1975 the Las Vegas Wash has been experiencing severe vertical and lateral erosion. Rapid growth of Las Vegas Valley since 1930 has increased municipal and industrial wastewater discharge, which has altered flood-plain vegetation and ultimately promoted channel degradation (Glancy and Whitney 1986). Urbanization has enhanced flood volumes and peak flows. For example, six of the 11 years since 1975 peak flows in the wash have exceeded 1000 CFS. In comparison, the 18 year period from 1957 to 1974 saw only two years when peak flows exceeded 1000 CFS.

The following factors are generally considered to be the most important in accelerating the erosion process:

- 1) sustained high wastewater flows;
- 2) major floods of 1975 and 1984;
- 3) increasing flood volumes and peak flows; and
- 4) removal of road culvert at North Shore Road.



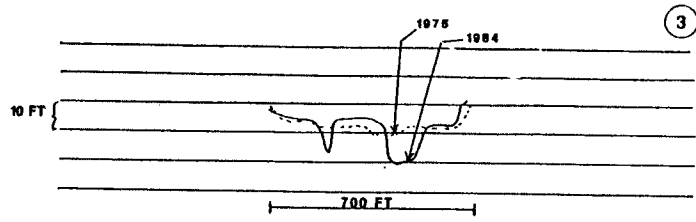
Figure 3 presents cross sections of the Las Vegas Wash at six sites between the narrows (Cross Section 3) and the Las Vegas Valley Lateral (Cross Section 24) in 1975 and 1984. The measurements were taken by Boyle Engineering Corporation as part of a study for the protection of the lateral from erosion (Colorado River Commission 1985). It is apparent from these figures that the wash channel has experienced severe downcutting and lateral erosion. In some sections the channel has downcut over 30 feet and eroded laterally over 500 feet since 1975 (Cross Sections 12 and 16). The net effect of this channelization is that the water is losing contact with the wetlands and has lost much of its capability to "polish" wastewater flows before entering the bay. Hydraulic detention time from the treatment plants to the Lake has decreased from 18-20 hours in 1980 to 9-10 hours in 1985.

Discharge of the Las Vegas Wash has increased significantly since the early 1970's. The average flow of the wash has increased from about 60 CFS in 1973 to about 120 CFS in 1985 (Figure 4). This trend reflects continuing population growth in Clark County from roughly 300,000 in the early 1970's to about 600,000 in 1985 and the resulting wastewater discharge (Figure 5).

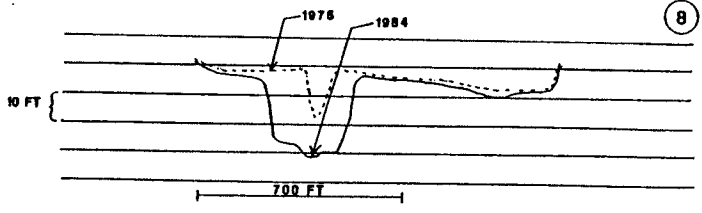
Increasing wastewater flows in the wash have diluted the total dissolved solids (TDS) from about 4500 mg/l in 1969 to about 2000 mg/l in 1985 at North Shore Road. These flows act primarily in diluting major inflows of salt-laden groundwater between Pabco and North Shore Roads (Morris and Paulson 1981). Although TDS concentrations have declined in the wash the TDS load has remained relatively constant at about 1.1 million lbs/day.

Also of significance is the formation of a delta at the mouth of Las Vegas Wash. Approximately 4.25 million cubic yards of eroded wash material has been deposited in a large fan shaped delta at the wash mouth. (Glancy and Whitney 1986). This newly formed delta may influence plume dynamics. Spreading of the water over the delta may increase temperature causing the plume to become more buoyant. Also, a non-channeled flow would have less momentum which would also contribute to increased surface mixing.

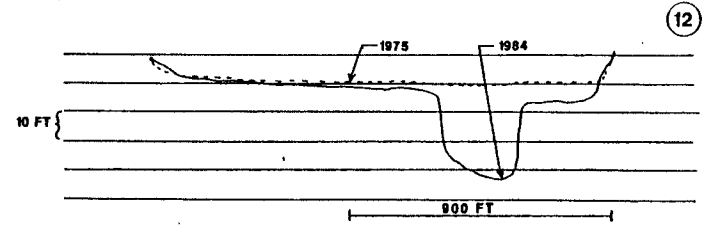
It must be concluded that a combination of the above factors have changed the hydrodynamics of the wash plume. These changes have resulted in 1) more nutrients being transported down the wash, and 2) a greater percentage of the nutrients in the wash being transported to epilimnetic waters of the lake. It should be pointed out here that our understanding of the processes governing



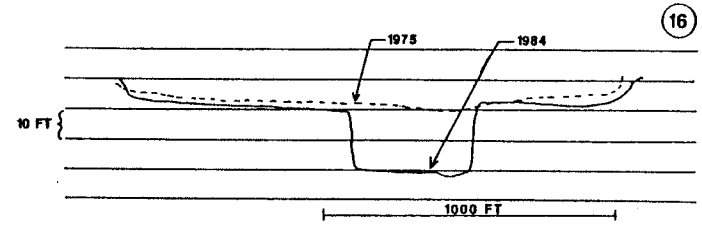
LAS VEGAS WASH CROSS SECTION



LAS VEGAS WASH CROSS SECTION



LAS VEGAS WASH CROSS SECTION



LAS VEGAS WASH CROSS SECTION

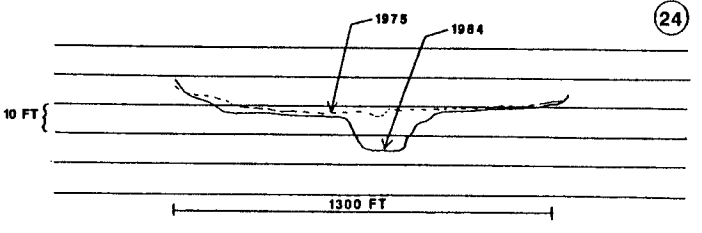
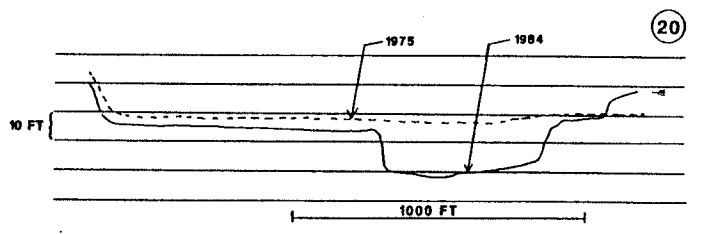


Figure 3. Las Vegas Wash cross sections at six sites between narrows (cross section 3) and the Las Vegas Valley lateral (cross section 24) in 1975 and 1984.

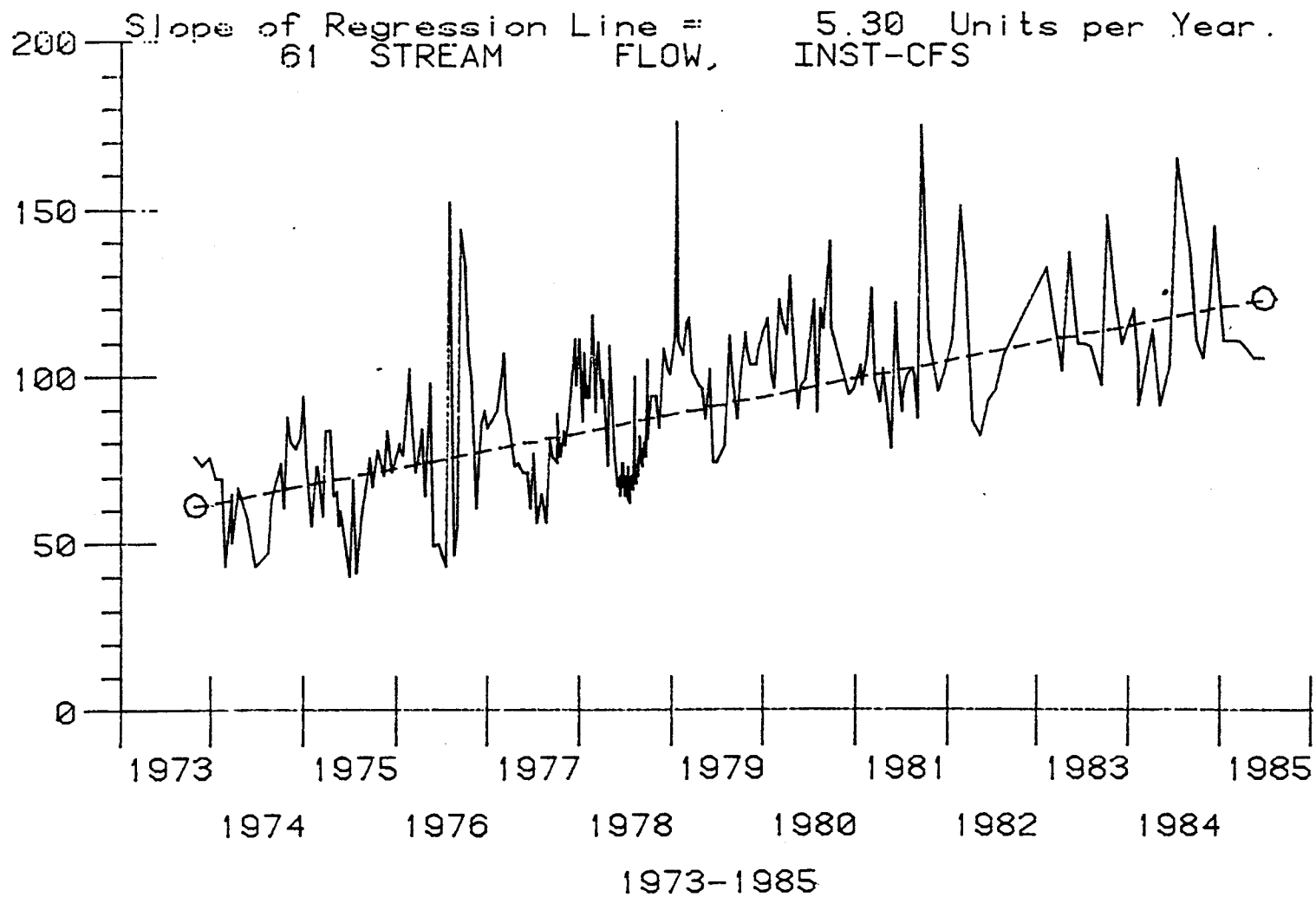


Figure 4. North Shore Road flows from 1973 through 1985.

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D.8.

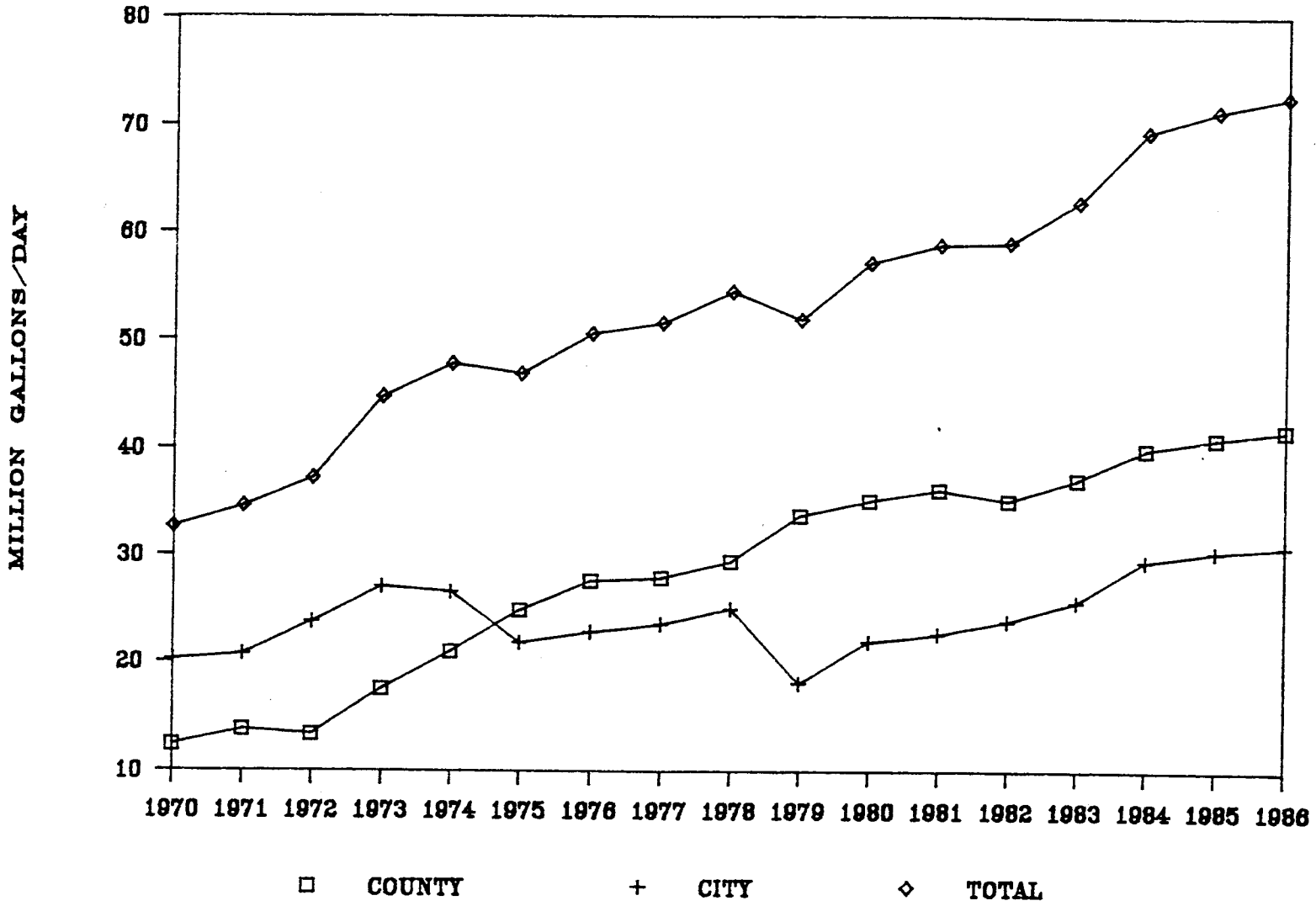


Figure 5. Wastewater flows from Clark County and City of Las Vegas sewage treatment plants from 1970 through 1986.

water quality within the wash and plume dynamics is not well understood, but we do know that the changes that have taken place have adversely impacted water quality in LVB.

#### LAS VEGAS WASH, NORTH SHORE ROAD LOADING

##### Total Phosphorus

Between 1972 to 1981 total phosphorus loading at North Shore Road fluctuated between 1200 to 1500 lbs/day (Figure 6). Beginning in July 1981 both the City and County plants instituted phosphorus removal and the loading was reduced to about 400 lbs/day. Since July 1981 loading has gradually increased to the average 1986 load of about 620 lbs/day. It appears that summer phosphorus retention within the wash has become less efficient since about 1979 likely as a result of less water contact with the marsh due to channelization.

##### Total Nitrogen

Nitrogen loading also exhibits a seasonal cycle of summer removal that was more efficient in the 1970's. Loads have increased from 1972 (3000 lbs/day) to 1980 (7500 lbs/day) (Figure 7). Loading decreased from 1980 to 1982 (4500 lbs/day) possibly as a result of marsh re-establishment. Since 1982, nitrogen loading has increased to its current 1986 level of about 9600 lbs/day.

##### Total Ammonia

Historically the Las Vegas Wash was a very efficient nitrifier of ammonia. Prior to 1978 over 90 percent of the ammonia load was converted to nitrate by North Shore Road (Figure 8). Loading at that time ranged from 50 to 400 lbs/day. Loading began increasing in 1978 (2000 lbs/day), increasing steadily through 1980 (4400 lbs/day) but then declined from 1980 to 1982 (2500 lbs/day). Ammonia loads have increased since 1982 to the current 1986 level of 7400 lbs/day. The steady increase in ammonia loading at North Shore Road is likely a function of increased loading from the treatment plants and a lack of nitrification in the wash due to channelization.

#### LAS VEGAS BAY WATER QUALITY

Because the worst problems associated with eutrophication are manifested in summer (July, August, September) the following discussion of water quality conditions in LVB will be limited to this season. In addition, more water quality data from the bay has been collected during summer than any other time period.

# NORTH SHORE ROAD

TOTAL PHOSPHORUS

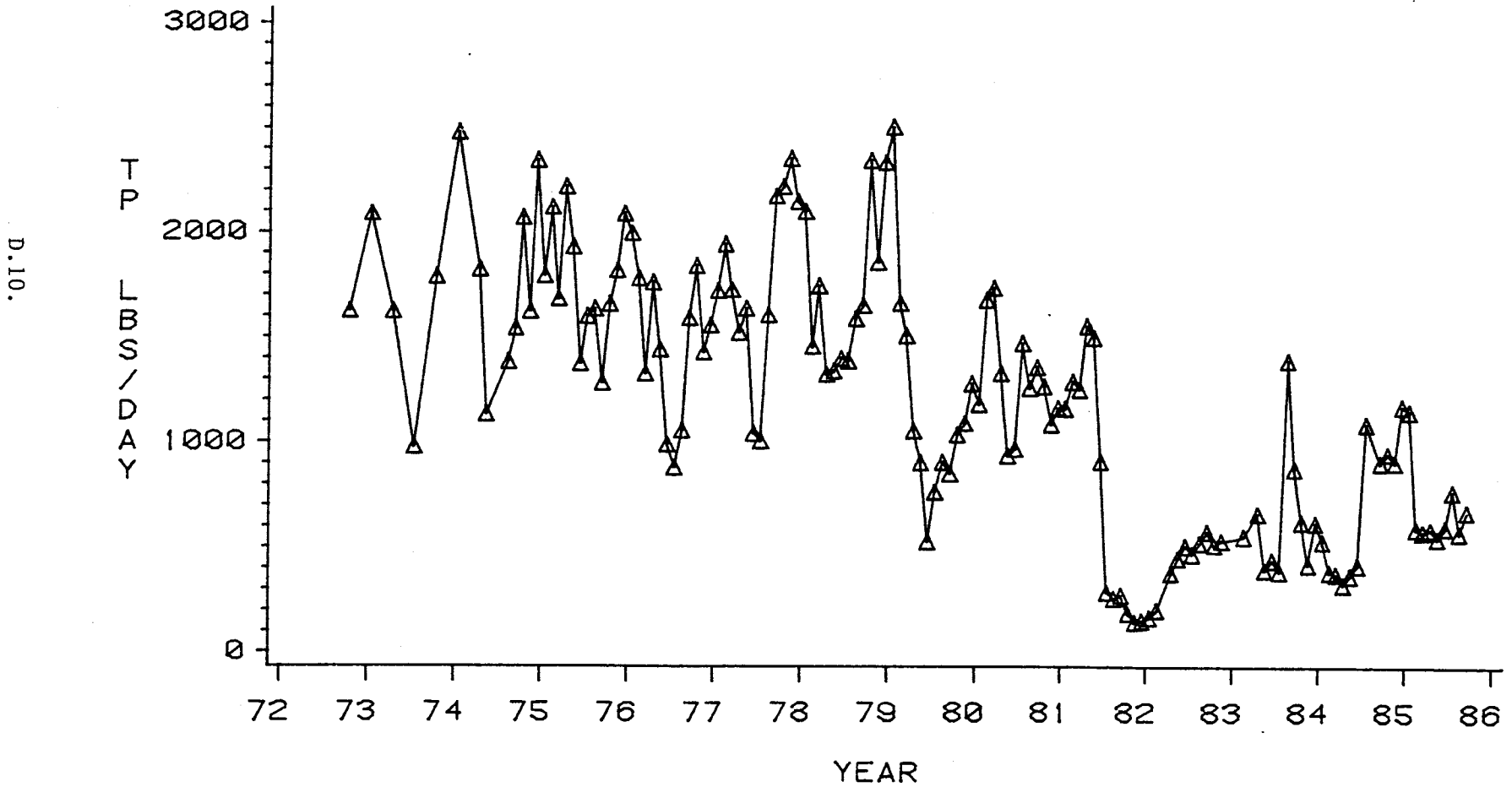


Figure 6. Total phosphorus loading at North Shore Road from 1972 through 1985.

# NORTH SHORE ROAD

TOTAL NITROGEN

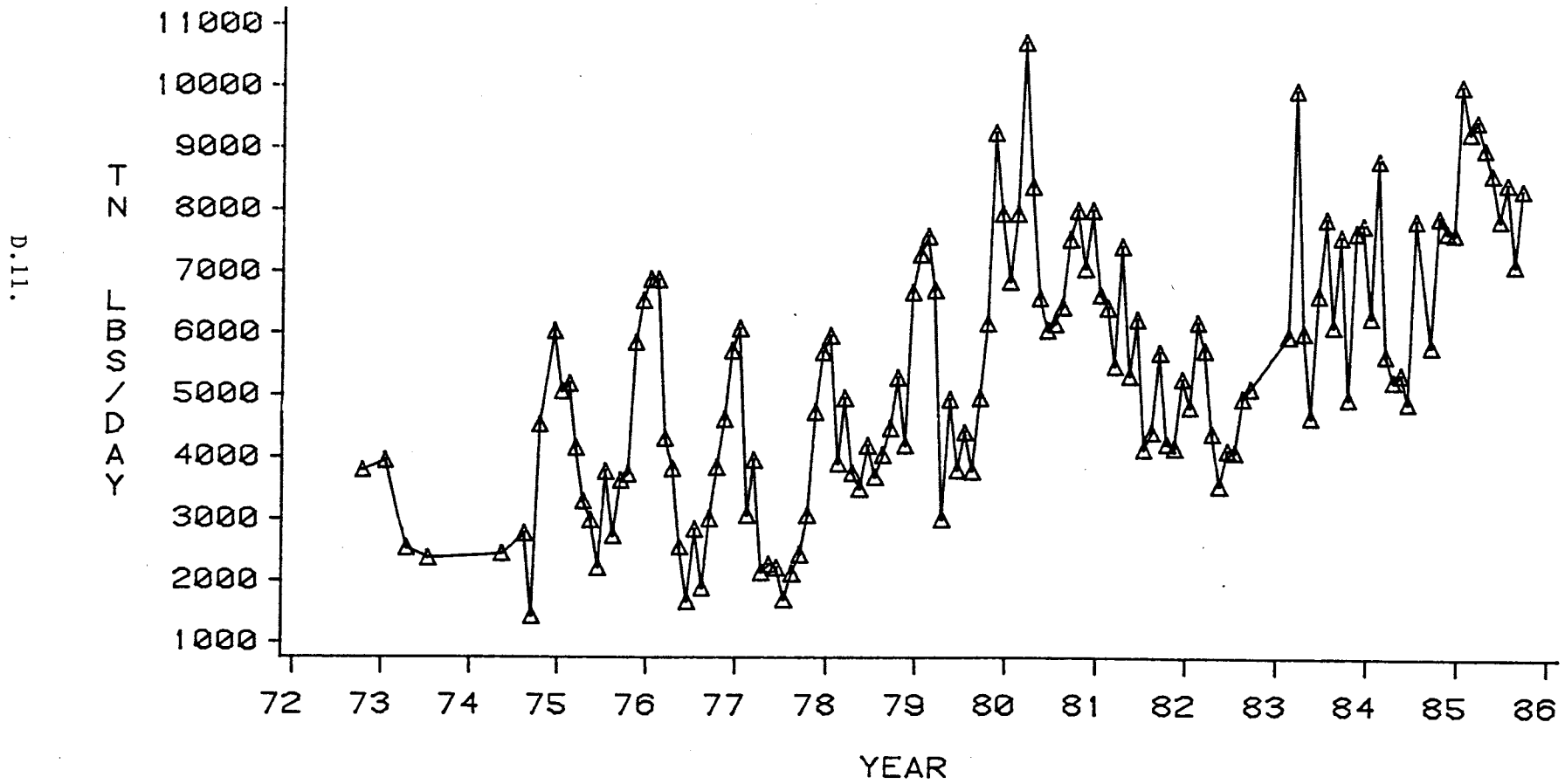


Figure 7. Total nitrogen loading at North Shore Road from 1972 through 1985.

# NORTH SHORE ROAD

TOTAL AMMONIA

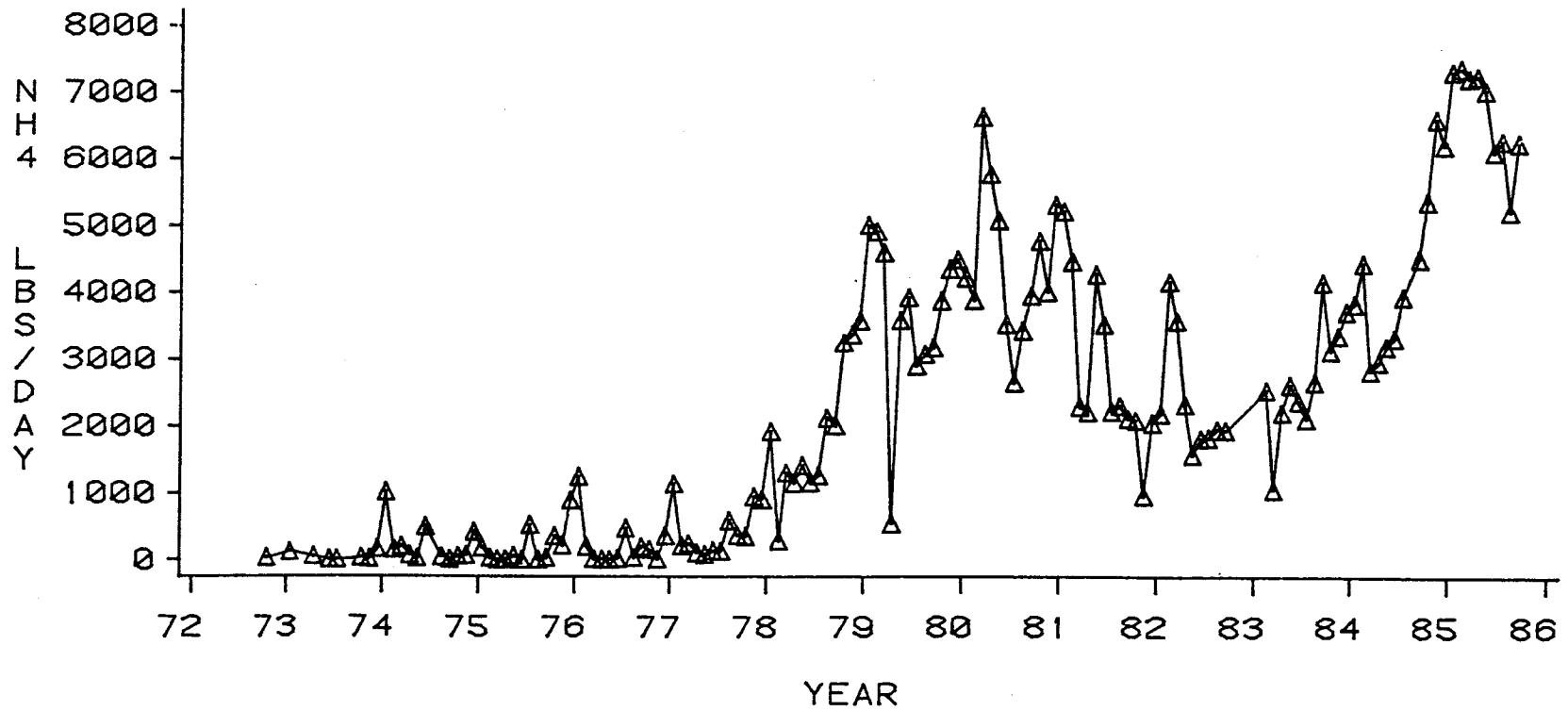


Figure 8. Total Ammonia loading at North Shore Road from 1972 through 1985.



## Nutrients

As with any tributary flow into a lake or reservoir there is a strong gradient in nutrient concentrations moving from the inner bay (STA 2) to Boulder Basin (STA 8). The highest gradients in concentrations occur between stations 2 and 3 and stations 3 and 4. Lower gradients occur outside of station 4. Likewise, large variations in nutrient levels occur at stations 2 and 3 with smaller variations at stations 4, 5 and 8.

### Total Phosphorus

Despite phosphorus removal from both sewage treatment facilities in 1981, summer phosphorus concentrations have more than doubled at station 2, tripled at station 3, and doubled at station 4 and 5 between 1979 and 1986 (Figure 9). Within this time period summer total phosphorus concentrations ranged from a mean of .079 mg/l at station 2 to .007 mg/l at station 8 with stations 3, 4 and 5 falling within these extremes. Concentrations have remained relatively stable (.006 - .009 mg/l) at station 8. Maximum total phosphorus was measured in 1986 at stations 2 and 3 coinciding with maximum chlorophyll a concentrations. Thus, despite a significant phosphorus load reduction at North Shore Road in 1981, in-lake concentrations were unaffected and have continued to increase. We believe the reason we did not observe a reduction of in-lake phosphorus is due to changes in plume dynamics; a higher percentage of wash nutrients are being transported to the epilimnetic waters of LVB. These changes are directly related to increasing wastewater flows, severe vertical and lateral erosion, and a loss of wetlands which have combined to alter wash water quality and thus plume characteristics. The exact hydrodynamic changes are not well understood, but it is unequivocal that these changes have occurred and to the detriment of water quality.

### Total Nitrogen

Although large variations exist in the data, total nitrogen has been increasing in Las Vegas Bay and Boulder Basin since 1979 (Figure 10). This closely follows annual nitrogen loading at NSR that has increased from 5800 lbs/day in 1979 to approximately 9400 lbs/day in 1986; a 64% increase. With the exception of 1982 and 1983 in-lake total nitrogen has progressively increased every year since 1979. Levels in 1985 and 1986 are 3 times those measured in 1979 at stations 2 and 3 and over 2 times those at stations 4 and 5. Increased loading and changing plume dynamics have increased total nitrogen all of the way out to station 8 where levels have increased by about 30%.

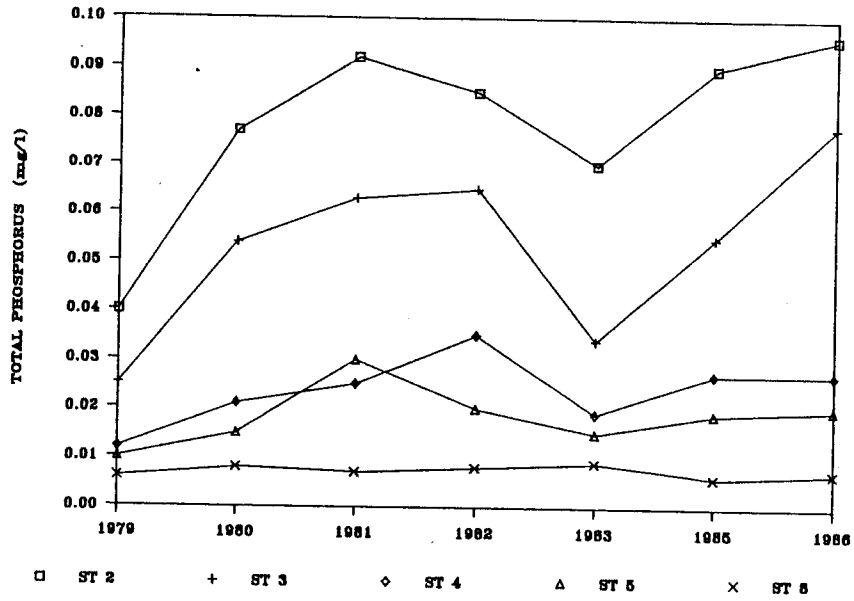


Figure 9. Mean summer total phosphorus concentrations in Las Vegas Bay from 1979 through 1986.

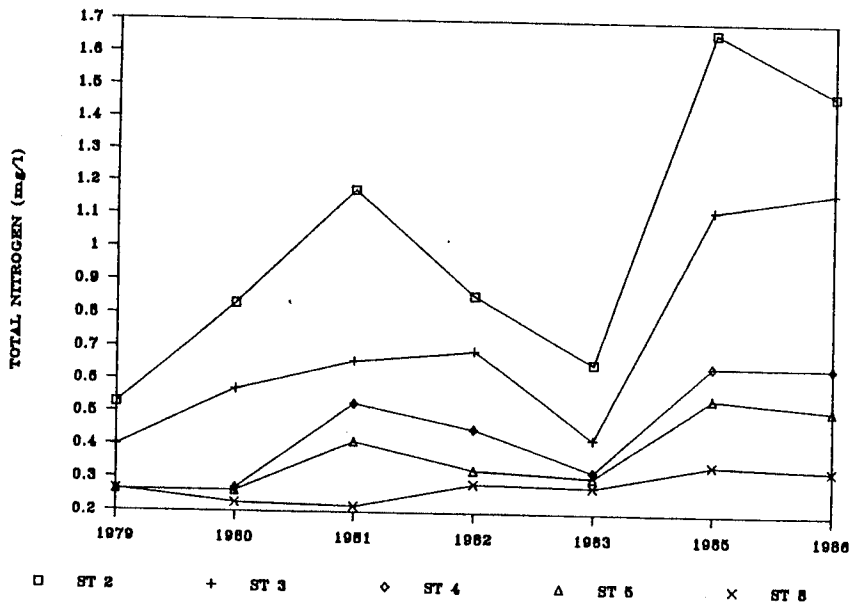


Figure 10. Mean summer total nitrogen concentrations in Las Vegas Bay from 1979 through 1986.

## Total Ammonia

Total ammonia concentrations at all stations remained relatively stable from 1979 through 1983. Between 1983 and 1985 station 2 total ammonia increased from .043 mg/l to .423 mg/l; an increase of about 8.8 times (Figure 11). Station 3 showed a similar trend increasing from .046 mg/l to .279 mg/l. This trend continued into 1986 with only slightly lower values. Stations 4, 5 and 8 increased slightly from 1982 to 1983 and by a large increment in 1985. From 1983 to 1985 total ammonia levels tripled at station 4 doubled at station 5, and increased slightly at station 8. This trend continued in the 1986 data.

## Chlorophyll a

As was the case with the nutrient concentrations, chlorophyll a, a measure of algal biomass, shows a strong gradient from the inner bay to Boulder Basin (Figure 12). This is not unexpected, as it is the nutrients that are supporting the algal growth rate.

Mean summer chlorophyll a from 1979 through 1986 at stations 2, 3, 4, 5 and 8 were 49.0, 34.4, 12.7, 7.9 and 1.7 ug/l, respectively. Stations 2 and 3 exhibited record high monthly mean chlorophyll a levels as well as record maximum levels during spring-summer 1986. At Station 2 chlorophyll a peaked at an all-time high of 378 ug/l on June 26 and averaged 147.8 ug/l in June, 63.3 ug/l in July and 100.7 ug/l in August. In 1986, chlorophyll a at station 3 averaged 43.7 ug/l in June, 49.3 ug/l in July, and 113.9 ug/l in August; all time peak chlorophyll a was measured on August 7 at 331.5 ug/l.

Station 2 summer chlorophyll a levels have been increasing since the mid-1970's (Figure 13). For example, at station 2 mean summer chlorophyll a levels have increased from an average of 15 ug/l from 1974 to 1978 to about 50 ug/l from 1979 to 1986. Summer peak chlorophyll a has increased from less than 40 ug/l in the mid-1970's to well over 100 ug/l since 1980 (Figure 14). In comparison, mean summer values have remained relatively steady at station 5 (Figure 13). However, summer maximum values have increased from less than 15 ug/l (1974-1978) to over 30 ug/l (1979-1986). Station 8 chlorophyll a declined slightly from 1974 to 1978, but has remained relatively stable (1.3-2.6 ug/l) since 1979.

High summer chlorophyll a in the inner bay in 1986 was associated with a large bloom of Microcystis, a group of noxious, scum-forming blue-green algae. The species is one of the most common bloom-forming algae (Prescott 1970) and is generally considered a sign of gross eutrophication. The species has been seen in Lake Mead before but never at densities observed in 1986 (Paulson 1986).

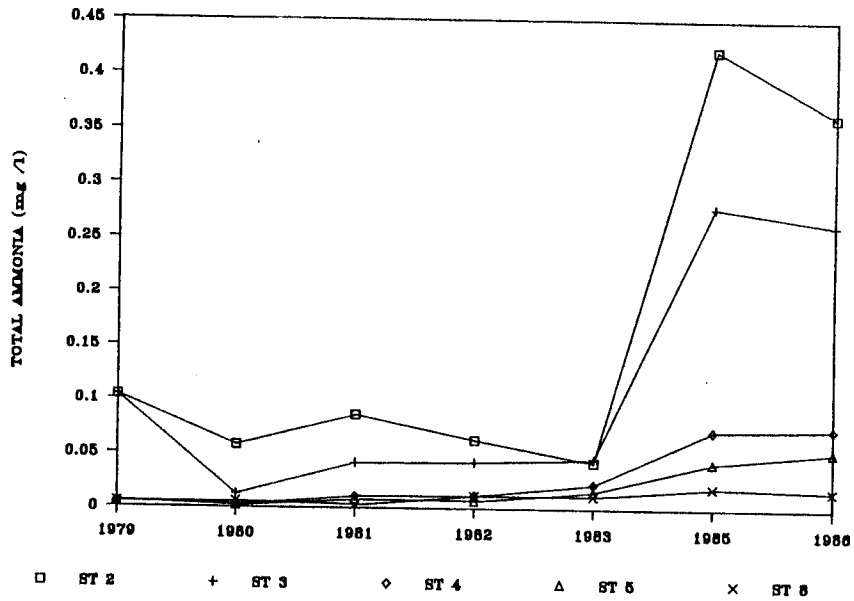


Figure 11. Mean summer total ammonia concentrations in Las Vegas Bay from 1979 through 1986.

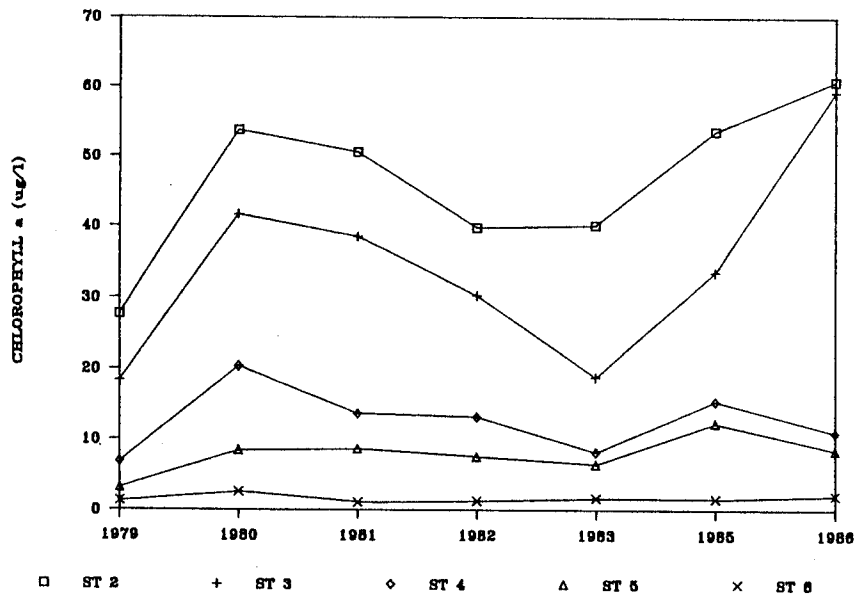


Figure 12. Mean summer chlorophyll a concentrations in Las Vegas Bay from 1979 through 1986.

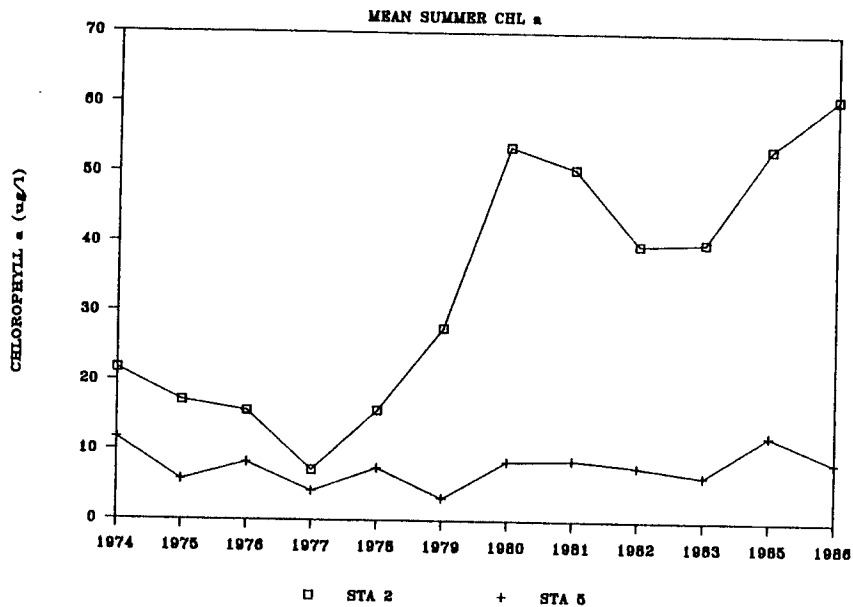


Figure 13. Mean summer chlorophyll a concentrations at Las Vegas Bay stations 2 and 5 from 1974 through 1986.

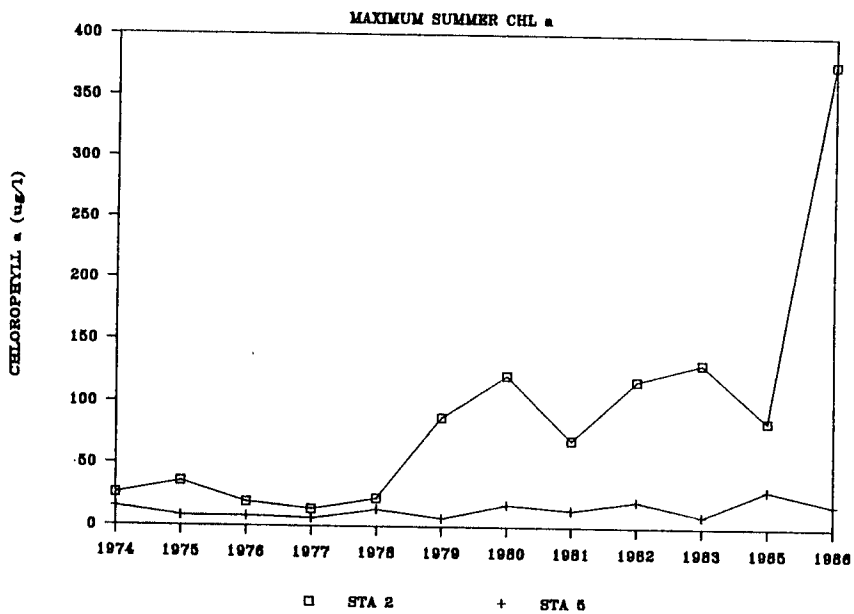


Figure 14. Maximum summer chlorophyll a concentrations at Las Vegas Bay stations 2 and 5 from 1974 through 1986.

During the 1986 bloom, surface scums appeared in late May and peaked in late June and early July. The bloom was especially apparent on calm days such as June 26 when surface scums covered most of the inner bay and extended to areas around the Las Vegas Wash Marina and boat ramp. The bloom was not as severe in the middle Las Vegas Bay, but colonies were visible past station 5 at times seen all the way out to Boulder Basin.

The dramatic increase in chlorophyll a in the inner bay in 1986 is directly related to the shift in algal species composition. Studies have shown that blue-green algae are not readily ingested or digested by zooplankton, and therefore do not represent a good food source (Lefevre 1950; Burns 1968; Schindler 1971; Hayward and Gallup 1976). Lack of grazing on the algae by the zooplankton leads to high concentrations of blue-greens commonly observed during a bloom. Due to the fact that zooplankton do not feed well on blue-green algae, a block in the food chain is created that effects the entire bioenergetics of the system on which the ecosystem depends. This phenomenon will have an adverse effect on all organisms within the food chain including the sport fish.

#### Nitrogen/Phosphorus Ratio

As a result of the photosynthetic reaction, algae will assimilate nitrogen and phosphorus from their aquatic environment in a ratio of between about 10 to 16 parts nitrogen to one part phosphorus until one of these two nutrients becomes depleted in the water assuming no other limitation exists. At that time, the nutrient present in the water body in the lowest concentration, relative to the physiological needs of the algae, will limit subsequent growth of the algae. Although there are large variations from one algal species to another it is generally accepted that the N/P ratio remains constant enough to accurately assess which of these two nutrients is likely to limit algal growth in a lake. Thus, an examination of the relative quantities of nitrogen and phosphorus in a lake at a given time, especially during the growing season, will indicate which of the two nutrients is "left over" after the other has been depleted by the algae. Clearly, the nutrient which is present in large quantities during periods of excessive algal growth is not limiting growth of the algae.

Several different ways of expressing the N/P ratio are possible. Some advocate using the total nitrogen (organic + inorganic nitrogen) to total phosphorus (organic + inorganic phosphorus) ratio and others the soluble nitrogen ( $\text{NH}_4\text{-N} + \text{NO}_3\text{-N} + \text{NO}_2\text{-N}$ ) to soluble phosphorus (orthophosphate) forms. The dissolved forms of nitrogen and phosphorus are generally considered to be immediately available for algal uptake.

Total nitrogen (TN) to total phosphorus (TP) ratios increase from the inner to outer Las Vegas Bay (Figure 15). Average summer TN/TP ratios from 1979 to 1986 ranged from 14.0 at station 2 to 38.7 at station 8. This suggests that Las Vegas Bay is largely phosphorus limited coming closer to nitrogen limitation in the inner bay. The TN/TP ratio in Las Vegas Bay has generally been increasing in recent years largely as a result of increasing nitrogen levels.

Total soluble inorganic nitrogen (TIN) to soluble orthophosphate (OP) ratios have increased dramatically from 1979 to 1986 (Figure 16). Within this period inner bay TIN/OP increased from less than 10 to over 60 and the middle bay from less than 10 to over 50. A large increase in the TIN/OP ratio occurred between 1980 (pre-phosphorus removal) and 1981 (post-phosphorus removal). In this time period summer dissolved orthophosphorus decreased from .037 mg/l to .012 mg/l at station 2 and from .025 mg/l to .006 mg/l at station 3. During the same period the TIN levels doubled at station 2 and tripled at station 3. Similar changes occurred in the wash TIN/OP ratio. The summer wash ratio increased from about 3 in 1980 to over 30 in 1981 at North Shore Road.

Clearly, the nutrient present in the largest quantity relative to the needs of algal growth is inorganic nitrogen and the lowest quantity is orthophosphorus. This analysis strongly suggests that, on the basis of TIN/OP ratios, phosphorus is the limiting nutrient in Las Vegas Bay.

#### Secchi Depth (Water Clarity)

Secchi depth is a measure of visibility or the depth to which one may see into the water. The Secchi disc is a simple device used to estimate this depth. It consists of a weighted circular plate, 20 cm in diameter with the surface painted with opposing black and white quarters. The disc is attached to a calibrated line that is slowly lowered into the water until it disappears and then slowly raised until it reappears. The average of the two readings is the Secchi disc visibility (Lind 1974).

In lakes with low inorganic turbidity, there is usually an inverse relationship between Secchi depth and chlorophyll a; as chlorophyll a increases Secchi depth (water clarity) decreases. This relationship is very strong for Las Vegas Bay (Figure 17 and 18). The relationship can be described by the equation,  $\log \text{Secchi depth} = (-.52)(\log \text{chl}_a) + .98$ . Mean summer Secchi depth is relatively low (1.5m (5 ft.) from 1980-1986) at station 2 where chlorophyll a is high and gradually increases out into the middle and outer bay as chlorophyll a

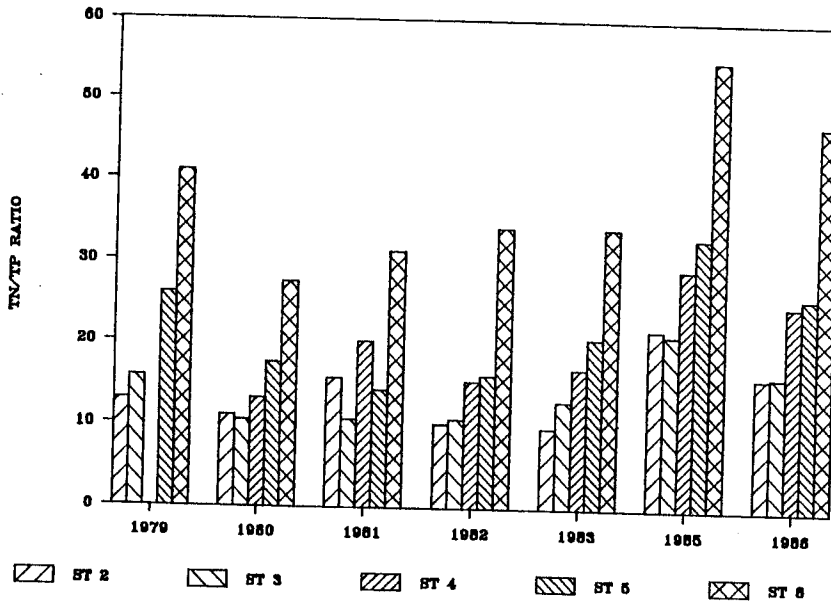


Figure 15. Summer mean total nitrogen to total phosphorus ratios in Las Vegas Bay from 1979 through 1986.

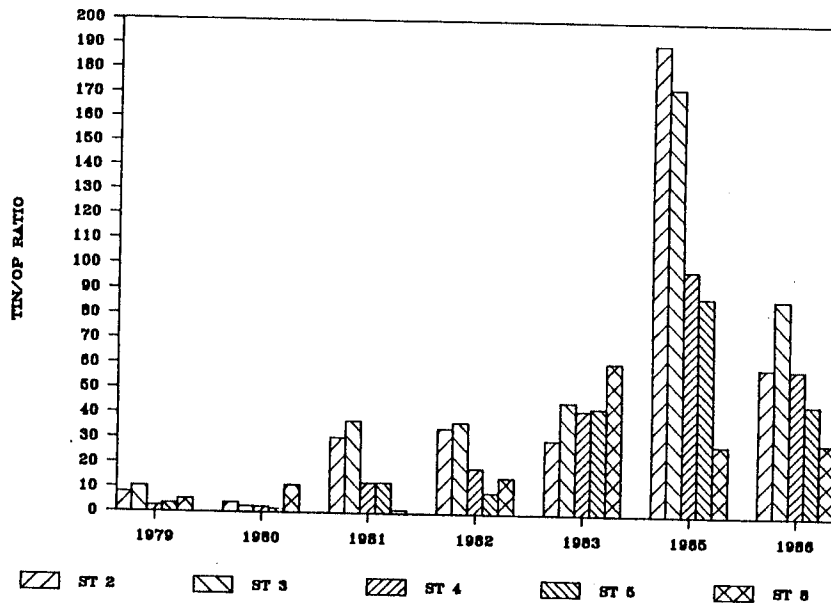


Figure 16. Summer mean soluble total inorganic nitrogen (TIN) to soluble orthophosphorus in Las Vegas Bay from 1979 through 1986.



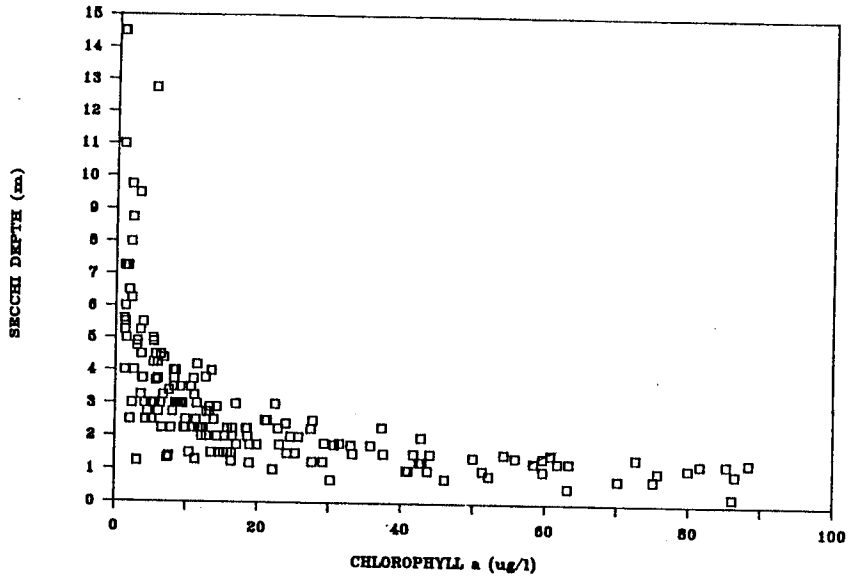


Figure 17. Relationships between Secchi depth and chlorophyll a in Las Vegas Bay.

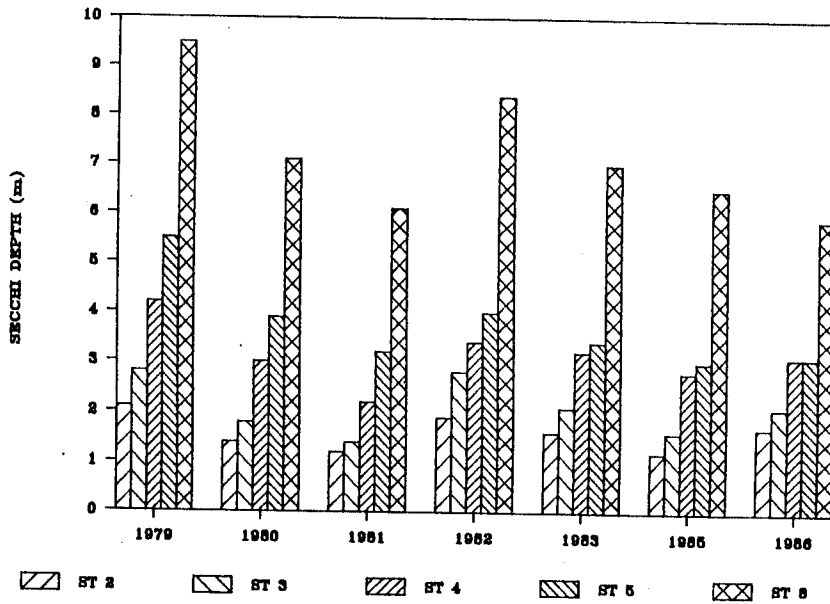


Figure 18. Mean summer Secchi depth at Las Vegas Bay stations from 1979 through 1986.

decreases. Station 8 summer Secchi depth has averaged slightly over 7 m (23 ft.) since 1979, which is an indication of its very low chlorophyll a levels and concurrent productivity.

### Lake Elevation

Lake Mead's surface elevation has been suggested by some to be an important factor in controlling Las Vegas Bay water quality (Deacon 1977; Brown and Caldwell 1982). Deacon (1977) attributed improvements in water quality to dilution resulting from increased water levels in Lake Mead. Figure 19 shows that Lake Mead's average summer surface elevation increased from 1970 up until the high runoff year of 1983 when it overflowed the spillway. From 1983 through 1986 the lake's surface elevation has shown a general decline and projections by the U.S. Bureau of Reclamation indicate that the decline will continue for the next several years (U.S.B.R., personal communication). Although the diluting effect of lake elevation is not well understood and not quantifiable it must be assumed that it cannot be used as a mitigating factor in the future management of water quality in Las Vegas Bay. Declining water levels may, in fact, cause a deterioration of existing water quality at current nutrient loading rates.

### Trophic Classification

Lakes are commonly classified according to their biological productivity as measured by physical, chemical and biological parameters. Oligotrophic lakes are characterized by low nutrient levels, low biological productivity and usually maintain high hypolimnetic and benthic oxygen levels throughout the year (Goldman and Horne 1983). There is good light penetration through the clear waters and there is little or no rooted aquatic vegetation. In contrast, eutrophic lakes have high nutrient and inorganic matter levels and hypolimnetic oxygen is likely to be depleted in the summer. Due to the high production of algae, light penetration is limited. Mesotrophic lakes are generally considered to have a moderate productivity level and fall somewhere between the two extremes.

Based on a review of the OECD Cooperative Program on eutrophication, data from 128 lakes and reservoirs from around the world (40 from U.S.) were analyzed and a trophic state classification scheme developed (Table 1). The lakes and reservoirs from which the data were collected ranged from ultra-oligotrophic pristine lakes to highly eutrophic ones, and from small, shallow, highly flushed lakes to the Great Lakes.

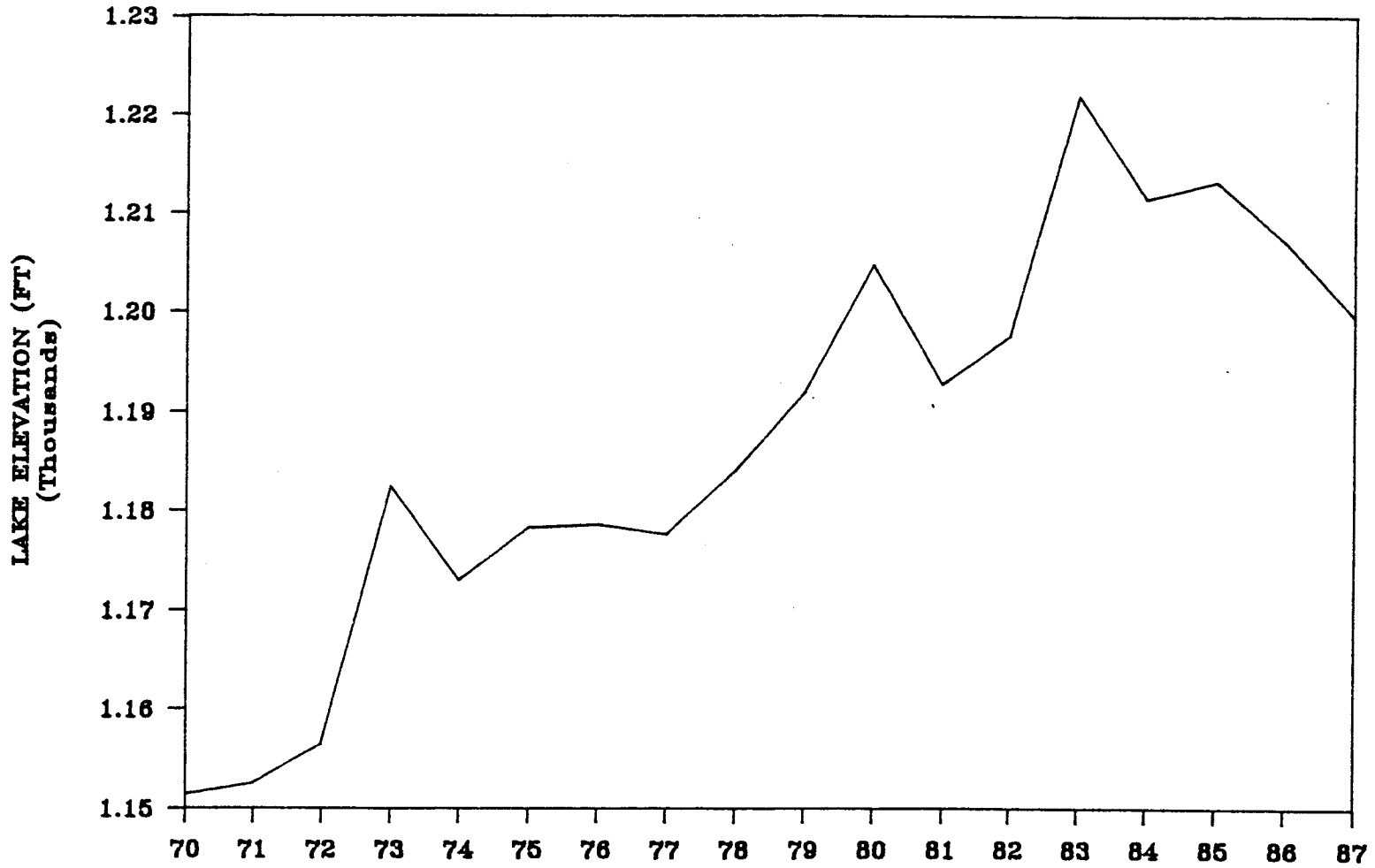


Figure 19. Mean summer Lake Mead surface elevation from 1970 through 1986 (1987 projected.)

Table 1. Classification of trophic status of lakes and reservoirs from the OECD eutrophication study (Jones and Lee 1982)

<u>Classification</u>	<u>Average Chlorophyll a (ug/l)</u>	<u>Average Secchi Depth (m)</u>	<u>Average Total Phosphorus (mg/l)</u>
Oligotrophic	<2.0	>4.6	<.006
Oligo-Mestrophic	2.1-2.9	4.5-3.8	.006-.010
Mesotrophic	3.0-6.9	3.7-2.4	.010-.029
Meso-Eutrophic	7.0-9.9	2.3-1.8	.030-.045
Eutrophic	<u>&gt;10.0</u>	<u>&lt;1.7</u>	<u>&gt;0.46</u>

Table 2. Trophic classification of Las Vegas Bay stations 2 through 8 using OECD method.

<u>Parameter</u>	<u>Station 2</u>	<u>Station 3</u>	<u>Station 4</u>	<u>Station 5</u>	<u>Station 8</u>
Chlorophyll a	eutrophic	eutrophic	eutrophic	meso-eutrophic	oligotrophic
Secchi depth	eutrophic	meso-eutrophic	mesotrophic	mesotrophic	oligotrophic
Total Phosphorus	eutrophic	eutrophic	mesotrophic	mesotrophic	oligo-mesotrophic
Overall Classification	highly eutrophic	eutrophic	mesotrophic	mesotrophic	oligotrophic

It was generally found that waterbodies were classified as eutrophic when chlorophyll a exceeded 10 ug/l and oligotrophic if they were less than 2 ug/l. Between these values is a transition zone with waterbodies having planktonic chlorophyll concentrations of 3-7 ug/l. This classification was extended to use Secchi depth and total phosphorus.

Using this classification scheme station 2 is classified as highly eutrophic station 3 as eutrophic, stations 4 and 5 as mesotrophic and station 8 as oligotrophic.

Another trophic state index was developed by Carlson (1977) that incorporates most lakes in a scale of 0 to 100. Each major division (10, 20, 30, etc.) represents a doubling in algal biomass. The index number can be calculated from chlorophyll a, Secchi depth, and total phosphorus using the following equations:

$$TSI (SD) = 10 \left( 6 - \frac{\ln SD}{\ln 2} \right)$$

$$TSI (CHL) = 10 \left( 6 - \frac{2.04 - 0.68 \ln CHL}{\ln 2} \right)$$

$$TSI (TP) = 10 \left( 6 - \frac{\ln TP}{\ln 2} \right)$$

In general, lakes and reservoirs with a TSI from 0-40 are oligotrophic, 40-50 mesotrophic, and greater than 50 eutrophic. The method classified regions of the bay consistent with the OECD method (Table 2). Stations 2 and 3 were classified as eutrophic, station 4 as meso-eutrophic, station 5 as mesotrophic, and station 8 as oligotrophic.

Table 3. Application of Carlson's trophic state index (TSI) to Las Vegas Bay mean summer values for 1979-1986.

		<u>Station 2</u>	<u>Station 3</u>	<u>Station 4</u>	<u>Station 5</u>	<u>Station 8</u>
Chloro- phyll <u>a</u>	TSI	54.2	49.3	43.7	41.1	31.5
	Trophic State	eutrophic	meso- eutrophic	mesotrophic	oligo- mesotrophic	oligotrophic
Secchi Depth	TSI	68.8	65.2	56.9	50.9	35.8
	Trophic State	eutrophic	eutrophic	eutrophic	meso- eutrophic	oligotrophic
Total Phosphorus	TSI	67.2	61.4	50.0	45.8	32.2
	Trophic State	eutrophic	eutrophic	meso- eutrophic	mesotrophic	oligotrophic
Overall	TSI	63.4	58.6	50.2	45.9	33.2
	Trophic State	eutrophic	eutrophic	meso- eutrophic	mesotrophic	oligotrophic

The two classification schemes are also in good agreement with many others that strictly rely on chlorophyll a as the trophic state indicator (Sakamoto 1966; National Academy of Science 1972; U.S. EPA 1974).

### Dissolved Oxygen

Dissolved oxygen concentrations are an important gauge of existing water quality and the ability of a waterbody to support a well-balanced aquatic fauna. As pointed out earlier hypolimnetic dissolved oxygen depressions are a symptom of eutrophication. Oxygen depletion is generally caused by increased amounts of planktonic algae in the surface waters, which settle through the thermocline and become a source of biochemical oxygen demand (BOD) in the hypolimnetic water column and sediments. In Las Vegas Bay, which has a significant ammonia load, the oxygen demand through nitrification ( $\text{NH}_4$   $\text{NO}_2$   $\text{NO}_3$ ) is another significant source of BOD to the hypolimnion.

EPA (1976) recommends that a minimum concentration of dissolved oxygen to maintain good fish populations is 5.0 mg/l. Further, decreased dissolved oxygen levels, if sufficiently severe, can adversely affect aquatic insects and zooplankton upon which fish feed.

Another important consideration is the potential release of phosphorus from sediments under low dissolved oxygen conditions. Much of the phosphorus found in sediments is adsorbed on ferric hydroxides. Under reducing conditions, these iron compounds dissolve and phosphorus is released. Investigators have generally found that when dissolved oxygen levels fall below 1 mg/l phosphorus will be released from lake sediments (Mortimer 1971; Fillos and Swanson 1975).

Most parts of Lake Mead experience a metalimnetic oxygen depression, which is not an uncommon condition. The metalimnetic depletion in the major portions of Lake Mead begin in late April and becomes more extensive as the summer progresses. Dissolved oxygen levels only occasionally drop below 5 mg/l and this depletion is limited to the metalimnion only. The depletion begins to dissipate with the lowering of the thermocline in October. However, due to the higher oxygen demanding substances, the inner and middle Las Vegas Bay zone of oxygen depletion extends into the hypolimnion to the lake bottom and by late summer becomes quite severe.

Station 2 is shallow enough to remain well mixed throughout the summer months and does not experience oxygen depletion. Between station 2 and 3 the lake becomes deep enough for a thermocline to become established and a hypolimnion forms.

Hypolimnetic depletion begins in late April in Las Vegas Bay and becomes more extensive as the summer progresses (Figures 20 through 22). Minimum dissolved oxygen concentrations increase with increasing distance from Las Vegas Wash likely as a function of BOD and hypolimnetic volume. For example, on June 26 at station 3 most of the hypolimnion had dissolved oxygen levels less than 1 mg/l. In comparison, station 4 and 5 both had severe metalimnetic depletions with higher hypolimnetic values. By August 28, depletion remained about the same at station 3 and became more severe at stations 4 and 5. At station 4, hypolimnetic dissolved oxygen levels had been reduced to less than 2 mg/l and less than 3 mg/l at station 5. By the end of October station 3 was well mixed and reoxygenated throughout the water column. Stations 4 and 5 had mixed to about 30m, both still showing signs of the summer depletion below this level.

Station 8 exhibits dissolved oxygen profiles entirely different from those in Las Vegas Bay (Figure 23). By late summer a true metalimnetic depletion had developed which persisted into fall. Rarely does dissolved oxygen fall below 5 mg/l during summer-fall stratification at station 8 in Boulder Basin.

The progression of the dissolved oxygen depletion at station 5 from May through November of 1980 through 1986 is plotted on Figure 24. The figure shows the minimum dissolved oxygen concentrations for each sampling date. The same general pattern occurred during each year. However, prior to 1985 minimum dissolved oxygen levels did not drop below 5 mg/l until the end of June. In fact, since 1968 dissolved oxygen had not been depleted to 5 mg/l before late June or early July (Brown and Caldwell 1982). In 1985 and 1986, however, the depletion to 5 mg/l occurred in early June and remained lower throughout the season than in previous years. This pattern has emerged in spite of the fact that lake elevation and thus hypolimnetic volume has generally been increasing since 1970. The projected future decline in lake elevation in conjunction with or without an increasing load of oxygen demanding substances will exacerbate this problem.

Studies conducted by the Division of Environmental Protection in 1985 suggest that fish survival is low below the thermocline at stations 3 and 4. Young largemouth bass held in suspended live-cages showed significant mortality



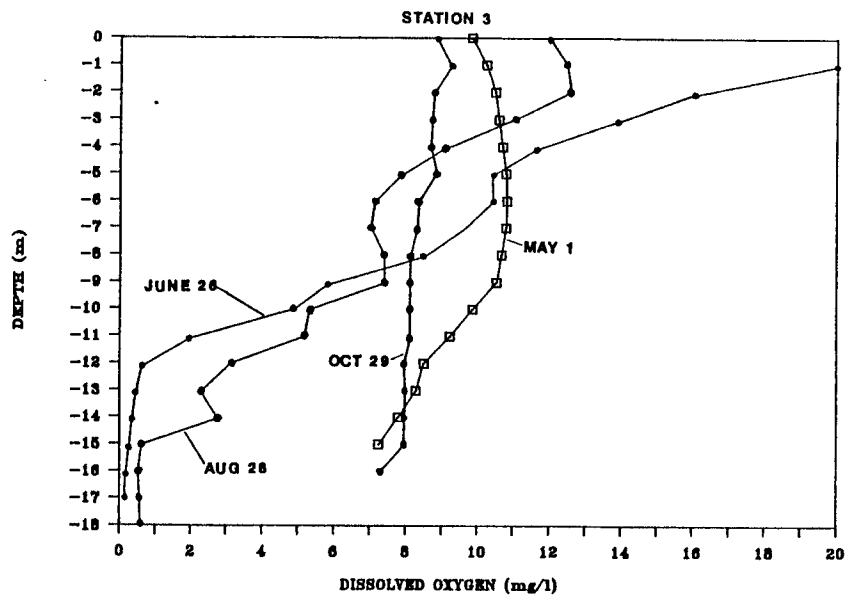


Figure 20. Dissolved oxygen profiles at station 3 on four selected days in 1986.

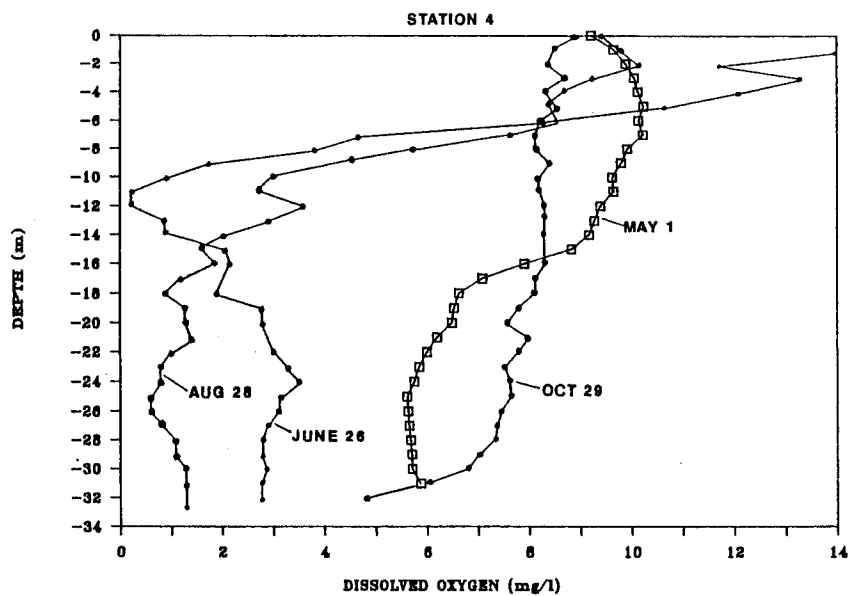


Figure 21. Dissolved oxygen profiles at station 4 on four selected days in 1986.

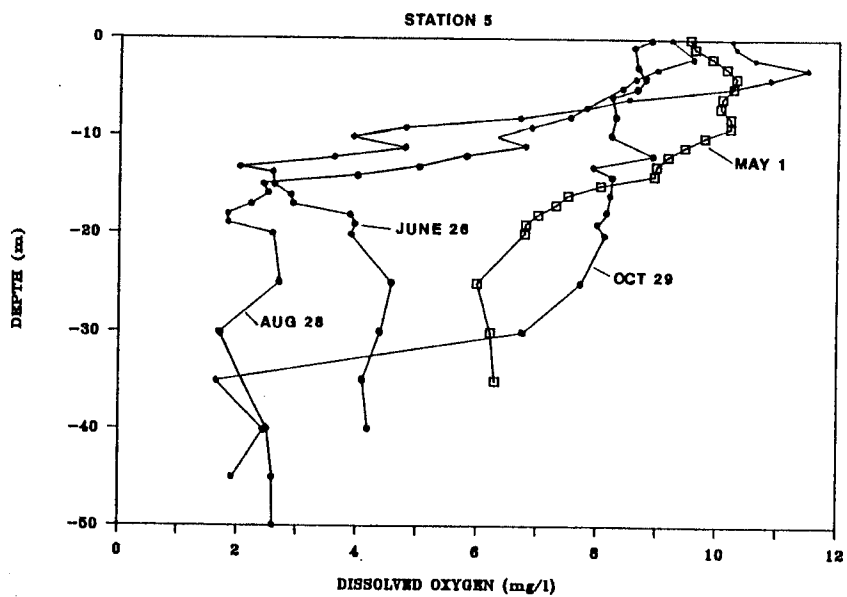


Figure 22. Dissolved oxygen profiles at station 5 on four selected days in 1986.

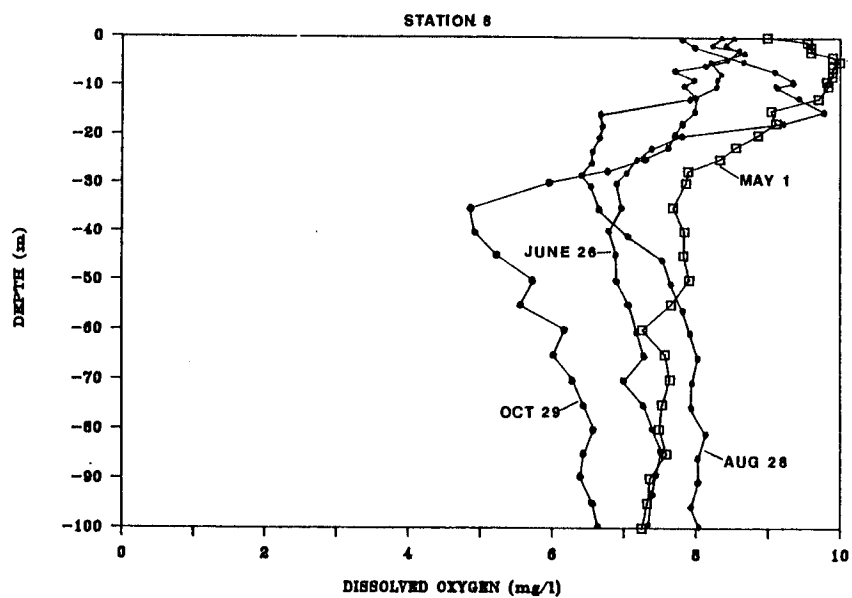


Figure 23. Dissolved oxygen profiles at station 8 on four selected days in 1986.

D.31.

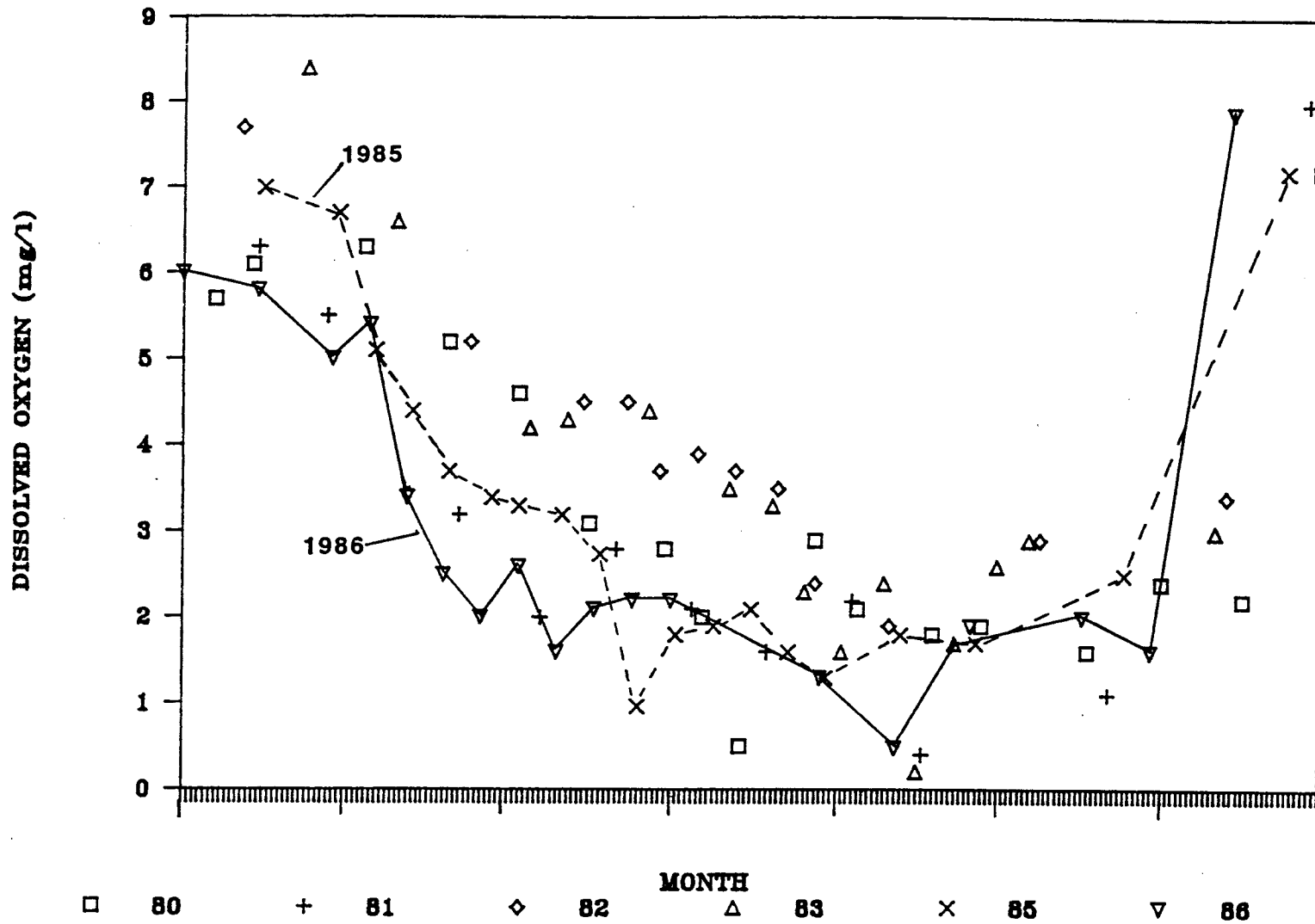


Figure 24. Minimum water column dissolved oxygen concentration during the growing season at station 5 from 1980 through 1986.

in areas where dissolved oxygen dropped below 1.5 to 2.0 mg/l (NDEP 1985). Wild fish in the bay would likely avoid areas with dissolved oxygen levels less than about 3 mg/l. The bioassay supports the contention that fish are likely restricted to epilimnetic habitat during hypolimnetic dissolved oxygen depletions during most of the summer and fall period in parts of the inner and middle Las Vegas Bay.

Many would argue that low hypolimnetic dissolved oxygen levels have little impact on a warmwater fishery. However, adult striped bass are considered to be a cool-water fish and prefer water temperatures less than 23 C (Turner and Farley 1971). Temperatures below 23 C are generally confined to the area below the thermocline during summer months. Under these conditions striped bass stay below the thermocline and swim up into surface waters to feed before returning to the cooler water. In late summer, striped bass may avoid Las Vegas Bay inward of station 5. This scenerio could remove striped bass from their food supply in the surface waters of the inner and middle bay.

Further decreases in the hypolimnetic dissolved oxygen concentrations in Las Vegas Bay will adversely affect available fish habitat during summer-fall periods. If dissolved oxygen levels drop below 1 mg/l over the sediments, internal phosphorus loading would be expected to become a future nutrient source to the bay.

#### Management Objectives for Las Vegas Bay - Lake Mead Water Quality

Lake management involves the formulation of objectives, not all of which are compatible in a given waterbody. Common objectives such as high quality water supply, suitability for contact recreation, and pleasing aesthetic properties are generally associated with low algal biomass and chlorophyll a values. Increases in plankton biomass in a lake elevate the cost of treatment for water supply, both where human consumption is involved and in the case of industrial process water. Removal of plankton from a water supply becomes necessary when plankton numbers become high enough to cause odor, taste, health, or aesthetic problems or clogs the distribution system. Costs rise abruptly at each new level of treatment resulting from capital expenses and gradually increase between steps as a function of operational costs largely associated with filtration and chemical additives. Where water supply is concerned, maintenance of the lowest possible plankton biomass is clearly desirable.

Water supply, contact recreation and aesthetics are recognized beneficial uses of Las Vegas Bay and Lake Mead. If these were the only uses, management for an oligotrophic bay (chlorophyll a <2-5 ug/l) would be the objective. However, production of fish for sportfishing is often impaired by decreases in phytoplankton growth. Sportfishing is an important beneficial use in Lake Mead and the waterbody, as a whole, is considered lacking in the food resources necessary to support a productive sport fishery (Baker and Paulson 1983; Evans and Paulson 1985; Paulson and Baker 1983; Prentki et al. 1981). The relationships between phytoplankton biomass and fish yield varies considerably among lakes, but a distinct relationship exists. Empirically derived relationships indicate that increased phytoplankton production does lead to greater fish production (Ryder et al. 1974; Oglesby 1977; Mills and Schiavone 1982). Based on this premise, experimental fertilization of a large area of the Overton Arm for the purpose of increasing fish productivity is planned for Spring 1987 (Paulson et al. 1987). Experimentation during summer 1986 demonstrated that additions of nitrogen and phosphorus can increase the level of productivity in the lake from an oligotrophic to a mesotrophic state (5-10 ug/l chlorophyll a) in just a few days.

The above generalizations suggest that there is a potential conflict or incompatibility between fishery optimization and other management objectives. The available data suggests that during the summer months the Las Vegas Wash nutrient load has little effect on the productivity in the open waters of Boulder Basin (near station 8). Even during 1986, when record high chlorophyll a values were measured in Las Vegas Bay, extremely high chlorophyll a values at station 3 did nothing to benefit station 8 productivity.

The algal scums that developed in 1986 were composed of blue-green algae that are considered undesirable to the fishery food chain. The surface scum extended into the middle bay where it was highly visible to Las Vegas Wash campground, marina, and boat ramp users. Plankton counts on May 2 at the Southern Nevada Water system inlet were dominated by Anacystis sp. (Microcystis sp.) (29,000 cells/ml) and as a result the water treatment plant experienced decreased filter runs (letter from Las Vegas Valley Water District dated June 30, 1986).

Surface scums or dense blooms of algae are generally considered unattractive and in some cases represent a health hazard. Many species of blue-green algae are known to cause gastroenteritis in humans. When blooms of these toxic species become concentrated enough it can cause illness or death in almost any mammal, bird, or fish which ingest enough of the toxic cells (Carmichael 1981; Gorham and Carmichael 1980). A visible abundance of planktonic plants may deter swimming. Decreased water clarity reduces recreational safety, especially where subsurface obstructions are prevalent.

Periphyton (attached algae) growth in Las Vegas Bay has been a problem in the past and was first reported in 1967 when floating mats of Cladophora were seen in the bay (Brown and Caldwell 1982, Paulson, UNLV Personal Communication). There were also complaints about algae growth on boat hulls by boat owners at Las Vegas Wash Marina, particularly during the early 1970's.

The water quality conditions observed in Las Vegas Bay during spring-summer 1986 were clearly unacceptable and degrading to the beneficial uses of the bay, including the fishery. In cooperation with the Nevada Department of Wildlife, Lake Mead Limnological Research Center, and other agency personnel, a consensus was reached that the water quality characteristics related to productivity (specifically chlorophyll a levels) and associated desirable algal species observed in Las Vegas Bay between 1981 and 1985 was protective of the beneficial uses associated with the bay such as the marina, campground and water supply, and yet provided an acceptable level of productivity for the bay sport fishery.

Management objectives for Las Vegas Bay are as follows:

- 1) The dominant algae shall be of the non-surface scum forming variety.
- 2) The trophic status of inner Las Vegas Bay must not deteriorate below its 1981-1985 eutrophic classification with summer mean chlorophyll a of 45 ug/l at station 2 and 30 ug/l at station 3.
- 3) The trophic status of middle Las Vegas Bay will maintain its 1981-1985 mesotrophic classification with summer mean chlorophyll a of 12 ug/l at station 4 and 9 ug/l at station 5.
- 4) Hypolimnetic dissolved oxygen depletions should improve over 1985-86 levels due to a reduction in oxygen demanding materials (NH<sub>4</sub> and algal biomass).
- 5) Water clarity will be maintained at desirable levels (e.g. Secchi depth: sta 3, 1.6 m; sta 4, 2.6m; sta 5, 3.0 m; sta 8, >6m using the equation,  $\log \text{Secchi depth} = (-.52)(\log \text{CHL}_a) + .98$ ).
- 6) Efforts will be made to increase the productivity of the overall Boulder Basin area from an oligotrophic to a meso-oligotrophic level by recommending a seasonal discharge limit for total phosphorus.

## Recommended Chlorophyll a Standard

In order to protect the beneficial uses of Las Vegas Bay the NDEP feels that chlorophyll a values must be maintained below 1986 values and the species composition be of the non-blue-green variety. NDEP believes, on average, that summer water quality conditions observed between 1981 through 1985 were protective of the beneficial uses and that the long-term summer average chlorophyll should not increase above the average levels of 1981 through 1985. Thus, the development of the recommended standard to meet the objective must rely on data collected over this period. The following describes the methodology used by the Division to arrive at its recommended standard to achieve this objective.

- 1) Summer data (July-September) was used because it contained from 2 to 4 measurements per month (n=41) compared to spring when sampling frequency was low (n=13). Maximum chlorophyll a concentrations occurred during summer and we feel these values would be protective of the entire growing season (April-September).
- 2) Target chlorophyll a concentrations were developed by first calculating mean monthly values for the summer periods of 1981-1985 for stations 2, 3, 4, 5 and 8; annual summer means were calculated from the monthly means of summer months (July-Sept.) for each year. The means for each year were then averaged for a grand mean chlorophyll a concentration. They are as follows:

### Long Term Target Summer Means

Station 2	45 ug/l
Station 3	30 ug/l
Station 4	12 ug/l
Station 5	9 ug/l

- 3) The Las Vegas Bay chlorophyll a standard will be controlled at station 3 and will be based on a distributional analysis of the 1981-85 chlorophyll a data set. The rationale is that if the target chlorophyll a value is achieved at station 3, then target values outside and inside of station 3 will also be achieved. Station 3 was selected as the control point because it is "upstream" from the marina-boat ramp area and a logical location from which to control eutrophication.

- 4) Mean monthly summer chlorophyll a from the 1981-85 data set was plotted on log probability paper to estimate the probability of non-exceedance (Figure 25). The plotting position is ranked from low to high and is approximately equal to the probability of non-exceedance. Our objectives would be to see the same distribution of mean summer chlorophyll a in the future. The plot suggests that to achieve a long-term summer mean of 30 ug/l, one must accept a few monthly means above this value.
- 5) Figure 26 shows the sample distribution of summer chlorophyll a at station 3 from 1979-1986. The figure shows the mean, median, minimum, maximum, and the 25th and 75th percentiles by year. Examination of the figure shows that maximum chlorophyll a is more closely related to the mean than the median. A comparison of the 1985 and 1986 data sets illustrates this point. Although 1986 water quality conditions were clearly undesirable, the median was lower than in 1985 when conditions were acceptable. The mean more accurately reflected the poor water quality conditions of 1986 ( $x = 62$  ug/l) than the more desirable 1985 conditions ( $x = 34$  ug/l). We, therefore, feel the mean is a more reliable indicator of water quality than the median. Figure 26 shows that to achieve a long-term summer mean of 30 ug/l one must accept a few summer means above this value.

Based on the distribution of mean monthly summer chlorophyll a in Figure 25 and mean summer chlorophyll a in Figure 26 NDEP recommends the following water quality standard at station 3 and the open waters of Lake Mead:

- No more than one monthly mean shall exceed 45 ug/l in any calendar year.
- Mean summer (July-September) chlorophyll a shall not exceed 40 ug/l. The 4 year mean of summer means shall not exceed 30 ug/l.
- Mean is defined here as the average of at least two samples per month and the daily value to be used will consist of the average of at least three sights at the cross section of Station 3 which shall be representative of the top 5 meters of the cross section.
- Station 3 is that location in the center of the channel where the depth is 16 to 18 meters.



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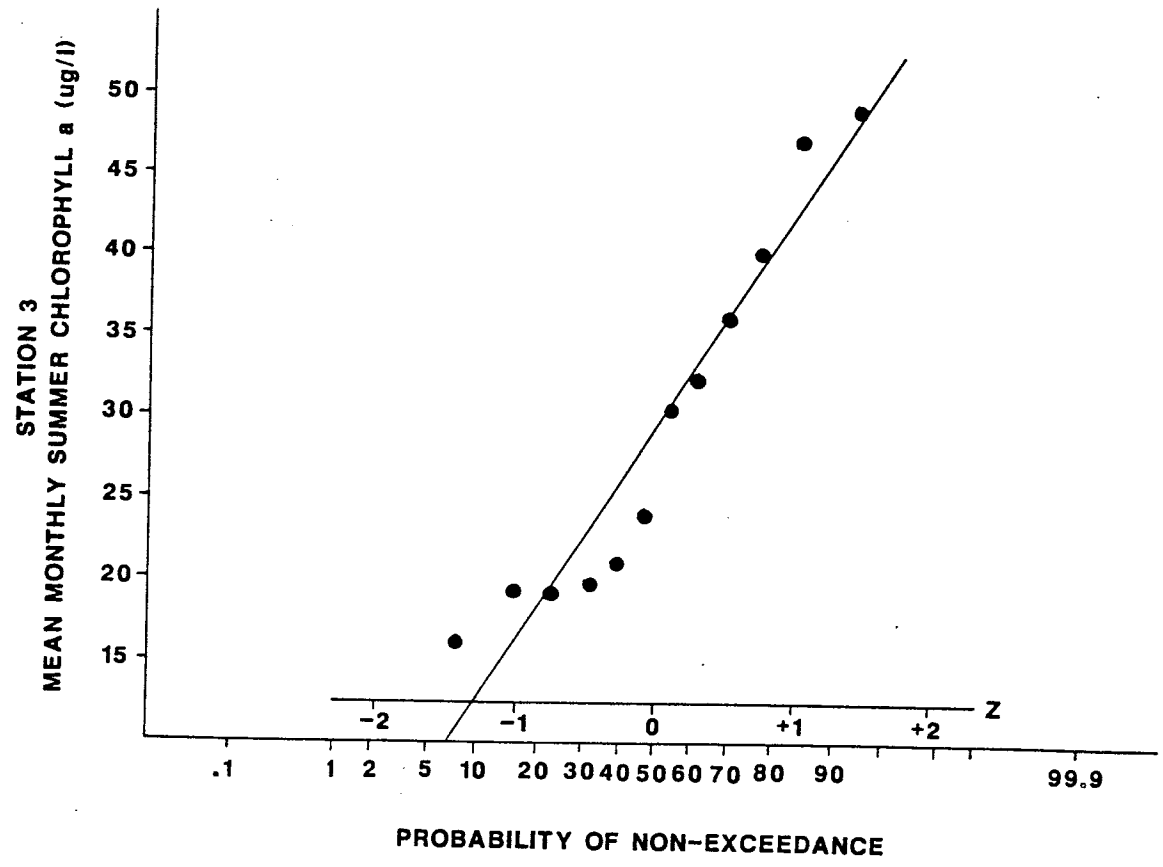


Figure 25. Probability plot of mean monthly summer chlorophyll a at station 3.

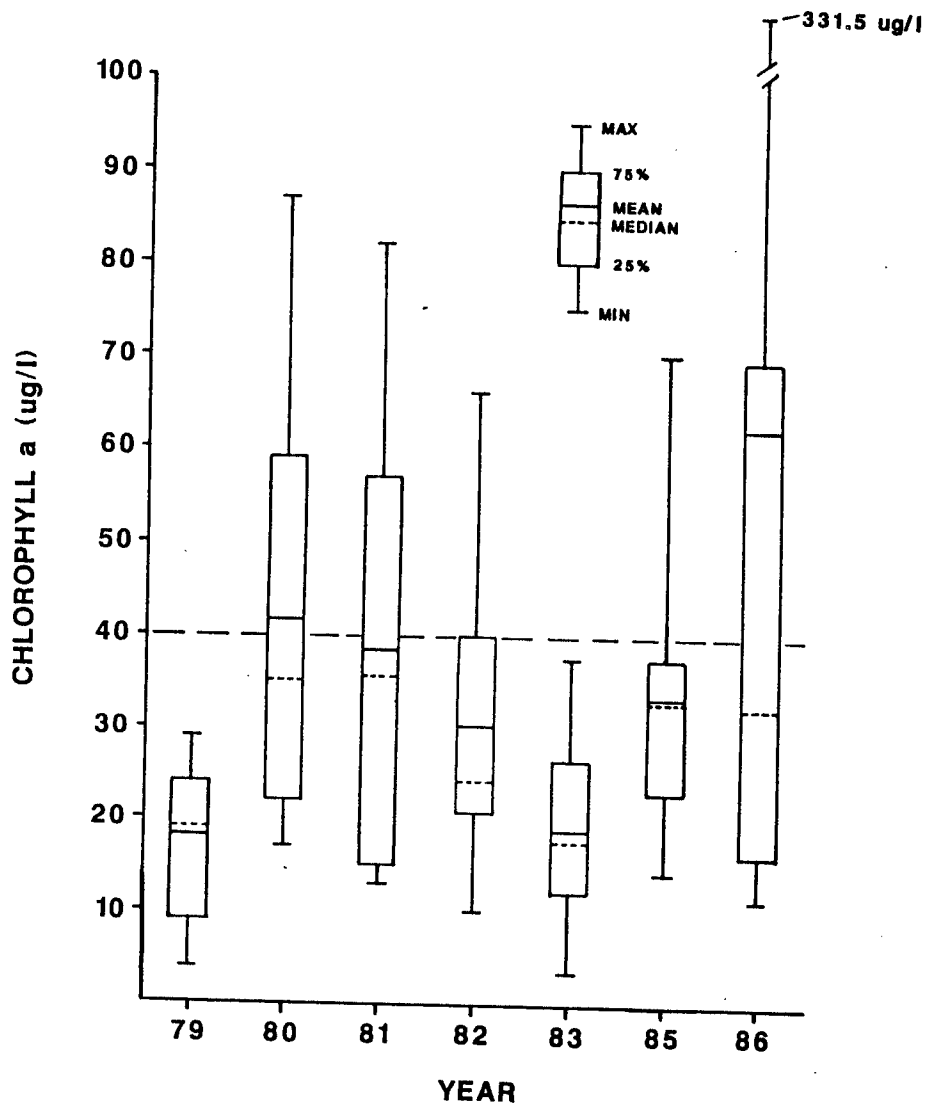


Figure 26. Summer chlorophyll a sample distributions at station 3 from 1979 through 1986.

- Mean growing season (April-September) chlorophyll a shall not exceed 5 ug/l in the open waters of Boulder Basin, Virgin Basin, Gregg Basin or Pierce Basin. No more than 10% of the samples (single value) shall exceed 10 mg/l.

Exceedance of either the monthly mean or growing season mean chlorophyll a standard shall trigger a review of the data and an investigation into the significance of the problem. At minimum the following will be reviewed:

- 1) Species composition of the phytoplankton associated with the exceedance.
- 2) Concentration of major nutrients associated with the exceedance.
- 3) Chlorophyll a levels associated with the exceedance.
- 4) North Shore Road nitrogen and phosphorus loading associated with the exceedance.
- 5) Short narrative interpreting the above data and analyzing the physical, chemical, and biological relationships which led to and followed the exceedance.

Based on N/P ratios the NDEP believes phosphorus control can achieve the recommended chlorophyll a standards. In addition to phosphorus control it may be necessary to reduce ammonia loading to control species composition. In the next triennial review, the recommended standard will be evaluated to determine if water quality objectives are being achieved.

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APPENDIX E

Un-ionized Ammonia Rationale  
for Las Vegas Bay, Lake Mead

## INTRODUCTION

Ammonia in water can be in two forms, un-ionized ( $\text{NH}_3$ ) and ionized ( $\text{NH}_4^+$ ). The term total ammonia refers to the sum of these; i.e.,  $\text{NH}_3 + \text{NH}_4^+$ .

The toxicity of aqueous ammonia solutions to aquatic organisms is primarily attributable to the  $\text{NH}_3$  form, with the  $\text{NH}_4^+$  species being relatively less toxic. It is therefore, important to know the concentration of  $\text{NH}_3$  in any aqueous ammonia solution in order to determine what concentrations of total ammonia are toxic to aquatic life.

The concentration of  $\text{NH}_3$  is dependant on a number of factors in addition to total ammonia concentration. Primary among these other factors are pH and temperature; with the concentration of  $\text{NH}_3$  increasing as a function of increasing pH and increasing temperature. Ionic strength is also another important influence on this equilibrium. There is a decrease in the percentage of un-ionized ammonia as the ionic strength increases. Thus, in saline or hard water, there will be a small but measurable decrease in the percent  $\text{NH}_3$ .

It has been known since early in this century that ammonia is toxic to fishes and that toxicity varies with the pH of the water. In most natural waters, the pH range is such that the  $\text{NH}_4^+$  fraction of ammonia predominates; however, in alkaline or highly productive water where the pH is high, the  $\text{NH}_3$  fraction can reach toxic levels.

Many laboratory experiments have shown that the lethal concentration (acute toxicity) for a variety of fish species are in the range of 0.2 to 2.0 mg/l  $\text{NH}_3$ , with cold water species such as trout generally being more sensitive than warm-water species. Concurrent with these studies has been the increasing realization that there are a whole range of more subtle effects (chronic toxicity). Chronic toxicity is extremely difficult to measure but includes poor reproduction, retarded growth, kidney dysfunction, gill tissue damage, and brain lesions.

Acute toxicity of ammonia to freshwater invertebrates has been studied much less than with fish. Data are available for 12 species representing 14 families and 16 genera (EPA 1985a). In general, invertebrates are more tolerant to un-ionized ammonia than are fishes.



Acute toxicity tests with freshwater fish species have been conducted with 29 different species from 9 families and 18 genera. Table 1 in "Ambient Water Quality Criteria for Ammonia" (EPA 1985a) lists over 100 acute toxicity values for non-salmonid fishes. Factors affecting the acute toxicity of ammonia include dissolved oxygen, temperature, pH, acclimation and fluctuating exposure, carbon dioxide, salinity, and the presence of other chemicals.

Very few studies have been conducted on long-term exposure of freshwater invertebrates to ammonia; life cycle tests have been conducted only for cladocerans. A number of studies have been conducted on the long-term effects of ammonia on fishes, including complete life-cycle tests on rainbow trout and fathead minnows. Several effects have been studied including spawning, egg incubation, growth, survival, and tissues. Table 2 in "Ambient Water Quality Criteria for Ammonia"(EPA 1985a) presents 26 chronic toxicity studies on 11 different species of freshwater organisms.

#### TRENDS IN UN-IONIZED AMMONIA IN LAS VEGAS BAY

Since 1983 total ammonia and un-ionized ammonia levels in Las Vegas Bay have increased significantly. The most dramatic increase has occurred at stations 2 and 3 with smaller increases having occurred outside of these stations. The mean summer un-ionized ammonia concentrations at station 2 have increased from .007 mg/l in 1983 to .090 mg/l in 1985 and .137 mg/l in 1986 (Figure 1). Station 3 summer levels have increased from .007 mg/l in 1983 to .053 mg/l in 1985 and .048 mg/l in 1986.

Figure 2 shows the individual (daily) measurements of un-ionized ammonia at station 2 from May through November of 1985 and 1986. Concentrations were extremely variable (greater than 500% in one week) throughout both years and peaked in June. In 1985 concentrations ranged from .031 mg/l in July to a peak of .527 mg/l in June. In 1986 levels ranged from .008 mg/l in October to .414 mg/l in June.

#### NATIONAL AMMONIA CRITERIA

EPA issued Ambient Water Quality Criteria for Ammonia - 1984 (EPA 1985a) and the document set forth various criteria depending on temperature, pH and the presence of salmonids or other sensitive coldwater species. For those temperatures and pH's of concern, the National Criteria for Waters with salmonids or other sensitive coldwater species present (Table (1)A. and (2)A.) are:

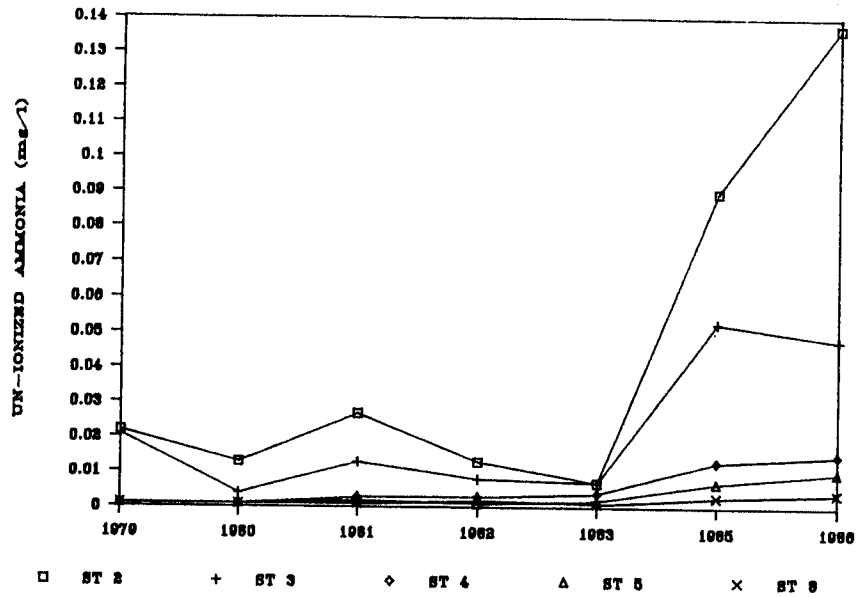


Figure 1. Mean summer un-ionized ammonia in Las Vegas Bay from 1979 through 1986.

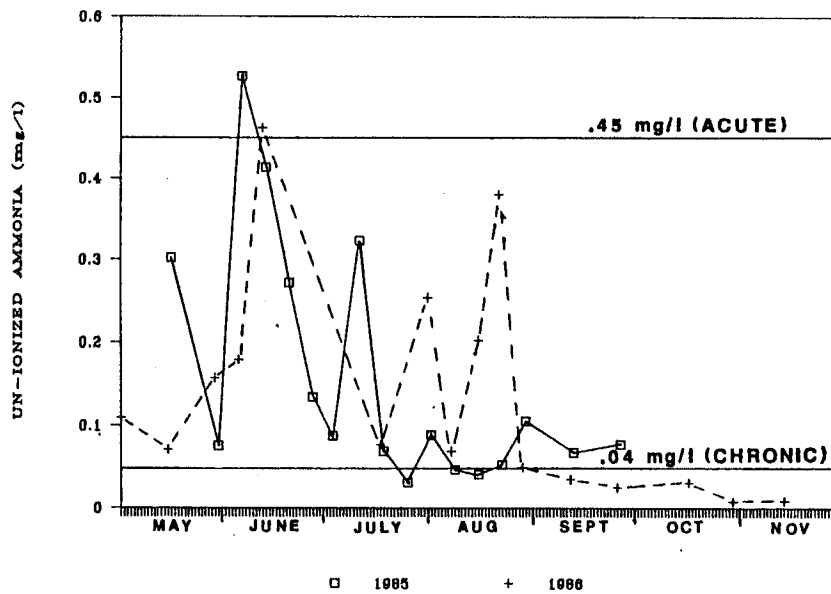


Figure 2. Daily un-ionized ammonia in Las Vegas Bay, Station 2 in 1985 and 1986.

Acute (1-hour average concentration @T=25°C and pH 8.0): 0.21 mg/l  
NH<sub>3</sub>-N.

Chronic (4-day average concentration @T=20°C and pH 8.0): 0.03 mg/l  
NH<sub>3</sub>-N.

With salmonids and other sensitive coldwater species absent (Tables (1)B.  
and (2)B.) are:

Acute (1-hour average concentrations @ T=25°C & pH 8.0):  
0.30 mg/l NH<sub>3</sub>-N

Chronic (4-day average concentrations @ T=20°C & pH 8.0):  
0.04 mg/l NH<sub>3</sub>-N

EPA based its National Criteria on an FAV<sub>ref</sub>\* of 0.52 (for the acute calculations) and an FAV<sub>ref</sub>\* of 0.80 (for the chronic calculations). These values are largely driven by the salmonid family, which includes trout, salmon, and mountain whitefish, but also include species found in the inner bay such as largemouth bass.

The National Ammonia Criteria and other EPA guidance sets forth methods for site specific adjustment to the National criteria to reflect local conditions.

#### Site Specific Adjustment To National Ammonia Criteria

The U.S. EPA issued a national statement entitled, "Policy for the Development of Water Quality - Based Permit Limitations for Toxic Pollutants," in the Federal Register Vol. 49, No. 48, Friday, March 9, 1984. A technical support document on the use of effluent and receiving water toxicity data also has been prepared by the Office of Water Enforcement and Permits and the Office of Water Regulations and Standards to provide additional guidance on the implementation of the biomonitoring policy (EPA 1985). The policy states that "EPA and the states will use biological techniques and available data on chemical effects to assess toxicity impacts and human health hazards based on the general standard of "no toxic materials in toxic amounts". Further, the policy states that "to carry out this policy, EPA Regional Administrators will assure that each Region has the capability to conduct water quality assessments using both

\*NOTE: The use of these terms will be discussed later.

biological and chemical methods and provide technical assistance to the State". Following this policy the NDEP requested assistance from Region IX EPA who in turn requested Region VIII assistance in the development of a site-specific modification of the national ammonia criteria for Lake Mead.

EPA recommends three basic procedures for modifying the national criteria recommendations (EPA 1983). The procedures for the derivation of a site specific criterion are:

- 1) The recalculation procedure to account for differences in resident species sensitivity.
- 2) The indicator species procedure to account for differences in biological availability and/or toxicity of a chemical caused by physical and/or chemical characteristics of a site water.
- 3) The resident species procedure to account for differences in resident species sensitivity and differences in the biological availability and/or toxicity of a chemical due to physical and/or chemical characteristics of a site water.

EPA Region VIII (T. Willingham, personal communication) recommended a combination of the recalculation and indicator species procedures.

#### Recalculation Procedure

##### Recommended Maximum and Four-Day Average Ammonia Criteria for Lake Mead

The reference species mean acute value ( $SMAV_{ref}$ ) is the geometric mean of the reference acute values ( $AV_{ref}$ ), usually LC50 values, available for a given species.  $SMAV_{ref}$ 's for un-ionized ammonia are available for 48 species of freshwater organisms. The reference genus mean acute value ( $GMAV_{ref}$ ) is the geometric mean of the  $SMAV_{ref}$ 's for species in the same genera.  $GMAV_{ref}$ 's for un-ionized ammonia are available for 34 genera of freshwater organisms.

The reference final acute value ( $FAV_{ref}$ ) is an estimate of the 0.05 cumulative proportion in the cumulative distribution of  $GMAV_{ref}$ 's and  $SMAV_{ref}$ 's for un-ionized ammonia. This 0.05 estimate is subsequently divided by 2 to approximate the concentration of un-ionized ammonia which if not exceeded, would protect 95 percent of the aquatic community from acute exposure.

Table 1 lists the  $GMAV_{ref}$ 's and  $SMAV_{ref}$ 's published in the ammonia guidance document (EPA 1985a) for species which have been identified in inner Las Vegas Bay of Lake Mead. (Allen and Roden 1978; Paulson, Personal Communication).

Table 1. Ranked Genus Mean Acute Values With Species Mean Acute/Chronic Ratios

Rank	Reference Genus Mean Acute Value (mg/l NH <sub>3</sub> )	Species	Reference Species Mean Acute Value (mg/l NH <sub>3</sub> )	Species Mean Acute-Chronic Ratio
12	8.48	Crayfish <u>Orconectes nais</u>	3.15	--
11	3.12	Amphipod, <u>Crangonyx pseudogracilis</u>	3.12	--
10	2.76	Snail, <u>Helisoma trivolvis</u>	2.76	--
9	2.70	Tubificid worm, <u>Tubifex tubifex</u>	2.70	--
8	2.48	Mosquitofish, <u>Gambusia affinis</u>	2.48	--
7	--	Striped Bass <u>Morone saxatilis</u>	2.10	--
6	2.07	Fathead Minnow, <u>Pimephales promelas</u>	2.07	20
5	1.96	Clodoceran <u>Ceriodaphnia acanthina</u>	1.96	3.5
4	1.63	Channel catfish, <u>Ictalurus punctatus</u>	1.63	7.5
3	1.49	Cladoceran <u>Daphnia magna</u>	1.91	3.1
2	1.16	Green sunfish, <u>Lepomis cyanellus</u>	1.57	6.3
		Pumpkinseed, <u>Lepomis gibbosus</u>	0.85	--
		Bluegill, <u>Lepomis macrochirus</u>	1.16	12
1		Largemouth bass, <u>Micropterus salmoides</u>	0.93	--

The four most sensitive organisms were selected from the list as follows:

<u>Organism</u>	<u>Most Sensitive GMAV or SMAV</u>
Largemouth Bass	0.93
Bluegill or Green Sunfish	1.16
Cladoceran ( <u>Daphnia</u> )	1.49
Channel Catfish	1.63

The temperature caps (TCAP) for the log-linear temperature relationship for FAVs and FCVs were set at maximum allowable level as specified in the national criterion for sites with salmonids and other sensitive coldwater species absent (25°C for FAVs, 20°C for FCVs).

The Site-Specific Criteria Guildines method (EPA 1983) for estimating the FAV as the fifth percentile of MAVs was applied to the above set of GMAV<sub>refs</sub> and SMAV<sub>refs</sub> selected for the Lake Mead site (n=12). The FAV was then computed by adjusting the FAV<sub>ref</sub> to the specified temperature (25°C) and pH (8.0 and above) using the relationship FAV<sub>ref</sub>/FT/FPH, where FT and FPH are as specified for the national criterion. The one-hour average concentration criteria was set to one-half of the site FAV. The FCV at each particular temperature and pH were computed by the formula FAV<sub>ref</sub>/FT/FPH/RATIO, where FT, FPH and RATIO are as specified for the national criterion. The 4-day average concentration criteria were set to the FCVs.

In summary, using pH greater than 8.0 and T=20°C for chronic toxicity and T=25°C for acute toxicity, the following values were derived:

Acute: 0.45 mg/l NH<sub>3</sub>-N  
Chronic: 0.04 mg/l NH<sub>3</sub>-N

#### Indicator Species Procedure

The indicator species procedure is based on the assumption that physical and/or chemical characteristics of water at a site may influence biological availability and/or toxicity of a chemical. Acute toxicity in site water and laboratory water is determined using species resident to the site, or acceptable non-resident species, as indicators or surrogates for species found at the site. The difference in toxicity values, expressed as a water effect ratio, was used to convert the recalculated maximum concentration for ammonia to a site-specific maximum concentration from which a site specific Final Acute Value is derived. The species used in the Lake Mead bioassays were the vertebrate fathead minnow, Pimephales promelas and the invertebrate Ceriodaphnia dubia. Both the fathead minnow and the genera Ceriodaphnia are represented in Lake Mead biota.

Results have shown that there is no significant difference between toxicity of site water to laboratory water using fathead minnow and Ceriodaphnia (Willingham, EPA 1987, personal communication) and no adjustments to the recalculation procedure is necessary (i.e. the water effect ratio is 1).

#### Recommendations for a Site Specific Criteria for Lake Mead

The recommended site specific criteria is the result of combining the effects of the recalculation procedure with the indicator species procedure.

Site Specific Criteria	=	Recalculated Criteria	*	Indicator Species Factor
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Since the Indicator Species Factor is one, the site-specific criteria is the recalculated criteria which again is:

Acute:	0.45 mg/l	NH <sub>3</sub> -N
Chronic:	0.04 mg/l	NH <sub>3</sub> -N

#### Duration and Frequency

Toxic effect is a function of both magnitude (concentration) and duration (time). Toxicity tests measure concentrations that cause adverse impacts over the testing period. In addition to limiting the concentration of toxicants, the NDEP must also specify and limit the length of time the biota are exposed to these concentrations. For example, a very brief exposure to a relatively high concentration may be less harmful than a prolonged exposure to a lower concentration. Therefore, two duration specifications must be set: a maximum duration for protection against acute effects, and a maximum duration for protection against chronic effects.

For acute effects, the duration must be as short as practicable because acute toxicity can occur quickly. An instantaneous value as a maximum limit would be most protective. Determination of an instantaneous maximum would require impractical and resource-intensive continuous monitoring. Therefore, acute criteria are expressed as a criterion maximum concentration occurring in a one-hour averaging period. The hourly average is based on a daily measurement in most cases (EPA 1985b).

It is more complicated to set the tolerable duration of exposure for chronic effects. Since chronic toxicity occurs over an extended time period, chronic effect concentrations can be exceeded for a relatively short period of time with no adverse effect so long as the acute criteria is not exceeded. The

objective is to maintain the un-ionized ammonia concentration at or below the chronic criteria over a protracted period of time, but still allow some excursion above the chronic criteria that will not cause toxic effect.

The guidance recommends criteria based on a 4-day average. If it can be shown that data variability are low, then the averaging period can approach 30 days. However, as shown in figure 2, the current available data indicate variability of the un-ionized ammonia in Las Vegas Bay is high and averaging periods of longer than 4 days are inappropriate.

The frequency with which the criteria can be allowed to be exceeded will depend on the structure and function of the community and the spatial relationships to other non-affected areas. The recommended exceedance frequency of no more than once in three years is the EPA's best scientific judgement of the average amount of time it will take an unstressed system to recover from a pollution event in which exposure to ammonia exceeds the criterion.

Due to potential un-ionized ammonia gradients within the cross-section at station 2, the NDEP is proposing that the chronic criteria (0.04 mg/l) be met as a cross-sectional average of samples collected from at least three sites in the transect. The samples will be collected at a time during the day that will account for diurnal fluctuations in un-ionized ammonia levels. No single value would be allowed to exceed the acute criteria (0.45 mg/l) more frequently than once in three years.

Our rationale is that if higher concentrations extend over a large area in the middle of the bay, averaging in the two outer stations (north and south of center channel) will result in exceedance of the chronic value. However, if only a small area of the transect exceeds the chronic criteria, but not the acute, fish populations will not be significantly impacted due to their relatively random movements. The assumption is that prolonged exposure to un-ionized ammonia concentrations exceeding the chronic criteria would not occur.

#### RECOMMENDED AMMONIA STANDARD FOR LAKE MEAD

- The 4-day average concentration of un-ionized ammonia shall not exceed, more often than once every three years, 0.04 mg/l. The daily value to be used will consist of the average of at least three sites at the cross section of Station 2 which shall be representative of the top 2.5 meters of the cross section and take into account diurnal fluctuations. This is applicable to all of Lake Mead except between Station 2 and the confluence of Las Vegas Wash.



- The single value of un-ionized ammonia shall not exceed, more often than once every three years, 0.45 mg/l.
- When the temperature is greater than 20°C the standard will be adjusted according to accepted U.S. Environmental Protection Agency methods.
- Station 2 is that location in the center of the channel where the depth is 10 meters.

## Literature Cited

- Allan, R.C. and D.L. Roden. 1978 Fish of Lake Mead and Lake Mohave, Nevada Department of Wildlife, Biol. Bull. No. 7, 105p.
- U.S. EPA. 1985a. Ambient Water Quality Criteria for Ammonia - 1984. Office of Water Regulations and Standards, Criteria and Standards Division. EPA
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APPENDIX F  
USE ATTAINABILITY ANALYSIS

## Use Attainability Analysis for Striped Bass in Inner and Middle Las Vegas Bay

As discussed in the chlorophyll a rationale hypolimnetic oxygen concentrations in the inner and middle Las Vegas Bay are likely too low to support fish life. Based on Ambient Water Quality Criteria for Dissolved Oxygen (EPA 1986), direct mortality occurs at concentrations less than 3 mg/l. Concentrations between 3 to 5 mg/l may effect growth, early life stages, reproduction, behavior, and swimming. However, the document fails to address the issue of hypolimnetic dissolved oxygen depletions on warmwater lake populations; these fish are tolerant to warm surface water temperatures and can therefore avoid areas of the lake with low oxygen levels. This is not the case for salmonid fisheries that require a cool, well oxygenated hypolimnetic habitat for survival.

The literature suggests that adult striped bass, an important Lake Mead sport fish, prefer temperatures less than 23 C and are therefore considered a cool-water species (Coutant 1978). Temperatures 23 C and below are confined to areas below the thermocline during summer and fall months. This coincides with the area depleted of oxygen at this time period inside of station 5. If the striped bass avoided this zone of low dissolved oxygen they would be forced to remain in the surface waters where the temperature ranged from 24 C to 26 C or they would be forced into the area below the thermocline somewhere outside of station 5. This may remove them from their food supply in the surface waters of the inner and middle bay during summer-fall periods.

Echo sounding data show that threadfin shad, the major forage fish in Lake Mead, have high densities in the inner and middle bay (Brown and Caldwell 1982; Paulson, personal communication). Since major portions of the lake experience extremely low threadfin shad densities due to extremely low productivity, access to the inner and middle bay may be relatively important to the local striped bass population.

However, young striped bass and other gamefish such as largemouth bass, that feed on the threadfin shad, are tolerant to warm (>23C) surface temperatures and can utilize this important food source in the bay. Further, adult striped bass are not permanently excluded from the inner and middle bay, and can utilize "overflow" from the bay in summer and fall and move through the entire bay during other seasons.

The NDEP feels that the relatively high level of algal biomass (chlorophyll a) proposed for Las Vegas Bay, while providing a rich food supply for the fishery, may be impacting the habitat of a key species the food supply is

intended to benefit. NDEP admits that Las Vegas Bay is a complex ecosystem and at our current level of understanding of these processes, we feel we have selected a level of algal productivity that provides a balance for all beneficial uses including the fishery. As our understanding of the processes grow we may be able to fine-tune this balance between hypolimnetic dissolved oxygen and the chlorophyll a concentration. Future development of a water quality model for the bay would provide a tool to predict the nutrient load necessary to achieve a desired dissolved oxygen level. Reduction of the total ammonia load to the bay should result in an increase in the level of dissolved oxygen.

Based on the above discussion NDEP chooses not to change the current water quality standard for dissolved oxygen at this time. However, this does not preclude establishment of a new and possibly more stringent standard in the future.

APPENDIX G

ANTIDEGRADATION ANALYSIS

## Antidegradation Analysis in Support of Las Vegas Wash/Lake Mead Water Quality Standards

Since there exists no national criteria document or other specific guidance for selection of a particular chlorophyll a water quality standard (WQS), a site-specific analysis was necessary to determine the appropriate level and location for a chlorophyll a standard in Las Vegas Bay that satisfies tier 1 of federal antidegradation regulations (40 CFR 131.12). NDEP has carried out this analysis, coming up with a target level of 30 ug/l overall summer mean chlorophyll a at station 3 as protective of existing uses and prohibitive of the excessive and harmful levels recorded in 1986. NDEP has also conducted a use attainability analysis to demonstrate that on occasion, access to the inner Las Vegas Bay (inside station 5) may be restricted for striped bass due to low hypolimnetic dissolved oxygen associated with the proposed standard.

NDEP has further explained why there has been an increase in the level of eutrophication of inner Las Vegas Bay in recent years, and why it has selected the data base it has as the basis for its standard. Las Vegas Bay phosphorus (P) and resulting chlorophyll a levels were only temporarily lowered by construction and operation since July 1981 of P removal facilities at the City or County Wastewater Treatment Plants. Other factors later contributed to an overall increase in P in Las Vegas Bay. As indicated in NDEP's chlorophyll a rationale, the reason a continued reduction of in-lake phosphorus was not observed is believed to be due in part to changes in plume dynamics: a higher percentage of Wash nutrients are being transported to the epilimnetic waters of Las Vegas Bay. These plume changes are directly related to increasing wastewater flows, severe vertical and lateral erosion of the Wash resulting in the establishment of a "delta", and a loss of wetlands which provided some "natural" capacity to transform nutrients. (Draft Chlorophyll a Rationale, p.7). Due to the developments and to the large increase in the ratio of total inorganic nitrogen to soluble orthophosphate since P removal was initiated in 1981 (which reinforces the argument that P is the principle limiting nutrient in Las Vegas Bay--see Rationale, p.19), the State is justified in selecting the most recent data base, representative of the 'post-phosphorus removal period', as the basis for attempting to control further increases in Las Vegas Bay chlorophyll a levels.

It is apparent from the State's analysis that the deterioration in water quality since 1975 (when federal antidegradation regulations were first promulgated) is a result of both higher wastewater flows attributable to population growth, and to physical erosion of the Wash and destruction of the marsh within it. Thus, lower water quality may be said to have resulted from a combination of 'important economic or social development' and uncontrolled natural events coupled with a lack of wetland management. Whether such degradation is thus justified on the basis of state and federal antidegradation regulations is to some extent a matter of perspective and interpretation, but it is undeniable that it has occurred.

Antidegradation regulations require that:

"...there will be achieved the highest statutory and regulatory requirements for all new and existing point sources and all cost-effective and reasonable best management practices for nonpoint source control."

(40 CFR 131.12 (a)(2))

It is understood that in order for the WQS--both chlorophyll a and ammonia--and the related total maximum daily loads which need to be developed by NDEP, to be achieved, it will be necessary for local authorities to meet the above-mentioned requirement. Although the exact nature of the necessary measures is up to local agencies and communities to decide, it appears that in order to achieve the approximate order-of-magnitude reductions in ammonia loading being contemplated and to limit phosphorus loading to levels necessary to achieve target chlorophyll a concentrations, it may be necessary to not only implement additional point source controls, but also to restore the marsh within Las Vegas Wash to its previous role as transformer and remover of the substantial nutrient levels, or to take other action to reduce the overall nutrient loading to Las Vegas Bay. For example, an additional option that may be considered by local authorities in order to attain WQS is to remove effluent discharges from the Wash and/or inner bay altogether, although such a strategy will of course have to insure protection of the WQS protecting the rest of Lake Mead (NAC 445.1350 and 445.1351).



APPENDIX H

PROPOSED REVISIONS TO WATER QUALITY STANDARDS

Section 1. Chapter 445 of Nevada Administrative Code (NAC) is hereby amended as specified in Sections 2 through 11 of this regulation.

Sec. 2. Amend NAC 445.1351 by replacing the standard for TPO<sub>4</sub> including footnote c with a "Water Quality Standards for Beneficial Uses" standard for Chlorophyll a

Chlorophyll a - ug/l -- c Bathing and water contact sports,<sup>b</sup> aquatic life,<sup>b</sup> warmwater fishery,<sup>b</sup> non-contact sports and esthetics,<sup>b</sup> drinking water supply.<sup>b</sup>

c - No more than one monthly mean shall exceed 45 ug/l in any calendar year at Station 3.

- Mean summer (July-September) chlorophyll a shall not exceed 40 ug/l at Station 3. The 4 year mean of summer means shall not exceed 30 ug/l.

- Mean is defined here as the average of at least two samples per month and the daily value to be used will consist of the average of at least three sights at the cross section of Station 3 which shall be representative of the top 5 meters of the cross section.

- Station 3 is that location in the center of the channel where the depth is 16 to 18 meters.

- Mean growing season (April-September) chlorophyll a shall not exceed 5 ug/l in the open waters of Boulder Basin, Virgin Basin, Gregg Basin or Pierce Basin. No more than 10 percent of the samples (single value) shall exceed 10 ug/l.

Sec. 3. Amend NAC 445.1351 by amending footnote d to read:

d See NAC 445.1353 footnote d.

Sec. 4. Amend NAC 445.1353 by deleting the standard for TPO<sub>4</sub> including footnote c.

Sec. 5.

Amend NAC 445.1353 by replacing the standard for un-ionized ammonia including footnote d with a "Water Quality Standards for Beneficial Uses" standard for un-ionized ammonia.

Un-ionized ammonia -- d Warmwater fishery,<sup>b</sup> aquatic  
as N - mg/l life<sup>b</sup>

- d - The 4-day average concentration of un-ionized ammonia shall not exceed, more often than once every three years, 0.04 mg/l. The daily value to be used will consist of the average of at least three sites at the cross section of Station 2 which shall be representative of the top 2.5 meters of the cross section and take into account diurnal fluctuations. This is applicable to all of Lake Mead except between Station 2 and the confluence of Las Vegas Wash.
- The single value of un-ionized ammonia shall not exceed, more often than once every three years, 0.45 mg/l.
- When the temperature is greater than 20°C the standard will be adjusted according to accepted U.S. Environmental Protection Agency methods.
- Station 2 is that location in the center of the channel where the depth is 10 meters.

Sec. 6.

Amend NAC 445.1351 by changing the standard for pH to read:

pH - standard unit Single value in 95% of samples not to exceed	- S.V.:7.0-9.0  8.8	-  -	Bathing and water contact sports, <sup>b</sup> wildlife propaga- tion, <sup>b</sup> warmwater fishery, aquatic life, drinking water supply, industrial water supply, agricultural use.
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Sec. 7. Amend NAC 445.1353 by changing the standard for pH to read:

pH - standard unit	-	S.V.:7.0-9.0	Bathing and water contact
Single Value in 95%			sports, <sup>b</sup> wildlife propaga-
of samples not to			tion, <sup>b</sup> warmwater fishery,
exceed	8.9	-	aquatic life, drinking
			water supply, industrial
			water supply, agricultural
			use.

Sec. 8 Amend NAC 445.1350 to read;

445.1350 Beneficial uses for area of Lake Mead not covered by NAC 445.1352.

The water quality standards for the area of Lake Mead which is not covered by NAC 445.1353 are prescribed in NAC 445.1351. The beneficial uses for this area are:

1. Drinking water supply;
2. Industrial supply;
3. Aquatic life including warmwater fishery and propagation;
4. Wildlife propagation;
5. Agricultural use;
6. Bathing and water contact sports; and
7. Noncontact sports and esthetics.]

~~(Added to NAC by Environmental Comm'n, eff. 11-22-82)~~

1. Irrigation.
2. Watering of livestock;
3. Recreation involving contact with the water;
4. Recreation not involving contact with the water;
5. Industrial supply;
6. Municipal or domestic supply, or both;
7. Propagation of wildlife; and
8. Propagation of aquatic life including warmwater fishery.

Sec. 9 Amend NAC 445.1352 to read:

445.1352 Beneficial uses for Lake Mead from western boundary of Las Vegas Marina Campground to confluence of Las Vegas Wash.

The water quality standards for Lake Mead from the western boundary of the Las Vegas Marina Campground to the confluence of the Las Vegas Wash are prescribed in NAC 445.1353. The beneficial uses for this area are:

1. Industrial supply;
2. Aquatic life including warmwater fishery and propagation;
3. Agricultural use;
4. Noncontact sports and esthetics; and
5. Wildlife propagation.]

(~~Added to NAC by Environmental Comm'n, eff. 11-22-82~~)

1. Irrigation;
2. Watering of livestock;
3. Recreation not involving contact with the water;
4. Industrial supply;
5. Propagation of wildlife; and
6. Propagation of aquatic life including warmwater fishery.

Sec. 10 Amend NAC 445.1354 to read:

445.1354 Beneficial uses for Las Vegas Wash from Pabco Road to city and county sewage treatment plants.

The water quality standards for the Las Vegas Wash from Pabco Road to the confluence of the discharges from the city and county sewage treatment plants are prescribed in NAC 445.1355. The beneficial uses for this area are:

[1. Aquatic life excluding fish. This does not preclude establishment of a fishery.

2. Wildlife propagation.

3. Agricultural use.

4. Freshwater marsh maintenance.

5. Noncontact sports and esthetics.]

(Added to NAC by Environmental Comm'n, eff. 11-22-82)

1. Irrigation;

2. Watering of livestock;

3. Recreation not involving contact with the water;

4. Maintenance of a freshwater marsh;

5. Propagation of wildlife; and

6. Propagation of aquatic life excluding fish. This does not preclude establishment of a fishery.

Sec. 11 Amend NAC 445.1356 to read:

445.1356 Beneficial uses for Las Vegas Wash from Pabco Road to Lake Mead.

The water quality standards for the Las Vegas Wash from Pabco Road to the confluence of Las Vegas Wash with Lake Mead are prescribed in NAC 445.1367. The beneficial uses for this area are:

1. Aquatic life excluding fish. This does not preclude establishment of a fishery.

2. Wildlife propagation.

3. Agricultural use.

4. Freshwater marsh maintenance.

5. Noncontact sports and esthetics.]

(Added to NAC by Environmental Comm'n, eff. 11-22-82)

1. Irrigation;

2. Watering of livestock;

3. Recreation not involving contact with the water;

4. Maintenance of a freshwater marsh;

5. Propagation of wildlife; and

6. Propagation of aquatic life excluding fish. This does not preclude establishment of a fishery.



[ ] = delete  
\_ = addition

Amendments relating to water pollution control regulations; revising water quality standards and designated beneficial uses for Las Vegas Wash, Lake Mead and the Colorado River; and providing definitions and explanations for aquatic life, designated beneficial uses, beneficial use standard and nondegradation standard.

The State Environmental Commission does adopt as follows:

Section 1. Article 4.1.1.b is hereby amended to read as follows:

4.1.1.b Aquatic life. The water shall be suitable as a habitat for fish or other aquatic life [indigenous to] existing in a body of water.

Section 2. Article 4.2.5 is hereby amended to read as follows:

4.2.5 Numerical Water Quality Standards for Selected Waters of the State

4.2.5.1 Control Point - Control points are specific locations where water quality criteria are specified. Criteria so specified apply to all surface waters of Nevada in the watershed upstream from the control point, or to the next upstream control point, or to the next water specifically named in Article 4.2. Where there are no control points downstream from a particular control point the criteria for that control point also apply to all surface waters of Nevada in the watershed downstream of the control point or to the next water specifically named in Article 4.2.

4.2.5.2 Designated Beneficial Uses - The designated beneficial uses which the commission has determined to be applicable to each stream segment or other body of surface water are listed in the following tables.

4.2.5.3 Beneficial Use Standard - Beneficial use standards are set to protect the most sensitive designated beneficial use. The beneficial uses the parameter is to protect are listed with the most sensitive beneficial use being underlined. The beneficial use standard applies to diffuse sources existing on July 1, 1979 and normal agricultural rotation, improvement or farming practices. The beneficial use standard also applies to all other sources of pollution when a nondegradation standard has not been adopted.

**4.2.5.4**

**Nondegradation Standard - Nondegradation standards are set to protect existing high quality waters which are of better quality than necessary to protect the designated beneficial uses. Nondegradation standards apply to any diffuse source created after July 1, 1979 except for normal agricultural rotation, improvement or farming practice. The nondegradation standards apply to all point sources.**

Section 3. Article 4.2.5 Table 45 is hereby amended to read as follows on the attached Table A-45, Table A-45.1, Table 45 and Table 45.1.

Section 4. Article 4.2.5 Table 47 is hereby amended to read as follows on the attached Table A-47, Table 47 and Table 47.1.

Table A-45

**BENEFICIAL USES:**  
Lake Mead

**REACH:**

Lake Mead except the area covered by Table A-45.1

**BENEFICIAL USES:**

Drinking Water Supply, Industrial Water Supply, Aquatic Life including Warmwater Fishery and Propagation, Wildlife Propagation, Irrigation, Stockwatering, Bathing and Contact Sports, Non-contact Sports and Aesthetics

Table A-45.1

**BENEFICIAL USES:**  
Lake Mead

**REACH:**

That portion of Lake Mead lying west of the western boundary of the Las Vegas Marina Campground to the confluence of Las Vegas Wash

**BENEFICIAL USES:**

Industrial Water Supply, Aquatic Life including Warmwater Fishery and Propagation, Wildlife Propagation, Irrigation, Stockwatering, Non-contact Sports and Aesthetics

**TABLE 45**  
**WATER QUALITY STANDARDS**  
**Colorado River**

**Control Point**

One mile below Willow Beach Resort and various points in Lake Mead

**Temperature °C**

Average (June through September) . . . . . not more than 16

Summer Single Value. . . . . not more than 18

Winter Single Value. . . . . not more than 14

Maximum allowable temperature increase above natural receiving water temperature:

None when water temperature is greater than or equal to 14°C.

1° when water temperature is less than or equal to 13°C.

**pH Units**

Annual Median . . . . . within range 7.5-8.2

Single Value. . . . . within range 7.0-8.5

**Dissolved Oxygen - mg/l**

Average (June through September) . . . . . not less than 6.0

Single Value . . . . . not less than 5.0

**BOD - mg/l**

Single Value . . . . . not more than 2

**Phosphates (PO<sub>4</sub>) - mg/l**

Annual Average . . . . . not more than 0.040

Maximum value in 90% of samples. . . . . not more than 0.060

Interpretation of this standard shall not be construed to restrict the phosphorus passing the North Shore Road control point as defined in Table 47, i.e, monthly mean of not more than 0.5 mg/l as P and single value in 90% of samples of not more than 1.0 mg/l as P but not to exceed 400 pounds/day during April through October.

**Nitrates (NO<sub>3</sub>) - mg/l**

Single Value. . . . . not more than 7

Annual Average. . . . . not more than 4

**Fecal Coliform** - The fecal coliform concentration, based on a minimum of 5 samples during any 30-day period shall not exceed a geometric mean of 200 per 100 milliliters, nor shall more than 10% of total samples during any 30-day period exceed 400 per 100 milliliters.

**Color** - Color shall not exceed that characteristic of natural conditions by more than 10 units Platinum Cobalt Scale.

**Turbidity** - Turbidity shall not exceed that characteristic of natural conditions by more than 10 Jackson Units.

The "Guidelines for Formulating Water Quality Standards for the Interstate Waters of the Colorado River System" adopted January 13, 1967, are incorporated as a supplement to the standards for this stream (Appendix A).

The salinity standard for the Colorado River System is included in Appendix B.]

WATER QUALITY STANDARDS

LAKE MEAD

Excluding the Area Covered in Table .1

Control Point at Various Points in Lake Mead

PARAMETER	NONDEGRADATION STANDARD	BENEFICIAL USE STANDARD	BENEFICIAL USE
Temperature °C T Single Value <sup>a</sup>	—	2	Warmwater Fishery
pH - Standard Unit Single Value	—	Within Range 6.5-9.3	Bathing and Water Contact Sports Wildlife Propagation
pH Single Value <sup>b</sup>	0.5	—	Irrigation Stockwatering, Warmwater Fishery, Aquatic Life, Drinking Water Supply, Industrial Water Supply
Dissolved Oxygen—mg/l Single Value	—	>5 mg/l in the epilimnion >5 mg/l average in water column during periods of non-stratification	Warmwater Fishery Aquatic Life Stockwatering, Bathing & Contact Sports, Non-contact Sports & Aesthetics, Drinking Water Supply, Wildlife Propagation
TPO <sub>4</sub> (as P) - mg/l 30 day average	—	1 as a discharge limit for any point source. RFPs for all diffuse sources. <sup>c</sup>	Bathing and Water Contact Sports Warmwater Fishery, Aquatic Life, Non-contact Sports & Aesthetics Drinking Water Supply
Un-ionized Ammonia—mg/l	—	d	Warmwater Fishery Aquatic Life
Total Dissolved Solids Flow Weighted Annual Average Single Value	<723 measured at Hoover Dam	— <1000	Drinking Water Supply Stockwatering, Irrigation
Chloride - mg/l Single Value	e	<400	Drinking Water Supply Stockwatering, wildlife propagation
Sulfate - mg/l Single Value	e	<300	Drinking Water Supply
Suspended Solids—mg/l Single Value	—	<25	Warmwater Fishery Aquatic Life
Nitrogen Species as N - mg/l Annual Average in water column Single Value	Total Inorganic Nitrogen <2 <5	Nitrate Nitrite — — <10 <1	Drinking Water Supply Stockwatering, Warmwater Fishery, Aquatic Life, Wildlife Propagation
Turbidity - NTU Single Value	f	<25	Warmwater Fishery Aquatic Life, Drinking Water Supply
Fecal Coliform MF/100 ml	—	<200/4008	Bathing and Water Contact Sports Irrigation, Stockwatering, Non-contact Sports & Aesthetics, Drinking Water Supply, Wildlife Propagation

(Continuation of Table 45)

- a. Maximum allowable temperature increase above receiving water temperature at the point of discharge.
- b. Maximum allowable pH change of receiving water pH at the point of discharge.
- c. Total phosphorus is known to be related to the beneficial uses of bathing and water contact sports, fishery, aquatic life, non-contact sports, aesthetics and drinking water supply in a qualitative manner. The best known quantitative method of controlling phosphorus to protect and enhance the related beneficial uses for Lake Mead at this time is application of 1 mg/l total phosphorus as an effluent limit (30-day average) for point source and Best Management Practices for diffuse source discharges into Lake Mead or its tributaries.
- d. Un-ionized Ammonia is known to be toxic to fish. However, the limitation for the species in existence in Lake Mead is not known at this time, but will be evaluated with future studies.
- e. The combination of this parameter with other parameters comprising TDS shall not result in the violation of the TDS standards for Lake Mead and the Colorado River.
- f. Turbidity shall not exceed that characteristic of natural conditions by more than 10 Nephelometric Units.
- g. Based on a minimum of not less than five samples taken over a 30-day period, the fecal coliform bacterial level should not exceed a log mean of 200 per 100 ml nor should more than 10 percent of the total samples taken during any 30-day period exceed 400 per 100 ml.

The "Guidelines for Formulating Water Quality Standards for the Interstate Waters of the Colorado River System" adopted January 13, 1967, are incorporated as a supplement to the standards for this stream (Appendix A).

The salinity standard for the Colorado River System is included in Appendix B.

**Table 45.1  
WATER QUALITY STANDARDS  
LAKE MEAD**

From the Western Boundary of Las Vegas Marina  
Campground to the Confluence of Las Vegas Wash

Control Point at the Western Boundary  
of Las Vegas Marina Campground

PARAMETER	NONDEGRADATION STANDARD	BENEFICIAL USE STANDARD	BENEFICIAL USE
Temperature - °C T-Single Value <sup>a</sup>	—	2	<u>Warmwater Fishery</u>
pH - Standard Unit Annual Average in the water column Single Value pH Single Value <sup>b</sup>	Within Range 8.2-8.6 — 0.5	Within Range 7.0 - 9.6 —	<u>Wildlife Propagation</u> <u>Irrigation, Stockwatering,</u> <u>Warmwater Fishery, Aquatic</u> <u>Life, Industrial Water Supply</u>
Dissolved Oxygen-mg/l Single Value	—	≥5 mg/l	<u>Warmwater Fishery</u> <u>Aquatic Life, Stockwatering,</u> <u>Non-contact Sports, &amp; Aes-</u> <u>thetics, Wildlife Propagation</u>
TPO <sub>4</sub> (as P) - mg/l 30 day average	—	1 as a discharge limit for any point source. BMPs for all diffuse sources. <sup>c</sup>	<u>Warmwater Fishery, Aquatic</u> <u>Life, Non-contact Sports &amp;</u> <u>Aesthetics</u>
Nitrogen Species as N-mg/l Annual Average in water column Single Value	Total Inorganic Nitrogen ≤2 ≤5	— Nitrate ≤90	<u>Warmwater Fishery</u> <u>Stockwatering,</u> <u>Wildlife Propagation</u> <u>Stockwatering, Wildlife</u> <u>Propagation</u>
Single Value	—	Nitrite ≤10	<u>Warmwater Fishery</u> <u>Aquatic Life</u>
Un-ionized Ammonia as NH <sub>3</sub> - mg/l	—	d	<u>Warmwater Fishery</u> <u>Aquatic Life</u>
Total Dissolved Solids - mg/l Single Value	—	≤3000	<u>Stockwatering</u> <u>Irrigation</u>
Suspended Solids-mg/l Single Value	—	≤25	<u>Warmwater Fishery</u> <u>Aquatic Life</u>
Turbidity - NTU Single Value	e	≤25	<u>Warmwater Fishery</u> <u>Aquatic Life</u>
Fecal Coliform MF/100 ml Single Value	—	≤1000	<u>Irrigation, Stockwatering,</u> <u>Wildlife Propagation</u> <u>Non-contact Sports &amp; Aesthetics</u>

(Continuation of Table 45.1)

- a. Maximum allowable temperature increase above receiving water temperature at the point of discharge.
- b. Maximum allowable pH change of receiving water pH at the point of discharge.
- c. Total phosphorus is known to be related to the beneficial uses of bathing and water contact sports, fishery, aquatic life, non-contact sports, aesthetics and drinking water supply in a qualitative manner. The best known quantitative method of controlling phosphorus to protect and enhance the related beneficial uses for Lake Mead at this time is application of 1 mg/l total phosphorus as an effluent limit (30-day average) for point source and Best Management Practices for diffuse source discharges into Lake Mead or its tributaries.
- d. Un-ionized Ammonia is known to be toxic to fish. However, the limitation for the species in existence in Lake Mead is not known at this time, but will be evaluated with future studies.
- e. Turbidity shall not exceed that characteristic of natural conditions by more than 10 Nephelometric Units.

The "Guidelines for Formulating Water Quality Standards for the Interstate Waters of the Colorado River System" adopted January 13, 1967, are incorporated as a supplement to the standards for this stream (Appendix A).

The salinity standard for the Colorado River System is included in Appendix B.



**NEW TABLES - CONSIDER ALL UNDERLINED**

**Table A-47**

**BENEFICIAL USES  
Las Vegas Wash**

**REACH:**

From the confluence of Las Vegas Wash with Lake Mead to the confluence of the discharges from the City and County sewage treatment plants.

**BENEFICIAL USES:**

Aquatic Life excluding fish, Wildlife Propagation, Irrigation, Marsh Maintenance, Stockwatering, Non-contact Sports and Aesthetics.

**TABLE 47**  
**WATER QUALITY STANDARDS**  
**Las Vegas Wash**

**Control Point**

North Shore Road (no sampling will be required upstream of the control point if the regulations are satisfied at the control point)

**Temperature °C**

Monthly mean - June 1 to September 30 . . . . . not more than 27  
 October 1 to May 31. . . . . not more than 23  
 Single value in 90 percent of samples:  
 June 1 to September 30 . . . . . not more than 31  
 October 1 to May 31. . . . . not more than 27

**pH Units**

Annual Median . . . . . within range 6.5-8.5  
 Single Value in 90% of samples. . . . . within range 6.5-8.5

**Dissolved Oxygen - mg/l**

Monthly Mean . . . . . not less than 5.0  
 Single Value in 90% of samples . . . . . not less than 4.0

**BOD - mg/l**

Monthly Mean. . . . . not more than 10.0  
 Single Value . . . . . not more than 15.0

**COD - mg/l**

Monthly Mean . . . . . not more than 40.0  
 Single Value in 90% of samples . . . . . not more than 50.0

**SS - mg/l**

Monthly Mean . . . . . not more than 2.0  
 Single Value in 90% of samples . . . . . not more than 5.0

**MBAS - mg/l**

Monthly Mean . . . . . not more than 0.8  
 Single Value in 90% of samples . . . . . not more than 1.0

**Phosphorus as P - mg/l**

Monthly Mean . . . . . not more than 0.5\*  
 Single Value in 90% of samples . . . . . not more than 1.0\*  
 \*But not exceed 400 pounds/day during April through October

**Turbidity - JTU**

Monthly Mean . . . . . not more than 5.0  
 Single Value in 90% of samples . . . . . not more than 10.0

**Fecal Coliform -** The fecal coliform concentration, based on a minimum of 5 samples during any 30-day period shall not exceed a geometric mean of 200 per 100 milliliters, nor shall more than 10% of total samples during any 30-day period exceed 400 per 100 milliliters.

The beneficial uses to be protected in the Las Vegas Wash are as follows: Fish and wildlife, esthetics, irrigation and stock watering and recreation.]

TABLE 47

WATER QUALITY STANDARDS  
LAS VEGAS WASH

Control Point at Northshore Road. The limits in this table apply from Pabco Road to the confluence of the Las Vegas Wash with Lake Mead.

PARAMETER	NONDEGRADATION STANDARD	BENEFICIAL USE STANDARD	BENEFICIAL USE
Temperature T (°C) Single Value <sup>a</sup>	5	—	—
pH - Standard Unit Annual Average	Within Range 7.3-7.9	—	<u>Wildlife Propagation</u> <u>Irrigation, Stockwatering</u>
Single Value	Within Range 7.2-8.7	Within Range 7.0-9.0	
Dissolved Oxygen-mg/l		b	<u>Stockwatering, non-contact sports &amp; aesthetics, wild-life propagation</u>
Nitrogen Species as N-mg/l	Total Inorganic Nitrogen	Nitrate Nitrite	<u>Stockwatering, Wild-life Propagation</u>
Annual Average	<14	—	
Single Value	<17	<100      <10	
Total Filterable Residue at 180°C-mg/l			<u>Stockwatering</u>
Annual Average	<2500		
Single Value	<2600	<3000	
Fecal Coliform mf/100 ml	—	<200/400 <sup>c</sup>	<u>Non-contact Sports, Aesthetics, Irrigation, Stockwatering, Wildlife Propagation</u>

a - Maximum allowable temperature increase above receiving water temperature at the point of discharge.

b - It is known that aerobic conditions are desirable for the beneficial uses of stockwatering, non-contact sports and aesthetics and wildlife propagation. Monitoring information indicates natural conditions prevent the attainment of aerobic conditions at this time. Therefore aerobic conditions are established as a goal rather than a standard at this time.

c - Any point source discharge into Las Vegas Wash must not exceed a log mean of 200 per 100 ml based on a minimum of not less than five samples taken over a 30-day period nor should more than 10 percent of the total samples taken during any 30-day period exceed 400 per 100 ml.

TABLE 47.1

**WATER QUALITY STANDARDS  
LAS VEGAS WASH**

Control Point at Pabco Road. The limits in this table apply from Pabco Road to the confluence of the discharges from the City and County sewage treatment plants.

PARAMETER	NONDEGRADATION STANDARD	BENEFICIAL USE STANDARD	BENEFICIAL USE
Temperature T (°C) Single Value <sup>a</sup>	5	—	—
pH - Standard Unit Annual Average	Within Range 7.0-7.6	—	<u>Wildlife Propagation</u> <u>Irrigation, Stockwatering</u>
Single Value	Within Range 6.5-7.8	Within Range 6.5-9.0	
Dissolved Oxygen-mg/l	—	b	<u>Stockwatering, non-contact</u> <u>sports &amp; aesthetics, wild-</u> <u>life propagation</u>
Nitrogen Species as N-mg/l Annual Average	Total Inorganic Nitrogen ≤16	Nitrate Nitrite	<u>Stockwatering, Wild-</u> <u>life Propagation</u>
Single Value	≤20	≤100    ≤10	
Total Filterable Residue at 180°C-mg/l Annual Average	≤200	—	<u>Stockwatering</u>
Single Value	≤300	≤3000	
Fecal Coliform mf/100 ml	—	≤200/400 <sup>c</sup>	<u>Non-contact Sports,</u> <u>Aesthetics, Irrigation,</u> <u>Stockwatering, Wildlife</u> <u>Propagation</u>

a - Maximum allowable temperature increase above receiving water temperature at the point of discharge.

b - It is known that aerobic conditions are desirable for the beneficial uses of stockwatering, non-contact sports and aesthetics and wildlife propagation. Monitoring information indicates natural conditions prevent the attainment of aerobic conditions at this time. Therefore aerobic conditions are established as a goal rather than a standard at this time.

c - Any discharge into Las Vegas Wash must not exceed a log mean of 200 per 100 ml based on a minimum of not less than five samples taken over a 30-day period nor should more than 10 percent of the total samples taken during any 30-day period exceed 400 per 100 ml.