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**MOUNTAIN LAKE
MONITORING REPORT
NOVEMBER 1993 - OCTOBER 1994**

by
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**PRELIMINARY
SUBJECT TO REVISION**

for
**National Park Service
Golden Gate National Recreational Area
Building 201 -- Fort Mason
San Francisco, CA 94123**

Final Publication Date: 1994

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INTRODUCTION

Mountain Lake is located in the Presidio of San Francisco, and is one of the few remaining natural lakes in San Francisco. Mountain Lake is fed by two subterranean springs and serves as habitat for a variety of aquatic organisms. Prior to the construction of Park Presidio Boulevard in 1937, the lake was known to vary in depth from 20 to 30 feet. Presently, however, the lake reaches a maximum depth of approximately 10 feet.

The lake and its surrounding park serve as a recreational area for the residents and tourists of San Francisco. Hydrologic and biologic data concerning the historic characteristics of Mountain Lake is limited. The extent to which settlement altered the lake's native conditions is largely unknown. The purpose of this investigation was to document the hydrologic, biologic, and limnologic components of Mountain Lake. Historic literature was also studied to compare present conditions with past physical characteristics. This report reflects data collected from November 1993 to October 1994. Figure 1 shows the location of the lake and the sampling stations.

PRELIMINARY
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HISTORY

Mountain Lake was first cited in history in the diaries of Colonel Juan Bautista de Anza and Father Pedro Font (1776). The lake and its surrounding area served as a camp site and water source for Anza and his troops during the construction of the Presidio. In the mid 1800's, Mountain Lake provided the municipal water supply of San Francisco. The Mountain Lake Water Works was formed in 1851 with the intent of obtaining water from Mountain Lake and Lobos Creek to meet the needs of the City of San Francisco. Following a series of legal problems, the Mountain Lake Water Works failed and subsequently was bought out by the Spring Valley Water Works in 1865. Water from both Mountain Lake and Lobos Creek was diverted for municipal use until 1895. By the middle of 1895, the amount of water obtained from both watersheds was fractional compared to the amount required by the city; therefore, it was no longer feasible to continue pumping water from the lake for the City of San Francisco.

In 1897, the Army installed a pumping system to divert water from Mountain Lake for domestic use within the Presidio. The plant was sold between 1910 and 1912 following the construction of a pumping plant on Lobos Creek and a six million- gallon reservoir on Presidio Hill. The Lake remained unused by the Presidio and the City of San Francisco until the late 1930's. In 1939, excavated material from the lowering of the Funston Avenue approach to the Golden Gate Bridge was dumped into the lake, reducing its size by half. Prior to 1939, Mountain Lake averaged in depth from 20 to 30 feet; presently, the maximum depth of the lake is approximately 10 feet.

Currently, Mountain Lake provides a recreational area for tourists and residents of San Francisco. The lake also serves as habitat for a variety of waterfowl, fish, and wildlife. The following annotated bibliography cites all literature relating to Mountain Lake. A brief description of the work follows the citation.

ANNOTATED BIBLIOGRAPHY

[Bancroft, Hubert Howe]. History of California. Vol. I (1542-1800). In The Works of Hubert Howe Bancroft. Vol. XVIII. Wallace Heberd Publisher, Santa Barbara.

Page 280 depicts a 1776 map showing Mountain Lake and Lobos Creek as connected. An interpretation of the original Spanish written description of Mountain Lake and Lobos Creek is found on page 282. On March 27th, Anza encamped at a lake near the "mouth of a port". (This lake was referred to as Laguna del Presidio on La Pérouse's map of 1786.) The lake was not named at this time by the Spaniards, but the outlet which flowed with enough water to operate a mill was called Arroyo del Puerto, presently known as Lobos Creek.

Codemo, C. M. and R. J. Brown. 1993. Mountain Lake Initial Study: June-July 1993. Published by the Institute of Chemical Biology (USF).

The physical, chemical, and biological components of Mountain Lake are discussed. The study emphasized water quality and phytoplankton populations. The report reflects the data collected from June 1993 to July 1993. The results of water quality, element scans, bacteria levels, and phytoplankton populations are presented in the report.

Davidson, George. 1907. The Discovery of San Francisco Bay: The Rediscovery of the Port of Monterey; the Establishment of the Presidio, and the Founding of the Mission of San Francisco. From Transactions and Proceedings of the Geographical Society of the Pacific, Vol. IV, Series II. San Francisco, 153 p.

Mountain Lake and its resources are discussed on pages 118-119. Colonel Juan Bautista de Anza and his troops camped at Mountain Lake (Laguna del Presidio) at eleven o'clock A. M. on March 27, 1774. A small creek with sufficient water to operate a mill flowed from the lake. The creek was named Arroyo del Puerto and is presently known as Lobos Creek. The area provided sufficient resources to support inhabitants, but the timber required to construct the Presidio and buildings was not available.

Dwinelle, John W. 1867. The Colonial History: City of San Francisco. 4th edition. Towne and Bacon, San Francisco, 390 p.

Pages 20 and 21 discuss the historic appearance of the lake and surrounding area. Approximately four miles west of the ruins of Mission Dolores lied a

small pond or laguna, presently named Mountain Lake. No inlet or outlet was visible, but a small stream (Lobos Creek) rose within a short distance. This stream flowed directly to the Pacific Ocean and provided sufficient water for the inhabitants of San Francisco.

Eldredge, Zoeth Skinner. *The Beginnings of San Francisco from the Expedition of Anza, 1774 to the City Charter of April 15, 1850*. C. Rankin Company, New York, 837 p.

Page 132 discusses Mountain Lake with regard to the Spanish colonization of the Presidio. Colonel Juan Bautista de Anza, a Spanish military explorer, arrived at the Presidio in San Francisco. He and his army camped at Laguna del Presidio (Mountain Lake). The creek flowing from Mountain Lake, presently known as Lobos Creek, was named Arroyo del Puerto by Anza.

Engelhardt, Fr. Zephyrin. 1924. *San Francisco or Mission Dolores*. Franciscan Herald Press, Chicago, Illinois, 432 p.

Page 413 depicts Mountain Lake in a chart of the San Francisco Bay and the surrounding landscape. The map is a zincograph copy of the original created in 1786 by officers of the French Admiral La Pérouse. The chart is No. 33 of the maps of that expedition.

Font, Pedro. 1931. *Font's Complete Diary: A Chronicle of the Founding of San Francisco*. Bolton, Herbert Eugene (Ed.). University of California Press, Berkeley, 552 p.

Spanish colonization of the Presidio and the significance of Mountain Lake are discussed on pages 330-331 and 340-341. Father Pedro Font along with Captain Ribera and his Spanish troops marched through San Francisco and the surrounding bay area. They camped at Mountain Lake and selected the area as the site for a new settlement and fort. Eventually, the lake came to serve as the water source for the inhabitants of the Presidio.

Geo/Resource Consultants, Inc. 1991. *Groundwater Assessment and Drought Response for the Presidio, San Francisco, California*. Job No. 1602-009-00.

The hydraulic connection between Mountain Lake and Lobos Creek is discussed on page ES-4. The work completed by Geo/Resource Consultants, Inc. confirms that the two watersheds are connected. The report also states that Mountain Lake water is diluted before reaching Lobos Creek and that the majority of recharge to Lobos Creek is from the southern basin.

Gilliam, Harold. 1966. *The Natural World of San Francisco*. Doubleday and Company, Inc., Garden City, New York, 256 p.

Gilliam suggests on pages 48 and 49 that Mountain Lake and other lakes in San Francisco may have been formed by Ice Age streams "running swiftly down to a far lower sea level." Reference is made on page 96 to Father Pedro Font's diary of 1776 where he noted while camping at Mountain Lake that "there is not a tree on all these hills." Page 142 contains a photograph of Mountain Lake taken by Michael Bry during or before 1966 (exact year not noted).

Kinnard, Lawrence. 1966. *History of the Greater San Francisco Bay Region*. Vol. I. Lewis Historical Publishing Company, New York, 800 p.

The book sites a diary entry by Colonel Juan Bautista de Anza (pages 80-81). On March 27, 1776, Anza and his men reached "a fine lake or spring of very good water near the mouth of the port of San Francisco". The lake is presently known as Mountain Lake.

Lewis, Emanuel Raymond. 1982. *A History of San Francisco Harbor Defense Installations Forts Baker, Barry, Cronkhite, and Funston*. Prepared for the Division of Beaches and Parks, State of California.

An Executive Order by United States President Millard Fillmore dated November 6, 1850, is found on pages 17-18. The Order discusses lands exempted from sale and reserved for military usage. Page 17 contains the Presidio boundary description and refers to the boundary of the reserve as "passing by the southern extremity of a pond (presently known as Mountain Lake) that has its outlet into the channel between Fort Point and Point Lobos".

Manson, Marsden. 1907. *Outline of History of the Water Supply of the City of San Francisco*. In *Reports on the Water Supply of San Francisco, California: 1900 to 1908, Inclusive*. Britton and Rey, San Francisco, pp. 3-13.

The work reports the historical significance of Mountain Lake with respect to municipal water supplies. On June 1, 1851, the Mountain Lake Water Company made a contract with San Francisco to supply the City with water from Mountain Lake and Lobos Creek. In 1857 the San Francisco Water Works was organized to divert water from Lobos Creek to San Francisco. Shortly thereafter, the Mountain Lake Water Company was confronted with numerous lawsuits and subsequently folded in 1862. A small company, the Spring Valley Water Works,

was also emerging at this time. The company grew to be substantially stronger than the San Francisco Water Works, and in 1965 the former bought out the latter, inheriting all rights to Mountain Lake and Lobos Creek. Lobos Creek continued to supply between one and two million gallons of water per day until it was abandoned in 1895. Water from Lobos Creek and Mountain Lake was again used in 1901 to supply water to the Richmond district after several dry seasons. Foul water, however, forced the company to abandon the supply a second time.

Nolte and Associates. 1993. Water Supply Evaluation, Presidio of San Francisco. Volume I.

The report the water supply and water distribution of the Presidio. The Presidio Golf Course has historically drawn water for irrigation from Mountain Lake and the wells along its northeast bank (page i). These wells are currently considered non-potable, and under one option proposed by Nolte and Associates, these non-potable wells would be replaced with two new wells (page iv).

Purdy, Helen Throop. 1912. San Francisco: As It Was, As It Is, and How to See It. Paul Elder and Company, San Francisco, 221 p.

On pages 42-43, Throop reports that in 1858, a flume was constructed to divert water from Lobos Creek and Mountain Lake to town. At the beginning of the twentieth century, Mountain Lake Park comprised approximately twenty acres (pages 91-92).

Riegert, Ray. 1984. Hidden San Francisco and Northern California: The Adventurer's Guide. Sayre Van Young (Ed.). Ulysses Press, Berkeley, 421 p.

This book for tourists of San Francisco discusses the location of Mountain Lake and its park on pages 92-93. Mountain Lake Park, located at the southern end of the Presidio, serves as a watering hole for a variety of waterfowl and is skirted with tule reeds and overhanging willows.

Thompson, Erwin N. and Sally B. Woodbridge. 1992. Special History Study of the Presidio of San Francisco: An Outline of its Evolution as a U. S. Army Post, 1847- 1900. United States Department of the Interior, 250 p.

Page 62 contains a 1907 map of Major Hart's proposal for the development of the Presidio. Mountain Lake is also depicted on the map. Page 180 discusses the historical significance of Mountain Lake as a municipal water source. In

1853, Mountain Lake Water Company was formed with the intent to obtain water from Mountain Lake. The company subsequently failed and was taken over by the San Francisco Water Works. In 1897, the Army installed a new pumping system at Mountain Lake to divert water for domestic use. A 1904 study deemed the water from the wells at Mountain Lake of good quality. Between 1910 and 1912, the pumping plant was sold off and a new plant was constructed at the mouth of Lobos Creek along with a new six million- gallon reservoir on Presidio Hill (page 182).

Treutlein, Theodore E. 1968. San Francisco Bay: Discovery and Colonization, 1769-1776. California Historical Society, San Francisco, 152 p.

The book cites diary entries by Colonel Juan Bautista de Anza and Father Pedro Font on page 79. On March 27, 1776, Anza and his men camped on the banks "a fine lake or spring of very good water near the mouth of the port of San Francisco". Father Font also referred to Mountain Lake in the following passage from his diary:

"This place (Presidio) and its vicinity has abundant pasturage, plenty of firewood, and fine water, all good advantages for establishing here the presidio or fort which is planned."

San Francisco the Bay and Its Cities (Compiled by Workers of the Writers' Program of the Work Projects Administration in Northern California). 1940. Hastings House, New York, 531 p.

On page 313, Mountain Lake is referred to as a government-protected sanctuary for waterfowl. Also noted is a significant reduction in the size of Mountain Lake which occurred in 1939. According to the report, earth "excavated in lowering the grade of the Funston Avenue approach to the Golden Gate" was dumped into the lake, reducing it to half its former size.

PLANT COMMUNITIES

Presented is a description of the plant communities surrounding Mountain Lake, an ancient natural lake in the Presidio of San Francisco. Data was collected through field investigations and a survey of relevant literature. Wetland and riparian plant communities along the lake margin were classified according to Holland's Preliminary Descriptions of the Terrestrial Natural Communities of California (1986). Communities were mapped (Figure 2) and two 35 mm slides of each community are also presented in conjunction with this report.

Vegetation surrounding Mountain Lake was surveyed throughout the spring and summer of 1994 when plant growth and blooming were at or near their respective peaks. Vegetation was classified as either non-native or native; native species were then grouped into riparian or more xeric species.

Factors such as moisture, soil type, light, and wind affect the composition of the vegetation surrounding Mountain Lake. In addition, species diversity and density of native riparian vegetation have been strongly influenced by development near the lake and park area, road construction, and the invasion of non-native, weedy plant species. The non-native plant species pose the largest threat to the native riparian and wetland vegetation; they aggressively out-compete native species and simplify complex communities through a reduction of species diversity. These species commonly include blue gum eucalyptus (*Eucalyptus globulus*), German ivy (*Senecio mikanooides*), and Monterey cypress (*Cupressus macrocarpa*).

Several native species indicative of healthy riparian and wetland communities are present at Mountain Lake. These species include arroyo willow (*Salix lasiolepis*), California blackberry (*Rubus ursinus*), tules (*Scirpus spp.*), rushes (*Juncus spp.*), lady ferns (*Athyrium filix-femina*), and water cress (*Rorippa nasturtium-aquaticum*). The arroyo willow is an indicator species of a riparian community, and is the dominant species of the Central Coast Arroyo Willow Riparian Forest. Tules and rushes are a major component of the Coastal Freshwater Marsh as defined by Holland (1986). Among the native species which are not indicative of riparian or wetland communities is the bush lupine (*Lupinus arboreus*), characteristic of Northern Dune Scrub (Holland, 1986).

The following is a description of plant communities surrounding Mountain Lake. Table 1 list all indicator species found within the communities and present non-native species.

RIPARIAN COMMUNITY

Riparian vegetation is found along the edges of permanent streams and ponds in many types of climates. Dense growth of California blackberry (*Rubus ursinus*)

and thickets of arroyo willow (*Salix lasiolepis*) are indicative of riparian areas. These species are found in abundance along portions of the lake's margin. According to Holland (1986), these areas are classified as riparian communities.

Riparian vegetation provides habitat for fish and amphibians along with food, migratory routes, and breeding grounds for many avian and mammalian species. Lakeside riparian vegetation also reduces erosion and sedimentation and controls the introduction of nutrients into the aquatic environment. Shade from dense tree and shrub growth prevents lake water from warming, thereby aiding in the control of phytoplankton blooms and in the retention of dissolved oxygen.

FRESHWATER MARSH

Mountain Lake is a wetland possessing several characteristics of a freshwater marsh. The lake is a perennial body of standing water with dense patches of tules and rushes along the margin. Mountain Lake cannot be classified as a true freshwater marsh community. Instead it contains elements of several plant communities. Many of the plant species are non-native and common to the urban park lands of coastal California. The original freshwater wetland has been significantly altered and degraded by road building, building construction, and the introduction of exotic plants near the margin of the lake. At best the vegetation at this site may be described as disturbed and typical of urban environments.

The aquatic emergent vegetation is more characteristic of natural freshwater marsh and riparian environments and may be described as such. Wetlands, including riparian and marsh communities are often among the most productive of all environments. These ecosystems may provide ample food forage and cover and serve as habitat for numerous species of birds, amphibians, fish, and other animals.

TABLE 1: PLANT SPECIES. The following table lists all plant species found at Mountain Lake. The family, scientific name and common name are reported. Plants are also classified as native or non-native.

Non-native

Family	Scientific Name	Common name
Asteraceae	<i>Taraxacum officinale</i>	Dandelion
Asteraceae	<i>Matricaria matricoides</i>	Pineapple Weed
Asteraceae	<i>Senecio mikanoides</i>	German Ivy
Brassicaceae	<i>Brassica sp.</i>	Wild Mustard
Brassicaceae	<i>Raphanus sativus</i>	Wild Radish
Cupressaceae	<i>Cupressus macrocarpa</i>	Monterey Cypress
Poaceae	<i>Lolium perrene</i>	Perennial Ryegrass
Poaceae	<i>Hordeum leporinum</i>	Farmer's Foxtail
Poaceae	<i>Bromus rigidus</i>	Ripgut Grass
Fabaceae	<i>Acacia sp.</i>	Acacia
Fabaceae	<i>Trifolium repens</i>	White Clover
Fabaceae	<i>Medicago hispida</i>	Bur Clover
Malvaceae	<i>Malva nicaensis</i>	Mallow
Myrtaceae	<i>Eucalyptus sp.</i>	Blue Gum Eucalyptus
Polygonaceae	<i>Rumex acetosella</i>	Sheep sorrel, Sour Sorrel
Primulaceae	<i>Anagallis arvensis</i>	Scarlet Pimpernel
Tropaeolaceae	<i>Tropaeolum majus</i>	Garden Nasturtium
Apiaceae	<i>Anthriscus caucalis</i>	Bur Chervil *
Apiaceae	<i>Conium maculatum</i>	Poison Hemlock

Native

Family	Scientific Name	Common name
Anacardiaceae	<i>Toxicodendron diversilobum</i>	Western Poison Oak
Asteraceae	<i>Achillea millefolium</i>	Yarrow
Brassicaceae	<i>Rorippa nasturtium-aquaticum</i>	Water Cress
Cyperaceae	<i>Scirpus sp.</i>	
Dryopteridaceae	<i>Athyrium filix-femina</i>	Common Lady Fern
Juncaceae	<i>Juncus sp.</i>	
Fabaceae	<i>Lupinus arboreus</i>	Yellow Bush Lupine
Rosaceae	<i>Rubus ursinus</i>	California Blackberry
Salicaceae	<i>Salix lasiolepis</i>	Arroyo Willow

BATHYMETRIC MAP

A bathymetric map of Mountain Lake was constructed on September 18, 1994. Prior to the construction of Park Presidio Boulevard in 1937, the lake was known to vary in depth from 6.1 m to 9.15 m (20 to 30 feet). Presently, however, the lake reaches a maximum depth of approximately 3.02 m (9.9 feet).

Mountain Lake was mapped using a Meridian 8080 Level- Transit, a 25 foot leveling rod, and a 700 foot non-stretchable rope marked at 5 m intervals. The transit was established on the southwest shore (Figure 3). From the transit, a total of 17 transects were established on the lake. The transit was used to determine the angles between transects, and depths were recorded at 5 m intervals. Depth was measured with respect to the water level of Mountain Lake on September 18, 1994, (i.e., water level equal to zero m depth, or 30 cm on the staff gauge).

Transects were drawn at a scale of 1 cm equal to 10 m. Distance measurements of the transects provided the outline/shoreline of the lake. Contour lines are presented at 0.5 m intervals (Figure 3).

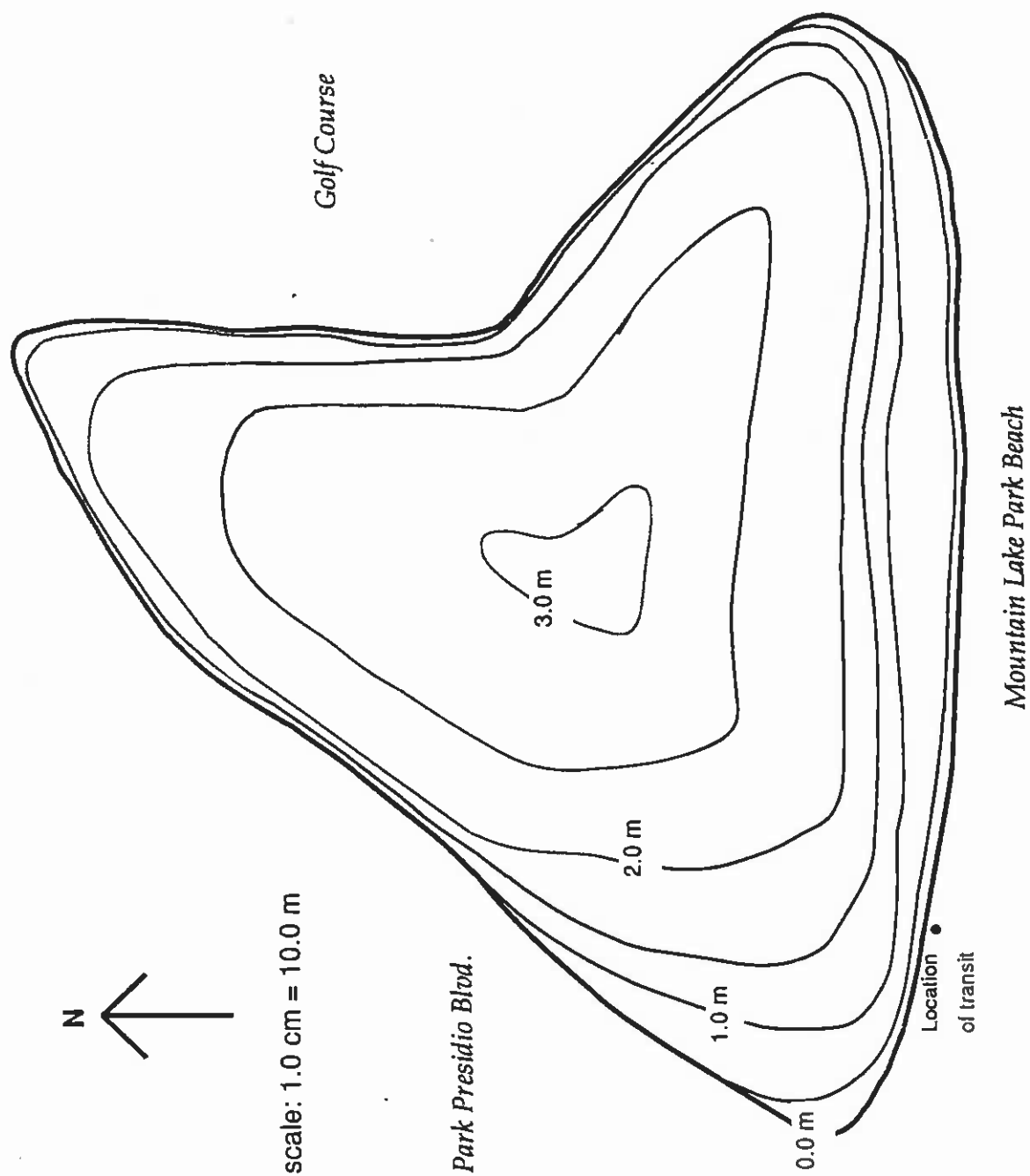


Figure 3: Bathymetric map of Mountain Lake. Contour lines indicate depths in 0.5 m increments. All depth measurements were taken relative to the water level of the lake on 9/17/94.

WATER QUALITY

Water quality stations were established at the deepest part of the lake (depth approximately 3.3 m) and at another location of intermediate depth (approximately 1.7 m). Stations were designated ML 1 and ML 2, respectively. Figure 4 shows the lake and position of sampling locations.

Water quality parameters were assessed quarterly and once following a storm event. Water temperature, conductivity, dissolved oxygen, percent saturation, turbidity, and pH were measured in the field. All measurements were performed at a depth of 0.5 m. Vertical profiles of dissolved oxygen, percent saturation, and water temperature were performed at 0.5 m intervals.

Samples for chemical water quality analysis were collected quarterly and following a storm event. Water samples were collected at a depth of 0.5 m following standard methods and analysis was performed within 24 hours. A complete description of analysis methods can be found in the Water Analysis Handbook (Hach Company) and the Standard Methods for the Examination of Water and Wastewater (American Public Health Association): Alkalinity (Hach, 81-85), Ammonia (APHA, 384-386), Chloride (Hach, 145-148), Nitrate (Hach, 392-395), Phosphate (APHA, 446-448), Total Phosphate (Hach, 514-515) and Sulfate (Hach, 567-571).

Tables 2-3 list the values obtained for the tested parameters. Figures 4-7 compare measured values at ML 1 and ML 2 on the following sampling dates: November 11, and November 30, 1993; March 16, June 15, and September 18, 1994.

WATER TEMPERATURE

Water temperature was measured in the field using a YSI model 58 meter and probe and recorded to the nearest 0.1 degree Celsius.

Water temperatures naturally fluctuate according to the season and the time of day. High temperatures are critical to aquatic life and reduce the solubility of oxygen, accelerate the metabolism of aquatic organisms, increase the toxicity of heavy metals and alter the species composition within the community (McKee and Wolf, 1963).

During the sample period, the lowest surface water temperature (11.2 °C) was recorded on November 30, 1993 at ML 1. The highest recorded temperature was 21.1 °C at ML 2 on September 18, 1994. Vertical profiles of water temperature were also performed at ML 1 and ML 2. At both sites, water temperature decreased while depth increased.

SPECIFIC CONDUCTANCE

Specific conductance (electrical conductivity) was measured using a YSI transistorized meter equipped with a platinized nickel electrode and recorded to the nearest 5 $\mu\text{mhos}/\text{cm}$.

Specific conductance refers to the water's capacity to conduct an electrical current and is a quick method of measuring ion concentration and indicating total dissolved matter and alkalinity. All substances in solution collectively exert osmotic pressure on aquatic organisms. When the osmotic pressure is sufficiently high, water drawn over respiratory membranes and other delicate external organs can cause considerable cell damage. High concentrations of many kinds of pollutants present this danger apart from any other toxic or corrosive effects they may exhibit (Eckblad, 1978).

Conductivity values ranged from 450 $\mu\text{mhos}/\text{cm}$ to 675 $\mu\text{mhos}/\text{cm}$ at ML 1 and 500 $\mu\text{mhos}/\text{cm}$ to 675 $\mu\text{mhos}/\text{cm}$ at ML 2. Generally, measurements for specific conductance were slightly higher at ML 2.

DISSOLVED OXYGEN

Dissolved oxygen was measured in the field using a YSI model 58 meter and probe and recorded to the nearest 0.1 mg/l.

Dissolved oxygen concentrations vary considerably with water depth, temperature, time of day, flow rate and other natural factors (Eckblad, 1978). Aquatic organisms require dissolved oxygen, and many fish species are rather specific to the concentration required. As discussed by Karfiol and McMillan (1983) and based on the requirements of the fish community, the CSWRCB (1975) recognized a lower limit of 7.0 mg/l. Although the USEPA (1986) states 4.0 mg/l as adequate, such a limited amount may have a deleterious effect on resident fish populations.

The highest measurement recorded at depth 0.5 m was 14.1 mg/l at ML 1 on September 18, 1994. The minimum value recorded was 3.1 mg/l (ML 1) on November 11, 1993. Vertical profiles of dissolved oxygen were also performed at 0.5 m intervals. Generally, ML 1 showed a considerable drop in levels at depth greater than 1.5 m. Levels beyond this point remained relatively constant, decreasing only slightly as depth increased. At station ML 1, levels of dissolved oxygen averaged 8.24 mg/l for depths less than or equal to 0.5 m. Measurements recorded at ML 2 revealed only minor discrepancies in dissolved oxygen levels as depth increased. These readings probably resulted from the shallow depth of the station. The average measurement at depth 0.5 m at ML 2

was 7.88 mg/l. Measurements at ML 1 and ML 2 were positively correlated with water temperature (Figure 6).

TURBIDITY

Turbidity of water samples was determined in the field using a Hach 2100P turbidimeter, which is accurate to 0.01 nephelometric turbidity units (NTU).

Turbidity is a measure of an optical property of water (Thurston *et al.*, 1979) and is attributable to suspended and colloidal organic and inorganic matter which affect the penetration of light. For stream water designated for domestic use, the upper limit of 250 NTU has been recommended by McKee and Wolf (1963), who also indicated that turbidity levels over 400 NTU may be harmful to some fish life stages. High turbidity can kill adult fish, smother eggs and fry, reduce primary productivity, and alter temperature regimes.

Turbidity measurements ranged from 3.27 NTU to 49.00 NTU, with a mean of 12.97 NTU for the duration of the study. On all sampling dates, measurements at ML 1 and ML 2 showed only slight variation. Levels did not exceed McKee and Wolf's recommended limit for the protection of aquatic life.

ALKALINITY

Total alkalinity was determined by potentiometric titration (APHA, 1985) and reported in mg/l (as calcium carbonate equivalents).

Alkalinity refers to the total amount of alkalinities in water capable of neutralizing acids (*i. e.*, buffering capacity). Alkalinity above 600 mg/l may be harmful to irrigated crops, and those above approximately 400 mg/l may be a problem to human health (USEPA, 1976). Alkalinity is important to aquatic life because it buffers pH changes and reduces the toxicity of some heavy metals (McMillan, 1985). There is no maximum criterion for aquatic life, but the USEPA (1976) has established a minimum level of 20 mg/l.

Alkalinity levels ranged from 165 mg/l to 238 mg/l for ML 1 and 167 mg/l and 207 mg/l for ML 2. Measurements from both stations met the minimum criterion for aquatic life.

AMMONIA

The amount of ammonia (unionized) in water samples was determined using an Orion selective electrode coupled to an Orion specific ion meter. Ammonia concentrations equal to or above 0.02 mg/l are reported in increments of 0.01 mg/l.

Ammonia concentrations in water samples naturally occur as a product of organic decomposition. The USEPA (1976) criterion for protection of aquatic life is 0.02 mg/l of ammonia (NH_3).

Ammonia concentrations at Mountain Lake ranged from <0.02 mg/l to 0.45 mg/l for station ML 1 and <0.02 mg/l to 0.42 mg/l for ML 2. Levels exceeded the USEPA (1976) criterion for the protection of aquatic life on November 11, November 30, and March 16 at both ML 1 and ML 2.

NITRATE

Nitrates were measured by the cadmium reduction method and are reported as milligrams nitrogen per liter (mg N/l; to convert to mg NO_3 /l multiply by 4.4). Levels above 0.02 milligrams nitrogen/liter (mg N/l) are reported to the nearest 0.01 mg N/l.

Nitrates that occur in water are often normal decomposition products of organic materials. Nitrate is also the common form in which nitrogen is added as fertilizer to agricultural crops and revegetation projects. The nitrate criterion for domestic water is 10.2 mg N/l; tested fish species have proved tolerant of much higher levels.

On all sampling dates, nitrate levels for each station were similar. Levels fluctuated during the study, measuring a minimum of 0.12 mg/L (ML 1) on June 15, and a maximum of 0.96 mg/l (ML 2) on November 30. Nitrate levels did not exceed the 10.2 mg N/l nitrate criterion for domestic water.

SULFATE

Sulfate concentrations were measured using the turbidimetric method of analysis and reported in increments of 1.0 mg/l.

Sulfates appear in natural streams in a wide range of concentrations, often because of leaching of minerals and oxidation of sulfurous material associated with mining operations. The USEPA (1976) has set an upper limit of 250 mg/l for sulfates in drinking water.

The sulfate levels at Mountain Lake remained relatively constant throughout the study, averaging 34 mg/l for ML 1 and 32 mg/l for ML 2. Measurements did not exceed the USEPA (1976) criterion for sulfates in drinking water.

TOTAL PHOSPHORUS

Total phosphate analysis was executed using hydrolysis to orthophosphate proceeded by the stannous chloride method (Standard Methods, 1985). A lower analytical limit of 0.005 mg/l was established for analysis.

Phosphorus occurs in natural waters almost solely as phosphates and is classified as reactive phosphates, acid hydrolyzable phosphates, and orthophosphates. Phosphorus is an essential to the growth of organisms and can be the nutrient that limits the primary productivity of a body of water (Standard Methods, 1985). There is no one accepted total phosphorus criterion to control nuisance growths of aquatic plants. The USEPA (1986) has proposed an upper limit of 25 µg/l for total phosphates in lakes and reservoirs. Concentrations above 25 µg/l may occasionally stimulate excessive or nuisance growths of aquatic plants and algae, resulting in undesirable tastes and odors, aesthetically unpleasant environments, and altered water chemistry.

Concentrations of total phosphates varied throughout the study. The minimum and maximum levels measured were recorded at ML 1 and were 0.021 mg/l (September 18) and 0.250 mg/l (June 15), respectively. Increases in concentrations during June may have stimulated growth of the alga *Aphanizomenon flos-aquae* resulting in a nuisance bloom.

ORTHOPHOSPHATES

Orthophosphate analysis was executed using the stannous chloride method (Standard Methods, 1985). A lower analytical limit of 0.005 mg/l was established for analysis.

Orthophosphate is a general indicator of water quality and is an essential nutrient or aquatic life. Excessive amounts of orthophosphate can stimulate nuisance blooms of aquatic algae and perhaps higher plants. Although no criteria have been established for freshwater, it is recommended (USEPA, 1976) that orthophosphate concentrations should not exceed 0.05 mg/l in order to avoid nuisance growths.

The concentrations of orthophosphates at Mountain Lake ranged from 0.168 mg/l to 0.010 mg/l for ML 1, and 0.165 mg/l to 0.014 mg/l at ML 2. Elevated levels may have contributed to nuisance phytoplankton blooms noted in the spring.

HYDROGEN ION CONCENTRATION

A Nester pH pen was used to measure pH in the field. Measured values were recorded to the nearest 0.1 pH unit.

The logarithm of the reciprocal of the hydrogen ion concentration is known as pH; consequently, a change of one pH unit represents a tenfold increase in hydrogen ion concentration. The solubility of metals in sediments and suspended material and the toxicity of many compounds are affected by pH. According to McMillan (1985) the CSWRCB (1975) has recommended a pH of 6.5 to 8.5 for the protection of aquatic life; the USEPA (1976) recognizes a criterion for domestic water (prior to treatment) of 5.0 to 9.0.

The pH values recorded ranged from a minimum of 7.1 at ML 1 (November 11) to a maximum of 8.6 at ML 2 (September 18). The yearly averages for ML 1 and ML 2 are 7.8 and 8.0, respectively.

TABLE 2: WATER QUALITY DATA FOR ML 1. The table lists basic water quality measurements recorded from November 1993 through September 1994. --- indicates data not available.

Date	11/11/93	11/30/93	3/16/94	6/15/94	9/18/94
Time	2:00pm	11:00am	10:00am	9:30am	2:20pm
Weather	Overcast	Clear	Overcast	Clear	Overcast
Water Temp (C)					
@ depth 0.5m	16.5	11.2	16.1	18.0	19.8
@ depth 1.0m	---	11.0	16.0	17.9	19.3
@ depth 1.5m	---	11.0	15.8	17.8	18.6
@ depth 2.0m	---	10.9	15.6	17.9	17.7
@ depth 2.5m	---	10.8	15.3	17.7	16.7
@ depth 3.0m	---	10.8	14.9	17.4	14.1
Conduct (umhos/cm)	550	500	450	600	675
DO (mg/l)					
@ depth 0.5m	3.1	5.2	8.4	10.4	14.1
@ depth 1.0m	---	4.6	7.9	10.0	11.8
@ depth 1.5m	---	3.3	7.3	10.1	10.0
@ depth 2.0m	---	2.9	6.5	7.1	9.1
@ depth 2.5m	---	2.7	4.5	6.2	7.1
@ depth 3.0m	---	2.5	3.0	5.8	6.2
DO Sat (%)					
@ depth 0.5m	31	46	85	110	149
@ depth 1.0m	---	40	76	110	126
@ depth 1.5m	---	29	68	107	106
@ depth 2.0m	---	26	57	75	99
@ depth 2.5m	---	24	39	71	94
@ depth 3.0m	---	22	23	63	74
Turbidity (NTU)	5.61	5.27	3.27	28.4	11.1
Alkalinity (mg/l)	238	180	165	197	202
Ammonia (mg/l)	0.34	0.34	0.45	<0.02	<0.02
Nitrate (mg N/l)	0.58	0.76	0.60	0.12	0.32
Sulfate (mg/l)	39.0	35.0	35.0	34.0	26.0
Orthophosphate (mg/l)	0.168	0.145	0.029	0.035	0.010
Total P (mg/l)	---	---	0.054	0.250	0.021
Reactive and Acid					
Hydrolyzable P (mg/l)	---	---	0.025	0.215	0.011
pH (pH units)	7.1	7.6	7.8	8.2	8.5
Transparency (m)	1.31	1.36	2.01	0.43	0.53
Hardness (mg/l)	---	---	219	231	
Total Coliform (MPN)	---	>1600	1600	500	2200
Fecal Coliform (MPN)	---	>1600	900	23	600

TABLE 3: WATER QUALITY DATA FOR ML 2. The table lists basic water quality measurements recorded from November 1993 through September 1994. --- indicates data not available.

Date	11/11/93	11/30/93	3/16/94	6/15/94	9/18/94
Time	1:30pm	11:30pm	10:30am	10:00am	3:20pm
Weather	Overcast	Clear	Overcast	Clear	Overcast
Water Temp (C)					
@ depth 0.5m	15.7	11.4	16.1	18.4	21.1
@ depth 1.0m	---	11.1	16.1	18.3	21.0
@ depth 1.5m	---	10.9	16.1	18.2	---
Conduct (umhos/cm)	575	520	500	600	675
DO (mg/l)					
@ depth 0.5m	3.4	4.9	8.7	12.1	10.3
@ depth 1.0m	---	4.8	8.5	12.1	9.4
@ depth 1.5m	---	4.6	8.2	8.9	---
DO Sat (%)					
@ depth 0.5m	31	45	87	131	110
@ depth 1.0m	---	44	85	131	111
@ depth 1.5m	---	41	79	91	---
Turbidity (NTU)	5.38	5.16	3.81	49.00	12.70
Alkalinity (mg/l)	207	184	168	167	207
Ammonia (mg/l)	0.38	0.34	0.42	<0.02	<0.02
Nitrate (mg N/l)	0.60	0.96	0.62	0.14	0.32
Sulfate (mg/l)	38.0	34.0	33.0	35.0	26.0
Orthophosphate (mg/l)	0.165	0.136	0.014	0.045	0.027
Total P (mg/l)	---	---	0.041	0.213	0.033
Reactive and Acid					
Hydrolyzable P (mg/l)	---	---	0.027	0.168	0.006
pH (pH units)	7.3	7.8	7.9	8.3	8.6
Transparency (m)	1.37	1.19	bottom	0.43	0.43
Hardness (mg/l)	---	---	216	226	
Total Coliform (MPN)	---	>1600	900	220	3000
Fecal Coliform (MPN)	---	>1600	280	30	2400

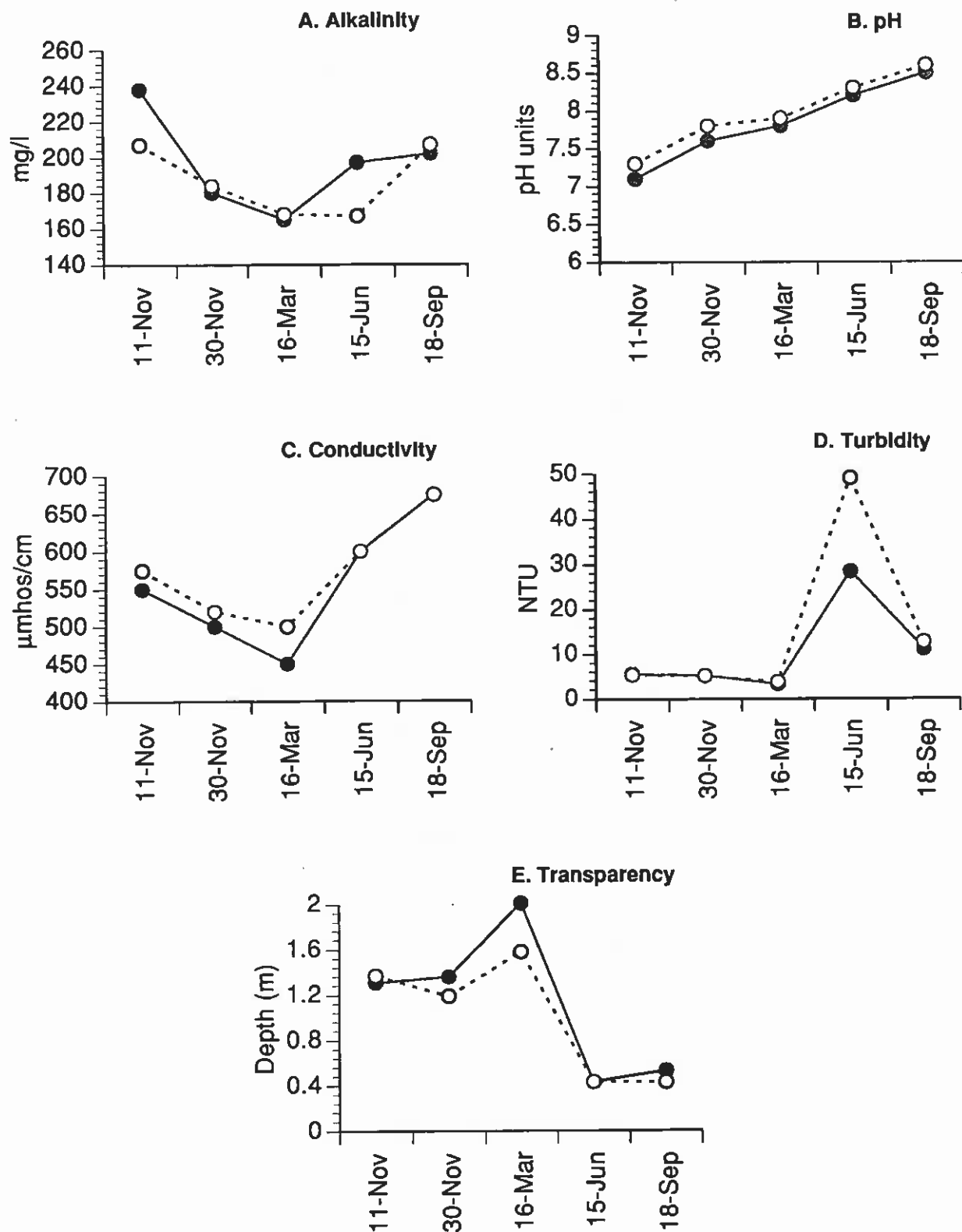


FIGURE 4: WATER QUALITY MEASUREMENTS. Figures A-E show basic water quality parameters for the following sampling dates: 11/11/93, 11/30/93, 3/16/94, 6/15/94, 9/ /94. Solid lines and circles refer to ML 1; dashed lines and open circles refer to ML 2. *Note: Transparency data for 3/16/94 indicates a bottom depth for ML 2.

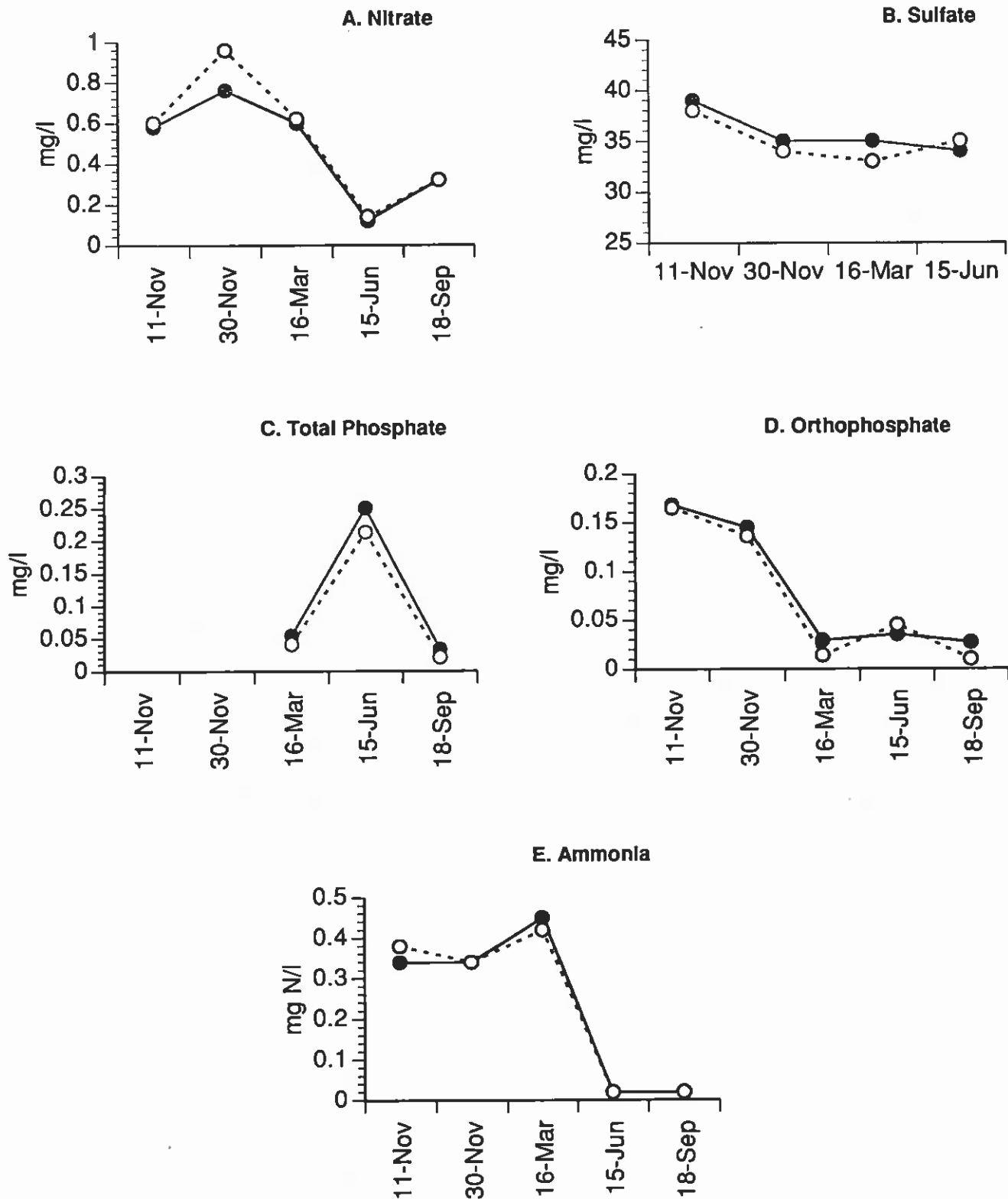


FIGURE 5: NUTRIENT CONCENTRATIONS. Figures A-E show nutrient concentrations for the following sampling dates: 11/11/93, 11/30/93, 3/16/94, 6/15/94, and 9/ /94. Solid lines and circles refer to ML 1; dashed lines and open circles refer to ML 2. *Note: Ammonia value for 6/15/94 is <0.02 mg/l. Total phosphate data not available for 11/11/93 and 11/30/93.

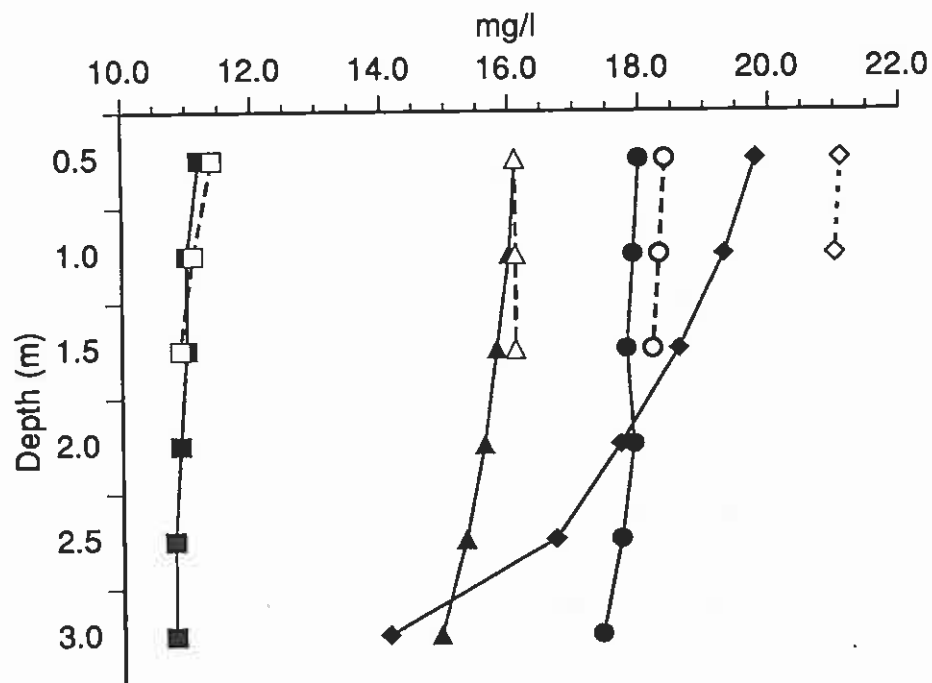


FIGURE 6: VERTICAL PROFILE OF WATER TEMPERATURE. The graph shows water temperature for the following dates: 11/30 (squares), 3/16/94 (triangles), 6/15/95 (squares), and 9/18/94 (diamonds). Measurements were recorded at 0.5 m intervals. Solid lines and symbols refer to ML 1; dashed lines and open symbols refer to ML 2.

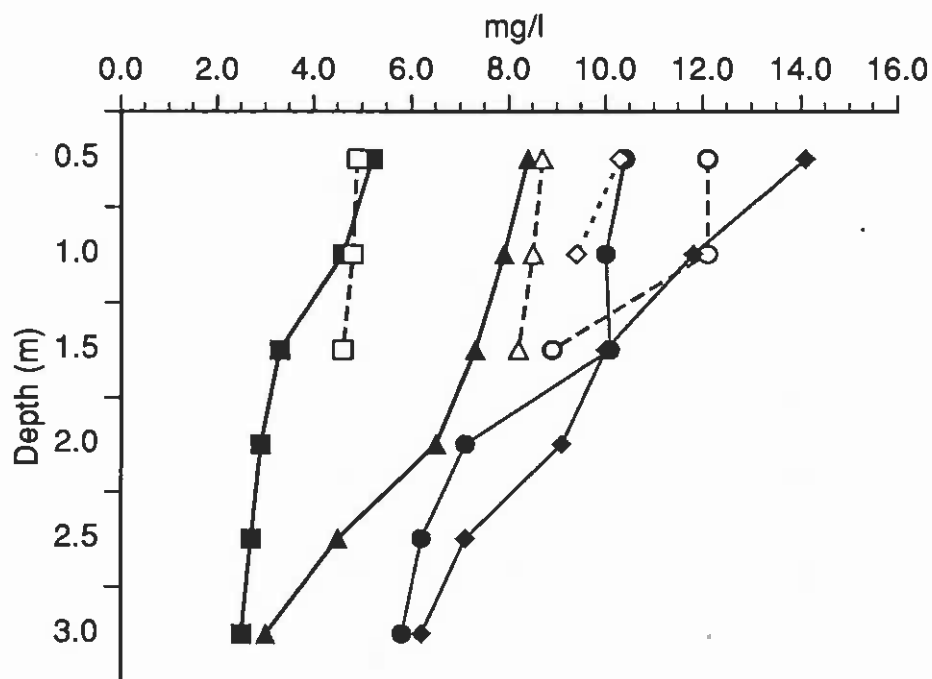


FIGURE 7: VERTICAL PROFILE OF DISSOLVED OXYGEN. The graph shows levels of dissolved oxygen for the following sampling dates: 11/30/93 (squares), 3/16/94 (triangles), 6/15/94 (circles), and 9/18/94 (diamonds). Measurements were recorded at 0.5 m intervals. Solid lines and symbols refer to ML 1; dashed lines and open symbols refer to ML 2.

COLIFORM BACTERIA

The coliform bacteria comprise all of the aerobic and facultative anaerobic, gram-negative, non-endospore forming, rod-shaped bacteria which ferment lactose with gas formation within 48 hours at 35°C (APHA, 1985). Because these organisms are commonly found in human (and other mammalian) feces, they are used in water quality analysis as indicative of fecal waste pollution. Because some coliform bacteria are not enteric (found in the digestive system) but are found in plant and soil samples, fecal coliform counts are often made to distinguish between the two.

Total coliform and fecal coliform bacteria were measured using multiple tube fermentation techniques as described in Standard Methods (APHA, 1985) and reported as the most probable number (MPN) of bacteria per 100 ml of water sample. Treated or chlorinated drinking water should contain no coliform bacteria per 100 ml of sample (APHA, 1985); coliform bacteria in untreated water samples are to be expected. Contact recreation water should contain a level of total coliform less than 240 MPN per 100 ml and a fecal coliform level less than 200 MPN (log mean) per 100 ml of sample (SFBBR, 1986).

TOTAL COLIFORM

	ML 1	ML 2
November 30, 1993	>1600 MPN	>1600 MPN
March 16, 1994	1600 MPN	900 MPN
June 15, 1994	500 MPN	220 MPN
September 18, 1994	2200 MPN	3000 MPN

The total coliform levels exceeded the APHA criteria for drinking water on all dates. The maximum and minimum levels were recorded at ML 2 and were 220 MPN and 3000 MPN, respectively. Coliform levels are to be expected in untreated waters, however, levels as elevated as 3000 MPN pose health risks.

FECAL COLIFORM

	ML 1	ML 2
November 30, 1993	>1600 MPN	>1600 MPN
March 16, 1994	900 MPN	280 MPN
June 15, 1994	23 MPN	30 MPN
September 18, 1994	600 MPN	2400 MPN

The fecal coliform levels varied from a high of 2400 MPN (ML 2) to a low of 23 MPN (ML 1). Levels exceeded the APHA criteria for drinking water on all dates except June 15.

DISCUSSION

The recorded levels for coliform bacteria well surpassed the USEPA criteria for contact and non-contact recreational waters for all sampling dates with the exception of June 15. Since the lake serves as habitat to a variety of aquatic water fowl, coliform bacteria is to be expected. Aquatic birds and wildlife can contribute to total and fecal coliform levels with the introduction of fecal material. Levels as high as those reported, however, may also be the result of another source of eutrophication.

FISH

On July 28, 1994, a fish kill occurred at Mountain Lake. In order to prevent subsequent fatalities, the National Park Service removed all surviving fish on July 29, 1994. Identification based on the mortalities of resident fish were subsequently performed.

All fish identified at Mountain Lake were non-native, introduced species. The resident population is comprised of channel catfish (*Ictalurus punctatus*), carp (*Cyprinus carpio*), spotted bass (*Micropterus punctalutus*), hitch (*Lavinia exilicauda*), and fathead minnows (*Pimephales promelas*). Table 3 lists common names and scientific names as well as population estimates based on mortalities.

The fish kill was possibly the result of extremely low dissolved oxygen levels at the lake. Oxygen levels on July 27, 1994, measured 8.2 mg/l (78% saturation); approximately 24 hours later, levels declined to 1.4 mg/l (8% saturation). USEPA (1976) states the minimum level of dissolved oxygen for the protection of aquatic life is 5.0 mg/l. Levels below this criteria can be detrimental to aquatic organisms.

An additional factor possibly contributing to the decline in dissolved oxygen levels was the crash of a phytoplankton bloom. The blue-green alga *Aphanizomenon flos-aquae* had reached bloom proportions (400,000 cells/ml) two weeks prior to the fish kill. A tow performed on July 28, 1994, revealed an almost complete absence of phytoplankton from the lake, indicative of a severe population crash. The bacteria decomposing the algae may have depleted oxygen levels in the lake, resulting in levels incapable of supporting resident fish populations.

It is also possible, however, that the depleted oxygen levels were not the only cause of the fish kill. *Aphanizomenon flos-aquae* is known as a potentially toxic member of the Cyanophyta and has been previously associated with fish kills. Collins (1978) cites examples of fish kills in lakes treated with algaecides such as copper sulfate to reduce nuisance blooms of *A. flos-aquae*. Gentile and Maloney (1969) concluded that copper sulfate in particular is not responsible for the fish kills. The lethal substance is an endotoxin which is released only upon lysing of the algal cells, and copper sulfate "may enhance the toxicity" based on past incidents (Collins, 1978).

Following the fish kill, a quantitative inventory of the lake's fishery resources was conducted using gill nets and trot lines. The species collected was carp (*Cyprinus carpio*). Table 6 lists size and weight classification of all fish sampled. It is most likely that the fish kill drastically reduced native populations; therefore, sampling was rendered unsuccessful.

TABLE 6: SAMPLED FISH. The table lists all fish collected in gill nets or trot lines. Scientific names, common names, and size classifications are indicated.

Date	Length (mm)	Weight (g)	Scientific Name	Common Name	Native/ Non-native	Microhabitat
9/24/94	106	23.1	Cyprinus carpio	Carp	Non-native	Bottom
9/24/94	108	20.5	Cyprinus carpio	Carp	Non-native	Bottom
9/24/94	109	21.2	Cyprinus carpio	Carp	Non-native	Bottom
9/24/94	111	22.6	Cyprinus carpio	Carp	Non-native	Bottom
9/24/94	115	21.1	Cyprinus carpio	Carp	Non-native	Bottom
9/24/94	121	29.7	Cyprinus carpio	Carp	Non-native	Bottom
9/24/94	147	47.0	Cyprinus carpio	Carp	Non-native	Bottom
9/24/94	351	581.2	Cyprinus carpio	Carp	Non-native	Bottom
9/26/94	104	19.5	Cyprinus carpio	Carp	Non-native	Bottom
9/26/94	111	21.0	Cyprinus carpio	Carp	Non-native	Bottom
9/26/94	111	21.7	Cyprinus carpio	Carp	Non-native	Bottom
9/26/94	113	19.0	Cyprinus carpio	Carp	Non-native	Bottom
9/26/94	114	23.4	Cyprinus carpio	Carp	Non-native	Bottom
9/26/94	114	20.1	Cyprinus carpio	Carp	Non-native	Bottom

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