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Diagnostic Study of Myron Lake
Yakima County, Washington
July 1988 through December 1989

by

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ABSTRACT

A diagnostic study of Myron Lake was conducted between July 1988 and December 1989. The study was initiated to elucidate the causes of a fish kill that occurred in the fall of 1987. Fish kills in the fall of 1987, and again in 1988, were the result of low dissolved oxygen caused by mixing of anoxic water and oxidation of oxygen demanding materials from the hypolimnion with the whole lake at fall overturn.

Myron Lake is eutrophic due to excessive phosphorus loading via external (groundwater and springs) and internal (anoxic hypolimnetic sediment release) sources. Phosphorus is the most limiting nutrient for algal productivity.

Lake restoration techniques which emphasize direct control of hypolimnetic dissolved oxygen were suggested for prevention of future fish kills. Hypolimnetic aeration was proposed as a desirable method for maintaining sufficient dissolved oxygen and temperature in the hypolimnion for trout survival, and for reducing internal phosphorus recycling from anoxic lake sediments.

The likelihood of future fish kills at fall overturn is expected to remain high unless an effective restoration technique is implemented. Based on results of the present study, a feasibility analysis of alternative restoration techniques is recommended. The costs and benefits of hypolimnetic aeration should be evaluated and compared with other potentially appropriate techniques.

1.0 INTRODUCTION

1.1 Site Description and History

Myron Lake is located along U.S. Route 12 in northern Yakima County, Washington (Figure 1). It is a recently (1970) abandoned gravel pit with a surface area of about 49,000 m^2 (12 acres) and maximum and mean depths of 13.9 m and 9.1 m, respectively. The lake was filled with groundwater after excavation was completed in 1970. Water inflows include springs near the northwest corner and groundwater seepage. A single surface outlet is located at the northeast corner.

The predominant soil type in the watershed is Weirman sandy loam (USDA, 1985). This soil is deep and somewhat excessively drained, and is found on low terraces and flood plains. The soil is dissected by intermittent and perennial streams, and is formed in mixed alluvium. Permeability of Weirman soil is rapid. The predominant uses of this soil type includes irrigated crops and homesites. The main irrigated crops are apples, cherries, and pears.

Masco Products Inc., a metal plater, operated a surface impoundment (lagoon) and an underground concrete storage tank for hazardous waste storage and disposal. Masco's facilities were apparently downgradient from the lake (Wicks, 1984). The lagoon was used for hazardous materials from 1969 through September 1980. The underground storage tank was used from 1966 through 1970. The lagoon was located approximately 61 meters from the south shore of the lake. The storage tank was located 120 meters south of the lagoon. The company was permitted to discharge wastes in state waters and/or the municipal sewage system by the Department of Ecology.

Activities in the vicinity of the lake drainage basin include gravel digging and irrigation. Gravel digging activities are conducted along the northeast shore downgradient from the lake. The distance between the gravel activities and the lake is approximately 5 to 10 meters. Irrigated crops are located several hundred meters northwest of the lake. An irrigation canal (Union Canal), which carries water from the Naches River, flows adjacent to Myron Lake without entering the lake (Figure 1). The Union Canal runs parallel to the southwest lake shore. The Naches River flows parallel to the northern lake shore approximately 300 meters from the lake.

In November, 1987 a large fish kill was observed by the Departments of Wildlife and Ecology. Several hundred dead trout were picked up from the shoreline and many were seen floating in deeper water. Suspected causes of the fish kill were low dissolved oxygen (D.O.), approximately 2 mg/L at the surface, and possible elevated concentrations of hydrogen sulfide (personal communication, Kim Sherwood, Department of Ecology). Since no limnological data were available for Myron Lake, the present study was initiated to determine selected physical, chemical, and biological characteristics to elucidate causes of the fish kill.

1.2 Public Access and Fisheries Management

The Washington Department of Wildlife maintains a public access at the west side of Myron Lake. The lake is managed as a selective trout fishery. Selective fishery regulations require the use of single-pointed barbless hooks, no bait and two fish catch limits. The intent of the regulation is to increase and perpetuate carryover of larger trout, by limiting harvest and reducing mortality of released fish. The lake is popular with the local fishing public and is open year around. Fishing activity is fairly well distributed throughout the year with more intense activity during the spring.

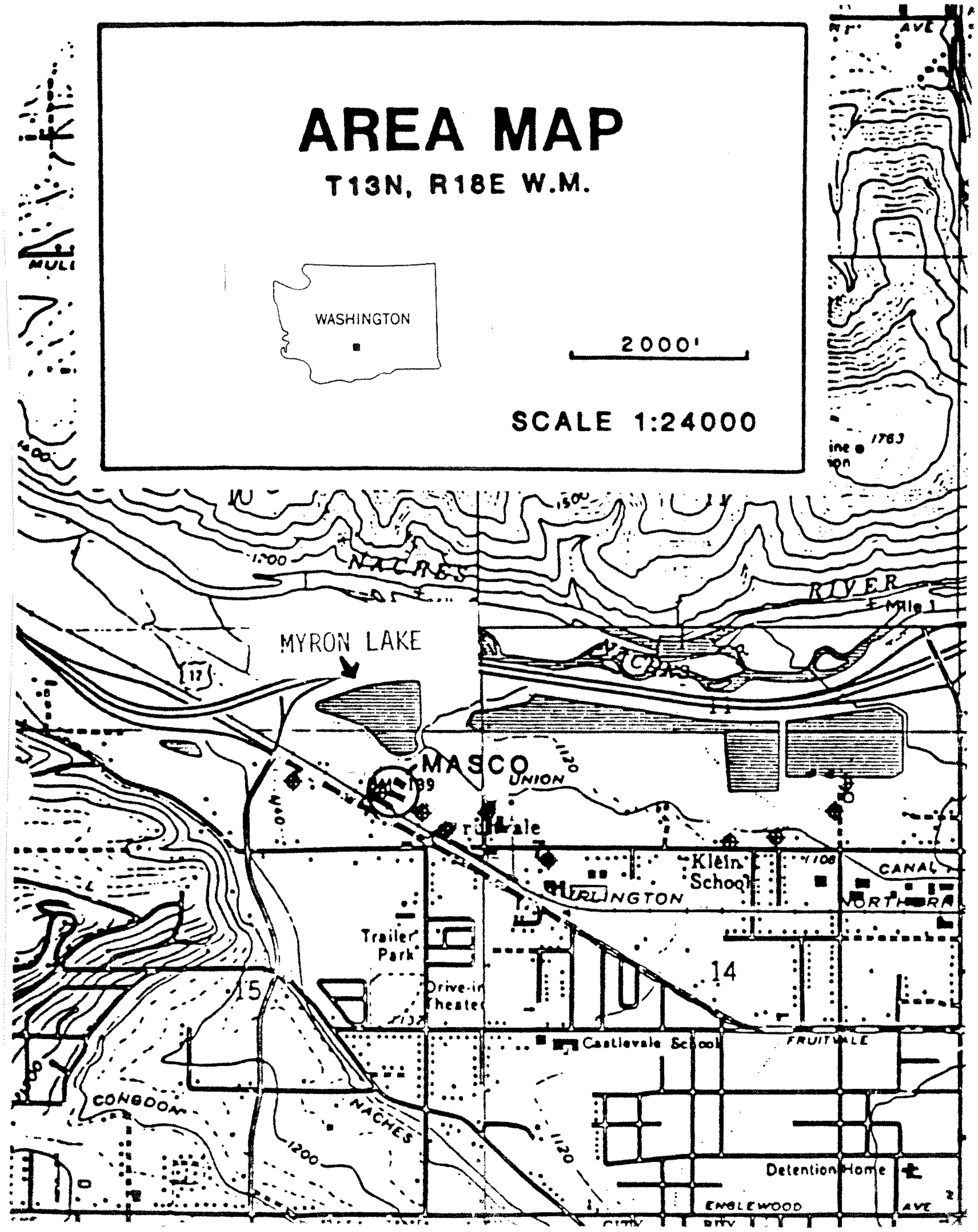


Figure 1. Vicinity of Myron Lake, Yakima County, Washington.

Rainbow trout have been stocked every year since 1971 (Table 1). From 1971 through 1987, the average number of trout stocked was 10,500 per year, in sizes ranging from 10 pounds each to 300 fish per pound. The majority ranged from 4 to 77 fish per pound. Occasional brown trout fry plants are also made. Since the fish kill in 1987, trout plants were reduced to 2,000 - 3,000 per year.

Rotenone has been applied as a rehabilitation method three times: September 1977, October 1983, and April 1988. The species eradicated include pumpkinseed, bluegills, large mouth bass, suckers, squawfish, chiselmouth, gold fish and trout. The toxicity of rotenone was expected to decrease within 30 days of application in each case.

1.3 Lake Chemistry During Stratification

Nutrient enrichment of natural and man made lakes leads to the production of algal biomass and oxygen (photosynthesis) in the epilimnion and heterotrophic metabolism (respiration and consumption) in the hypolimnion (Welch, 1980). The level of the respiration in the hypolimnion is determined by the amount of detritus raining into it. If epilimnetic production is high, the detritus is appreciable and a large amount of oxygen is removed from the water throughout the hypolimnion.

During the period of stratification, the hypolimnion is sealed from contact with the atmosphere. In addition, productivity below the thermocline is minimal because of light limitation. Therefore, the hypolimnion is effectively blocked from sources of oxygen, and hypolimnetic content of oxygen can rapidly decrease due to the oxidation of organic matter in the water column, oxidation of various inorganic species, and sediment oxygen demand (Hutchinson, 1975). The consumption of oxygen is greatest at the sediment surface of the lake bottom, where detritus and other organic matter accumulates, and the hypolimnion may become anaerobic.

Anaerobic conditions bring about drastic changes in the sediment-water interface. Among these are a decrease in redox potential, pH, and alkalinity, an increase in specific conductance, the disappearance of nitrate, an accumulation of ammonia, the reduction of manganese and iron, the generation of the organic products of anaerobic metabolism, the reduction of sulfate, and secondary effects of reduction such as an increase in solubility of phosphorous and silicon (Mortimer, 1941 and 1942; Stumm and Morgan, 1981). The biological decay of organic matter in reduced environments also results in the production of hydrogen sulfide. Such environments include the anaerobic hypolimnia of natural and man-made lakes and ponds.

1.4 Oxygen Requirements of Trout

Doudoroff and Shumway (1967) report that a range of 1.6 to 2.8 mg/L dissolved oxygen (D.O.) at temperatures of 9 to 21 °C initiates the death of juvenile trout. The lethal concentration killing 50% of exposed juvenile trout (LC50) was 1.5 to 2.5 mg/L, with complete kill at 1.3 to 2.3 mg/L. Juvenile brown trout were asphyxiated in 1.5 minutes at 19.1 °C with D.O. of 1.94 mg/L. The coldwater criteria for water column D.O. promulgated by EPA (1986) specify a 1-day minimum of not less than 4.0 mg/L and a minimum 7-day average of not less than 5.0 mg/L for protection from detrimental effects.

Table 1. Record of trout stocking in Myron Lake, 1971-1989.

Date	Species	No./lbs	Number Stocked	Wt Fish (Kg)	Source
5/13/71	RB	25	5,000	91	Naches Hatchery
9/01/71	"	7	3,220	209	" "
9/28/71	"	5.5	1,375	114	" "
4/28/72	"	5# ea.	70	159	" "
5/03/72	"	3.5	2,135	277	Yakima Hatchery
5/17/72	"	56	10,080	82	" "
6/20/72	"	5	2,375	215	" "
9/13/73	"	7	5,530	358	Naches Hatchery
9/19/73	"	7	4,130	268	" "
4/27/73	"	4	2,000	227	Yakima Hatchery
3/27/73	"	4# ea.	200	363	Naches Hatchery
3/23/73	"	4	5,200	590	Yakima Hatchery
5/16/73	"	90	10,800	54	" "
5/74	"	110	8,250	34	" "
4/12/74	"	5.5 # ea.	15	37	" "
3/75	"	5.8	4,959	388	" "
4/76	"	2.25 # ea.	36	37	" "
4/13/76	"	5.3	5,035	431	" "
3/77	"	6	5,010	379	" "
3/78	"	4.5	4,005	404	" "
5/78	"	77	6,930	41	" "
3/22/79	"	4	4,000	454	" "
6/79	"	120	6,000	23	" "
3/19/80	"	4	5,000	567	" "
7/30/80	"	150	5,250	16	" "
4/07/81	"	6	5,100	386	Goldendale
5/27/81	"	48	4,080	386	" "
6/03/81	"	300	5,100	8	" "
4/13/82	"	5	5,000	454	Yakima Hatchery
6/4/82	"	56	5,992	49	" "
4/14/83	"	6	5,010	379	" "
3/28/84	"	3	4,005	606	Naches Hatchery
3/01/84	SS	5# ea.	40	91	Yakima Hatchery
4/11/84	RB	4	1,320	150	Naches Hatchery
5/09/84	"	85	2,975	16	Yakima Hatchery
5/30/84	BT	120	2,040	8	Naches Hatchery
3/15/85	SS	10# ea.	26	118	Yakima Hatchery
4/02/85	RB	4.5	3,645	367	Naches Hatchery
5/29/85	"	76	3,040	18	Yakima Hatchery
8/07/85	BT	50	2,500	23	" "
4/86	RB	3	3,000	454	Naches Hatchery
5/07/86	BT	65	1,950	14	Chelan Hatchery
6/86	RB	50	3,000	27	Naches Hatchery
9/05/86	"	95	285	1	Yakima Hatchery
3/11/87	"	5	3,950	358	Naches Hatchery
5/12/87	BT	50	5,000	45	Chelan Hatchery
5/27/87	RB	136	5,032	17	Naches Hatchery
6/20/88	RB	2.5	2,000	363	" "
3/13/89	RB	5	2,250	204	" "
12/26/89	RB	5.5	1,001	82	Yakima Hatchery

RB = Rainbow Trout SS = Summer steelhead (i.e. Rainbow Trout) BT = Brown Trout

2.0 METHODS

2.1 Sampling

The water column of Myron Lake was sampled at a single midlake station at 3-week intervals from July 1988 through November 1988 and once per month from December 1988 through December 1989. Inflowing water was sampled from a spring near the northwest corner of the lake. The outflow discharge and lake stage was also measured. A summary of measured parameters is shown in Table 2.

From July 1988 through November 1988, water column profiles of temperature, pH, dissolved oxygen, specific conductance, and oxidation/reduction potential (ORP) were measured, using field probes, at one meter depth intervals from the surface to 12 meters. Light intensity was measured at one meter intervals. Field measurements were reduced to vertical profiles of temperature and D.O. from December 1988 through December 1989. Secchi disk transparency was monitored throughout the study.

The dates and the depths at which the water column was sampled are shown in Table 2. A Van Dorn type sampler was used. Water samples were collected for laboratory chemical analyses at 2 to 3 meter intervals from July 1988 through November 1988, and from 5 meter intervals from December 1988 through December 1989.

Discharge from the lake outflow was measured on each sampling occasion using a velocity meter or bucket and stopwatch. Lake level was also measured using the outlet culvert (lowest point inside the pipe at the entrance to the culvert) as a vertical reference datum. Direct measurement of inflow rates were not possible.

Zooplankton were collected in vertical hauls (6 m to 0 m) by using a Wisconsin plankton net with a 13 cm net opening and 80 μm mesh size. The sample was immediately preserved with a 70% ethanol solution. A composite phytoplankton sample was taken from 0 m, 3 m, and 6 m depths and preserved with Lugol's solution (APHA et al., 1985).

Sediment core samples were collected at mid-lake (about 13 meters deep) using a Ponar dredge. Coring tubes were inserted in undisturbed sediment at each side of the top openings of the dredge. Coring tubes were clear plastic with 34.5 mm inside diameters and a length of 10-20 cm. Each core was sliced at 1 cm intervals into pre-weighed polyethylene bottles (250 ml) and frozen for transport to the University of Washington Environmental Engineering laboratory for analysis.

2.2 Laboratory Analyses

Water samples were analyzed for nutrients (ammonia N, nitrate+ nitrite N, total N, soluble reactive P, total P), chlorophyll *a*, sulfate, hydrogen sulfide, alkalinity, total hardness, and metals (soluble and total Fe, Mn, Cr, Ni, Cu, and Zn). The methods of pretreatment and analysis (Table 2) were those recommended in Standard Methods (APHA et al., 1985) and EPA laboratory manuals (EPA, 1983).

Sediment core samples were thawed and weighed to determine wet weight, and weighed again after heating to dryness for 24 hours at 103 °C. The dried samples were then homogenized by using mortar and pestle. Subsamples of approximately 100 mg were placed into pre-weighed aluminum pans. Dry weights were again determined before samples were ignited at 550 °C for 1 hour. The samples were allowed to cool in a desiccator, then weighed again to determine weight loss after ignition.

Table 2. Summary of Myron Lake sampling and analytical methods.

PARAMETERS	<------------------------------Depth (meters)------------------------------>													Spring Outlet	Method/ Reference
	0	1	2	3	4	5	6	7	8	9	10	11	12		
pH	J,X	J,X	J,X	J,X	J,X	J,X	J,X	J,X	J,X	J,X	J,X	J,X	J,X	X	Field Probe; SM 423
Dissolved Oxygen	J,X,Z	J,X,Z	J,X,Z	J,X,Z	J,X,Z	J,X,Z	J,X,Z	J,X,Z	J,X,Z	J,X,Z	J,X,Z	J,X,Z	J,X,Z	X,Z	Field Probe; SM 421F
Sp. Conductance	X	X	X	X	X	X	X	X	X	X	X	X	X		Field Probe; SM 205
Temperature	J,X,Z	J,X,Z	J,X,Z	J,X,Z	J,X,Z	J,X,Z	J,X,Z	J,X,Z	J,X,Z	J,X,Z	J,X,Z	J,X,Z	J,X,Z	X,Z	Field Probe; SM 212
Light Intensity	X	X	X	X	X	X	X	X	X	X	X	X			Irradiameter
Secchi Disk	X,Z														Secchi Disk
Oxidation/Reduction Potential	X	X	X	X	X	X	X	X	X	X	X	X		X	Field Probe; Platimum electrode
Active Chlorophyll a	J,X,Z		J	X	J		X								SM 1002G
Nitrate plus Nitrite-N	J,X		J		J		J		J		J		J	X	SM 418C
Ammonia-N	J,X		J		J		J		J		J		J	X	SM 417C
Total Phosphorus	J,X,Z		J		J	Z	J		J		J,Z		J		EPA 365.3
Total Soluble P														X,Z	EPA 365.3
Total Nitrogen	J,X,Z		J		J	Z	J		J		J,Z		J		D'Elia et al., 1977
Total Soluble N														X,Z	D'Elia et al., 1977
Soluble Reactive P	J,X		J		J		J		J		J		J	X	SM 424F
Sulfate	J,X		J		J		J		J		J		J	X	SM 426C
Sulfide							X			X	X	X			EPA 376.1
Total Hardness	A23														SM 314B
Alkalinity	J,X		J		J		X			X		X		O24	SM 403
Total Soluble Fe	J,Y								J	Y		Y	J	J,O24	EPA 236.1, 236.2
" Mn	J,Y						Y		J	Y		Y	J	J,O24	EPA 243.1, 243.2
" Cu	J,A1						Y		J				J	J,O24	EPA 220.1, 220.2
" Zn	J,A1						A1		J				J	J,O24	EPA 289.1, 289.2
" Ni	J,A1						A1		J				J	J,O24	EPA 249.1, 249.2
" Cr	J,A1						A1		J				J	J,O24	EPA 218.1, 218.2
Total Fe	J,Y						Y		J	Y		Y	J	J,O24	EPA 236.1, 236.2
" Mn	J,Y						Y		J	Y		Y	J	J,O24	EPA 243.1, 243.2
" Cu	J,A1						Y		J				J	J,O24	EPA 220.1, 220.2
" Zn	J,A1						A1		J				J	J,O24	EPA 289.1, 289.2
" Ni	J,A1						A1		J				J	J,O24	EPA 249.1, 249.2
" Cr	J,A1						A1		J				J	J,O24	EPA 218.1, 218.2
Phytoplankton	W (composite 0m, 3m and 6m)														SM 1002
Zooplankton	A1,O24 (vertical tow from 0m to 6m)														SM 1002
Sediment core													024		EPA 160.3, 160.4
Outflow														J,X	USGS, 1962

J = Jul-88; A1 = 01-Aug-88;
A23 = 23-Aug-88; X = Aug-Nov-88;
Y = Aug-Nov-88 Except 23-Aug-88; O24 = 24-Oct-88;
Z = Dec-88 to Dec-89 W = 12-Jul-88, 12-Sep-88, 04-Oct-88, and 24-Oct-88
SM = APHA et al., 1985 EPA = EPA, 1983;

D'Elia et al. 1977 = D'Elia, C.F. et al. 1977. Determination of total N in aquaous samples using persulfate digestion. Limn. Ocean. 22:760-764.

USGS, 1962 = USGS. 1962. Stream Gaging Procedure. Water Supply Paper 888.

Lake and spring water samples were transported to the Eastern Washington University laboratory in Cheney, Washington for processing. Water samples for chlorophyll *a*, soluble nutrients (soluble reactive P, total soluble P, ammonia N, nitrate+nitrite N, total soluble N), sulfate, and soluble metals were filtered in the laboratory within six to twelve hours of collection and placed on ice before laboratory analysis.

2.3 Bathymetry

The subsurface topography of Myron Lake was surveyed September 12, 1988, using standard bathymetric techniques (Welch, 1948; Wetzel, 1982). Three transects were made: from the northeast corner near the outlet to the boat launch area at the west side of the lake; from the southeast corner to the middle of the north shore; and from the northwest corner near the spring inlet to the east shore. Continuous echosounding profiles of the lake bottom were recorded for each transect using a boat operated at a constant speed. The recording fathometer was a Lowrance X-15B with a 192-kilohertz, 20 degree transducer transom-mounted to the boat by a suction cup. The depth readings from the fathometer were calibrated by lowering a weighted reflector attached to a tape measure.

Bathymetric maps were digitized and the morphometric parameters calculated. The volume of strata (layers) between contours was calculated using the formula for a truncated cone (Wetzel, 1982; Welch, 1948):

(1) $$V = h\,[\,a_1 + a_2 + (a_1 * a_2)^{0.5}\,]/3$$

where:
- V = the volume of stratum from a_1 to a_2
- h = depth of stratum from a_1 to a_2
- a_1 = area of upper surface of stratum
- a_2 = area of lower surface of stratum

2.4 Nutrient Mass Balance Models

The principle algal nutrients, nitrogen (N) and phosphorus (P), generally control the biological productivity of aquatic systems, and thus indirectly determine a wide range of important water quality characteristics (OECD, 1982; Welch, 1980). The control each nutrient exerts within the lake system can be evaluated by the ratios of N to P. Ratios of N:P above 15:1 (by mass) indicates that algal productivity is limited by P (Mancini et al., 1983). Phosphorus is most often the limiting nutrient in freshwater systems (Welch, 1980).

The steady-state solution of the phosphorus budget equation is as follows (Reckhow and Chapra, 1983):

(2) $$P = \frac{W}{v_s A_s + Q_{out}} = \frac{L}{v_s + q_s}$$

where:
- P = steady-state whole lake total P (mg P/m^3)
- W = total P load (mg/year)
- v_s = apparent P settling velocity (m/year)
- A_s = lake surface area (m^2)
- Q_{out} = lake outflow corrected for storage (m^3/year)
- L = areal load of P (mg P/m^2/year)
- q_s = areal hydraulic overflow (m/year).

Equation 2 can be rearranged to estimate loading when P, v_s, and q_s are known (Mancini et al., 1983):

(3) $L = P (v_s + q_s)$

where v_s normally ranges from 10 to 16 m/year for both nitrogen and phosphorus. Equation 3 can be used to estimate existing loading using measured lake P, or to estimate critical loading, in which case criteria for P are specified (e.g. meso-eutrophic boundary of 20 to 35 μg P/L).

2.5 Hypolimnetic Oxygen Deficit and Aerator Sizing

The rate of depletion of oxygen per unit of sediment area is referred to as the areal hypolimnetic oxygen deficit rate (HODR). The HODR can be determined from a plot of the average hypolimnetic oxygen concentrations over time (Cooke et al., 1986):

(4) $$HODR = \frac{D.O._1 - D.O._2}{t_2 - t_1} * z * 1000$$

where: HODR = hypolimnetic oxygen deficit rate ($mg/m^2/day$)
$D.O.^1$ = hypolimnetic D.O. (mg/L) at start of period
$D.O.^2$ = hypolimnetic D.O. (mg/L) at end of period (prior to any concentrations < 1 mg/L)
$t_2 - t_1$ = elapsed time in days
z = mean depth of the hypolimnion (4.4 m)

Once the HODR is known, the air flow required to aerate the hypolimnion during stratification is calculated as a second step (Cooke et al., 1986; NALMS, 1989):

(5) $$\text{Air Flow} = \frac{HODR * A_h * 2 * (1e\text{-}6) * (100/(2.5*D))}{1.205 * 0.2}$$

where: Air Flow = amount of free air required to supply to the hypolimnion to overcome the HODR (m^3/day)
A_h = area of the hypolimnion (m^2)
2 = safety factor to allow for unmeasured D.O. demand
1e-6 = Kg/mg
D = depth of the air diffuser (m).
1.205 = kg/m^3 air at 1 atm and 20 °C
0.2 = fraction of air as O_2

The factor of 2 in the numerator of equation 5 is an arbitrary safety factor to account for unmeasured D.O. demand. A factor of 4 is recommended if hypolimnetic temperature increases significantly as a result of aeration (Steinberg and Arzet, 1984). Equation 5 computes the required amount of air to be supplied to the hypolimnion to overcome the demand of oxygen during stratification, and includes compensation for reduced efficiency of gas-solute phase transfer which varies as a function of pressure.

2.6 Uncertainty Analysis

The information value contained within a given estimated or predicted quantity is only as good as the confidence bounds which surround the estimate. Since the mass balance models used in this study are based on discharge and chemical measurements, a variety of potential measurement and modeling errors can contribute to the total uncertainty of a given quantity. Quantification and propagation of the uncertainty common to each term in a calculated value is necessary in order to determine the degree of confidence which can be placed on the prediction.

Statistical techniques which describe the effects of contributing uncertainties are broadly characterized as error propagation methods. For this report, we have utilized a first-order uncertainty methodology. The theory and application of first-order uncertainty analysis techniques have been described by Reckhow and Chapra (1983), Cornell (1973), and Lettenmaier and Richey (1979). Briefly, the technique is based upon the assumption that parameter variations can be propagated about the first derivative (i.e. first-order) of a function relative to those variables which make up the function. In general, for any calculated quantity Y which is derived from parameters denoted by X_i:

(6) $$Y = f(X_1, X_2, \ldots, X_n)$$

the first-order variance of Y can be estimated as:

(7) $$Var(Y) = \sum_{i=1}^{n} [(\delta Y/\delta X_i)^2 Var(X_i)]$$

The quantity $(\delta Y/\delta X_i)^2$ describes the sensitivity of the calculated value (Y) to changes in each parameter (X_i) of the function. Unless otherwise stated herein, parameter estimates are presented as the mean values plus or minus (±) the standard error (SE) of the mean (Zar, 1974). A summary of error propagation formulas for some simple algebraic functions is presented in Appendix A.

3.0 RESULTS AND DISCUSSION

3.1 Morphometry

Myron lake has a surface area of 49,000 m^2 (12 acres). The lake bottom is steeply sloped to a relatively flat profundal area (Figure 2). The lake has few shallow areas. Hypsographic (depth-area and depth-volume) curves of Myron lake were drawn to show the relationship of lake area and volume to depth (Figure 3) and to interpolate volume-weighting factors for averaging water column constituents. Lake mean depth is 9.1 m and maximum depth is 13.9 m. The lake volume is 447,000 cubic meters, of which the hypolimnion is approximately one third (below a depth of 7.5 m).

3.2 Water Budget

The annual water budget for the lake was determined for the period of October 1988 through September 1989. Losses of water from the lake included discharge from the surface outflow and evaporation (Table 3). The lake had a net loss in volume during the study period. The only identified sources of water to the lake included precipitation onto the lake surface and ground-water seepage and springs. Net groundwater and spring inflow (the net result of groundwater in-seepage and out-seepage) was calculated from the water budget (Table 3), and represented the major source of water. The outflow and inflows to the lake are most active during the spring and summer months (Figure 4).

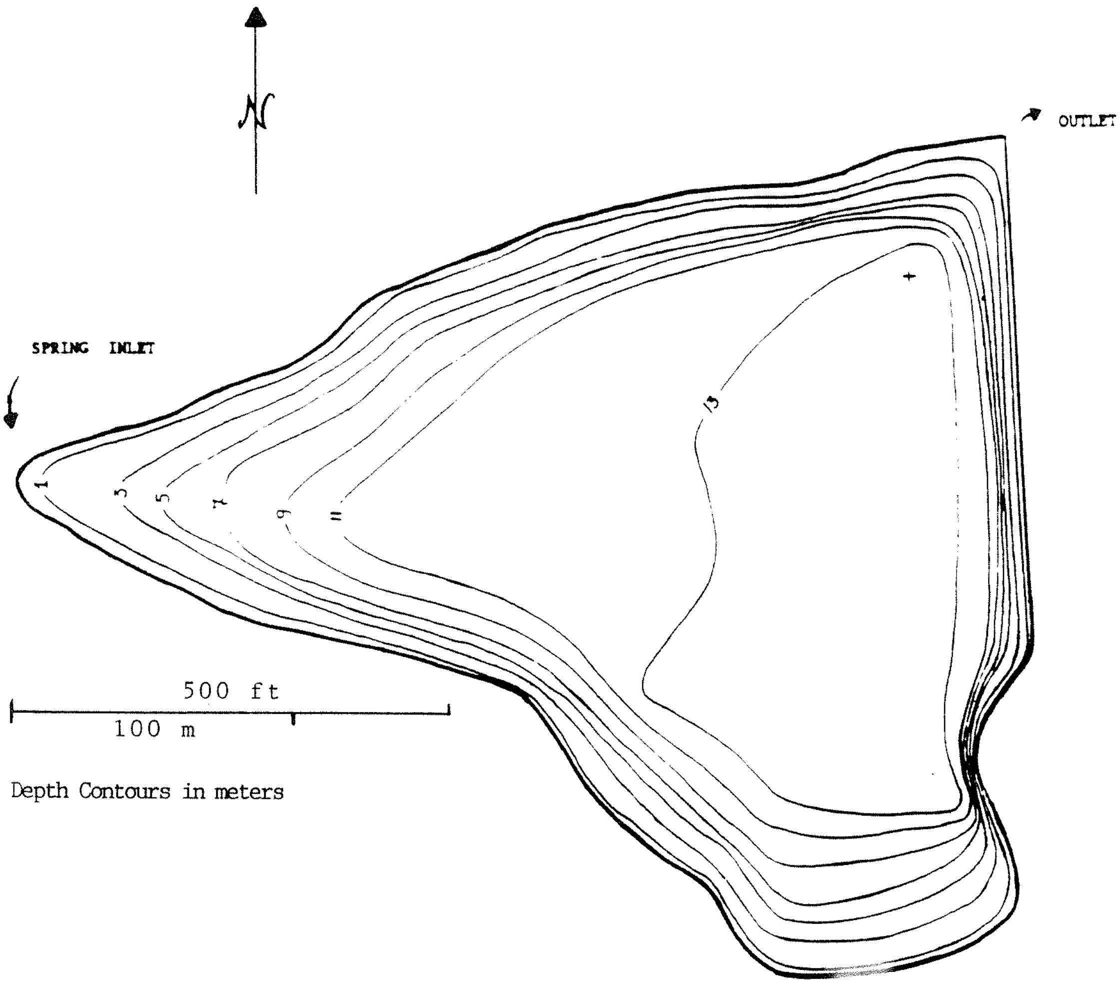
The average flushing rate for the lake was 0.9 lake volumes per year, which corresponds to a complete exchange of water (residence time) every 1.1 years (13 months). Annual outflow, corrected for lake storage change, corresponds to an areal hydraulic overflow (applied to the lake surface area) of 8.0 ± 1.6 m/year.

3.3 Nutrient Budgets

The annual budgets of phosphorus and nitrogen are presented in Table 4. The primary external loading sources were groundwater and spring inputs, with some precipitation onto the lake surface. Loading from groundwater and spring inputs was calculated from the estimated discharge (Table 3) and outflow-weighted concentrations (Appendix B). The difference between estimated external loads and outflow loads corrected for change in storage was assumed to represent net sedimentation within the lake.

The total areal P load to Myron Lake, from external and internal sources, was estimated to be 927 ± 159 mg P/m^2/year (Table 4) using equation 3, based on measured annual whole lake total P of 44.2 ± 2.3 μg P/L, measured q_s of 8.0 ± 1.6 m/year, and expected P settling velocity of 10 to 16 m/year (13 ± 3 m/year assumed). The difference between total loading and the calculated external load was assumed to represent internal loading, which was estimated to be 357 ± 192 mg P/m^2/year. Therefore, of the total P load to the lake water column, approximately 61 percent is from external sources, and 39 percent from internal sources. The major source of internal P loading is probably release of sediment P in the anoxic hypolimnion during stratification.

The steady-state mass balance equations may be used to estimate the critical load that would cause a eutrophic state in the lake (equation 3). A whole lake annual average concentration of total P of 20 to 35 μg P/L is commonly assumed to represent the boundary condition between mesotrophic and eutrophic conditions (Mancini et al., 1983). Using that range of criteria, critical total P loading (from external and internal sources) is estimated to range from 420 to 730 mg P/m^2/year.



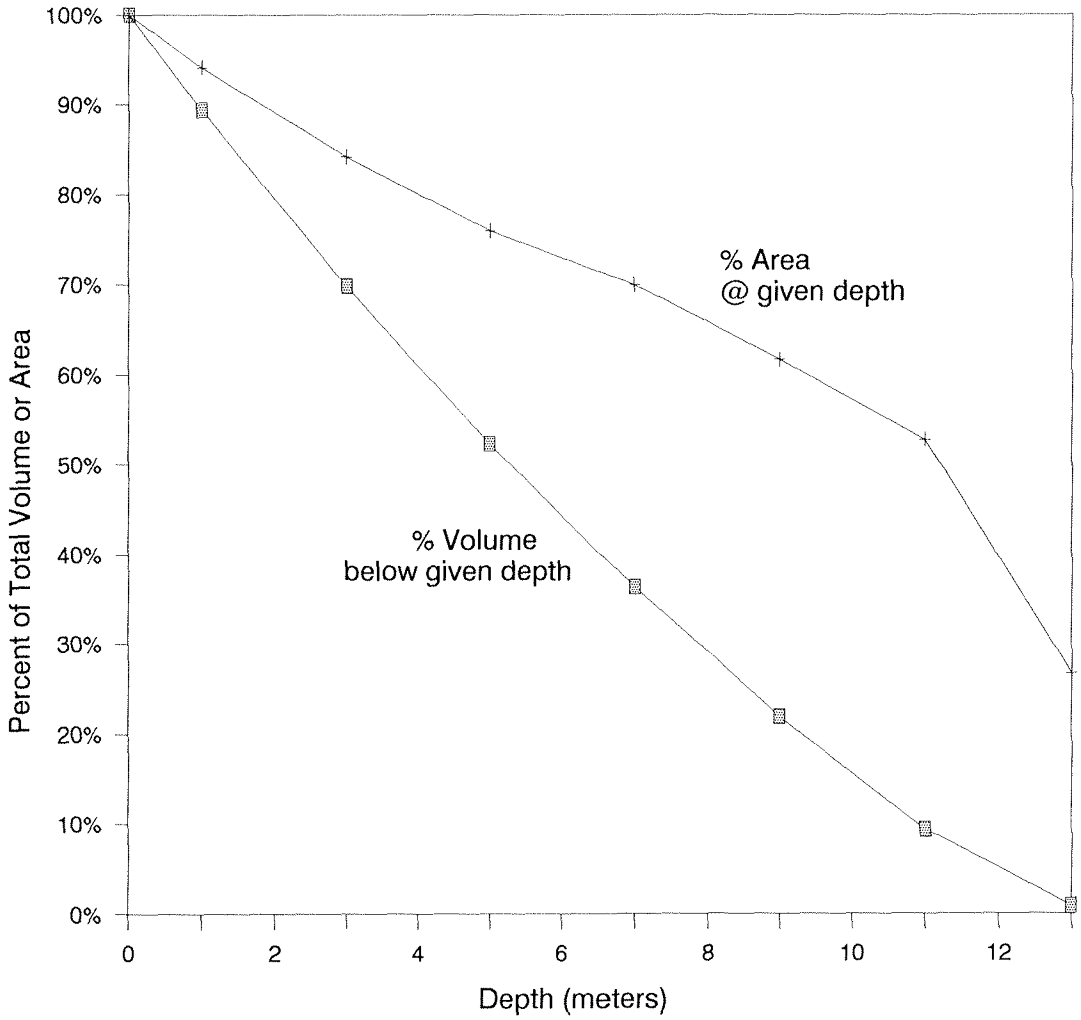
WHOLE LAKE CHARACTERISTICS

Volume (m^3)	447,000.
Surface Area (m^2)	49,000.
Mean Depth (m)	9.1
Maximum Depth (m)	13.9
Flushing Rate (volumes per year)	0.9
Hydraulic Residence Time (years)	1.1
Areal Hydraulic Overflow (m/year)	8.0

HYPOLIMNION CHARACTERISTICS (7.5 m to Bottom)

Volume (m^3)	146,000.
Surface Area (m^2)	33,300.
Mean Depth (m)	4.4

Figure 2. Morphological and hydrological characteristics of Myron Lake.



AREA @ 100% = 49,000 sq. meters

VOLUME @ 100% = 447,000 cu. meters

Figure 3. Hypsographic Curves of Depth-Volume and Depth-Area Relationships in Myron Lake.

Table 3. Myron Lake annual water budget summary, October, 1988 through September, 1989.

WATER BUDGET COMPONENT	ANNUAL TOTAL (m^3/year) Mean ± Std Err	ESTIMATED COEFFICIENT OF VARIATION (3)
LOSSES		
O = Outflow	402,800 ± 80,560	20%
E = Evaporation (1)	37,200 ± 11,160	30%
S = STORAGE CHANGE	-12,300 ± 1,230	10%
SOURCES		
P = Precipitation (1)	8,900 ± 1,335	15%
Groundwater/Springs (2)	418,800 ± 81,350	19%

1) Evaporation and precipitation are based on NOAA climatoligical data from the Yakima WSO airport station. Lake evaporation was estimated from pan data assuming a pan coefficient of 0.6 (Linsley et al., 1975).
2) G = S - P + E + O
3) Coefficient of variation estimated as SE as percent of mean.

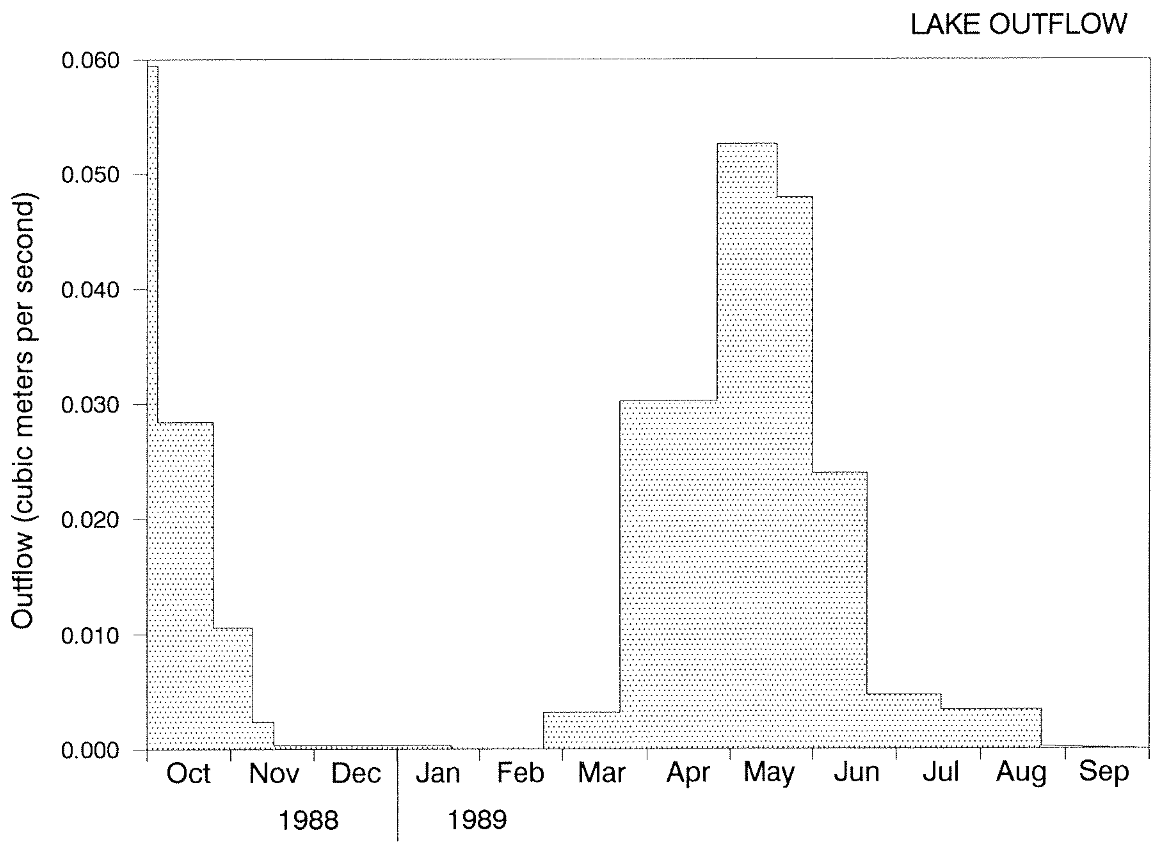


Figure 4. Outflow Rates from Myron Lake, October 1988 through September 1989.

Table 4. Myron Lake annual phosphorus and nitrogen budgets, October, 1988 through September, 1989.

NUTRIENT BUDGET COMPONENT	PHOSPHORUS LOADING			NITROGEN LOADING		
	Mean	±	SE	Mean	±	SE
	(Kg P/year)			(Kg N/year)		
EXTERNAL LOADING						
Groundwater/Springs (1)	26.6	±	5.3	467	±	111
Precipitation (2)	1.4	±	0.3	54	±	11
Total External Load	27.9	±	5.3	521	±	112
OUTFLOW (3)	11.9	±	2.6	277	±	60
STORAGE INCREASE (4)	-0.4	±	0.05	-8	±	1
NET SEDIMENTATION (5)	16.4	±	5.9	252	±	127
	(mg P/m²/year)			(mgN/m²/year)		
EXTERNAL LOADING						
Groundwater/Springs (1)	542	±	108	9,530	±	2,266
Precipitation (2)	28	±	6	1,100	±	220
Total External Load	570	±	108	10,630	±	2,277
ESTIMATED TOTAL AREAL LOAD (6)	927	±	159	17,800	±	3,040
ESTIMATED INTERNAL LOAD (7)	357	±	192	7,170	±	3,798

FOOTNOTES:

1) External loading from groundwater and springs estimated as groundwater/spring discharge from water budget multiplied by flow-weighted average concentration of total P (63.4 ± 2.7 µg P/L) and total N (1,115 ± 153 µg N/L) in the spring.

2) Estimated from areal total P (28 mg $P/m^2/yr$) and total N (1,100 mg $N/m^2/yr$) (Patmont et al., 1989). Coefficient of variation was assumed equal to 20%.

3) Estimated as outflow discharge from the water budget multiplied by time-weighted lake surface total P (29.6 ± 2.4 µg P/L) and total N (688 ± 57 µg N/L) from October 1988 through September 1989.

4) Estimated as storage volume increase multiplied by time-weighted lake surface total P (29.6 ± 2.4 µg P/L) and total N (688 ± 57 µg N/L).

5) Estimated as External Loading - Outflow - Storage Increase.

6) Estimated as $L=P(v_s + q_s)$ where P=44.2 ± 2.3 µgP/L; v_s=13 ± 3 m/y; q_s= 8.0 ± 1.6 m/yr.

7) Estimated as difference between Total Areal Load and External Load.

Comparison of critical loading estimates with the existing external loading of total P (570 ± 108 mg $P/m^2/year$) suggests that trophic status of the lake would be in the mid-mesotrophic range if internal loading was eliminated. However, the current lake status is eutrophic due to excessive P loading from the combination of external loading and internal recycling.

3.4 Water Quality Results

Appendices B and C contain complete listings of water quality data for lake and spring samples. Appendix D contains phytoplankton biovolume data.

3.4.1 Temperature

Thermal stratification begins in approximately April and lasts until late October or November (Figure 5). The thermocline, during the periods of stratification, generally ranged from 6 to 9 meters. Throughout the winter and early spring months (approximately December through March) the lake is completely mixed.

3.4.2 Dissolved Oxygen

Hypolimnetic oxygen rapidly decreased with the onset of stratification (Figures 5 and 6) due to oxidation of organic matter in the water column, oxidation of various inorganic species, and sediment oxygen demand (Hutchinson, 1975). The majority of the hypolimnion became practically devoid of oxygen by June, 1989 during the second year of study. Hypolimnetic D.O. had already been reduced to near anoxia at the start of study in July 1988.

Two periods of destratification were observed during the study. The first period, in the fall of 1988 resulted in near anoxia of the whole lake water column (< 1 mg/L at all depths) on November 21, 1988 (Figure 6). A large fish kill was also observed at this time, after which approximately 200 dead trout were picked up from the shoreline areas. The second period of destratification, in the fall of 1989, did not result in D.O. concentrations as low as 1988, but the whole lake D.O. dropped below the approximate chronic effects threshold of 5 mg/L (Figure 6). A fish kill was not observed during the fall of 1989.

Epilimnetic concentrations of D.O. exceeded saturation during summer months because of algal productivity (Figure 5). Values in excess of 160 percent of saturation were observed, with prolonged periods (about 2 to 4 months) of concentrations in excess of 120 percent of saturation in the entire epilimnion.

3.4.3 Hypolimnetic Oxygen Deficit

Hypolimnetic oxygen deficit rates are related to P loading, net productivity, temperature, and hypolimnetic depth (Cornett and Rigler, 1979; Welch and Perkins, 1979). HODR's ranging from 250 to 550 $mg/m^2/day$ are typical of mesotrophic lakes (Mortimer, 1942). Values in excess of this range indicate eutrophication.

The HODR was determined, using equation 4, from a plot of the average hypolimnetic oxygen concentrations over time during the onset of stratification from March through June, 1989 (Figure 7). The greatest rate of decrease in hypolimnetic D.O. was observed between April 26 and May 18, 1989. HODR during this period was 1000 $mg/m^2/day$, which is indicative of a eutrophic condition.

The HODR probably has not always been as high as the present rate. The profundal sediments show a relatively thin (approximately 2 to 3 cm) surface layer of highly organic material which overlays the original relatively inorganic alluvium (Table 5). Therefore it seems likely that prior

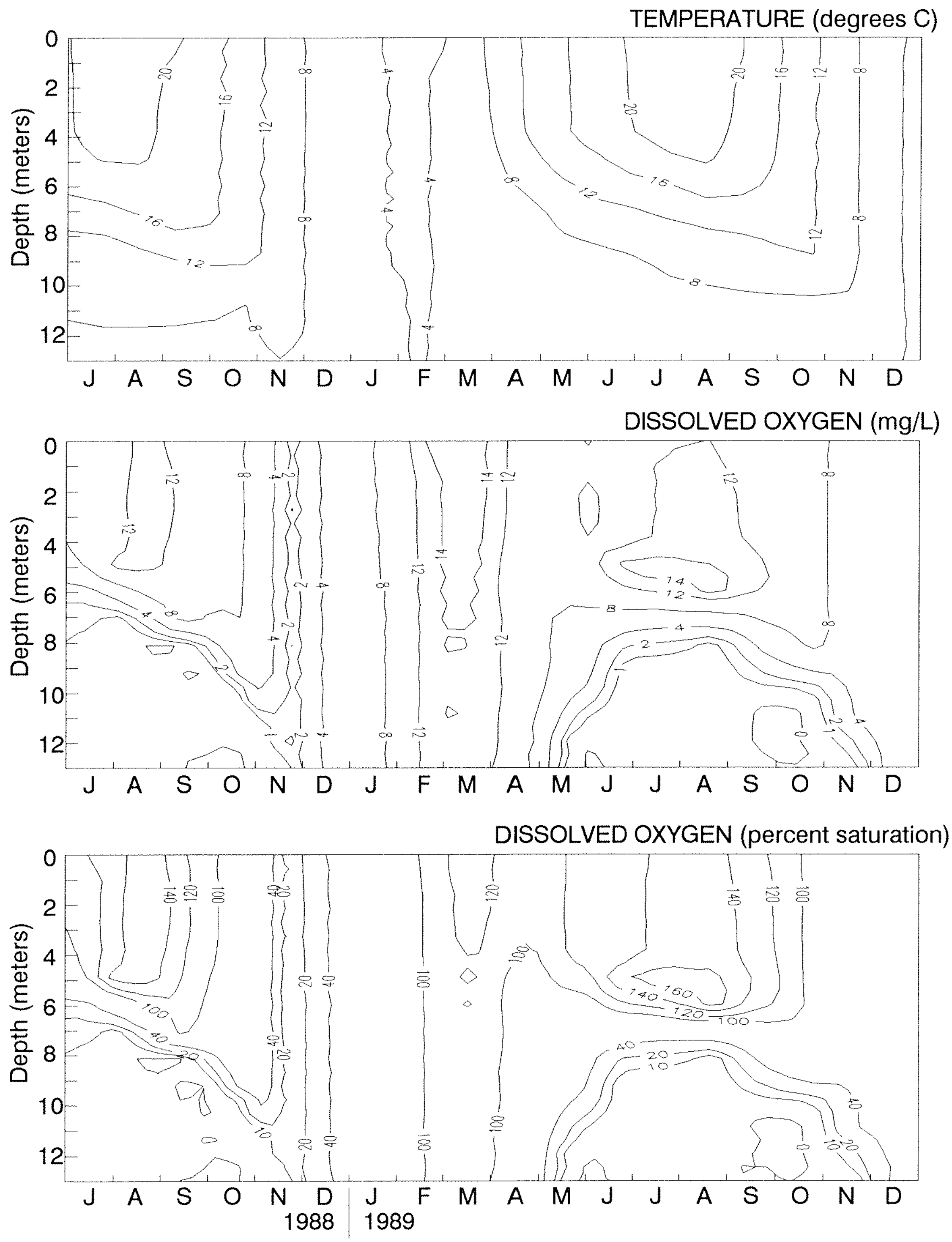


Figure 5. Temperature and dissolved oxygen isopleths in Myron Lake, July 1988 to December 1989.

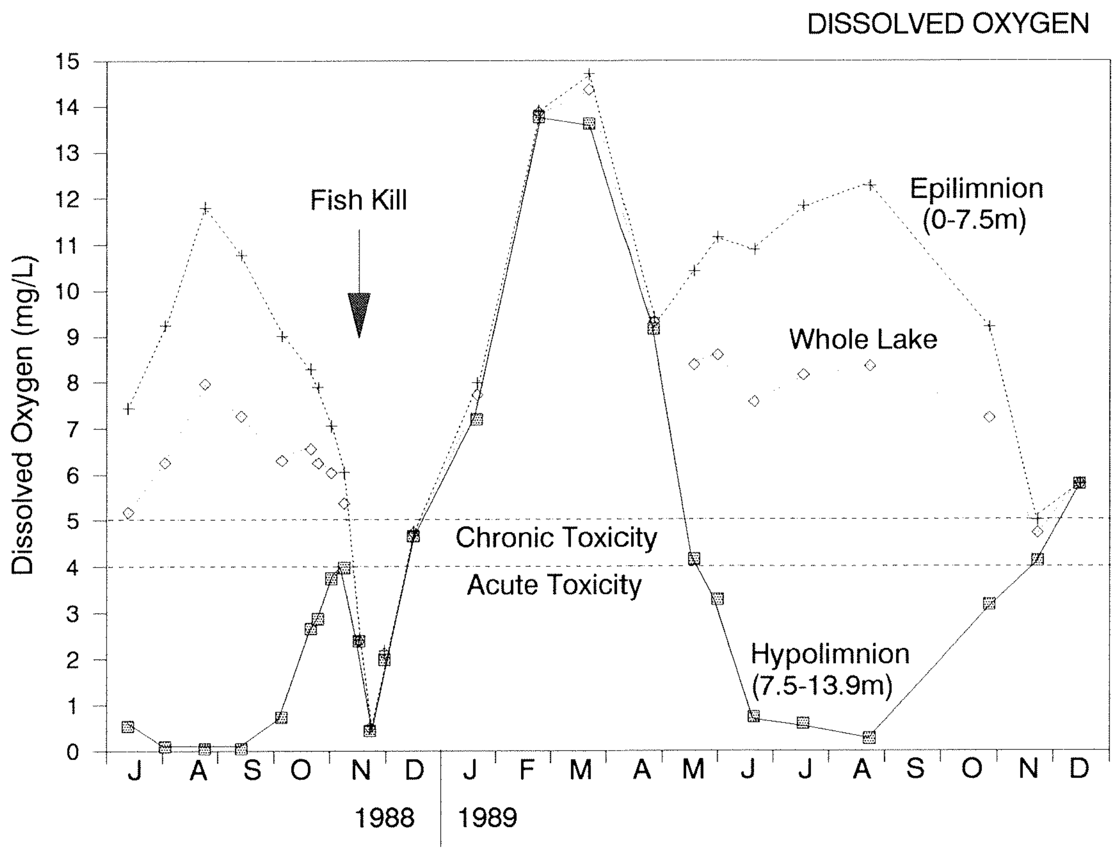


Figure 6. Dissolved Oxygen in Myron Lake; July 1988 through December 1989. Chronic and Acute Toxicity Criteria for Cold Water are from EPA (1986).

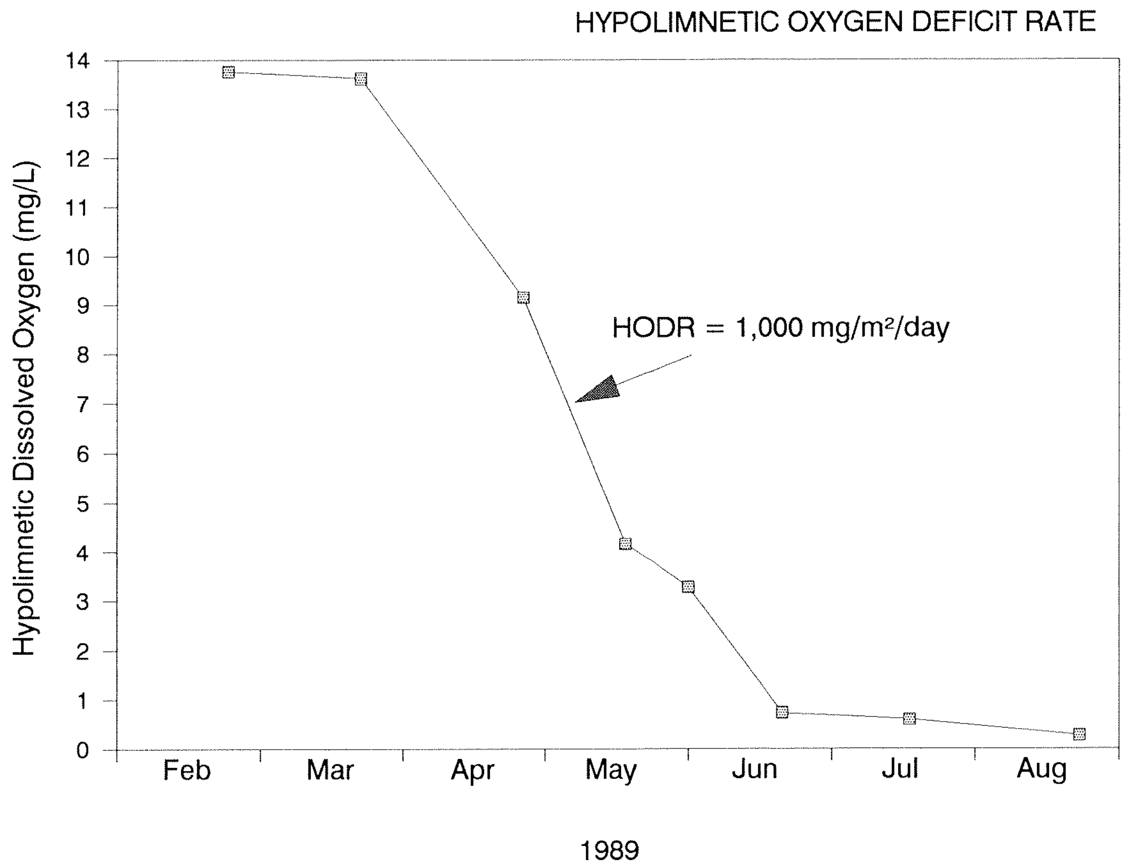


Figure 7. Hypolimnetic Oxygen Deficit Rate Determined by Changes in Dissolved Oxygen Concentration in the Hypolimnion (7.5m to 13.9m) After Stratification.

Table 5. Summary of sediment percent water and organic matter.

Sediment Depth (cm)	Percent Water	Percent Weight Loss on Ignition (Percent Organic)
Core A		
0-1	95.5	35.1
1-2	89.5	18.5
2-3	80.0	12.5
3-4	81.4	6.6
4-5	70.1	5.7
Core B		
0-1	94.5	23.6
1-2	93.6	15.3
2-3	89.6	20.0
3-4	75.4	7.8
4-5	77.9	6.7

to development of the organic sediment layer, which probably has a higher oxygen demand than the underlying inorganic alluvium, HODR was much less than the present rate. This finding may help explain why fish kills were not observed until recently.

3.4.4 Nutrients and Algal Biomass

Ratios of total N and total P in Myron Lake generally exceed 15, which indicates P limitation (Table 6). The annual whole lake average concentration of total P (time- and volume-weighted average) was 44.2 ± 2.3 µg P/L, which indicates a eutrophic condition. As discussed previously, a range of 20 to 35 µg P/L is suggested as the mid-mesotrophic level, above which eutrophic conditions predominate. Summer chlorophyll *a* concentrations also indicate eutrophic conditions. However, average Secchi disk transparency during summer was within the typical range for mesotrophic lakes. Seasonal changes in total P, total N and chlorophyll *a* are shown in Figure 8.

The highest biomass (chlorophyll *a* of 13.9 ± 1.9 µg/L) and lowest Secchi transparency (1.7 m) were observed in September 1988 (Figure 9). Light limitation in the epilimnion is probably not significant in Myron Lake, since the euphotic zone depth (depth to 1 percent of incident light) generally extended to greater than 7 m even during the periods of maximum algal biomass.

Concentrations of total P, soluble reactive P, total N, and ammonia N were typically greatest in the hypolimnion during stratification (Figures 10 and 11). Un-ionized ammonia concentrations (Figure 12) during destratification in the fall of 1988 reached nearly 30 percent of the criterion for chronic toxicity (4-day exposure; EPA, 1986). While un-ionized ammonia did not exceed the chronic criterion, this condition may have contributed to mortality during the observed fish kill.

Summer (July-September 1988) phytoplankton biovolume averaged 0.4 ± 0.1 mm^3/L (Table 6). The main groups of phytoplankton found were Cryptomonads, blue-green algae (*Anabaenae flos-aquae*, *Anacystis marina*, *Aphanizomenon flos-aquae*, and *Chroococcus sp.*), green algae, and pennate diatoms (Appendix D). The species found in Myron Lake are common to mesotrophic and eutrophic lakes in the Pacific Northwest (Sweet, 1986).

Zooplankton identification (Table 7) showed a predomination of *Daphnia sp.* Zooplankton densities in the epilimnion ranged from 11 to 34 per L, which is within the range reported for several eastern Washington lakes which support successful trout and mixed-species sport fisheries (Willms, 1989).

3.4.5 Hydrogen Sulfide

Sulfate concentrations in the lake ranged from 2 to 15 mg/L. The highest values were in the epilimnion and the lowest values were in the hypolimnion. Sulfate concentrations in the hypolimnion decreased from July to October 1988 due to reduction of sulfate to sulfide by bacteria.

Sulfide concentrations deep in the hypolimnion (below 11m) from July to November 1988 reached maxima of 1.8 to 3.9 mg/L (Figure 13). By November 15, 1988, sulfide was not detectable at all depths by the method used. Rapid oxidation rates of hydrogen sulfide compounds in the presence of excess oxygen have been reported, with half-times ranging from 0.3 to 64 hours (Chen and Morris, 1987). Two processes account for the disappearance of sulfide during destratification: oxidation and the formation of iron-sulfide minerals.

On November 10, 1988, an in-situ fish bioassay was conducted to test the possible toxic effect of hydrogen sulfide from mixing of the bottom water with the whole lake. Two cages of fish (5 rainbow trout fingerlings each) were placed, one at one meter depth (control) and another at 10

Table 6. Summary of selected water quality characteristics of Myron Lake.

	Myron Lake Mean ± SE	Mid-Mesotrophic Criteria (1)
ANNUAL WHOLE LAKE (Oct 88-Sep 89)		
Total N (μg N/L)	848 ± 43	--
Total P (μg P/L)	44.2 ± 2.3	20 - 35
N:P Ratio	19 ± 1.4	--
ANNUAL LAKE SURFACE (Oct 88-Sep 89)		
Total N (μg N/L)	688 ± 57	--
Total P (μg P/L)	29.6 ± 2.4	--
N:P Ratio	23 ± 2.7	--
SUMMER (Jul-Sep)		
Chlorophyll a (μg/L)	6.4 ± 1.0	4 - 6
Cell Biovolume (mm^3/L)	0.4 ± 0.1	1.5 - 5
Secchi Transparency (m)	2.8 ± 0.4	2 - 3

1) Mancini et al., 1983; Welch, 1980; OECD, 1982.

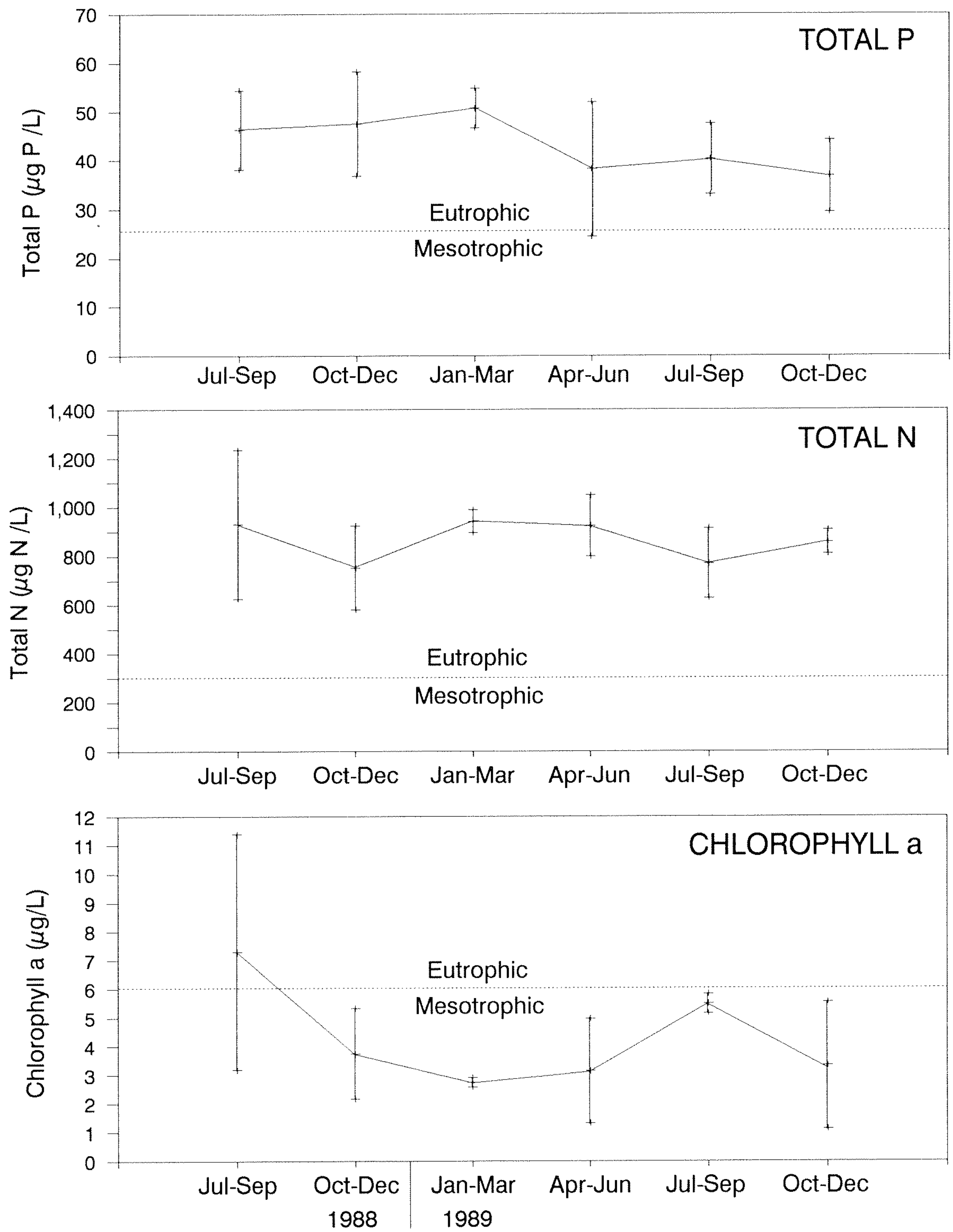


Figure 8. Whole-lake Total P and Total N, and Epilimnetic Chlorophyll a in Myron Lake from July 1988 through December 1989. (Seasonal means ± std dev).

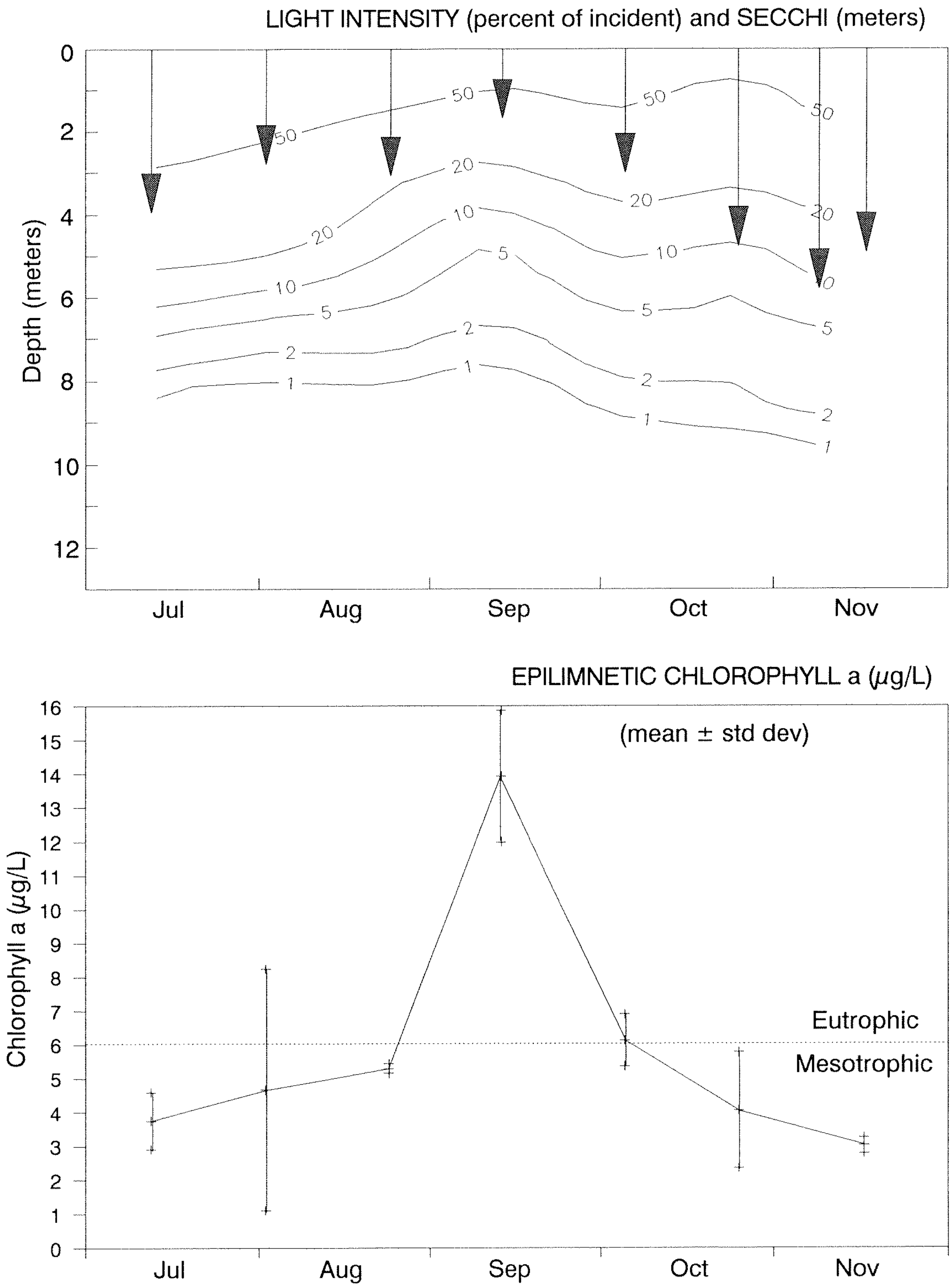


Figure 9. Light intensity isopleths and secchi disk depths (arrows) and epilimnetic chlorophyll in Myron Lake, July through November, 1988.

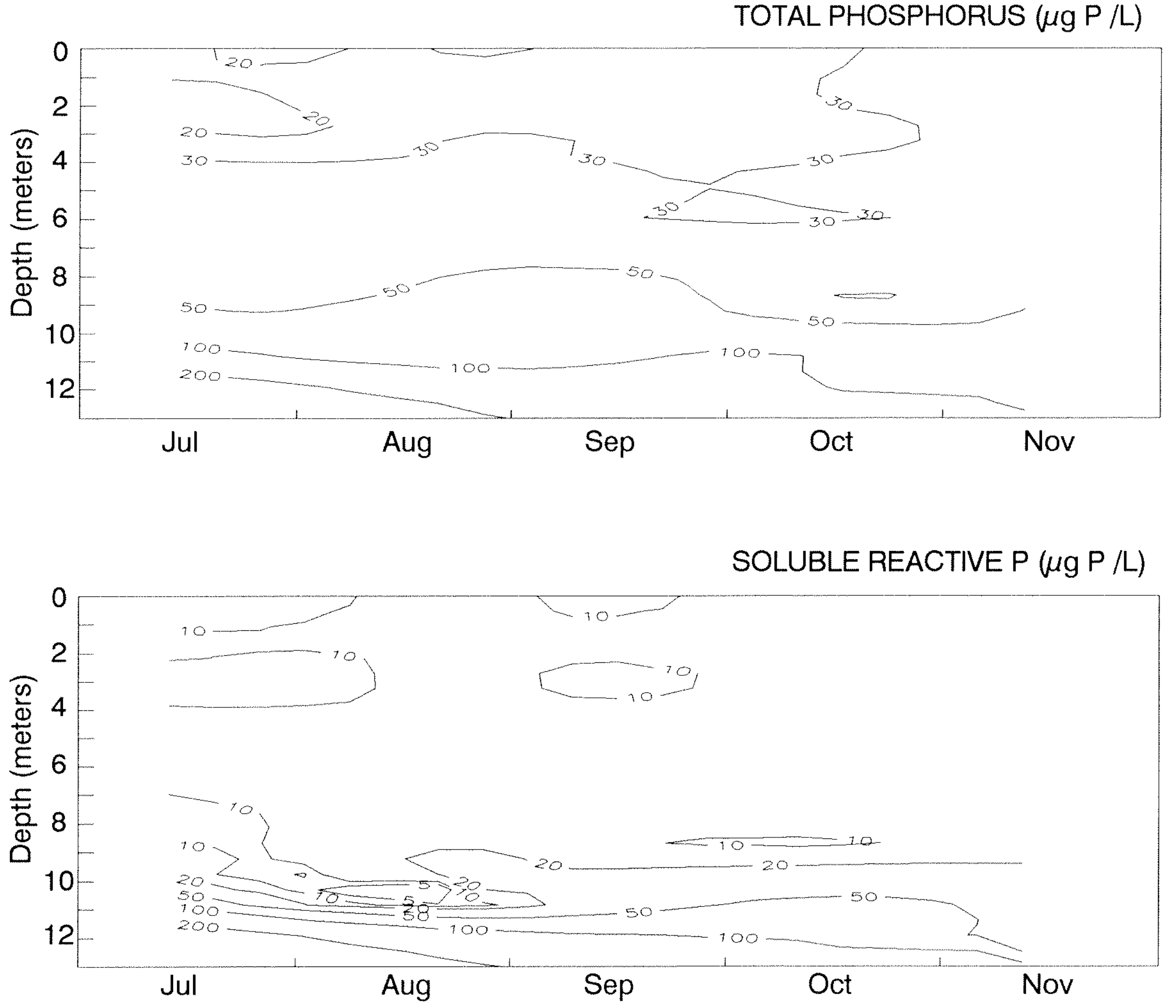


Figure 10. Total P and Soluble Reactive P Isopleths in Myron Lake, July through November, 1988.

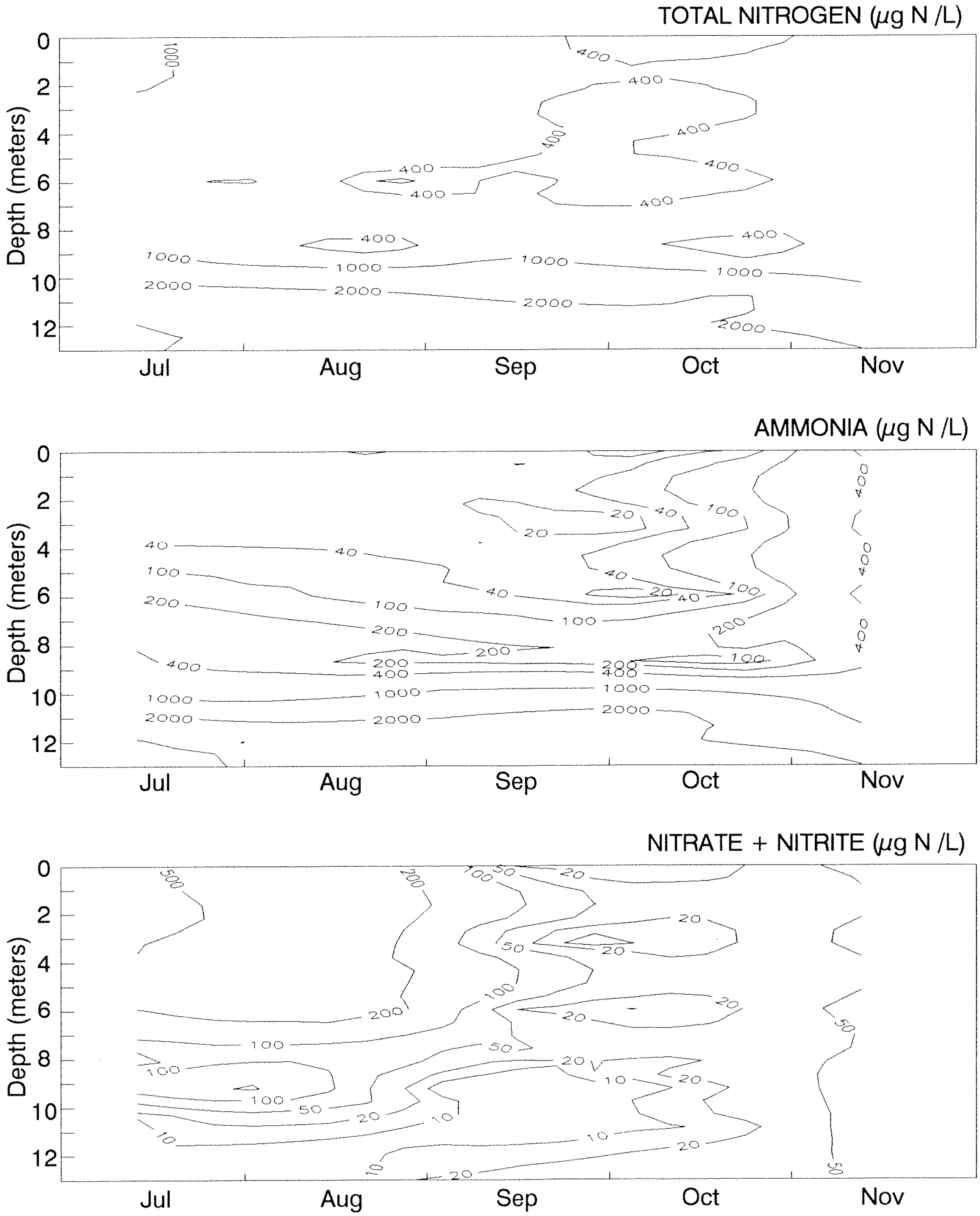


Figure 11. Total N, Ammonia, and Nitrate + Nitrite Isopleths in Myron Lake, July through November 1988.

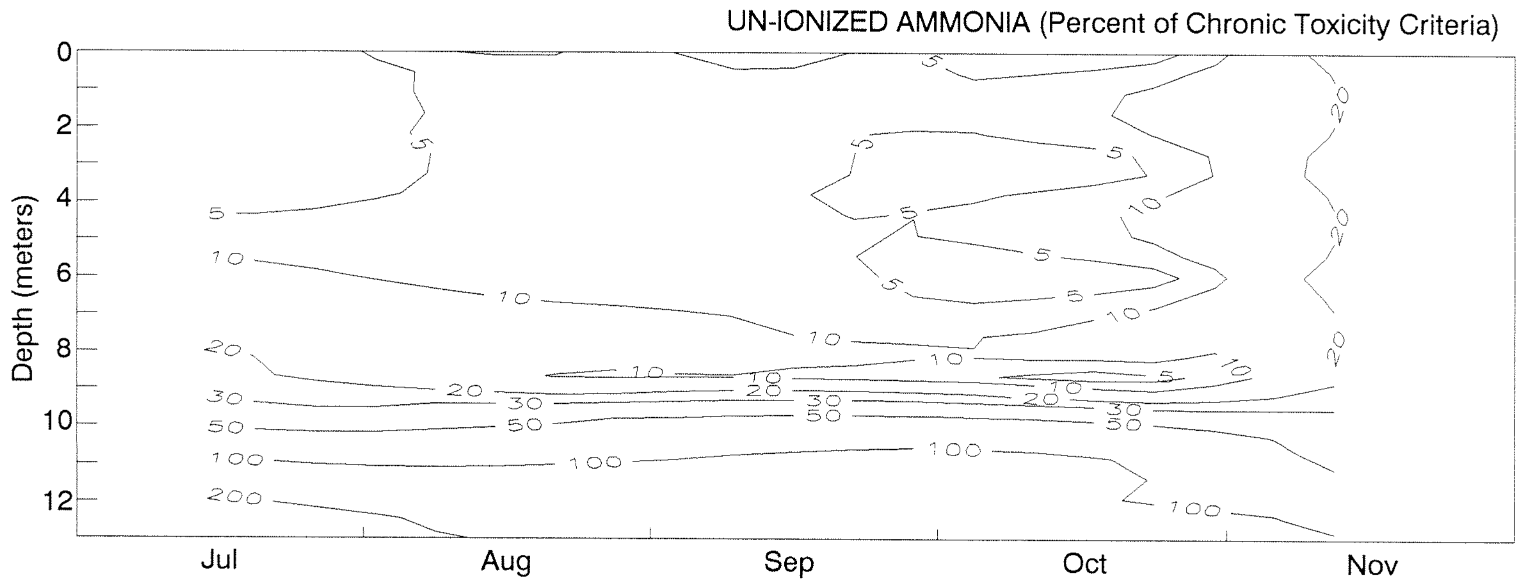


Figure 12. Un-ionized ammonia isopleths in Myron Lake, July through November, 1988.

Table 7. Summary of zooplankton density for Myron Lake samples.

Sampling Date	Cladocera Daphnia sp. (No./L)	Copepoda (No./L)	Total (No./L)
01-Aug-88	34.0	0.3	34.3
24-Oct-88	10.7	0.2	10.9
Average	22.4	0.2	22.6
Typical Range for Eastern Washington Lakes[1]	5-130	9-220	15-340

[1]Range for mesotrophic and eutrophic lakes in eastern Washington with successful trout and mixed-species sport fisheries (Willms, 1989).

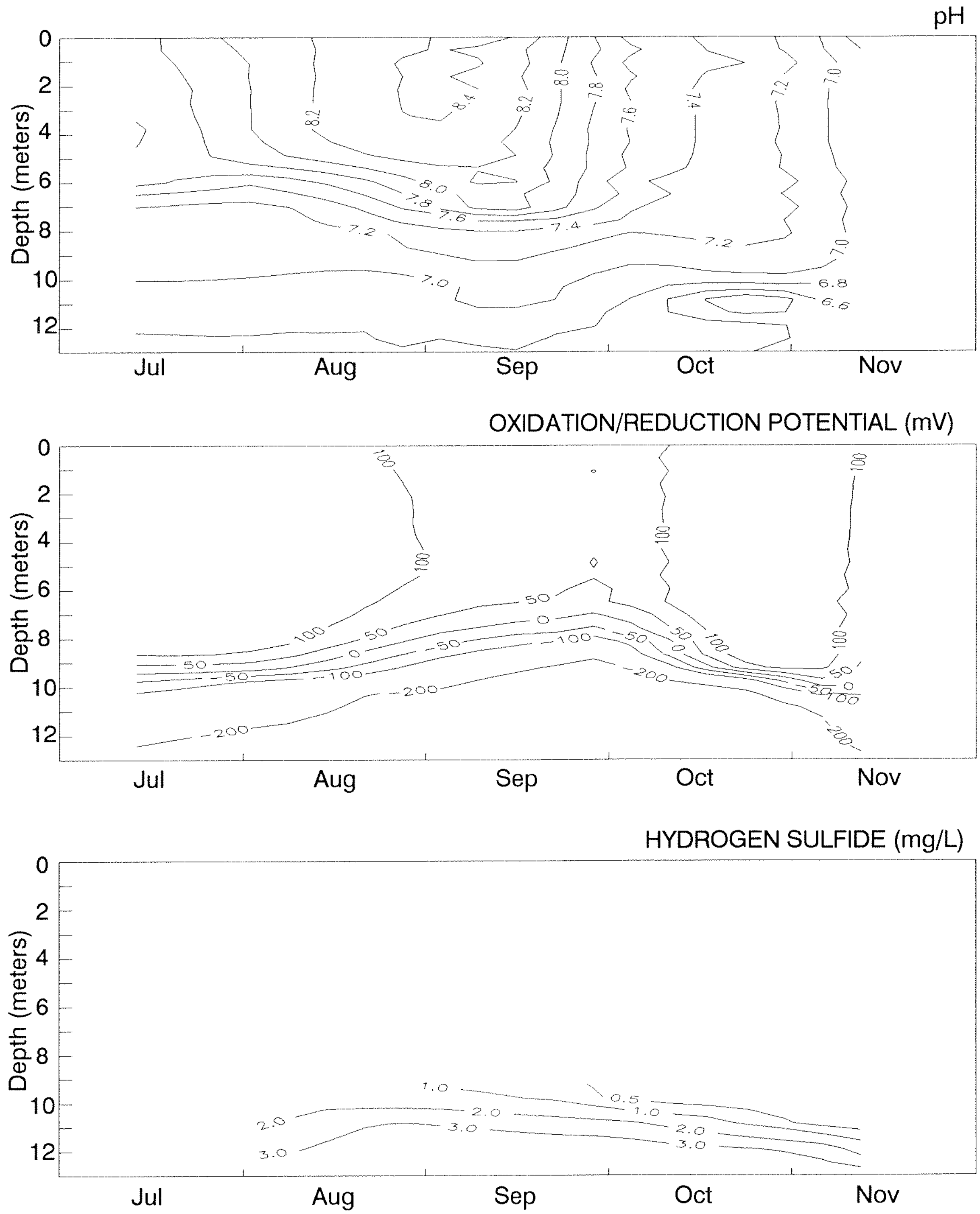


Figure 13. Isopleths of pH, oxidation/reduction potential and hydrogen sulfide in Myron Lake, July through November, 1988.

meters depth (just above the thermocline on that date). The fish were left in the lake until November 15. One fish in the control died, but no mortality occurred at 10 meters. While this test is not conclusive, it minimizes the likelihood of sulfide toxicity as a factor in the fish kill later in November.

3.4.6 Metals

Metals data from the lake and spring are presented in Table 8. In general, concentrations of metals were lower than aquatic life criteria, with the exception of copper. Copper concentrations ranged from 1 to 15 µg/L. Concentrations of copper up to 46 µg/L in groundwater are common in the Yakima area (Turney, 1986). Concentrations of metals do not appear to be a cause of fish mortality in Myron Lake, even though observed copper concentrations exceeded the aquatic life criteria at times.

3.5 Lake Restoration Alternatives

Lake restoration techniques may be grouped into two general categories: 1) methods that emphasize control of nutrient loading, and 2) methods that emphasize internal control of lake processes. Each category includes several potential techniques as summarized in Table 9 (Cooke et al., 1986).

It is beyond the scope of this report to examine the feasibility of all potential restoration measures. Techniques which emphasize direct control of hypolimnetic D.O. are probably most appropriate since excessive D.O. depletion is the major problem in the lake. However, any technique which reduces algal biomass would potentially reduce the oxygen demand in the hypolimnion. Techniques which are probably not feasible for restoration of Myron Lake include nutrient diversion (groundwater and spring inputs are too diffuse), and macrophyte controls (macrophytes are not a nuisance or significant nutrient load).

Three techniques are suggested as potentially appropriate: 1) hypolimnetic withdrawal, 2) hypolimnetic aeration, and 3) artificial circulation. Both hypolimnetic withdrawal and artificial circulation would have the negative effect of raising the temperature of the hypolimnion to a point which may not be desirable for a cold water fishery. Furthermore, hypolimnetic withdrawal would increase P loading to downstream receiving waters, and artificial circulation may increase internal P loading. Therefore, hypolimnetic aeration is probably the most appropriate in-lake restoration technique.

In addition to maintaining suitable D.O. and temperature in the hypolimnion for trout habitat, hypolimnetic aeration would also reduce internal recycling of phosphorus from lake sediments. Therefore, hypolimnetic aeration would prevent future fish kills by maintaining D.O., and may also have the secondary benefit of reducing nutrient loads and improving trophic state. Analysis of existing and critical loading suggests that if internal P loading is reduced to insignificant levels, the trophic state may improve to a mid-mesotrophic condition.

The required air flow for hypolimnetic aeration can be estimated from equation 5. Since HODR is estimated to be 1000 $mg/m^2/day$, the required air supply to the hypolimnion would be 794 m^3/day or 19.5 cubic feet per minute (CFM). This quantity of air could be supplied with a 6 horsepower (HP) compressor, assuming about 3.5 CFM/HP (NALMS, 1989). A safety factor of 4 may be warranted in equation 5, since hypolimnetic temperature may increase following aeration, and HODR may increase as organic material is added to the sediment layer. If a safety factor of 4 is assumed, then about 40 CFM of air supply would be required, which could probably be supplied using a 12 HP compressor. If hypolimnetic aeration is implemented, seasonal operation (approximately April through November) would probably be appropriate.

Table 8. Summary of Myron Lake metals data.

Station	Depth (m)	Date	Total Fe (µg/L)	Total Mn (µg/L)	Total Cu (µg/L)	Total Zn (µg/L)	Total Ni (µg/L)	Total Cr (µg/L)	Total Soluble Fe (µg/L)	Total Soluble Mn (µg/L)	Total Soluble Cu (µg/L)	Total Soluble Zn (µg/L)	Total Soluble Ni (µg/L)	Total Soluble Cr (µg/L)
Spring		01-Aug-88	35	5 U	10 U	8	5	1 U						
Spring		24-Oct-88	10 U	5 U	10 U	5 U	20 U	20 U	50 U	20 U	10 U	5 U	20 U	20 U
Myron L	2	12-Jul-88			9 *	15	7	1 U						
Myron L	4	12-Jul-88	50	5										
Myron L	6	12-Jul-88			10 *	6	6	1 U						
Myron L	8	12-Jul-88	65	13										
Myron L	10	12-Jul-88			15 *	55	7	1 U						
Myron L	12	12-Jul-88	125	90										
Myron L	0	01-Aug-88	25	1	3	5	6	1 U						
Myron L	6	01-Aug-88	55	5	4	9	6	1 U						
Myron L	9	01-Aug-88		5 U										
Myron L	11	01-Aug-88	102	85	1	3	4	1 U						
Myron L	9	04-Oct-88	72	70					50	52				
Myron L	11	04-Oct-88	350	280					280	125				
Myron L	6	24-Oct-88	25	16	10 *	5 U	10	20 U	50 U	20 U	10 U	10	40	20 U
Myron L	9	04-Oct-88												
Myron L	11	04-Oct-88	420	151	10 U	5 U	20 U	20 U	50 U	160	10 U	5 U	20 U	20 U
Chronic Aquatic Life Criteria														
Hardness = 50 mg CaCO3/L			1,000	--	7	59	88	120	1,000	--	7	59	88	120
Hardness = 100 mg CaCO3/L			1,000	--	12	110	160	210	1,000	--	12	110	160	210
Acute Aquatic Life Criteria														
Hardness = 50 mg CaCO3/L			1,000	--	9	65	790	980	1,000	--	9	65	790	980
Hardness = 100 mg CaCO3/L			1,000	--	18	120	1,400	1,700	1,000	--	18	120	1,400	1,700

DATA QUALIFIERS:

U = Compound was analyzed for but not detected. The number reported is the detection limit.
* = Concentration exceeds chronic aquatic life criteria.

Table 9. Summary of Lake Restoration Techniques (after Cooke. et al., 1986).

NUTRIENT LOADING CONTROL TECHNIQUES

  1) Nutrient Diversion
  2) Dilution and Flushing
  3) Phosphorus Inactivation- (e.g. Alum application)
  4) Sediment Oxidation- (e.g. nitrate addition)
  5) Sediment Removal
* 6) Hypolimnetic Withdrawal

DIRECT CONTROL OF INTERNAL LAKE PROCESSES

* 1) Hypolimnetic Aeration
* 2) Artificial Circulation
  3) Biological Controls- (e.g. manipulating food webs)
  4) Macrophyte Controls
    - Lake Level Drawdown
    - Macrophyte Harvesting
    - Sediment Covers

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* denotes most applicable techniques for Myron Lake

4.0 CONCLUSIONS AND RECOMMENDATIONS

The major conclusions of the present study are as follows:

1. Fish kills observed in the fall of 1987 and 1988 probably were caused by low D.O. from mixing of anoxic water and oxidation of oxygen demanding materials from the hypolimnion with the whole lake at fall overturn.

2. Myron Lake is eutrophic due to excessive phosphorus loading via external (groundwater and springs) and internal (anoxic hypolimnetic sediment release) sources. Phosphorus is the most limiting nutrient for algal productivity.

3. Lake restoration techniques which emphasize direct control of hypolimnetic D.O. are the most suitable for lake restoration and prevention of future fish kills. Hypolimnetic aeration is proposed as a desirable method for maintaining sufficient D.O. and temperature in the hypolimnion for trout survival, and for reducing internal P recycling from anoxic lake sediments.

4. The likelihood of future fish kills at fall overturn will probably remain high unless an effective restoration technique is implemented.

5. Based on the results of the present study, a feasibility analysis of alternative restoration techniques should be conducted. The costs and benefits of hypolimnetic aeration should be evaluated and compared with other potentially appropriate techniques.

6. Until a restoration technique can be implemented, trout stocking rates should be reduced. Plants of catchable sized fish should be made prior to peak fishing activity such that maximum harvest rates occur before fall overturn.

7. If fish kills continue to occur on a regular basis, selective fishery regulations (i.e., two fish catch limits) should be replaced by basic regulations (i.e., eight fish catch limits) in order to maximize harvest rates and minimize the number of dead trout during fall overturn.

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APPENDIX A

Example Error Propagation Formulas

Simple Error Propagation Formulas. The following formulas represent application of the first-order error propagation technique to simple algebraic relationships between independent random variables. For all formulas, the quantity σ^2 represents the variance term (i.e. σ_z^2=variance of z, σ_x^2=variance of x, etc.); z is a function of random variables x and y; a and b are constants.

1. **Addition/Subtraction**

   Function: $z = ax + by$ or $z = ax - by$

   Variance: $\sigma_z^2 = (\delta z/\delta x)^2\sigma_x^2 + (\delta z/\delta y)^2\sigma_y^2 = a^2\sigma_x^2 + b^2\sigma_y^2$

2. **Multiplication**

   Function: $z = xy$

   Variance: $\sigma_z^2 = (\delta z/\delta x)^2\sigma_x^2 + (\delta z/\delta y)^2\sigma_y^2 = y^2\sigma_x^2 + x^2\sigma_y^2$

3. **Division**

   Function: $z = x/y$

   Variance: $\sigma_z^2 = (\delta z/\delta x)^2\sigma_x^2 + (\delta z/\delta y)^2\sigma_y^2 = (1/y)^2\sigma_x^2 + (-x/y^2)^2\sigma_y^2$

APPENDIX B

Inlet Spring, Outlet, and Lake Level Data

Appendix B. Water Quality Data from a Representative Spring; Outlet Discharge; and Lake Level Data; Myron Lake.

Date	Temper-ature (deg C)	Sp.Cond. (umho/cm @25 C)	Alkalinity (mg CaCO3 /L)	pH	DO (mg/L)	Sulfate (mgSO4/L)	Sulfide (mgH2S/l)	Ammonia (ug N/L)	Nitrate +Nitrite (ug N/L)	TSN (ug N/L)	TSP (ug P/L)	SRP (ug P/L)	Outlet Discharge (cfs)	Lake Level(1) (ft)
	<------------	------------	------------	------------	------------	Inlet Spring	------------	------------	------------	------------	------------	------------>		
12-Jul-88														0.65
01-Aug-88	14.3	225		7.2	1.9	9.0		10 U		2,289	74.3	67.4	1	0.86
23-Aug-88	15.0	230		6.9	1.5	6.3		7	1,152	810	71.5	70.1	1.3	1.02
12-Sep-88	15.5	194		7.1	1.1	7.2		10 U	632	783	69.5	69.0	2.8	1.25
04-Oct-88	15.5	208		6.7	0.9	7.2		1	614		72.8	69.6	1.4	0.73
24 Oct-88	15.3	228	95.9	6.7	0.5	8.7		14	706	707	71.0	72.8	0.61	0.87
07-Nov-88	14.8	243		6.4	0.3									0.49
15-Nov-88	14.3	251		6.2	0.4	12.9		7	400	452	81.9	75.7	0.024	0.41
24-Jan-89	11.0				1.8									
22-Feb-89	10.2				2.4					660	44.9		0	0.00
22 Mar-89	9.5	286			2.2					950	45.7		0.22	0.33
26-Apr-89	9.5				3.0					1,050	53.8		1.91	1.08
18-May-89	10.5				1.4					1,015	48.8		1.8	1.04
31-May-89	11.5				1.6					1,400	58.8		1.58	0.96
20-Jun-89	12.0				1.8					2,501	56.5		0.11	0.33
17-Jul-89	13.0				2.2					1,842	62.5		0.22	0.54
22-Aug-89	14.5				1.2					822	69.3		0.016	0.33
26-Oct-89	14.0				0.6					746	58.5		0	
21-Nov-89	13.0	235			0.8					700	55.4		0	
14-Dec-89	11.0	254			1.4					636	51.6		0	
N										16	17			
Mean										1,085	61.58			
Std Err										610	11.03			
Outflow-Weighted Avg										1,115	63.41			

1) Lake level with respect to outlet culvert elevation.

APPENDIX C

Lake Chemistry Data

Appendix C. Myron Lake Water Quality Data

Date	Depth (m)	Temp (deg C)	Sp. Cond. (µmho/cm) @25 C)	Alk (mg/L CaCO3)	Hardness (mg/L CaCO3)	pH	DO (mg/L)	DO Sat. (%)	ORP (mV)	Sulfate (mg/L)	Sulfide (mg/L)	Ammonia (µgN/L)	Nitrate +Nitrite (µgN/L)	Total N (µgN/L)	Total P (µgP/L)	SRP (µgP/L)	Active Chl a (µg/L)	Light Intensity (% Incident)	Light Extinct (m^-1)	Secchi (m)
12-Jul-88	0	20.1	225	90.0		7.7	10.2	118	166	14.2		31	530 1,098	22.8	9.1	4.7	0.0			4.0
12-Jul-88	1	20.1				7.7	9.3	108												
12-Jul-88	2	20.1	222	90.0		7.6	9.3	108		12.1		35	605 1,059	18.2	10.7	3.1	0.0			
12-Jul-88	3	20.1				7.6	9.2	107												
12-Jul-88	4	20.0	222	89.5		7.5	8.9	103		11.8		41	502 961	32.0	10.5	3.4	0.0			
12-Jul-88	5	19.4				7.6	7.7	88.1												
12-Jul-88	6	17.1	238			7.7	2.3	25.3		13.2		202	184 880	34.8	10.4					
12-Jul-88	7	14.4				7.2	1.9	19.7												
12-Jul-88	8	11.3	255			7.1	0.7	6.77		12.5		392	10 U	781	30.7	7.6				
12-Jul-88	9	9.7				7.1	0.5	4.65												
12-Jul-88	10	8.8	266			7.0	0.5	4.55		12.1		807	10 U	1,684	75.4	19.3				
12-Jul-88	11	8.2				6.9	0.5	4.48												
12-Jul-88	12	7.7	307			6.8	0.5	4.16		7.9		4,244	10 U	4,107	293.0	319.0				
01-Aug-88	0	21.9	221	91.0		8.1	10.9	131		11.6		28	409	793	14.9	7.0	3.0		0.130	2.7
01-Aug-88	1	21.9	223			8.0	10.7	129	154									71.9		
01-Aug-88	2	22.0	222			8.0	10.8	130	159									54.1		
01-Aug-88	3	21.9	222	90.0		8.0	10.9	132	158	12.4		28	404	650	16.2	6.5	2.3	41.4		
01-Aug-88	4	22.0	220			8.0	10.8	130	158									33.8		
01-Aug-88	5	20.5	226			7.9	13.1	153	177									20.3		
01-Aug-88	6	18.3	237			7.4	5.3	59.3	154	13.4		134	282	1,067	32.6	15.5	8.8	7.90		
01-Aug-88	7	15.2	245			7.1	0.4	4.62	157									2.45		
01-Aug-88	8	12.1	251			7.1	0.1	0.86	141									0.95		
01-Aug-88	9	10.3	255			7.1	0.1	0.82	70	15.4		345	267	640	43.7	9.6		0.19		
01-Aug-88	10	8.9	272			7.0	0.2	1.59	-151									0.02		
01-Aug-88	11	8.5	283			6.9	0.1	0.79		7.2	1.8	1,560	16	2,773	99.5	27.4		0.004		
23-Aug-88	0	21.0	198	90.0	82	8.3	13.0	154		10.5		17	239	740	33.7	15.8	5.2		0.209	3.0
23-Aug-88	1	20.9	198			8.4	13.5	159										60.5		
23-Aug-88	2	20.2	196			8.4	14.0	163										39.0		
23-Aug-88	3	20.1	196			8.4	13.8	160		9.9		23	239	950	32.2	13.9	5.4	23.7		
23-Aug-88	4	20.0	197			8.4	13.5	157										14.5		
23-Aug-88	5	19.9	197			8.2	12.7	147										8.94		
23-Aug-88	6	19.0	208	89.3		7.8	9.1	103		10.5		64	247	80	47.4	13.2		5.36		
23-Aug-88	7	17.0	216			7.5	3.3	36.0										2.64		
23-Aug-88	8	13.9	209			7.2	0.1	0.51										1.15		
23-Aug-88	9	10.7	198			7.1	0.1	0.47		12.8		237	10 U	170	67.6	25.5		0.179		
23-Aug-88	10	9.3	196			6.9	0.1	0.46										0.016		
23-Aug-88	11	8.4	209	129.4		6.8	0.1	0.54		2.7	3.4	1,870	10 U	2,420	72.7	11.4		0.002		
23-Aug-88	12																			
12-Sep-88	0	20.6	207	83.8		8.5	10.6	124		9.4		39	17	477	26.6	5.3	11.8		0.292	1.7
12-Sep-88	1	19.1	207			8.4	11.2	127										48.6		
12-Sep-88	2	19.1	206			8.4	11.2	127										27.2		
12-Sep-88	3	18.9	206			8.4	11.2	126		9.7		28	13	491	29.1	7.0	15.6	13.4		
12-Sep-88	4	18.8	206			8.3	10.8	121										7.06		
12-Sep-88	5	18.8	208			8.3	10.6	119										3.32		
12-Sep-88	6	18.7	207	84.7		8.3	10.6	119		9.3		43	18	478	30.7	9.9	14.4	1.83		
12-Sep-88	7	18.7	207			8.2	9.9	111										x.989		
12-Sep-88	8	15.5	250			7.4	0.0	0.42										0.311		
12-Sep-88	9	11.9	260			7.3	0.1	0.49		12.0		311	2 J	1,033	89.8	12.0		0.026		
12-Sep-88	10	10.3	260			7.1	0.1	0.47										0.004		
12-Sep-88	11	9.1	285	119.0		7.1	0.1	0.55		5.3	2.9	2,119	3 J	1,949	89.0	33.5		0.000		

Appendix C. (Continued)

Date	Depth (m)	Temp (deg C)	Sp. Cond. (µmho/cm) @25 C)	Alk (mg/L CaCO3)	Hardness (mg/L CaCO3)	pH	DO (mg/L)	DO Sat. (%)	ORP (mV)	Sulfate (mg/L)	Sulfide (mg/L)	Ammonia (µgN/L)	Nitrate +Nitrite (µgN/L)	Total N (µgN/L)	Total P (µgP/L)	SRP (µgP/L)	Active Chl a (µg/L)	Light Intensity (% Incident)	Light Extinct (m^-1)	Secchi (m)
04-Oct-88	0	16.9	196			7.5	9.5	102	60	8.5		10 U	10 U	319	19.8	14.4	0.8		0.183	3.0
04-Oct-88	1	16.8	195			7.5	9.5	102	60									57.7		
04-Oct-88	2	16.8	195			7.5	9.5	102	59									47.8		
04-Oct-88	3	16.7	195			7.5	9.5	102	59	8.5		10 U	10 U	160	22.9	11.8	5.3	31.4		
04-Oct 88	4	16.6	195			7.5	9.4	101	59									18.3		
04-Oct-88	5	16.5	196			7.5	8.9	95.9	58									11.3		
04-Oct-88	6	16.3	196	83.0		7.4	8.2	88.5	57	8.5	0.3	10 U	10 U	305	28.4	15.4	6.8	6.63		
04-Oct-88	7	16.2	196			7.4	7.5	80.4	22									3.93		
04-Oct-88	8	15.6	280			7.2	3.2	33.3	-85									2.05		
04-Oct-88	9	12.6	245	92.2		7.0	0.0	0.46	-216	10.7	0.3 U	248	10 U	579	30.5	10.3		0.905		
04-Oct-88	10	9.9	263			6.9	0.1	0.51	-241		0.3 U							0.030		
04-Oct-88	11	8.9	288	122.4		6.8	0.1	0.50	-231	7.4	2.5	2,383	10 U	1,871	122.0	58.5		0.002		
20-Oct-88	0.0	13.0					8.3	82.7												
20-Oct-88	0.9	13.0					8.3	82.7												
20-Oct-88	1.8	13.0					8.3	82.7												
20-Oct-88	2.7	13.0					8.3	82.7												
20-Oct-88	3.7	13.0					8.3	82.7												
20-Oct-88	4.6	13.0					8.3	82.7												
20-Oct-88	5.5	13.0					8.3	82.7												
20-Oct-88	6.4	13.0					8.3	82.7												
20 Oct-88	7.3	13.0					8.2	81.7												
20-Oct-88	8.2	13.0					7.6	75.7												
20-Oct-88	9.1	12.0					5.0	48.6												
20-Oct-88	10.1	8.0					0.1	0.88												
20-Oct-88	11.0	7.0					0.1	0.86												
20-Oct-88	11.9	6.0					0.1	0.84												
20-Oct-88	12.8	6.0					0.0	0.00												
24-Oct-88	0	15.1	196	82.4		7.3	7.8	81.7	189	8.7		50	21	245	33.5	11.3	2.1		0.230	4.7
24-Oct-88	1	14.7	195			7.4	7.9	81.9	189									41.0		
24-Oct-88	2	14.7	195			7.3	7.9	81.9	190									36.0		
24-Oct-88	3	14.6	195			7.3	7.9	81.8	188	9.0	0.3 U	47	23	346	22.0	11.8	5.2	21.2		
24-Oct-88	4	14.4	195			7.3	7.9	81.4	188									12.5		
24-Oct-88	5	14.4	196			7.3	7.9	81.4	188									7.07		
24-Oct-88	6	14.3	196	83.0		7.3	7.9	81.2	190	9.0	0.3 U	43	21	267	29.5	16.0	4.9	4.67		
24-Oct-88	7	14.3	196			7.3	7.8	80.2	194									2.96		
24-Oct-88	8	14.3	280			7.3	7.8	80.2	195									1.89		
24-Oct-88	9	13.6	245			7.2	5.5	55.5	195	9.3	0.3 U	41	22	152	25.0	11.9		1.23		
24-Oct-88	10	10.8	263			6.9	0.0	0.37	-239		0.3 U							0.048		
24-Oct-88	11	9.1	288	127.0		6.0	0.0	0.44	-266	6.7	0.9	1,806	10 U	2,291	70.0	61.9		0.001		
24-Oct 88	12	8.1	337			6.7	0.0	0.43	-268		3.2									
24-Oct-88	13	7.9	356			6.6	0.0	0.43	-265											
31-Oct-88	0.0	13.5					7.2	72.4												
31-Oct-88	0.9	13.3					7.1	71.1												
31-Oct-88	1.8	13.2					7.1	71.0												
31-Oct 88	2.7	13.2					7.1	70.9												
31-Oct-88	3.7	13.1					7.1	70.8												
31-Oct-88	4.6	13.1					7.0	69.8												
31-Oct-88	5.5	13.0					7.0	69.7												
31-Oct-88	6.4	13.0					7.0	69.7												
31-Oct-88	7.3	13.0					6.9	68.7												

Appendix C. (Continued)

Date	Depth (m)	Temp (deg C)	Sp. Cond. (µmho/cm) @25 C)	Alk (mg/L CaCO3)	Hardness (mg/L CaCO3)	pH	DO (mg/L)	DO Sat. (%)	ORP (mV)	Sulfate (mg/L)	Sulfide (mg/L)	Ammonia (µgN/L)	Nitrate +Nitrite (µgN/L)	Total N (µgN/L)	Total P (µgP/L)	SRP (µgP/L)	Active Chl a (µg/L)	Light Intensity (% Incident)	Light Extinct (m^-1)	Secchi (m)
31-Oct-88	8.2	12.7					6.9	68.1												
31-Oct-88	9.1	11.3					6.8	65.0												
31-Oct-88	10.1	10.0					4.6	42.6												
31-Oct-88	11.0	8.2					0.2	1.77												
31-Oct-88	11.9	8.0					0.2	1.76												
31-Oct-88	12.8	8.0					0.2	1.76												
07-Nov-88	0	11.8	209			6.9	6.2	60.0	162											
07-Nov-88	1	11.8	209			7.0	6.1	59.0	152											
07-Nov-88	2	11.7	210			7.0	6.1	58.9	150											
07-Nov-88	3	11.7	209			7.0	6.0	57.9	149		0.3 U									
07-Nov-88	4	11.7	210			7.0	6.0	57.9	148											
07-Nov-88	5	11.7	209			7.0	6.0	57.9	148											
07-Nov-88	6	11.7	209			7.1	6.0	57.9	146		0.3 U									
07-Nov-88	7	11.7	209			7.1	6.1	58.9	145											5.8
07-Nov-88	8	11.7	210			7.1	6.1	58.9	145											
07-Nov-88	9	11.7	209			7.1	6.0	57.9	145		0.3 U									
07-Nov-88	10	11.7	210			7.0	5.8	56.0	144											
07-Nov-88	11	10.8	265			6.7	1.7	16.0	-187		0.3 U									
07-Nov-88	12	8.3	340			6.5	0.1	0.44	-226		2.7									
07-Nov-88	13	8.0	358			6.5	0.1	0.44	-231		3.9									
15-Nov-88	0.0	9.9	217	95.1		6.4	2.5	23.2	27	9.1										
15-Nov-88	1.0	9.9	217			6.7	2.5	23.2	17											
15-Nov-88	2.0	9.9	217			6.6	2.5	23.2	10											
15-Nov-88	3.0	9.9	217			6.6	2.4	22.2	7	9.7	0.3 U									
15-Nov-88	4.0	9.9	216			6.6	2.3	21.3	2											
15-Nov-88	5.0	9.9	216			6.7	2.3	21.3	-6											
15-Nov-88	6.0	9.9	216	95.0		6.7	2.3	21.3	-18	9.4	0.3 U	523	81	767	47.0	16.0	2.8		0.159	4.9
15-Nov-88	7.0	9.9	217			6.7	2.4	22.2	-28									69.2		
15-Nov-88	8.0	9.9	217			6.7	2.4	22.2	-44									47.0		
15-Nov 88	9.0	9.9	217			6.7	2.4	22.2	-58	10.2	0.3 U	562	79	867	55.8	18.7	3.0	34.6		
15 Nov-88	10.0	9.9	217			6.7	2.4	22.2	-70									23.5		
15-Nov-88	11.0	9.9	217	94.0		6.7	2.3	21.3	-95	10.2	0.3 U							15.7		
15-Nov-88	12.0	9.9	217			6.6	2.4	22.2	-98		0.3 U	545	79	1,062	56.6	16.2	3.3	10.3		
21-Nov-88	0.0	7.0					0.8	6.45										4.43		
21-Nov-88	0.9	7.0					0.7	5.59				498	81	784	57.3	15.0		5.15		
21-Nov-88	1.8	7.0					0.7	5.59										1.62		
21-Nov-88	2.7	7.0					0.6	5.16				558	81	760	53.9	36.1		1.08		
21-Nov-88	3.7	7.0					0.5	4.30										0.609		
21-Nov-88	4.6	7.0					0.5	4.30												
21-Nov-88	5.5	7.0					0.5	4.30												
21-Nov-88	6.4	7.0					0.5	4.30												
21-Nov-88	7.3	7.0					0.5	3.87												
21-Nov-88	8.2	7.0					0.5	3.87												
21-Nov-88	9.1	7.0					0.5	3.87												
21-Nov-88	10.1	7.0					0.5	3.87												
21-Nov-88	11.0	7.0					0.5	3.87												
21-Nov-88	11.9	7.0					0.4	3.44												
21-Nov-88	12.8	7.0					0.4	3.44												

Appendix C. (Continued)

Date	Depth (m)	Temp (deg C)	Sp. Cond. (µmho/cm) @25 C)	Alk (mg/L CaCO3)	Hardness (mg/L CaCO3)	pH	DO (mg/L)	DO Sat. (%)	ORP (mV)	Sulfate (mg/L)	Sulfide (mg/L)	Ammonia (µgN/L)	Nitrate +Nitrite (µgN/L)	Total N (µgN/L)	Total P (µgP/L)	SRP (µgP/L)	Active Chl a (µg/L)	Light Intensity (% Incident)	Light Extinct (m^-1)	Secchi (m)
29-Nov-88	0.0	6.0					2.4	20.1												
29-Nov-88	0.9	6.0					2.3	19.2												
29-Nov-88	1.8	6.0					2.3	19.2												
29-Nov-88	2.7	6.0					2.2	18.4												
29-Nov-88	3.7	6.0					2.2	18.4												
29-Nov-88	4.6	6.0					2.1	17.6												
29-Nov-88	5.5	6.0					2.1	17.6												
29-Nov-88	6.4	6.0					2.1	17.6												
29-Nov-88	7.3	6.0					2.0	16.7												
29-Nov-88	8.2	6.0					2.0	16.7												
29-Nov-88	9.1	6.0					2.0	16.7												
29-Nov-88	10.1	6.0					2.0	16.7												
29-Nov-88	11.0	6.0					2.0	16.7												
29-Nov-88	11.9	6.0					2.0	16.7												
29-Nov-88	12.8	6.0					2.0	16.7												
15-Dec-88	0.0	6.0					4.9	41.0												
15-Dec-88	0.9	6.0					4.8	40.2												
15-Dec-88	1.8	6.0					4.8	40.2												
15-Dec-88	2.7	6.0					4.8	40.2												
15-Dec-88	3.7	6.0					4.8	40.2												
15-Dec-88	4.6	6.0					4.7	39.4												
15-Dec-88	5.5	6.0					4.7	39.4												
15-Dec-88	6.4	6.0					4.7	39.4												
15-Dec-88	7.3	6.0					4.7	39.4												
15-Dec-88	8.2	6.0					4.7	39.4												
15-Dec-88	9.1	6.0					4.7	39.4												
15-Dec-88	10.1	6.0					4.7	39.4												
15-Dec-88	11.0	6.0					4.6	38.5												
15-Dec-88	11.9	6.0					4.6	38.5												
15-Dec-88	12.8	6.0					4.6	38.5												
19-Jan-89	0	4.0					8.4	66.8												
19-Jan-89	1	4.0					8.4	66.8												
19-Jan-89	2	4.0					8.2	65.2												
19-Jan-89	3	4.0					8.2	65.2												
19-Jan-89	4	4.0					8.0	63.6												
19-Jan-89	5	4.0					8.0	63.6												
19-Jan-89	6	4.0					7.4	58.8												
19-Jan-89	7	4.0					7.2	57.2												
19-Jan-89	8	4.0					7.2	57.2												
19-Jan-89	9	4.0					7.2	57.2												
19-Jan-89	10	4.2					7.2	57.5												
19-Jan-89	11	4.2					7.2	57.5												
19-Jan-89	12	4.2					7.2	57.5												
19-Jan-89	13	4.2					7.2	57.5												
22-Feb-89	0	2.0	220				15.0	113						460	32.3					
22-Feb-89	1	3.5					14.0	109												
22-Feb-89	2	3.8					13.8	109												
22-Feb-89	3	3.8					13.8	109												
22-Feb-89	4	3.8					13.8	109												
22-Feb-89	5	3.8	242				13.8	109						1190	58.9					
22-Feb-89	6	3.8					13.8	109												

Appendix C. (Continued)

Date	Depth (m)	Temp (deg C)	Sp. Cond. (µmho/cm) @25 C)	Alk (mg/L CaCO3)	Hardness (mg/L CaCO3)	pH	DO (mg/L)	DO Sat. (%)	ORP (mV)	Sulfate (mg/L)	Sulfide (mg/L)	Ammonia (µgN/L)	Nitrate +Nitrite (µgN/L)	Total N (µgN/L)	Total P (µgP/L)	SRP (µgP/L)	Active Chl a (µg/L)	Light Intensity (% Incident)	Light Extinct (m^-1)	Secchi (m)
22-Feb-89	7	3.8					13.8	109												
22-Feb-89	8	3.8					13.8	109												
22-Feb-89	9	3.8					13.8	109												
22-Feb-89	10	3.8	244				13.8	109						1050	58.7					
22-Feb-89	11	3.8					13.8	109												
22-Feb-89	12	3.9					13.6	107												
22-Feb-89	13	3.9					13.6	107												
22-Mar-89	0	7.5	211				15.0	130						830	35.2					
22-Mar-89	1	7.0					15.0	129												
22-Mar-89	2	6.5					15.0	127												
22-Mar-89	3	6.5					14.8	125												
22-Mar-89	4	6.0					14.6	122												
22-Mar-89	5	6.0	213				14.6	122						1090	56.9					
22-Mar-89	6	6.0					14.4	120												
22-Mar-89	7	6.0					14.2	119												
22-Mar-89	8	5.5					13.8	114												
22-Mar-89	9	5.0					13.6	111												
22-Mar-89	10	5.0	209				13.6	111						750	42.2					
22-Mar-89	11	5.0					13.6	111												
22-Mar-89	12	5.0					13.6	111												
22-Mar-89	13	5.0					13.4	109												
26-Apr-89	0	13.5					9.8	98.7						1130	23.6		2.44			4.4
26-Apr-89	1	13.5					9.8	98.7												
26-Apr-89	2	13.5					9.8	98.7												
26-Apr-89	3	13.5					9.8	98.7												
26-Apr-89	4	13.0					9.6	95.6												
26-Apr-89	5	10.5					8.6	80.7						1070	31.1					
26-Apr-89	6	9.0					8.4	76.0												
26-Apr-89	7	7.0					9.4	80.8												
26-Apr-89	8	6.5					9.4	79.8												
26-Apr-89	9	6.0					9.6	80.5												
26-Apr-89	10	6.0					9.8	82.1						820	46.6					
26-Apr-89	11	5.0					8.6	70.2												
26-Apr-89	12	5.0					8.6	70.2												
26-Apr-89	13	5.0					8.0	65.3												
18-May-89	0	16.0					11.2	119						640	17		3.9			4.3
18-May-89	1	16.0					11.2	119												
18-May-89	2	16.0					11.2	119												
18-May-89	3	16.0					11.1	118												
18-May-89	4	16.0					11.1	118												
18-May-89	5	15.0					11.0	114						730	17					
18-May-89	6	11.5					9.1	87.5												
18-May-89	7	9.5					7.1	65.0												
18-May-89	8	8.0					6.7	59.1												
18-May-89	9	7.0					6.5	55.9												
18-May-89	10	6.0					4.6	38.5						810	17.8					
18-May-89	11	6.0					2.6	21.8												
18-May-89	12	6.0					0.3	2.52												
18-May-89	13	6.0					0.1	0.84												

Appendix C. (Continued)

Date	Depth (m)	Temp (deg C)	Sp. Cond. (µmho/cm) @25 C)	Alk (mg/L CaCO3)	Hardness (mg/L CaCO3)	pH	DO (mg/L)	DO Sat. (%)	ORP (mV)	Sulfate (mg/L)	Sulfide (mg/L)	Ammonia (µgN/L)	Nitrate +Nitrite (µgN/L)	Total N (µgN/L)	Total P (µgP/L)	SRP (µgP/L)	Active Chl a (µg/L)	Light Intensity (% Incident)	Light Extinct (m^-1)	Secchi (m)
31-May-89	0	18.0					12.2	135						690	21.8		0.7			2.7
31-May-89	1	17.5					12.0	132												
31-May-89	2	17.0					12.8	139												
31-May-89	3	17.0					13.0	141												
31-May-89	4	16.5					12.2	131												
31-May-89	5	14.5					10.2	105						850	54.3					
31-May-89	6	12.5					8.7	85.6												
31-May-89	7	11.0					7.4	70.3												
31-May-89	8	8.5					5.9	52.7												
31-May-89	9	7.0					5.4	46.4												
31-May-89	10	6.5					3.8	32.2						975	57.5					
31-May-89	11	6.0					0.8	6.71												
31-May-89	12	6.0					0.2	1.68												
31-May-89	13	6.0					0.0	0.00												
20-Jun-89	0	19.5					10.8	124						768	19.1		5.64			4.6
20-Jun-89	1	19.5					10.8	124												
20-Jun-89	2	19.5					10.8	124												
20-Jun-89	3	19.5					11.0	126												
20-Jun-89	4	19.0					11.0	125												
20-Jun-89	5	17.0					14.6	159						967	29.7					
20-Jun-89	6	14.0					11.0	112												
20-Jun-89	7	11.0					6.8	64.6												
20-Jun-89	8	9.0					2.6	23.5												
20-Jun-89	9	7.0					0.4	3.44												
20-Jun-89	10	7.0					0.2	1.72						1353	103.3					
20-Jun-89	11	6.5					0.2	1.70												
20-Jun-89	12	6.0					0.1	0.84												
20-Jun-89	13	6.0					0.1	0.42												
17-Jul-89	0	22.5					11.8	144						718	20.3		5.9			2.7
17-Jul-89	1	22.0					12.2	147												
17-Jul-89	2	22.0					12.2	147												
17-Jul-89	3	21.5					12.2	146												
17-Jul-89	4	21.0					12.4	147												
17-Jul-89	5	19.0					15.0	170						594	42.9					
17-Jul-89	6	15.0					12.2	127												
17-Jul-89	7	12.5					6.0	59.0												
17-Jul-89	8	10.0					2.0	18.5												
17-Jul-89	9	8.5					0.4	3.58												
17-Jul-89	10	7.5					0.2	1.74						1271	61.2					
17-Jul-89	11	7.0					0.1	0.86												
17-Jul-89	12	6.5					0.1	0.85												
17-Jul-89	13	6.5					0.1	0.42												
22-Aug-89	0	22.5					12.0	146						822	25.6		5.27			2.7
22-Aug-89	1	22.0					12.2	147												
22-Aug-89	2	21.5					12.6	151												
22-Aug-89	3	21.5					12.6	151												
22-Aug-89	4	21.0					12.8	151												
22-Aug-89	5	20.5					14.0	164						657	33.5					
22-Aug-89	6	18.5					15.0	168												
22-Aug-89	7	14.0					6.4	65.2												

Appendix C. (Continued)

Date	Depth (m)	Temp (deg C)	Sp. Cond. (µmho/cm) @25 C)	Alk (mg/L CaCO3)	Hardness (mg/L CaCO3)	pH	DO (mg/L)	DO Sat. (%)	ORP (mV)	Sulfate (mg/L)	Sulfide (mg/L)	Ammonia (µgN/L)	Nitrate +Nitrite (µgN/L)	Total N (µgN/L)	Total P (µgP/L)	SRP (µgP/L)	Active Chl a (µg/L)	Light Intensity (% Incident)	Light Extinct (m^-1)	Secchi (m)
22-Aug-89	8	11.5					0.6	5.77												
22-Aug-89	9	9.5					0.4	3.66												
22-Aug-89	10	8.0					0.2	1.77						646	55.3					
22-Aug-89	11	7.0					0.1	0.43												
22-Aug-89	12	6.5					0.1	0.42												
22-Aug-89	13	6.5					0.1	0.42												
26-Oct-89	0	12.0					9.2	89.5						429	16.6		5.17			4.6
26-Oct-89	1	12.0					9.2	89.5												
26-Oct-89	2	12.0					9.2	89.5												
26-Oct-89	3	12.0					9.2	89.5												
26-Oct-89	4	12.0					9.2	89.5												
26-Oct-89	5	12.0					9.2	89.5						357	19.6					
26-Oct-89	6	12.0					9.2	89.5												
26-Oct-89	7	12.0					9.2	89.5												
26-Oct-89	8	12.0					9.2	89.5												
26-Oct-89	9	12.0					4.6	44.7												
26-Oct-89	10	8.5					0.6	5.36						1900	65.9					
26-Oct-89	11	7.0					0.3	2.58												
26-Oct-89	12	6.5					0.2	1.70												
26-Oct-89	13	6.0					0.2	1.68												
21-Nov-89	0	8.0	170				5.2	45.9						902	32.8		1.35			7.3
21-Nov-89	1	8.0					5.0	44.1												
21-Nov-89	2	8.0					5.0	44.1												
21-Nov-89	3	8.0					5.0	44.1												
21-Nov-89	4	8.0					5.0	44.1												
21-Nov-89	5	8.0	195				5.0	44.1						696	37.4					
21-Nov-89	6	8.0					5.0	44.1												
21-Nov-89	7	8.0					5.0	44.1												
21-Nov-89	8	8.0					5.0	44.1												
21-Nov-89	9	8.0					5.0	44.1												
21-Nov-89	10	8.0	204				5.0	44.1						872	37.2					
21-Nov-89	11	8.0					4.6	40.6												
21-Nov-89	12	8.0					2.0	17.6												
21-Nov-89	13	6.0					0.4	3.35												
14-Dec-89	0	4.0	209				5.8	46.1						893	50.4		1.31			6.1
14-Dec-89	1	4.0					5.8	46.1												
14-Dec-89	2	4.0					5.8	46.1												
14-Dec-89	3	4.0					5.8	46.1												
14-Dec-89	4	4.0					5.8	46.1												
14-Dec-89	5	4.0	215				5.8	46.1						906	46.3					
14-Dec-89	6	4.0					5.8	46.1												
14-Dec-89	7	4.0					5.8	46.1												
14-Dec-89	8	4.0					5.8	46.1												
14-Dec-89	9	4.0					5.8	46.1												
14-Dec-89	10	4.0	215				5.8	46.1						887	47.6					
14-Dec-89	11	4.0					5.8	46.1												
14-Dec-89	12	4.0					5.8	46.1												
14-Dec-89	13	4.0					5.6	44.5												

APPENDIX D

Phytoplankton Data

Myron Lake Phytoplankton Species List

November 11, 1988

Green Algae

Ankistrodesmus falcatus
Characium sp.
Chlamydomonas sp.
Chlamydomonas-like
Coelastrum scabrum
Coelastrum microporum
Nephrocytium sp.
Oocystis lacustris
Oocystis parva
Oocystis sp.
Quadrigula closterioides
Sphaerocystis schroeteri
Unidentified green alga

Diatoms, Pennate

Achnanthes minutissima
Amphora perpusilla
Epithemia sp.
Fragilaria crotonensis
Gomphonema angustatum
Synedra cyclopum
Synedra radians
Synedra rumpens
Synedra ulna

Chrysophytes

Dinobryon sertularia
Mallomonas sp.
Ochromonas sp.

Dinoflagellates

Ceratium hirundinella

Blue-green Algae

Anabaena flos-aquae
Anacystis marina
Aphanizomenon flos-aquae
Chroococcus limnetica
Chroococcus minimus
Chroococcus prescottii

Cryptomonads

Cryptomonas erosa
Cryptomonas ovata
Cryptomonas sp.
Rhodomonas minuta

PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Myron Lake, surface

SAMPLE DATE: 88-07-11

TOTAL DENSITY (#/ml): 1289

TOTAL BIOVOLUME (cu.uM/ml): 296206

DIVERSITY INDEX: 2.68

	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Ankistrodesmus falcatus	344	26.7	8609	2.9
2	Dinobryon sertularia	311	24.1	45163	15.2
3	Coelastrum scabrum	311	24.1	149766	50.6
4	Chroococcus minimus	111	8.6	8709	2.9
5	Cryptomonas erosa	67	5.2	34659	11.7
6	Achnanthes minutissima	33	2.6	1666	0.6
7	Synedra cyclopum	33	2.6	28160	9.5
8	Characium sp.	22	1.7	4221	1.4
9	Epithemia sp.	22	1.7	6665	2.3
10	Chlamydomonas sp.	11	0.9	3610	1.2
11	Quadrigula closterioides	11	0.9	533	0.2
12	Cryptomonas sp.	11	0.9	4443	1.5

PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Myron Lake, 1-0

SAMPLE DATE: 88-08-01

TOTAL DENSITY (#/ml): 917

TOTAL BIOVOLUME (cu.uM/ml): 563518

DIVERSITY INDEX: 3.18

--	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Dinobryon sertularia	280	30.5	39925	7.1
2	Coelastrum scabrum	157	17.1	82801	14.7
3	Nephrocytium sp.	96	10.5	53960	9.6
4	Rhodomonas minuta	70	7.6	1398	0.2
5	Cryptomonas erosa	52	5.7	27260	4.8
6	Oocystis lacustris	52	5.7	64584	11.5
7	Chroococcus minimus	52	5.7	1710	0.3
8	Ankistrodesmus falcatus	44	4.8	1092	0.2
9	Ceratium hirundinella	26	2.9	256870	45.6
10	Achnanthes minutissima	26	2.9	1311	0.2
11	Sphaerocystis schroeteri	26	2.9	11926	2.1
12	Synedra rumpens	17	1.9	2446	0.4
13	Gomphonema angustatum	9	1.0	3145	0.6
14	Cryptomonas ovata	9	1.0	15089	2.7

PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Myron Lake, composite

SAMPLE DATE: 88-09-12

TOTAL DENSITY (#/ml): 1224

TOTAL BIOVOLUME (cu.uM/ml): 371873

DIVERSITY INDEX: 2.81

--	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Chroococcus minimus	435	35.5	36988	9.9
2	Rhodomonas minuta	274	22.4	5489	1.5
3	Anacystis marina	172	14.0	51459	13.8
4	Coelastrum microporum	103	8.4	35692	9.6
5	Sphaerocystis schroeteri	80	6.5	44826	12.1
6	Fragilaria crotonensis	23	1.9	134479	36.2
7	Amphora perpusilla	23	1.9	7593	2.0
8	Chroococcus limnetica	11	0.9	8005	2.2
9	Synedra radians	11	0.9	4117	1.1
10	Synedra rumpens	11	0.9	1601	0.4
11	Oocystis sp.	11	0.9	13722	3.7
12	Anabaena flos-aquae	11	0.9	11435	3.1
13	Achnanthes minutissima	11	0.9	572	0.2
14	Oocystis parva	11	0.9	457	0.1
15	Coelastrum scabrum	11	0.9	5146	1.4
16	Epithemia sp.	11	0.9	3431	0.9
17	Aphanizomenon flos-aquae	11	0.9	6861	1.8

PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Myron Lake, composite

SAMPLE DATE: 88-10-04

TOTAL DENSITY (#/ml): 707

TOTAL BIOVOLUME (cu.uM/ml): 272349

DIVERSITY INDEX: 2.58

--	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Rhodomonas minuta	274	38.7	5481	2.0
2	Anacystis marina	210	29.7	63100	23.2
3	Chroococcus minimus	64	9.0	9459	3.5
4	Cryptomonas erosa	32	4.5	16572	6.1
5	Chroococcus prescottii	25	3.6	15705	5.8
6	Fragilaria crotonensis	19	2.7	117734	43.2
7	Mallomonas sp.	19	2.7	7266	2.7
8	Cryptomonas sp.	13	1.8	5099	1.9
9	Anabaena flos-aquae	13	1.8	12748	4.7
10	Chroococcus limnetica	13	1.8	11154	4.1
11	Nephrocytium sp.	6	0.9	4239	1.6
12	Ochromonas sp.	6	0.9	542	0.2
13	Coelastrum scabrum	6	0.9	2868	1.1
14	Coelastrum microporum	6	0.9	382	0.1

PHYTOPLANKTON SAMPLE ANALYSIS

SAMPLE: Myron Lake, (0-6)

SAMPLE DATE: 88-10-24

TOTAL DENSITY (#/ml): 411

TOTAL BIOVOLUME (cu.uM/ml): 170788

DIVERSITY INDEX: 3.23

	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Rhodomonas minuta	101	24.5	2019	1.2
2	Cryptomonas erosa	97	23.6	50544	29.6
3	Mallomonas sp.	45	10.9	17047	10.0
4	Anacystis marina	34	8.2	10094	5.9
5	Ankistrodesmus falcatus	30	7.3	748	0.4
6	Synedra cyclopum	26	6.4	22113	12.9
7	Anabaena flos-aquae	19	4.5	18692	10.9
8	Cryptomonas sp.	11	2.7	4486	2.6
9	Coelastrum scabrum	7	1.8	3365	2.0
10	Sphaerocystis schroeteri	7	1.8	6281	3.7
11	Chroococcus prescottii	7	1.8	9212	5.4
12	Nephrocytium sp.	7	1.8	5682	3.3
13	Synedra radians	4	0.9	2692	1.6
14	Chlamydomonas-like	4	0.9	1215	0.7
15	Synedra ulna	4	0.9	7440	4.4
16	Achnanthes minutissima	4	0.9	187	0.1
17	Unident. green alga	4	0.9	8972	5.3