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WATER QUALITY STATUS REPORT NO. 92

HAYDEN LAKE

KOOTENAI COUNTY, IDAHO

1987

Idaho Department of Health and Welfare
Division of Environmental Quality
Water Quality Bureau
1410 N. Hilton
Boise, Idaho 83706-1253

1990

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Kootenai County, Idaho

1987

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Idaho Department of Health and Welfare
Division of Environmental Quality
Water Quality Bureau

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ABSTRACT

Hayden Lake, Idaho is a 581 ha (3907 acre) high quality recreational lake located in Kootenai County, Idaho. The lake is situated in a 166 km^2 (64 mi^2) forested watershed at 682 meters (2238 feet) elevation. Hayden Lake has a maximum depth of 54.3 meters (178 feet), a mean depth of 28.2 meters (93 feet), and a volume of 4.46×10^8 m^3 (362,000 acre-feet).

Water quality investigations and trend monitoring data from 1985 until 1987 reveal that Hayden Lake is a relatively nutrient poor, oligo-mesotrophic lake with good water clarity and low algae production. Water quality profiles show that Hayden Lake is thermally stratified from June until October and a has a large, cool hypolimnion. Dissolved oxygen levels are adequate to support coldwater fish, however, there is some indication of oxygen depletion at the lower depths.

Phosphorus is the major limiting nutrient in Hayden Lake, with 69% of the total phosphorus load originating from tributary sources, 26% from atmospheric deposition, and 5% from septic system sources. There are no point sources of pollution in Hayden Lake.

As human population and land/water use continues to increase in the Hayden Lake watershed, comprehensive watershed planning and management will be essential for protecting high water quality and maintaining beneficial uses. Preparing a watershed land use inventory, continued water quality monitoring, and developing a water quality awareness program would be desirable ways to prevent nonpoint source pollution and meet water quality management goals.

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INTRODUCTION

Hayden Lake is a high quality recreational lake located 5 miles north of the City of Coeur d'Alene in Kootenai County, Idaho at latitude 47°45'37" and longitude 116°44'25" (Figure 1). The lake is situated in a 166 km^2 (64 mi^2) forested watershed at 682 meters (m) (2238 ft) elevation. Hayden Lake has a surface area of 1581 hectares (ha) (3907 acres), a maximum recorded depth of 54.3 m (178 ft), a mean depth of 28.2 m (93 ft) and an estimated volume of 4.46×10^8 m^3 (3.62×10^5 acre feet) (Table 1).

Hayden Lake is protected for several designated beneficial uses: domestic and agricultural water supply; cold water biota; salmonid spawning; primary and secondary contact recreation; and as a Special Resource Water with outstanding recreational or aesthetic qualities (Idaho Department of Health and Welfare 1985).

The southern and western shorelines of the Hayden Lake are bordered by the cities of Dalton Gardens, Hayden Lake, and Hayden (Figure 2). The combined estimated population of these areas is approximately 5500 residents. Eighty-five percent of the Hayden Lake shoreline is developed with summer and year-around residences. Sixty-three percent of the Hayden Lake watershed is federally administered as national forest land and 37% is privately owned (Figure 3). The Coeur d'Alene National Forest manages 10, 451 hectares (ha) (25,824 acres), the Idaho Pine Timber Association 158 ha (390.4 acres) and the Diamond International Corporation 10.4 ha (25.6 acres) (Perron 1987).

Hayden Lake receives water from direct precipitation and approximately 20 creeks or streams throughout the Hayden Lake watershed. Hayden Creek is the only perennial source of water, entering the lake at the shallow, northern end. Water leaves Hayden Lake by subsurface seepage and a surface outlet at the southwest corner of the lake. The surface outlet flows only during spring high water.

The first known water quality data for Hayden Lake was reported by Kemmerer in 1924 (Soltero et al. 1986). They found the lake to be thermally stratified with a large, cool, hypolimnion and high dissolved oxygen concentrations down to 50 m depth.

In 1983, the Classification of Idaho's Freshwater Lakes (Milligan et al. 1983) assigned Hayden Lake the highest priority of all Idaho lakes to "receive immediate consideration for protective or corrective measures." The rationale for this high priority designation was based on Hayden Lake's high use potential, nutrient loading capacity, and potential for management success.

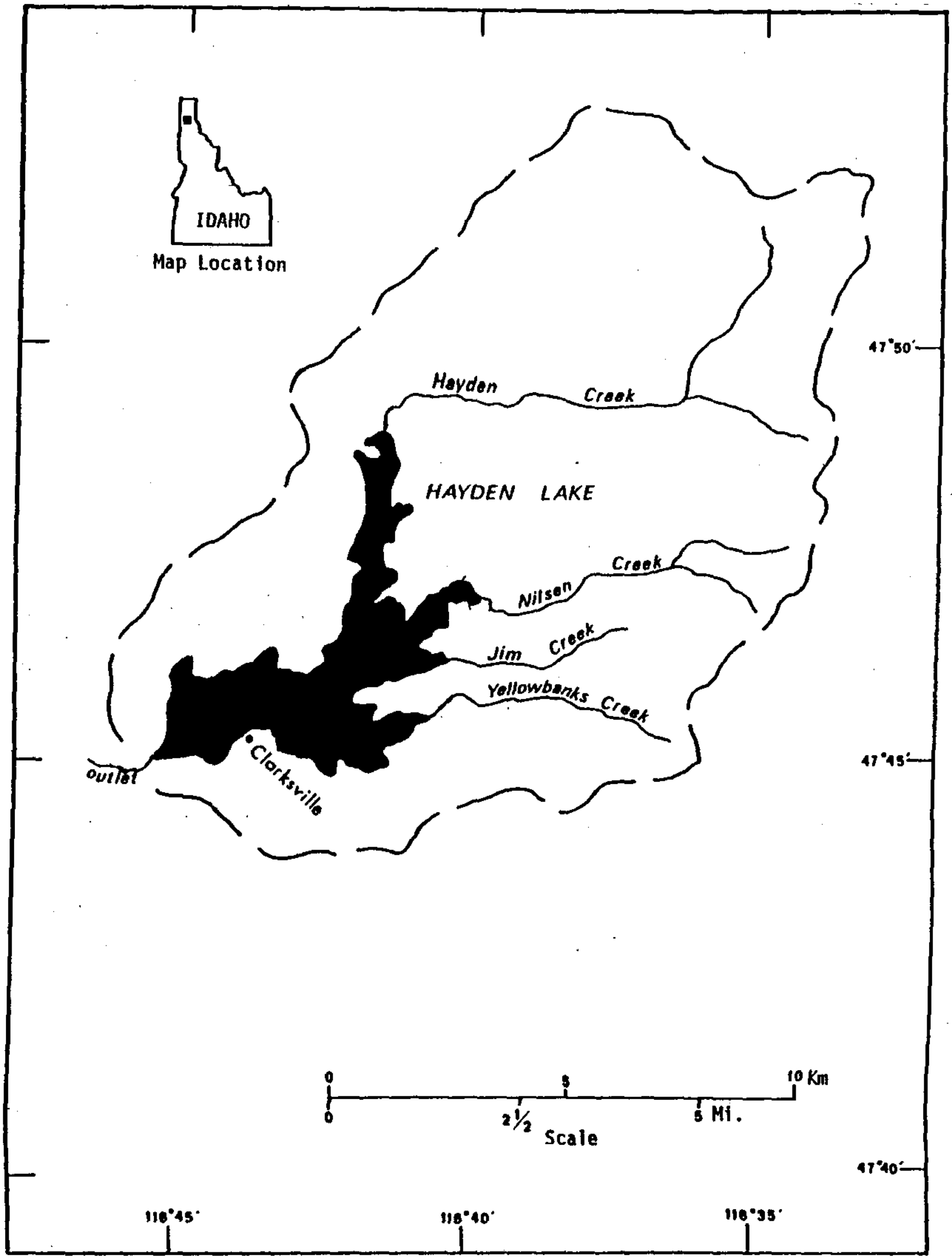

Figure 1. Location Map of Hayden Lake, Idaho. (EPA 1977)

Table 1. Morphometric Data for Hayden Lake, Idaho. (Soltero et al. 1986)

Maximum length	10.0 km (6.2 mi)
Maximum width	2.9 km (1.8 mi)
Maximum depth	54.3 m (178 ft)
Mean depth	28.2 m (93 ft)
Mean width	1.6 km (1.0 mi)
Surface area	1581 ha (3907 ac)
Volume	4.46×10^8 m^3 (3.62×10^5 ac-ft)
Shoreline development	3.1
Shoreline length	43.4 km (27.0 mi)

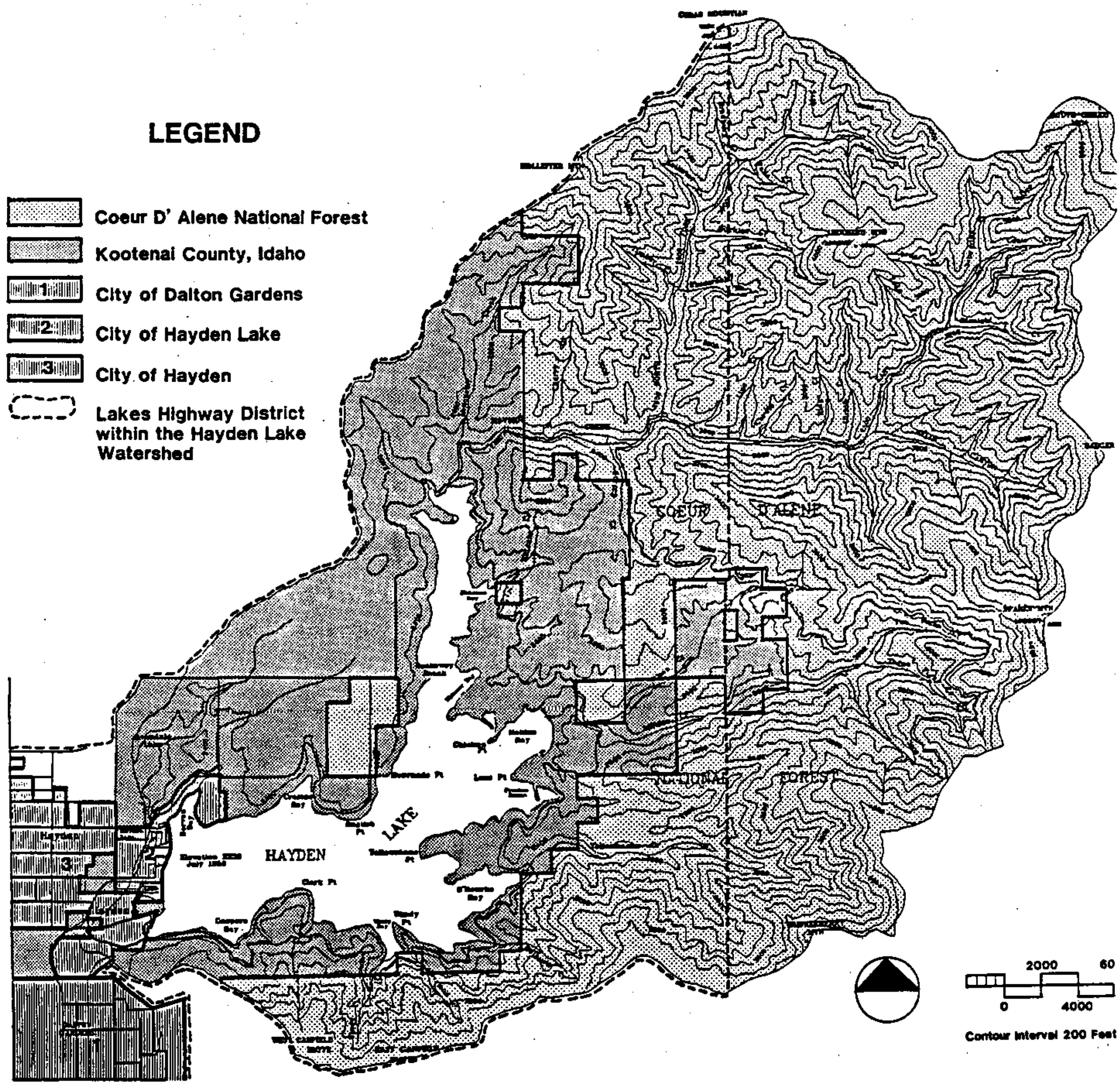

Figure 2. Jurisdictions in the Hayden Lake, Idaho Watershed. (Perron 1987)

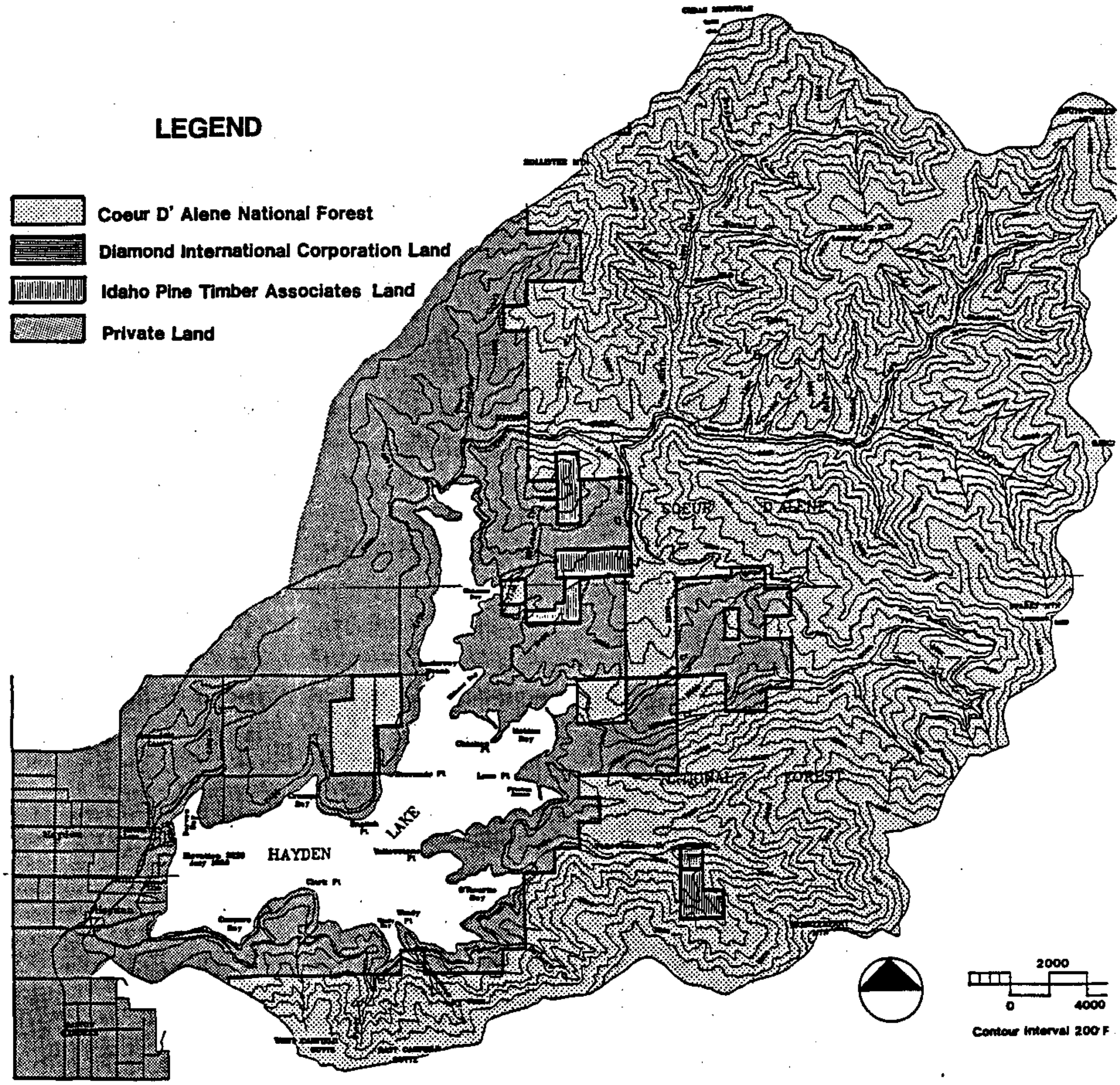

Figure 3. Ownership Patterns in the Hayden Lake, Idaho Watershed. (Perron 1987)

In 1985, a group of Hayden Lake property owners were organized and formed Save Hayden Lake, Inc. The Save Hayden Lake group, motivated by water quality concerns, generated enough private funds to contract with the Eastern Washington University Department of Biology to conduct an eight month water quality assessment of Hayden Lake. The goals of the study were to characterize baseline water quality and limnological conditions of Hayden Lake; identify water quality trends; determine nutrient loading to Hayden Lake and predict potential impacts from future watershed management practices; and make recommendations to maintain and/or improve the present water quality of Hayden Lake.

The results of this comprehensive water quality assessment indicate that Hayden Lake is a nutrient poor, oligotrophic ecosystem bordering on mesotrophy. This trophic condition was supported by measurements of good water clarity, little conductivity, low nutrient concentrations, and low chlorophyll a values. Temperature profiles revealed that Hayden Lake was thermally stratified during the mid-summer months and had a cool hypolimnion with some oxygen depletion. They found that phosphorus was the major limiting factor for algal growth, with 69% of the total phosphorus load originating from tributary sources, 26% from atmospheric fallout, and 5% from septic system sources. The researchers also concluded that the greatest threat to Hayden Lake water quality would probably be the cumulative impact of several timber harvest projects (Soltero et al. 1986). Falter et al. (1987) dispute the significance of these cumulative impact conclusions.

The Idaho Division of Environmental Quality (IDEQ) and the United States Forest Service (USFS) began a cooperative study in 1985 to monitor nutrient and sediment transport in the Hayden Creek watershed (Skille and Lider 1988). This study was prompted by the concerns for potential nutrient and sediment loading increases to Hayden Lake due to increased forest practice activities. The objectives of this study were to compare the nutrient and sediment contributions from the North and East Forks of Hayden Creek and to assess the potential impacts of forest practice activities on water quality and the trophic status of Hayden Lake. Preliminary results of this Hayden Creek study seem to indicate that mean annual phosphorus loading from Hayden Creek is comparable with Soltero et al. (1986) estimates. However, nonforest activities (i.e. agricultural grazing), particularly in the Lancaster Creek sub-drainage, appear be a significant source of nutrients to the Hayden Creek system.

In 1986, shortly after the completion of the Soltero et al. (1986) water quality assessment, the IDEQ conducted a follow-up water quality investigation of Hayden Lake to verify these lake eutrophication trends (Beckwith 1986). The objectives of this research were to continue gathering water quality monitoring data and to develop a technical basis for formulating and implementing long term water quality protection measures. This effort, the results of which are included in this report, incorporated the same water quality monitoring stations as the Soltero et al. (1986) research.

In November 1986, Save Hayden Lake, Inc. collected additional private funds and hired the consulting firm Robert Perron of Spokane, Washington to prepare a watershed management plan for the Hayden Lake watershed. This Step One report analyzed the policies of local, state, and federal agencies and provided recommendations for directing land use activities in the watershed and managing Hayden Lake water quality (Perron 1987).

During the summer of 1987, the IDEQ initiated a Citizen's Volunteer Monitoring Program (CVMP) to follow-up on the Soltero et al. (1986) and the IDEQ research and to develop a long term water quality trend monitoring database for Hayden Lake. The Program was designed to allow public participation in the water quality data gathering process and to increase public awareness of lake water quality issues. The first year results of this annual volunteer monitoring effort are also included in this report.

To date, Save Hayden Lake, Inc. members have financed a baseline water quality assessment and a partial watershed management plan for Hayden Lake. The results and recommendations of these studies, in addition to the IDEQ and volunteer monitoring data, will be useful for developing a comprehensive water quality management planning strategy for protecting and improving Hayden Lake water quality. This report is a compilation of the Soltero et al. (1986), IDEQ (1986) and the CVMP (1987) water quality investigations.

MATERIALS AND METHODS

DIVISION OF ENVIRONMENTAL QUALITY

IDEQ collected water quality samples and measured water quality parameters from four Hayden Lake stations on April 30, June 11, July 23 and Sept. 9, 1986. The STORET sampling station numbers are 2000279, 2000280, 2000281, and 2000282, hereafter referred to as stations 279, 280, 281 and 282 respectively (Fig. 4) (Table 2).

Lake water quality parameters, including water clarity, maximum depth, total ammonia, nitrite and nitrate nitrogen, total kjeldahl nitrogen, total phosphorus, orthophosphorus, hardness, total alkalinity, turbidity, chlorophyll a and water column profiles of specific conductance, dissolved oxygen, pH, and temperature were determined at each sampling station.

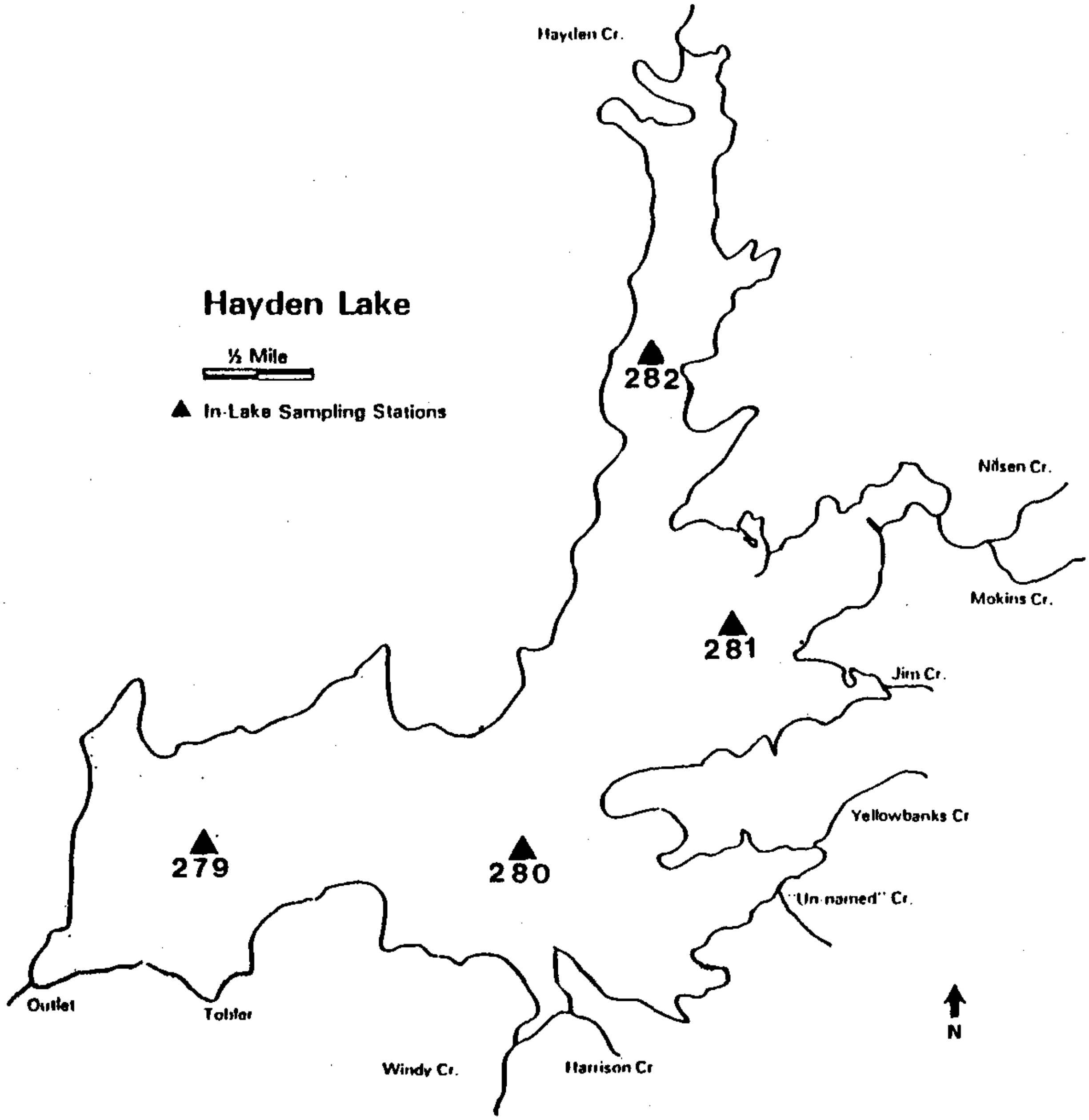

Figure 4. Water Quality Sampling Stations for Hayden Lake, Idaho. (Soltero et al. 1986)

Table 2. Hayden Lake Sampling Stations (Beckwith 1986).

STORET #	LATITUDE/LONGITUDE	DESCRIPTION
2000279	47°45'37"/116°44'25"	Hayden L. - west
2000280	47°45'26"/116°42'25"	Hayden L. - east
2000281	47°46'32"/116°41'25"	Hayden L. - north center
2000282	47°47'55"/115°115'35"	Hayden L. north

Water clarity was measured using a standard 20 cm black and white Secchi disk and an underwater viewing box. Water column profiles were determined at regular intervals from the surface to 1 m off the bottom using a Martek® Mark V submersible water quality analyzer. The dissolved oxygen function of this instrument was calibrated in the lab before each sampling session using the Winkler Titration Method. Results and other noteworthy conditions were recorded onto the field data sheets.

Euphotic zone composites and deep water grab samples were collected for chemical and biological analyses using a 1.2 liter brass Kemmerer bottle. The euphotic zone depths were determined by multiplying the Secchi disk transparency depth by a factor of 2.5 in clear non-turbid water and by a factor of 2 in turbid water. For example, in non-turbid water, with a Secchi disk transparency depth of 5 m, the euphotic zone was defined as 12. 5 m; samples were collected at 12, 9, 6, 3 m and immediately below the surface. In turbid water, with a Secchi disk transparency depth of 5 m, the euphotic zone was defined as 10 m and samples were collected at 10, 8, 6, 4, 2 m and immediately below the surface.

Euphotic zone subsamples were collected and poured into a rinsed 2-gallon churnsplitter. The resulting composites were thoroughly mixed and withdrawn for storage in non-reusable one liter polyethylene cubitainers. The cubitainers and lids were rinsed twice and labeled with the time and date of collection, the last three digits of the STORET station code, the sampling zone depth, and the presence or lack of preservative acid. Three euphotic zone composites were drawn from the churnsplitter. One was preserved with concentrated sulfuric acid, another was left unpreserved, and the third sample was prepared for chlorophyll a analyses.

Two deep water samples were collected from 1 m off the bottom. These samples were poured directly from the Kemmerer bottle into labeled and rinsed cubitainers. One sample was preserved with concentrated H_2SO_4, the other remained unpreserved.

All water quality samples were immediately placed on ice and cooled to 4°C. Water chemistry analyses were conducted by the Idaho Department of Health and Welfare, Bureau of Laboratories.

Chlorophyll and phytoplankton samples were collected from euphotic zone composites and stored in 250 ml brown polyethylene screw-top bottles containing 2.5 ml of Lugol's Iodine Solution. Chlorophyll samples (900-1000 ml) were vacuum filtered through 0.45 µm nitrocellulose membrane filters. The filters were placed in plastic Petri dishes, wrapped with aluminum foil and immediately frozen. Samples were processed upon return to the lab. In some instances, a maximum of 24 hours may have elapsed between the time of collection and the filtration or freezing.

Phytoplankton identification and enumeration were performed by Aquatic Analysts of Portland, Oregon. Permanent microscope slides were prepared for each sample and algal units (cells, colonies, or filaments) were counted along a measured transect of a microscope slide with a Zeiss standard microscope. A minimum of 100 algal units were counted for each sample and only algae which were alive at the time of collection were counted. Average biovolume estimates of each species were also obtained (Sweet 1986).

CITIZEN VOLUNTEER MONITORING PROGRAM

A Hayden Lake shoreline resident volunteered to collect lake water quality samples and obtain water quality profiles of Hayden Lake stations 279, 280, and 281 and 282 on five different occasions from August until November, 1987. The volunteer used a standard Secchi disk, a 1.2 liter acrylic Kemmerer sampling bottle, and a Yellow Spring Instruments (YSI) dissolved oxygen/temperature meter supplied by the North Idaho Lake Association Coalition (NILAC). The IDEQ, Water Quality Bureau, provided technical advice, sample storage cubitainers, preservative acids, and laboratory forms.

Lake water quality samples were collected at the secchi disk transparency depth and from 1 m off the bottom. The samples were analyzed for total phosphorus, orthophosphate, nitrate and nitrite nitrogen, total kjeldahl nitrogen, ammonia nitrogen, and chlorophyll (secchi depth only).

Three 1 liter cubitainers samples were collected from the secchi disk transparency depth and two cubitainers were collected at 1 m off the bottom; one cubitainer from each depth was preserved in the field with 2 milliliters (ml) of ultra-pure sulfuric acid and the other samples remained unpreserved. The secchi depth chlorophyll sample was immediately wrapped in aluminum foil to exclude light. Samples were stored on ice in a cooler and transported to the Bureau of Laboratories in Coeur d'Alene, Idaho. Unpreserved samples were filtered in the lab and analyzed for soluble reactive phosphorus (orthophosphate) and chlorophyll a.

Quality Assurance

Quality assurance was an important component of the volunteer monitoring program. IDEQ conducted training sessions for the volunteers and emphasized the need to collect reproducible water quality data. This training also provided volunteers with an opportunity to learn proper sampling protocol and equipment calibration.

A Water Quality Bureau staff member accompanied the volunteers on at least one occasion during the field season and collected a duplicate set of water quality samples. Lake water quality profiles were measured using a Martek Mark V submersible water quality analyzer. Spiked samples were not used because of the relatively small number of samples collected.

RESULTS AND DISCUSSION

HYDROLOGY

The greatest amount of average monthly precipitation occurs in the Hayden Lake watershed during the winter months, from November through March. As such, most of the water entering the watershed is stored as snowpack and becomes runoff during early spring. The majority of water entering the lake originates from the forested mountain sides to the south and southeast, draining Canfield Butte, Huckleberry, Spades, and Hudlow Mountains. Hayden Creek and Mokins Creek are the only tributaries maintaining substantial flows throughout the year. Maximum discharge usually occurs during the month of April (Meckel 1983).

Hayden Lake has a capacity for 362,000 acre-feet of water, however, for the eight month period between April and December 1985, total inflow only accounted for 32,000 acre feet of water. The water retention time for the lake, calculated by dividing the mean lake volume by the mean daily inflow, ranges between 1.3 and 71.9 years (Soltero et al. 1986).

Water leaves Hayden Lake by surface seepage and one surface outlet at the southwestern end of the lake. Groundwater from Hayden Lake represents a major contribution to the Spokane Valley-Rathdrum Prairie Aquifer in the Spokane River drainage basin. Groundwater discharge into the aquifer is estimated to be 2.27 cubic meters per second (m^3s) or 80 cubic feet per second (cfs). The surface outlet flows only after the lake has filled to capacity and spills into a meadow where it eventually disappears through percolation and evaporation.

NUTRIENT LOADING

Runoff and precipitation transports a variety of substances into Hayden Lake, including sediment, organic matter, nutrients, and other oxygen demanding materials. The elements nitrogen (N) and phosphorus (P) are of particular importance to Hayden Lake water quality because in-lake concentrations of these nutrients are usually the limiting factors controlling aquatic plant growth and the rate of lake eutrophication.

Soltero et al. (1986) in their eight month water quality assessment estimated total annual phosphorus loading to Hayden Lake to be 2.44 metric tons. They calculated that the tributaries collectively contribute 69 percent (1.69 metric tons) of the total phosphorus load to the lake. This value is comparable with a U.S. EPA (1977) estimate indicating 67.9% of the phosphorus originating from tributary sources. Soltero et al. (1986) also found that Hayden Creek accounted for 73 percent of the tributary loading and Mokins Creek added another 14 percent to the total tributary phosphorus load. Atmospheric fallout contributed 26% (0.63 metric tons) and shoreline septic systems accounted for about 5% (0.12 metric tons per year) of the total annual phosphorus load. The EPA (1977) estimate for Hayden Lake shoreline septic systems was 12% of the total phosphorus budget.

Although organic and inorganic sources of nitrogen are difficult to control and do not necessarily limit the rate of water quality change, they do contribute to Hayden Lake productivity. Soltero et al. (1986) estimated nitrogen loading into the Hayden Lake to be 27.56 metric tons. The tributaries contributed 51 percent of the total nitrogen load, with surface fallout and septic systems contributing an estimated 34 and 14 percent of the total nitrogen load, respectively.

THERMAL STRATIFICATION

Temperature and dissolved oxygen profile data for Hayden Lake are presented in tables 7 through 10 of Appendix A. As the profile data indicate, Hayden Lake annually stratifies into three distinct thermal layers known as the epilimnion, the metalimnion, and the hypolimnion. The epilimnion is the surface layer of warm, circulating water, typically 10 to 15 meters deep; the metalimnion is the middle zone, identified as the zone with the maximum rate of temperature change; the bottom layer or hypolimnion is the zone where water approaches maximum density at 4 degrees centigrade.

Thermal stratification usually lasts from June until October and is based on temperature induced density differences of water. Stratification usually lasts until the surface waters begin to cool in the fall of each year and is followed by mixing or destratification. This phenomenon is typical of most deep water lakes in the north Idaho region.

Dissolved Oxygen

The dissolved oxygen profile data for Hayden Lake (Appendix A) reveal that Hayden Lake exhibits a clinograde distribution of oxygen during the spring and early summer months. The clinograde distribution is characterized by thermal stratification and a gradual depletion of dissolved oxygen in the lower depths. Although anaerobic conditions did not develop in Hayden Lake, there was some oxygen depletion at the deepest parts of the lake where accumulating organic matter and bacterial metabolism are the greatest (Wetzel 1983).

As the summer progresses, the clinograde distribution transforms into a heterograde distribution. The heterograde distribution exhibits an irregular distribution of dissolved oxygen, sometimes attributed to a localized or concentrated population of respiring animals or photosynthesizing plants. Another source of oxygen curve anomalies may be the settling of cooled high-oxygen surface waters.

Except for an occasional reading below 5 mg/l, the dissolved oxygen profiles of Hayden Lake show highly-oxygenated water from the lake surface to the bottom.

LAKE NUTRIENT CONCENTRATIONS

Mean values for in-lake nutrient concentrations and other water quality parameters for Hayden Lake sampling stations 279, 280, 281, and 282 are presented in Tables 3, 4, 5, and 6. The raw data supporting IDEQ (1986) and CVMP (1987) values are included in Appendix B. It should be noted that there are some sampling station location discrepancies, based on differing maximum depth readings at stations 281 and 282. The maximum depth value for IDEQ sampling site location 281 significantly differs from the Soltero et al. (1986) and CVMP readings. Also, the Soltero et al. (1986) sampling location for site 282 differs from IDEQ and CVMP data.

Phosphorus

Soltero et al. (1986) determined that phosphorus was the limiting nutrient controlling the rate of eutrophication in Hayden Lake. Algae assimilate the nutrients nitrogen and phosphorus from their aquatic environment in a stoichiometric atomic ratio of approximately 16 N : 1 P until one of these two nutrients becomes depleted. The nutrient present in the lowest concentration, relative to the stoichiometric needs of algae, will limit subsequent growth of algae. The overall mean ratio of biologically available forms of nitrogen to phosphorus for Hayden Lake euphotic zone samples was approximately 40 : 1, verifying the phosphorus limitation. Although Soltero et al. (1986) found that there was no build up of phosphorus in the hypolimnion during summer stratification, IDEQ and CVMP data indicate there were slight increases of total phosphorus in the deep, open water areas. These increases might be evidence of increased productivity, as opposed to internal phosphorus loading. In more eutrophic lakes, a build up of nutrients usually occurs in the hypolimnion due to the absence of oxygen.

Table 3. Mean Annual Values of Selected Water Quality Parameters for Hayden Lake Sampling Station 279.

Investigator	Soltero et al.	DEQ	CVMP
Date	1985	1986	1987
Euphotic DVM (m)	16.9	21.5	
Deep sample depth (m)	51	50	50
Secchi Disk (m)	7.3	8.8	11.3
T. Ammonia as N mg/l (euphotic)	.006	.027	.030
T. Ammonia as N mg/l (deep)	.005	.006	.037
T. NO2+NO3 as N mg/l (euphotic)	.031	.030	.014
T. NO2+NO3 as N mg/l (deep)	.045	.008	.072
T.Kjeldahl as N mg/l (euphotic)	.35	.21	.20
T. Kjeldahl as N mg/l (deep)		.18	.17
T. Phosphorus as P mg/l (euphotic)	.007	.006	.009
T. Phosphorus as P mg/l (deep)	.007	.005	.016
Ortho phosphate as P mg/l (euphotic)	.005	.003	.001
Ortho phosphate as P mg/l (deep)	.006	.001	.006
Conductance umhos (euphotic)	51	57	57
Conductance umhos (deep)	49	56	56
Hardness as CaCO3 mg/l (euphotic)	23	24	26
Hardness as CaCO3 mg/l (deep)		24	23
T. Alkalinity as CaCO3 mg/l (euphotic	27	28	27
T. Alkalinity as CaCO3 mg/l (deep)		28	26
Turbidity ntu (euphotic)	.7	.3	
Turbidity ntu (deep)	.4	.2	
pH su (euphotic) range	6.6 - 7.6	7.3 - 7.7	7.1 - 8.1
pH su (deep) range	5.7 - 6.8	7.0 - 7.6	6.7 - 7.3
Dissolved oxygen mg/l (euphotic)	10.1		
Dissolved oxygen mg/l (deep)	7.2	5.9	6.9

Table 4. Mean Annual Values of Selected Water Quality Parameters for Hayden Lake Sampling Station 280.

Investigator	Soltero et al.	DEQ	CVMP
Date	1985	1986	1987
Euphotic DVM (m)	17	20.75	
Deep sample depth (m)	51	50	50.7
Secchi Disk (m)	7.65	8.3	10.1
T. Ammonia as N mg/l (euphotic)	.005	.011	.086
T. Ammonia as N mg/l (deep)	.005	.015	.026
T. NO2+NO3 as N mg/l (euphotic)	.030	.018	.009
T. NO2+NO3 as N mg/l (deep)	.048	.042	.081
T.Kjeldahl as N mg/l (euphotic)	.30	.13	.24
T. Kjeldahl as N mg/l (deep)	.21	.09	.20
T. Phosphorus as P mg/l (euphotic)	.030	.004	.008
T. Phosphorus as P mg/l (deep)	.008	.007	.018
Ortho phosphate as P mg/l (euphotic)	.005	.002	.002
Ortho phosphate as P mg/l (deep)	.006	.002	.008
Sp. Conductance umhos/cm (euphotic)	51	56	56
Sp. Conductivity umhos/cm (deep)	49	56	56
Hardness as CaCO3 mg/l (euphotic)	23	23	26
Hardness as CaCO3 mg/l (deep)		23	26
T. Alkalinity as CaCO3 mg/l (euphotic)	25	27	27
T. Alkalinity as CaCO3 mg/l (deep)		28	26
Turbidity ntu (euphotic)	1.0	.3	
Turbidity ntu (deep)	.4	.2	
pH su (euphotic) range	6.5 - 7.9	7.4 - 7.9	7.1 - 7.9
pH su (deep) range	5.2 - 6.9	7.0 - 7.5	6.8 - 7.4
Dissolved oxygen mg/l (euphotic)	10.3		8
Dissolved oxygen mg/l (deep)	7.8	6.1	7

Table 5. Mean Annual Values of Selected Water Quality Parameters for Hayden Lake Sampling Station 281.

Investigator	Soltéro et al.	DEQ	CVMP
Date	1985	1986	1987
Euphotic DVM (m)	16	20.75	
Deep sample depth (m)	27	50	28.1
Secchi Disk (m)	7.7	8.7	9.8
T. Ammonia as N mg/l (euphotic)	.005	.011	.068
T. Ammonia as N mg/l (deep)	.005	.009	.022
T. NO_2+NO_3 as N mg/l (euphotic)	.031	.012	.008
T. NO_2+NO_3 as N mg/l (deep)	.038	.017	.015
T.Kjeldahl as N mg/l (euphotic)	.32	.13	.28
T. Kjeldahl as N mg/l (deep)		0.1	0.18
T. Phosphorus as P mg/l (euphotic)	.010	.004	.009
T. Phosphorus as P mg/l (deep)	.011	.005	.010
Ortho phosphate as P mg/l (euphotic)	.005	.003	.002
Ortho phosphate as P mg/l (deep)	.006	.001	.002
Sp. Conductance umhos/cm (euphotic)	51	56	57
Sp. Conductivity umhos/cm (deep)	49	55	56
Hardness as $CaCO_3$ mg/l (euphotic)	23	24	26
Hardness as $CaCO_3$ mg/l (deep)		24	25
T. Alkalinity as $CaCO_3$ mg/l (euphotic)	25	28	27
T. Alkalinity as $CaCO_3$ mg/l (deep)		29	26
Turbidity ntu (euphotic)	.5	.3	
Turbidity ntu (deep)	.4	.2	
pH su (euphotic) range	6.6 - 7.8	7.3 - 7.8	7.2 - 7.7
pH su (deep) range	5.7 - 7.2	7.0 - 7.6	7.1 - 7.3
Dissolved oxygen mg/l (euphotic)	10.2		
Dissolved oxygen mg/l (deep)	9.3	5.8	6.1

Table 6. Mean Annual Values of Selected Water Quality Parameters for Hayden Lake Sampling Station 282.

Investigator	Soltero et al.	DEQ	CVMP
Date	1985	1986	1987
Euphotic DVM (m)	15	1.5	1
Deep sample depth (m)	21		
Secchi Disk (m)	6.7		
T. Ammonia as N mg/l (euphotic)	.005	.013	.026
T. Ammonia as N mg/l (deep)			
T. NO2+NO3 as N mg/l (euphotic)	.031	.014	.015
T. NO2+NO3 as N mg/l (deep)	.475		
T.Kjeldahl as N mg/l (euphotic)	.32	.49	.44
T. Kjeldahl as N mg/l (deep)			
T. Phosphorus as P mg/l (euphotic)	.010	.021	.026
T. Phosphorus as P mg/l (deep)	.011		
Ortho phosphate as P mg/l (euphotic)	.005	.003	.004
Ortho phosphate as P mg/l (deep)	.006		
Sp. Conductance umhos/cm (euphotic)	51	60	57
Sp. Conductivity umhos/cm (deep)			
Hardness as CaCO3 mg/l (euphotic)	23	26	26
Hardness as CaCO3 mg/l (deep)			
T. Alkalinity as CaCO3 mg/l (euphotic)	25	29	28
T. Alkalinity as CaCO3 mg/l (deep)			
Turbidity ntu (euphotic)	0.8	1.7	
Turbidity ntu (deep)			
pH su (euphotic) range	6.8 - 7.6	7.7 - 8.4	7.7 - 9.4
pH su (deep) range	6.0 - 7.2		
Dissolved oxygen mg/l (euphotic)	10.2		8.0
Dissolved oxygen mg/l (deep)		10.3	

Nitrogen

Concentrations of nitrate, nitrite, and kjeldahl nitrogen remained relatively low and stable throughout the period from 1985 until 1987. However, as the data in tables 3, 4, and 5 indicate, mean values of total ammonia in both the euphotic zone and the deep water areas significantly increased between 1985 and 1987. Soltero et al. (1986) did not observe an accumulation of ammonia in the hypolimnion. These changes might reflect increased amounts of algal productivity or oxygen depletion in the hypolimnion. Ammonia concentrations can increase when bacterial nitrification of ammonia to nitrate and nitrite ceases under relatively anaerobic conditions.

WATER CLARITY

Secchi disk transparency depth is a standardized measure of water transparency. Soltero et al. (1986) observed that the secchi disk transparency depth of Hayden Lake ranged from 7.1 meters to 9.2 meters at all stations. The Idaho Department of Health and Welfare (1977) found secchi disk transparency depths to be 9 meters at all open water stations during 1975.

Figure 5 shows secchi disk transparency depths in the open water of Hayden Lake steadily increasing between the years 1985 and 1987. Although CVMP values during the late summer and early fall indicate excellent water clarity, the maximum value of 16 meters on August 25, 1987 seems abnormally high. This reading might be an error.

The secchi disk transparency depth is most likely related to lake stratification and the rate of biological productivity. Soltero et al. (1986) found secchi disk transparency depths were highest in September when phytoplankton mean biovolume, chlorophyll *a* and turbidity levels were relatively low. Water clarity was at a minimum in April and May when the lake was mixed and the turbidity was highest because of spring runoff.

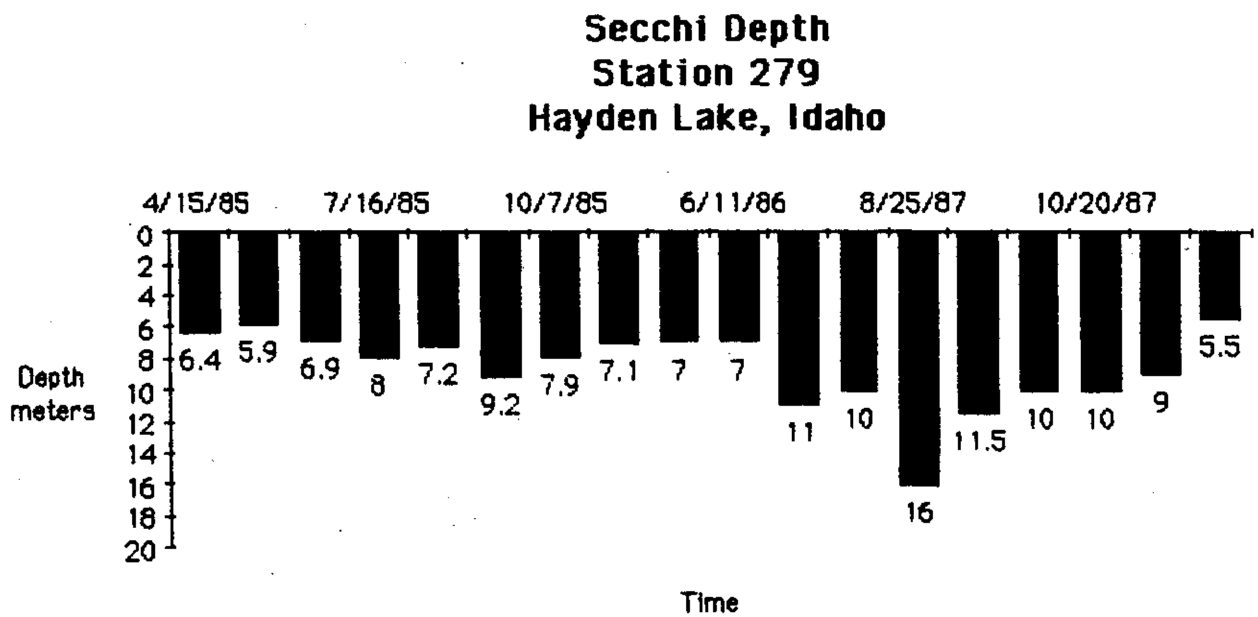

Figure 5. Secchi Disk Transparency Depths for Hayden Lake Sampling Station 279.

BACTERIOLOGICAL WATER QUALITY

Bacteria may constitute a potential health hazard and are of primary concern to recreational and water supply users. The occurrence of indicator bacteria such as fecal coliform (FC) and fecal streptococci (FS) in a water sample may indicate contamination by human or animal wastes and the potential presence of pathogenic organisms. The primary sources of bacterial contamination to Hayden Lake would be failed septic tanks, waterfowl, wildlife, or livestock grazing. Soltero et al. (1986) found essentially no indication of fecal contamination in the open water of Hayden Lake. Fecal coliform counts at the shoreline were also low, with 83 percent of the samples taken having no evidence of fecal contamination. However, they did locate fecal coliform contamination in Hayden and Nilsen Creek, attributed to the presence of cattle along their stream banks.

LAKE PHYTOPLANKTON

Phytoplankton are free-floating, often microscopic plants. Soltero et al. (1986) found a total of 62 species of phytoplankton during their sampling period between April 1985 and December 1985. The blue-green algae *Oscillatoria limnetica* had the largest mean biovolume, approximately 27 percent of the total estimated mean biovolume. Microplankton (unidentified cells less than five microns in size) ranked second in mean biovolume and accounted for 13 percent of the total mean biovolume.

Sweet (1986) (Appendix C) found phytoplankton abundances to be relatively stable, as opposed to a series of peaks. They found *Synedra radians* to be the most common algae in Hayden Lake, especially at the open water sites. *Synedra radians* is typically found in mesotrophic waters. Surprisingly, Sweet (1986) failed to find any of the blue-green algae *Oscillatoria limnetica*. The diatom *Cyclotella stelligera*, an indicator of oligotrophc conditions, was also very common.

Sweet (1986) reported that the shallow, northern end of the lake was dominated by *Rhodomonas minuta*, *Anabaena* spp., and *Cryptomonas* spp. Some of the open water phytoplankton species were also found at this site in the early spring.

Chlorophyll

Chlorophyll is a pigment molecule found in the tissues of green plants . Chlorophyll *a* is a type of chlorophyll which is used to determine the amount of algal biomass or weight of plant biological matter in a water sample. Soltero et al. (1986) found the mean chlorophyll *a* concentration to be 2.04 mg/m^3.

Normally, chlorophyll a values are good indicators of lake trophic condition because they correlate well with other water quality variables such as water clarity and nutrient concentrations. However, Soltero et al. (1986) found that seasonal fluctuations in chlorophyll a did not correlate with the seasonal fluctuations in algal biovolume. They speculated that this may be a function of changing species composition in the phytoplankton with differing ratios of chlorophyll a contents to cell biovolumes.

IDEQ chlorophyll a data for 1986 proved to be unreliable indicators of algal biomass (Beckwith 1989). Pheophytin a, a common degradation product of chlorophyll a, can interfere with the determination of chlorophyll a because it absorbs light and fluoresces in the same region of the spectrum as chlorophyll a and, if present, may cause errors in chlorophyll a values (APHA 1985).

LAKE ZOOPLANKTON

Zooplankton are free-floating microscopic animals which graze on detritus particles, bacteria, and algae. They frequently have cyclical relationships with phytoplankton populations. Soltero et al. (1986) found that seasonally there was an inverse relationship between zooplankton and phytoplankton standing crops. Zooplankton density was highest in the spring and lowest in the summer and fall. Phytoplankton biovolume dropped in June and July and peaked again in August when zooplankton density was low. Low zooplankton densities indicate that Hayden Lake would be an oligotrophic system, bordering on mesotrophy.

Zooplankton species composition can also be indicative of lake trophic condition. Soltero et al. (1986) found fifteen species of zooplankton during their water quality assessment, including 8 rotifers, 2 eucopods, and 5 cladocerans. Rotifers accounted for 53.5 % of the standing crop, copepods accounted for 44.6 %, and cladocerans only made up 1.92 % of the total zooplankton numbers. The Cladocerans are generally more abundant in eutrophic waters.

AQUATIC MACROPHYTES

Limited data exist on the macrophyte flora of Hayden Lake, however, the shallow northern end of the lake and Mokins Bay, O'Rourke Bay, and Windy Bay contain dense submergent and emergent macrophyte growth, predominantly Potomageton spp. It is reported that some of these areas were meadowlands prior to raising the lake in 1911 (Idaho Department of Health and Welfare 1977). The shallow, warm, and nutrient rich embayments of Hayden Lake will continue to provide ideal growing conditions for all types of aquatic plants.

LAKE TROPHIC STATUS

Researchers at Eastern Washington University (Soltero et al. 1986) consider Hayden Lake to be a relatively nutrient poor, oligotrophic aquatic ecosystem. They speculate that the reasons for this might include its large volume and depth (i.e. nutrient dilution factor) and a relatively undisturbed forested watershed.

A review by Falter et al. (1987) concludes that Hayden Lake should be characterized as oligo-mesotrophic system, rather than oligotrophic, based on deep water oxygen profiles, mean secchi disk transparency depths, chlorophyll a concentrations, and plankton populations.

CONCLUSIONS

Recent limnological evidence and water quality indicators reveal that Hayden Lake is a high quality lake. However, this designation is a temporary point on the eutrophication continuum. High quality lakes can be very sensitive to small amounts of change (e.g. phosphorus loading). As we continue to increase land use activities and alter the hydrologic regime and nutrient balance of the Hayden Lake watershed, we might begin to see more indications of water quality change (e.g. oxygen depletion) and a trend toward mesotrophic conditions.

RECOMMENDATIONS

Maintaining and or improving the high water quality of Hayden Lake as an oligotrophic or meso-oligotrophic aquatic ecosystem will require preventative action and the modification of our present land and water resource uses. Already, human activities in the Hayden Lake watershed have caused some irreversible biochemical changes in Hayden Lake. Recommendations which could be applied toward preventing water quality problems and maintaining beneficial uses would include conducting a watershed inventory, monitoring water quality trends in the lake and its tributaries, developing a comprehensive lake watershed management plan, and designing an educational program for environmentally conscientious watershed users.

Watershed Inventory

A comprehensive land use inventory, as outlined by Perron (1987) would be useful for a variety of reasons, including the need to document the nature and extent of various land uses affecting water quality, delineating sensitive environments, identifying vegetation, soils, slope, geology, and hydrologic conditions. Ultimately, the inventory could be used for lake management planning and water quality modeling applications.

Water Quality Monitoring

Continued water quality trend monitoring on Hayden Lake and its tributaries will be essential to document the water quality changes in Hayden Lake and to serve as a "red flag" to identify future water quality problems. The Citizens Volunteer Monitoring Program (CVMP) and the USFS-IDEQ cooperative study on Hayden Creek should be adequate to assess these eutrophication trends. Monitoring Hayden Lake for deep water concentrations of nutrients and dissolved oxygen will be especially important for predicting the future of Hayden Lake water quality.

Lake Watershed Management Plan

Developing a comprehensive lake watershed management plan, as proposed by Perron (1987), would be a desirable way to identify suitable land uses that will maintain high water quality values. The plan should promote interagency cooperation and contain realistic water quality goals with quantifiable objectives.

Soltero et al. (1986) indicated in their water quality assessment that the management of the upper watershed has the most potential for controlling impacts on the water quality since this part of the watershed represents the source of two-thirds of the total phosphorus loading to Hayden Lake.

Education

The Perron (1987) report also identified the need to establish an ongoing water quality awareness program. Although this recommendation is mandated by the Clean Lakes Act and is currently being implemented by the Clean Lake Coordinating Council (CLCC), it will require some site specific efforts to link Hayden Lake watershed users with proper land/water use best management practices (BMP's). The watershed inventory should help identify the types and extent of land users and their particular educational needs.

ACKNOWLEDGMENTS

The members of the Save Hayden Lake, Inc. and the water quality monitoring volunteers should be commended for having the foresight to invest in the future of Hayden Lake. The information they have contributed will be an important baseline from which to gauge our future water protection needs and performance.

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Appendix A

Hayden Lake Water Quality Profile Data for 1986 and 1987

Table 7. Water Quality Profile Data for Hayden Lake Sampling Station 279.

Dissolved Oxygen (mg/l)				
Depth (m)	4/30/86	6/11/86	7/22/86	9/9/86
0	12.3	12.3	13	11.4
5	12.2	12.2	13	11.6
10	12.2	11.3	13.9	12
15	11.9	10.1	11.8	12.9
20	11.6	8.8	9	10.8
25	10.6	7.8	7.8	7.9
30	10.2	7.2	7	7.2
35	9.9	6.7	6.4	6.8
40	9.4	6.2	5.8	6.5
45	9.1	5.5	5.3	6.2
49		4.6	4.7	5.3
Temperature (c)				
0	8.2	19.6	21.4	19.9
5	7.5	13.3	19	19.8
10	7.3	10.3	14.6	19.6
15	7.1	8.1	9	10.3
20	6.7	7	7.1	7.8
25	5.4	5.9	5.8	6.3
30	5.1	5.6	5.6	5.7
35	4.9	5.3	5.2	5.4
40	4.8	5.1	5	5.2
45	4.8	5	5.1	5.1
49		4.9	5	5
Conductance (umhos/cm)				
0	38	54	58	56
5	38	44	50	56
10	36	40	42	54
15	36	38	38	42
20	36	36	38	38
25	36	36	36	38
30	36	36	34	36
35	36	36	34	36
40	36	36	34	36
45	36	36	34	36
49		36	34	36
pH				
0	7.9	7.7	8.9	8.4
5	7.9	7.8	8.8	8.4
10	7.8	7.7	8.8	8.4
15	7.8	7.5	8.8	8
20	7.6	7.5	8.8	8
25	7.5	7.4	8.9	8.1
30	7.5	7.4	8.9	8.1
35	7.5	7.4	8.9	8.1
40	7.5	7.4	8.8	8.1
45	7.4	7.4	9	8.2
49		7.4	8.8	8.2

Table 7. (Continued)

Depth (m)	8/25/87	9/15/87	9/29/87	10/20/87
1	6	8	8.3	10.8
5	5.8	8.2	8.6	11
10	6.4	8.4	9	11
15	8.5	9.15	11.4	12
20	7.6	9.2	10.2	10
25	7.3	9.35	10.6	8.8
30	7.2	9.25	8.6	8.6
35	7.3	9.2	8.6	8.6
40	7.3	8.6	8.7	9
45	6.6	8	8.7	7
50	4.4	7.2	9	
Temperature (c)				
1	19.5			16
5	19			16
10	18			15
15	9			12
20	9			8
25	8.5			7
30	7			7
35	7			7
40	7.2			7
45	7.5			7
50	7.5			7
pH				
1	8.09	8.63	9.1	8.5
5	8.08	8.64	8.6	8.5
10	8.13	9	9.4	8.4
15	8.53	9.27	8.9	8.3
20	7.52	8.15	8.5	7.3
25	7.27	7.74	8.6	7.2
30	7.26	7.55	8.4	7.2
35	7.31	7.51	8.2	7.2
40	7.25	7.57	8.3	7.2
45	7.27	7.5	8.2	7.2
50	7.01	7.34	8.4	6.8

Table 8. Water Quality Profile Data for Hayden Lake Sampling Station 280.

Dissolved Oxygen (mg/l)				
Depth (m)	4/30/86	6/11/86	7/22/86	9/9/86
0	12.5	11.5	12.9	11.2
5	12.3	12.5	13	11.7
10	12.1	11.5	14.2	15.4
15	11.1	10.6	11.5	12.4
20	10.7	9.5	8.9	9.3
25	10.4	8.5	7.7	7.6
30	10.2	7.7	7.1	7
35	9.8	7.1	6.5	6.7
40	9.5	6.6	5.9	6.2
45	9	5.9	5.3	5.6
49		5.5	4.7	5.2
Temperature (c)				
0	8.1	20	21.3	19.9
5	7.4	18	19	19.8
10	7.1	10.2	14.1	17
15	5.7	8.4	8.9	10
20	5.4	7.3	6.9	7.2
25	5.1	6.3	5.9	6.1
30	5.1	5.7	5.6	5.6
35	4.9	5.4	5.3	5.3
40	4.8	5.2	5.2	5.2
45	4.8	5.1	5.1	5.1
49		5	5	5
Conductance (umhos/cm)				
0	38	54	54	56
5	38	50	50	56
10	38	40	44	50
15	36	38	38	40
20	36	38	36	38
25	36	36	36	36
30	36	36	34	36
35	36	36	34	36
40	36	36	34	36
45	36	36	34	36
49		36	36	38
pH				
0	7.8	7.6	8.9	8.5
5	7.8	7.6	9	8.5
10	7.7	7.5	9	8.6
15	7.5	7.4	8.8	8.1
20	7.4	7.4	8.8	8.1
25	7.4	7.3	8.8	8.1
30	7.3	7.3	8.8	8.1
35	7.3	7.3	8.9	8.2
40	7.3	7.3	8.9	8.2
45	7.3	7.3	9	8.2
49		7.3	9	8.2

Table 8. (Continued)

Dissolved Oxygen (mg/l)				
Depth (m)	8/25/87	9/15/87	9/29/87	10/20/87
1	6.6	8.2	8.4	
5	6.7	8.2	8.8	
10	6.8	8.7	8.8	
15	8.9	9.2	11.6	
20	8	9.2	10.3	
25	7.4	9	9.4	
30	7.2	8.8	10.4	
35	7.1	8.8	8.6	
40	6.8	8.3	7.8	
45	7.1	7.8	8.4	
50	5.1	7.6	5.2	
Temperature (c)				
1	19.8			
5	18.2			
10	18			
15	10			
20	7.3			
25	7.5			
30	7			
35	7.2			
40	7			
45	7.1			
50				
pH				
1	8.14	8.55	9	
5	8.16	8.57	8.9	
10	8.27	8.63	8.5	
15	8.24	9.06	9.4	
20	7.4	7.65	9.9	
25	7.28	754	9.6	
30	7.19	7.47	10.2	
35	7.23	7.62	10	
40	7.21	7.45	10.9	
45	6.2	7.48	8.3	
50	6.94	7.47	10.2	

Table 9. Water Quality Profile Data for Hayden Lake Sampling Station 281.

Dissolved Oxygen (mg/l)	4/30/86	6/11/86	7/22/86	9/9/86
Depth (m)				
0	12.3	12	12.8	11.3
5	12.1	12.3	12.7	11.7
10	12	11.5	13.4	12.1
15	12	10.6	11.5	12.8
20	11.9	9.4	9.2	8.9
25	11.4	7.9	7.6	8.1
30	11	7.5	6.9	7.6
35	10.1	7.1	6.4	7.4
40	9.4	6.6	5.9	7.2
45	8.8	6.2	5.4	6.4
49		4.6	4.7	4.9
Temperature (c)				
0	8.6	20.1	21.4	19.9
5	8	17.7	18.9	19.9
10	7.6	10.8	12.7	19.4
15	7.4	9.1	9.5	10.1
20	7.3	7.4	7.1	6.9
25	6.3	6	6.1	6
30	6	5.5	5.6	5.4
35	5.3	5.3	5.4	5.3
40	5	5.2	5.2	5.1
45	4.9	5.1	5.1	5.1
49		5	5.1	5
Conductance (umhos/cm)				
0	38	56	56	56
5	38	48	52	56
10	38	42	44	54
15	36	38	38	42
20	36	38	36	38
25	36	38	36	38
30	34	36	36	36
35	34	36	36	36
40	34	36	36	36
45	36	36	36	36
49		36	36	38
pH				
0	7.7	7.4	8.9	8.5
5	7.7	7.4	8.9	8.5
10	7.6	7.4	9	8
15	7.5	7.2	8.8	8.1
20	7.4	7.2	8.8	8.1
25	7.2	7.1	8.8	8.1
30	7.2	7.1	8.9	8.1
35	7.1	7.1	8.9	8.1
40	7.1	7.1	9	8.1
45	7	7	9.1	8.1
49		7	9.4	8

Table 9. (Continued)

Dissolved Oxygen (mg/l)				
Depth (m)	8/25/87	9/15/87	9/29/87	10/20/87
1	6.5	7.8	8.4	
5	6.6	8	9.3	
10	8.4	8.2	8.9	
15	8.4	8.2	11	
20	7.4	8	9.7	
25	6.8	7.2	8.8	
30	5.4		8	
Temperature (c)				
1	20	18.5		
5	18	18		
10	15	16		
15	9	16		
20	9	17.5		
25	11.5	18		
30	10			
pH				
1	8.26	8.62		
5	8.26	8.61		
10	8.87	8.54		
15	7.86	8.06		
20	7.35	7.65		
25	7.25	7.5		
30	7.27			

Table 10. Water Quality Profile Data for Hayden Lake Sampling Station 282.

Dissolved Oxygen (mg/l)				
Depth (m)	4/30/86	6/11/86	7/22/86	9/9/86
0	11.1			
1	11	8.8	11	9
2	11		12.2	
Temperature (c)				
0	9.6			
1	9.5	22.2	21.4	17.6
2	9.2		18.6	
Conductance (umhos/cm)				
0	38			
1	38	64	66	60
2	40		64	
pH				
0	7.8			
1	7.8	6.7	8.5	9.2
2	7.4		8.6	

Dissolved Oxygen (mg/l)					
Depth (m)	8/25/87	9/15/87	9/29/87	10/20/87	11/10/87
1	7.5	7.8	8.8		
Temperature (c)					
1	22	19			
pH					
1	9.3	9.6			

Appendix B

Hayden Lake Water Quality Data for 1986 and 1987

Table 11. Water Quality Data for Hayden Lake Sampling Station 279.

Investigator	DEQ	DEQ	DEQ	DEQ
Date	4/30/86	6/11/86	7/23/86	9/9/86
Euphotic DVM (m)	18	15	28	25
Deep sample depth (m)		50	50	50
Secchi Disk (m)	7	7	11	10
T. Ammonia as N mg/l (euphotic) det. limit=.01	0.032	0.013	0.062	0.002
T. Ammonia as N (deep)		0.012	0.004	0.002
T. NO2+NO3 as N mg/l (euphotic) det. limit=.001	0.021	0.012	0.084	0.004
T. NO2+NO3 as N (deep)		0.012	0.005	0.007
T.Kjeldahl as N mg/l (euphotic) det. limit=.01	0.12	0.27	0.12	0.31
T. Kjeldahl as N (deep)		0.11	0.12	0.31
T. Phosphorus as P mg/l (euphotic) det. limit=.01	0.004	0.004	0.005	0.011
T. Phosphorus as P (deep)		0.004	0.004	0.008
Ortho phosphate as P mg/l (euphotic) det. limit=.01	0.003	0.003	0.002	0.003
Ortho phosphate as P (deep)		0.001	0.0005	0.001
Sp. Conductivity (umhos/cm) euphotic	56	56	57	58
Sp. Conductivity (umhos/cm) deep		56	57	55
Hardness as CaCO3 (euphotic)	24	24	24	24
Hardness as CaCO3 (deep)		24	24	24
T. Alkalinity as CaCO3 (euphotic)	28	28	29	27
T. Alkalinity as CaCO3 (deep)		27	30	27
Turbidity (ntu) euphotic	0.28	0.28	0.3	0.3
Turbidity (ntu) deep		0.21	0.2	0.2
pH (su) euphotic	7.7	7.7	7.3	7.4
pH (su) deep		7.6	7.3	7
Dissolved oxygen (mg/L) euphotic				
Dissolved oxygen (mg/L) deep	9.1	4.6	4.7	5.3
Chlorophyll a (mg/m3)	0.16		<.08	<.08
Pheophytin (mg/m3)	4		<2	<2
Total Coliform (count/100 mls)	<1	<1	<1	<1
Fecal Coliform (count/100 mls)	<1	<1	<1	<1

Table 11. (Continued)

Investigator	CYMP	CYMP	CYMP	CYMP	CYMP
Date	8/25/87	9/15/87	9/29/87	10/20/87	11/10/87
Euphotic DVM (m)	16	11.5	10	10	9
Deep sample depth (m)	51	51	49	50	50
Secchi Disk (m)	16	11.5	10	10	9
T. Ammonia as N mg/l (euphotic) det. limit=.01	0.012	0.015	0.01	0.012	0.099
T. Ammonia as N (deep)	0.035	0.011	0.01	0.007	0.121
T. NO2+NO3 as N mg/l (euphotic) det. limit=.001	0.007	0.018	0.012	0.004	0.027
T. NO2+NO3 as N (deep)	0.073	0.106	0.053	0.11	0.019
T.Kjeldahl as N mg/l (euphotic) det. limit=.01	0.16	0.14	0.24	0.3	0.17
T. Kjeldahl as N (deep)	0.12	0.08	0.21	0.22	0.24
T. Phosphorus as P mg/l (euphotic) det. limit=.01	0.02	0.011	0.006	0.004	0.006
T. Phosphorus as P (deep)	0.02	0.016	0.009	0.012	0.022
Ortho phosphate as P mg/l (euphotic) det. limit=.01	0.002	0.002	0.001	0.001	0.001
Ortho phosphate as P (deep)	0.011	0.007	0.003	0.008	0.001
Sp. Conductivity (umhos/cm) euphotic	56	56	57	58	56
Sp. Conductivity (umhos/cm) deep	56	56	56	57	56
Hardness as CaCO3 (euphotic)	28	20	24	28	28
Hardness as CaCO3 (deep)	24	24	20	24	24
T. Alkalinity as CaCO3 (euphotic)	26	26	27	27	27
T. Alkalinity as CaCO3 (deep)	26	26	26	25	28
Turbidity (ntu) euphotic					
Turbidity (ntu) deep					
pH (su) euphotic	7.6	8.1	7.1	7.9	7.6
pH (su) deep	7.1	7.3	6.8	6.7	7.5
Dissolved oxygen (mg/L) euphotic					
Dissolved oxygen (mg/L) deep	4.4	7.2	9		

Table 12. Water Quality Data for Hayden Lake Sampling Station 280.

Investigator	DEQ	DEQ	DEQ	DEQ
Date	4/30/86	6/11/86	7/23/86	9/9/86
Euphotic DVM (m)	15	15	28	25
Deep sample depth (m)		50	50	50
Secchi Disk (m)	6	6.5	10.5	10.3
T. Ammonia as N mg/l (euphotic)	0.023	0.005	0.013	0.002
T. Ammonia as N mg/l (deep)		0.004	0.039	0.002
T. NO2+NO3 as N mg/l (euphotic)	0.025	0.009	0.03	0.007
T. NO2+NO3 as N mg/l (deep)		0.012	0.092	0.021
T.Kjeldahl as N mg/l (euphotic)	0.1	0.14	0.12	0.14
T. Kjeldahl as N mg/l (deep)		0.11	0.06	0.1
T. Phosphorus as P mg/l (euphotic)	0.001	0.003	0.003	0.008
T. Phosphorus as P mg/l (deep)		0.005	0.006	0.009
Ortho phosphate as P mg/l (euphotic)	0.001	0.002	0.002	0.003
Ortho phosphate as P mg/l (deep)		0.002	0.0005	0.002
Sp. Conductance umhos/cm (euphotic)	58	57	54	55
Sp. Conductivity umhos/cm (deep)		56	57	55
Hardness as CaCO3 mg/l (euphotic)	20	24	24	24
Hardness as CaCO3 mg/l (deep)		24	20	24
T. Alkalinity as CaCO3 mg/l (euphotic)	27	28	30	24
T. Alkalinity as CaCO3 mg/l (deep)		27	31	27
Turbidity ntu (euphotic)	0.3	0.26	0.3	0.3
Turbidity ntu (deep)		0.23	0.2	0.3
pH su (euphotic)	7.9	7.6	7.5	7.4
pH su (deep)		7.5	7.3	7
Dissolved oxygen mg/l (euphotic)				
Dissolved oxygen mg/l (deep)				
Chlorophyll a (mg/m3)	0.48		<.08	<.08
Pheophytin (mg/m3)	3.6		<2	<2
Total Coliform (count/100 mls)	<1	1	confluent	<1
Fecal Coliform (count/100 mls)	<1	<1	<1	<1

Table 12. (Continued)

Investigator	CVMP	CVMP	CVMP	CVMP	CVMP
Date	8/25/87	9/15/87	9/29/87	10/20/87	11/10/87
Euphotic DVM (m)	10	10.5	10	10	9
Deep sample depth (m)	51.5	51	51	50	50
Secchi Disk (m)	10	11.5	10	10	9
T. Ammonia as N mg/l (euphotic)	0.022	0.01	0.011	0.005	0.382
T. Ammonia as N mg/l (deep)	0.021	0.002	0.01	0.013	0.085
T. NO2+NO3 as N mg/l (euphotic)	0.01	0.018	0.011	0.007	0.0005
T. NO2+NO3 as N mg/l (deep)	0.098	0.064	0.103	0.125	0.017
T.Kjeldahl as N mg/l (euphotic)	0.0025	0.13	0.25	0.29	0.53
T. Kjeldahl as N mg/l (deep)	0.15	0.12	0.21	0.27	0.23
T. Phosphorus as P mg/l (euphotic)	0.01	0.008	0.006	0.005	0.012
T. Phosphorus as P mg/l (deep)	0.03	0.016	0.015	0.015	0.014
Ortho phosphate as P mg/l (euphotic)	0.002	0.001	0.001	0.001	0.007
Ortho phosphate as P mg/l (deep)	0.012	0.004	0.009	0.01	0.007
Sp. Conductance umhos/cm (euphotic)	56	56	56	57	56
Sp. Conductivity umhos/cm (deep)	56	56	56	58	56
Hardness as CaCO3 mg/l (euphotic)	24	28	24	28	24
Hardness as CaCO3 mg/l (deep)	24	28	28	24	28
T. Alkalinity as CaCO3 mg/l (euphotic)	28	27	26	26	27
T. Alkalinity as CaCO3 mg/l (deep)	27	26	26	26	26
Turbidity ntu (euphotic)					
Turbidity ntu (deep)					
pH su (euphotic)	7.9	7.2	7.1	7.7	7.4
pH su (deep)	7.1	7.2	6.8	6.9	7.4
Dissolved oxygen mg/l (euphotic)	6.4	8.7	9		
Dissolved oxygen mg/l (deep)	4.4	7.6	9		

Table 13. Water Quality Data for Hayden Lake Sampling Station 281.

Investigator	DEQ	DEQ	DEQ	DEQ
Date	4/30/86	6/11/86	7/23/86	9/9/86
Euphotic DYM (m)	15	15	28	25
Deep sample depth (m)	NONE	50	50	50
Secchi Disk (m)	6.5	6.5	11	10.8
T. Ammonia as N mg/l (euphotic)	0.024	0.004	0.014	0.002
T. Ammonia as N mg/l (deep)		0.004	0.009	0.013
T. NO2+NO3 as N mg/l (euphotic)	0.014	0.006	0.024	0.004
T. NO2+NO3 as N mg/l (deep)		0.009	0.016	0.025
T.Kjeldahl as N mg/l (euphotic)	0.11	0.13	0.15	0.12
T. Kjeldahl as N mg/l (deep)		0.11	0.09	0.1
T. Phosphorus as P mg/l (euphotic)	0.001	0.003	0.003	0.009
T. Phosphorus as P mg/l (deep)		0.004	0.002	0.009
Ortho phosphate as P mg/l (euphotic)	0.001	0.002	0.002	0.005
Ortho phosphate as P mg/l (deep)		0.001	0.0005	0.002
Sp. Conductance umhos/cm (euphotic)	57	56	57	55
Sp. Conductivity umhos/cm (deep)		56	54	55
Hardness as CaCO3 mg/l (euphotic)	24	24	24	24
Hardness as CaCO3 mg/l (deep)		24	24	24
T. Alkalinity as CaCO3 mg/l (euphotic)	27	27	30	26
T. Alkalinity as CaCO3 mg/l (deep)		28	30	28
Turbidity ntu (euphotic)	0.3	0.3	0.3	0.3
Turbidity ntu (deep)		0.23	0.3	0.2
pH su (euphotic) range	7.8	7.7	7.5	7.3
pH su (deep) range		7.6	7.4	7
Dissolved oxygen mg/l (euphotic)				
Dissolved oxygen mg/l (deep)	8.8	4.8	4.7	4.9
Chlorophyll a (mg/m3)	0.24	<.08	<.08	1.3
Pheophytin (mg/m3)	3.6	<2	<2	5.1
Total Coliform (count/100 mls)	<1	<1	3	<1
Fecal Coliform (count/100 mls)	<1	<1	<1	<1

Table 13. (Continued)

Investigator	CVMP	CVMP	CVMP	CVMP	CVMP
Date	8/25/87	9/15/87	9/29/87	10/20/87	11/10/87
Euphotic DVM (m)					
Deep sample depth (m)	32.5	26	28	26	28
Secchi Disk (m)	7	15	10	9	8
T. Ammonia as N mg/l (euphotic)	0.011	0.0005	0.01	0.01	0.308
T. Ammonia as N mg/l (deep)	0.012	0.004	0.013	0.024	0.059
T. NO2+NO3 as N mg/l (euphotic)	0.014	0.007	0.013	0.006	0.0005
T. NO2+NO3 as N mg/l (deep)	0.014	0.01	0.014	0.008	0.027
T.Kjeldahl as N mg/l (euphotic)	0.17	0.16	0.24	0.25	0.57
T. Kjeldahl as N mg/l (deep)	0.12	0.13	0.23	0.26	0.16
T. Phosphorus as P mg/l (euphotic)	0.01	0.014	0.008	0.004	0.007
T. Phosphorus as P mg/l (deep)	0.02	0.009	0.008	0.006	0.006
Ortho phosphate as P mg/l (euphotic)	0.002	0.003	0.001	0.001	0.004
Ortho phosphate as P mg/l (deep)	0.002	0.002	0.002	0.002	0.002
Sp. Conductance umhos/cm (euphotic)	56	56	59	60	56
Sp. Conductivity umhos/cm (deep)	56	56	56	57	53
Hardness as CaCO3 mg/l (euphotic)	28	24	24	28	28
Hardness as CaCO3 mg/l (deep)	24	24	24	28	24
T. Alkalinity as CaCO3 mg/l (euphotic)	27	26	27	27	28
T. Alkalinity as CaCO3 mg/l (deep)	27	26	25	26	27
Turbidity ntu (euphotic)					
Turbidity ntu (deep)					
pH su (euphotic) range	7.7	7.5	7.2	7.5	7.4
pH su (deep) range	7.1	7.3	7.2	7.2	7.3
Dissolved oxygen mg/l (euphotic)					
Dissolved oxygen mg/l (deep)	5.4	7.2	8	3.8	

Table 14. Water Quality Data for Hayden Lake Sampling Station 282.

Investigator	DEQ	DEQ	DEQ	DEQ
Date	4/30/86	6/11/86	7/23/86	9/9/86
Euphotic DVM (m)	2			1
Deep sample depth (m)				
Secchi Disk (m)				
T. Ammonia as N mg/l (euphotic)	0.024			0.002
T. Ammonia as N mg/l (deep)				
T. NO2+NO3 as N mg/l (euphotic)	0.014			0.014
T. NO2+NO3 as N mg/l (deep)				
T.Kjeldahl as N mg/l (euphotic)	0.32			0.65
T. Kjeldahl as N mg/l (deep)				
T. Phosphorus as P mg/l (euphotic)	0.006			0.035
T. Phosphorus as P mg/l (deep)				
Ortho phosphate as P mg/l (euphotic)	0.004			0.002
Ortho phosphate as P mg/l (deep)				
Sp. Conductance umhos/cm (euphotic)	57			62
Sp. Conductivity umhos/cm (deep)				
Hardness as CaCO3 mg/l (euphotic)	24			28
Hardness as CaCO3 mg/l (deep)				
T. Alkalinity as CaCO3 mg/l (euphotic)	28			30
T. Alkalinity as CaCO3 mg/l (deep)				
Turbidity ntu (euphotic)	0.5			2.8
Turbidity ntu (deep)				
pH su (euphotic) range	7.7			8.4
pH su (deep) range				
Dissolved oxygen mg/l (euphotic)				
Dissolved oxygen mg/l (deep)	11	8.8	12.2	9
Chlorophyll a (mg/m3)	0.46	0.56	0.4	1.1 dupe .5
Pheophytin (mg/m3)	4.1	5	12	1.9 dupe 20
Total Coliform (count/100 mls)	<1	<1	48	<1
Fecal Coliform (count/100 mls)	<1	<1	<1	<1

Table 14. (Continued)

Investigator	CVMP	CVMP	CVMP	CVMP	CVMP
Date	8/25/87	9/15/87	9/29/87	10/20/87	11/10/87
Euphotic DVM (m)					
Deep sample depth (m)					
Secchi Disk (m)					
T. Ammonia as N mg/l (euphotic)	0.007	0.007	0.01	0.011	0.096
T. Ammonia as N mg/l (deep)					
T. NO2+NO3 as N mg/l (euphotic)	0.0005	0.003	0.006	0.001	0.063
T. NO2+NO3 as N mg/l (deep)					
T.Kjeldahl as N mg/l (euphotic)	0.38	0.64	0.63	0.3	0.25
T. Kjeldahl as N mg/l (deep)					
T. Phosphorus as P mg/l (euphotic)	0.03	0.064	0.017	0.011	0.009
T. Phosphorus as P mg/l (deep)					
Ortho phosphate as P mg/l (euphotic)	0.003	0.001	0.003	0.002	0.013
Ortho phosphate as P mg/l (deep)					
Sp. Conductance umhos/cm (euphotic)	56	56	59	60	53
Sp. Conductivity umhos/cm (deep)					
Hardness as CaCO3 mg/l (euphotic)	28	28	24	28	24
Hardness as CaCO3 mg/l (deep)					
T. Alkalinity as CaCO3 mg/l (euphotic)	28	27	27	28	28
T. Alkalinity as CaCO3 mg/l (deep)					
Turbidity ntu (euphotic)					
Turbidity ntu (deep)					
pH su (euphotic) range	9.4	7.7	7.6	8.4	7.8
pH su (deep) range					
Dissolved oxygen mg/l (euphotic)	7.5	7.8	8.8		
Dissolved oxygen mg/l (deep)					

Appendix C

Hayden Lake Phytoplankton Sample Analyses for 1986

Table 15. Phytoplankton Sample Analysis for Hayden Lake Sampling Station 279 on April 30, 1986.

TOTAL DENSITY (#/ml): 556

TOTAL BIOVOLUME (cu.uM/ml): 145364

DIVERSITY INDEX: 2.94

	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Cyclotella stelligera	158	28.5	13447	9.3
2	Asterionella formosa	128	23.1	44978	30.9
3	Synedra radians	81	14.6	29245	20.1
4	Rhodomonas minuta	64	11.5	1283	0.9
5	Cryptomonas erosa	47	8.5	24456	16.8
6	Synedra rumpens	13	2.3	4810	3.3
7	Synedra delicatissima	13	2.3	8466	5.8
8	Cryptomonas sp.	9	1.5	3420	2.4
9	Ankistrodesmus falcatus	9	1.5	214	0.1
10	Ochromonas sp.	4	0.8	363	0.3
11	Synedra sp.	4	0.8	1197	0.8
12	Unident. pennate diatom	4	0.8	748	0.5
13	Achnanthes minutissima	4	0.8	214	0.1
14	Nitzschia sp.	4	0.8	513	0.4
15	Chlamydomonas sp.	4	0.8	1390	1.0
16	Achnanthes lanceolata	4	0.8	770	0.5
17	Fragilaria vaucheria	4	0.8	9851	6.8

Table 16. Phytoplankton Sample Analysis for Hayden Lake Sampling Station 280 on April 30, 1986.

TOTAL DENSITY (#/ml): 328

TOTAL BIOVOLUME (cu.uM/ml): 106639

DIVERSITY INDEX: 2.69

	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Asterionella formosa	103	31.3	37078	34.8
2	Synedra radians	83	25.2	29758	27.9
3	Rhodomonas minuta	51	15.7	1026	1.0
4	Cryptomonas erosa	37	11.3	19269	18.1
5	Synedra rumpens	17	5.2	6413	6.0
6	Cryptomonas sp.	11	3.5	4561	4.3
7	Fragilaria construens	6	1.7	638	0.6
8	Synedra delicatissima	6	1.7	3762	3.5
9	Navicula sp.	3	0.9	428	0.4
10	Synedra cyclopum	3	0.9	2409	2.3
11	Synedra sp.	3	0.9	798	0.7
12	Ankistrodesmus falcatus	3	0.9	71	0.1
13	Navicula sp.	3	0.9	428	0.4

Table 17. Phytoplankton Sample Analysis for Hayden Lake Sampling Station 281 on April 30, 1986.

TOTAL DENSITY (#/ml): 589

TOTAL BIOVOLUME (cu.uM/ml): 164882

DIVERSITY INDEX: 3.15

	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Cyclotella stelligera	155	26.3	13171	8.0
2	Synedra radians	114	19.3	40908	24.8
3	Asterionella formosa	72	12.3	28446	17.3
4	Cryptomonas erosa	72	12.3	37602	22.8
5	Rhodomonas minuta	72	12.3	1446	0.9
6	Unident. dinoflagellate	15	2.6	7748	4.7
7	Stephanodiscus astraea minutula	10	1.8	3616	2.2
8	Dinobryon sertularia	10	1.8	1240	0.8
9	Ankistrodesmus falcatus	10	1.8	258	0.2
10	Cryptomonas sp.	10	1.8	4132	2.5
11	Synedra delicatissima	10	1.8	6818	4.1
12	Synedra ulna	5	0.9	10279	6.2
13	Navicula cascadensis	5	0.9	310	0.2
14	Synedra rumpens	5	0.9	1937	1.2
15	Chrysococcus rufescens	5	0.9	439	0.3
16	Cymbella minuta	5	0.9	1911	1.2
17	Synedra cyclopum	5	0.9	4365	2.6
18	Achnanthes minutissima	5	0.9	258	0.2

Table 18. Phytoplankton Sample Analysis for Hayden Lake Sampling Station 282 on April 30, 1986.

TOTAL DENSITY (#/ml): 694

TOTAL BIOVOLUME (cu.uM/ml): 527982

DIVERSITY INDEX: 4.08

	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Cyclotella stelligera	103	14.9	8761	1.7
2	Asterionella formosa	96	13.9	46405	8.8
3	Synedra radians	76	10.9	27211	5.2
4	Chrysococcus rufescens	62	8.9	5257	1.0
5	Stephanodiscus astraea minutula	55	7.9	19240	3.6
6	Synedra rumpens	48	6.9	18038	3.4
7	Achnanthes minutissima	41	5.9	2061	0.4
8	Rhodomonas minuta	27	4.0	6047	1.1
9	Dinobryon sertularia	21	3.0	2474	0.5
10	Nitzschia acicularis	14	2.0	3848	0.7
11	Ankistrodesmus falcatus	14	2.0	344	0.1
12	Kephyrion-like	14	2.0	962	0.2
13	Cymbella cistula	14	2.0	82457	15.6
14	Stephanodiscus hantzschii	14	2.0	1649	0.3
15	Cyclotella meneghiniana	7	1.0	2611	0.5
16	Amphora perpusilla	7	1.0	1141	0.2
17	Cryptomonas erosa	7	1.0	3573	0.7
18	Nitzschia paleacea	7	1.0	673	0.1
19	Gomphonema sp.	7	1.0	1374	0.3
20	Achnanthes linearis	7	1.0	907	0.2
21	Navicula cocconeiformis	7	1.0	12094	2.3
22	Unident. dinoflagellate	7	1.0	3436	0.7
23	Epithemia turgida	7	1.0	260771	49.4
24	Cyclotella sp.	7	1.0	584	0.1
25	Scenedesmus sp.	7	1.0	344	0.1
26	Gomphonema gracile	7	1.0	1684	0.3
27	Synedra ulna	7	1.0	13674	2.6
28	Cymbella microcephala	7	1.0	364	0.1

Table 19. Phytoplankton Sample Analysis for Hayden Lake Sampling Station 279 on June 11, 1986.

TOTAL DENSITY (#/ml): 517

TOTAL BIOVOLUME (cu.uM/ml): 141170

DIVERSITY INDEX: 2.86

	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Synedra radians	162	31.3	58253	41.3
2	Rhodomonas minuta	138	26.7	2763	2.0
3	Synedra rumpens	95	18.3	41558	29.4
4	Cryptomonas erosa	16	3.1	8209	5.8
5	Ankistrodesmus falcatus	16	3.1	395	0.3
6	Cyclotella stelligera	12	2.3	1006	0.7
7	Dinobryon bavaricum	12	2.3	3794	2.7
8	Fragilaria construens	12	2.3	3541	2.5
9	Asterionella formosa	12	2.3	2108	1.5
10	Cryptomonas sp.	8	1.5	3157	2.2
11	Synedra ulna	4	0.8	7854	5.6
12	Unident. cryptophyte	4	0.8	99	0.1
13	Achnanthes peragalli	4	0.8	553	0.4
14	Tetraedron sp.	4	0.8	107	0.1
15	Navicula cascadensis	4	0.8	237	0.2
16	Synedra sp.	4	0.8	1105	0.8
17	Nitzschia sp.	4	0.8	474	0.3
18	Oocystis lacustris	4	0.8	4578	3.2
19	Stephanodiscus astraea minutula	4	0.8	1381	1.0

Table 20. Phytoplankton Sample Analysis for Hayden Lake Sampling Station 280 on June 11, 1986.

TOTAL DENSITY (#/ml): 548

TOTAL BIOVOLUME (cu.uM/ml): 235789

DIVERSITY INDEX: 3.21

	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Synedra radians	145	26.5	52203	22.1
2	Rhodomonas minuta	106	19.4	2122	0.9
3	Fragilaria construens	78	14.2	117647	49.9
4	Synedra rumpens	67	12.3	27971	11.9
5	Cyclotella stelligera	42	7.7	3608	1.5
6	Asterionella formosa	25	4.5	5685	2.4
7	Synedra delicatissima	14	2.6	11671	4.9
8	Dinobryon bavaricum	14	2.6	5093	2.2
9	Mallomonas sp.	7	1.3	2688	1.1
10	Chrysochromulina sp.	7	1.3	141	0.1
11	Unident. pennate diatom	7	1.3	1238	0.5
12	Ankistrodesmus falcatus	4	0.6	88	0.0
13	Navicula cryptocephala veneta	4	0.6	336	0.1
14	Cymbella microcephala	4	0.6	187	0.1
15	Dinobryon sertularia	4	0.6	424	0.2
16	Oocystis pusilla	4	0.6	937	0.4
17	Achnanthes lanceolata	4	0.6	637	0.3
18	Nitzschia acicularis	4	0.6	990	0.4
19	Achnanthes clevei	4	0.6	531	0.2
20	Cryptomonas sp.	4	0.6	1415	0.6
21	Achnanthes minutissima	4	0.6	177	0.1

Table 21. Phytoplankton Sample Analysis for Hayden Lake Sampling Station 281 on June 11, 1986.

TOTAL DENSITY (#/ml): 472

TOTAL BIOVOLUME (cu.uM/ml): 153383

DIVERSITY INDEX: 3.06

	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Synedra radians	130	27.4	49431	32.2
2	Synedra rumpens	107	22.6	44404	29.0
3	Rhodomonas minuta	91	19.4	1829	1.2
4	Cyclotella stelligera	30	6.5	2902	1.9
5	Dinobryon bavaricum	30	6.5	10058	6.6
6	Asterionella formosa	19	4.0	4069	2.7
7	Ankistrodesmus falcatus	8	1.6	190	0.1
8	Synedra ulna	8	1.6	15163	9.9
9	Cryptomonas erosa	8	1.6	3962	2.6
10	Achnanthes minutissima	4	0.8	190	0.1
11	Nitzschia linearis	4	0.8	5806	3.8
12	Diatoma vulgare	4	0.8	7467	4.9
13	Mallomonas sp.	4	0.8	1448	0.9
14	Fragilaria construens	4	0.8	853	0.6
15	Unident. dinoflagellate	4	0.8	1905	1.2
16	Fragilaria construens venter	4	0.8	183	0.1
17	Navicula sp.	4	0.8	571	0.4
18	Cymbella minuta	4	0.8	1410	0.9
19	Fragilaria pinnata	4	0.8	1372	0.9
20	Navicula minima	4	0.8	168	0.1

Table 22. Phytoplankton Sample Analysis for Hayden Lake Sampling Station 282 on June 11, 1986.

TOTAL DENSITY (#/ml): 454

TOTAL BIOVOLUME (cu.uM/ml): 1209987

DIVERSITY INDEX: 3.70

--	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Cryptomonas sp.	100	21.9	39807	3.3
2	Cryptomonas erosa	96	21.2	50024	4.1
3	Anabaena flos-aquae	53	11.7	85983	7.1
4	Rhodomonas minuta	40	8.8	796	0.1
5	Epithemia turgida	20	4.4	755336	62.4
6	Tetraedron sp.	20	4.4	537	0.0
7	Sphaerocystis schroeteri	13	2.9	6900	0.6
8	Scenedesmus quadricauda	13	2.9	3450	0.3
9	Achnanthes minutissima	13	2.9	663	0.1
10	Fragilaria crotonensis	13	2.9	72449	6.0
11	Cymbella microcephala	7	1.5	352	0.0
12	Mallomonas sp.	7	1.5	2521	0.2
13	Rhopalodia gibba	7	1.5	169843	14.0
14	Ankistrodesmus falcatus	7	1.5	166	0.0
15	Scenedesmus denticulatus	3	0.7	597	0.0
16	Cyclotella ocellata	3	0.7	448	0.0
17	Microcystis aeruginosa	3	0.7	332	0.0
18	Cosmarium sp.	3	0.7	464	0.0
19	Fragilaria construens	3	0.7	743	0.1
20	Navicula cascadensis	3	0.7	199	0.0
21	Gomphosphaeria lacustris	3	0.7	2786	0.2
22	Nephrocytium sp.	3	0.7	315	0.0
23	Ochromonas sp.	3	0.7	282	0.0
24	Chroomonas sp.	3	0.7	216	0.0
25	Scenedesmus sp.	3	0.7	663	0.1
26	Trachelomonas volvocina	3	0.7	6253	0.5
27	Oscillatoria sp.	3	0.7	6634	0.5
28	Cymbella minuta	3	0.7	1227	0.1

Table 23. Phytoplankton Sample Analysis for Hayden Lake Sampling Station 279 on July 22, 1986.

TOTAL DENSITY (#/ml): 188

TOTAL BIOVOLUME (cu.uM/ml): 67458

DIVERSITY INDEX: 2.84

	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Synedra radians	87	46.4	35066	52.0
2	Cyclotella stelligera	24	12.7	2171	3.2
3	Rhodomonas minuta	19	10.0	375	0.6
4	Dinobryon bavaricum	12	6.4	2048	3.0
5	Cryptomonas erosa	10	5.5	5320	7.9
6	Asterionella formosa	5	2.7	1821	2.7
7	Peridinium sp.	5	2.7	5372	8.0
8	Unident. dinoflagellate	3	1.8	1705	2.5
9	Fragilaria construens	3	1.8	1719	2.5
10	Mallomonas sp.	3	1.8	1296	1.9
11	Synedra rumpens	3	1.8	1279	1.9
12	Unident. green alga	2	0.9	256	0.4
13	Fragilaria crotonensis	2	0.9	5730	8.5
14	Chlamydomonas sp.	2	0.9	554	0.8
15	Nitzschia frustulum	2	0.9	205	0.3
16	Sphaerocystis schroeteri	2	0.9	887	1.3
17	Navicula pupula	2	0.9	460	0.7
18	Chroococcus sp.	2	0.9	1194	1.8

Table 24. Phytoplankton Sample Analysis for Hayden Lake Sampling Station 280 on July 22, 1986.

TOTAL DENSITY (#/ml): 213

TOTAL BIOVOLUME (cu.uM/ml): 149625

DIVERSITY INDEX: 2.78

	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Synedra radians	102	47.6	38021	25.4
2	Cyclotella stelligera	25	11.7	2114	1.4
3	Cryptomonas erosa	21	9.7	10777	7.2
4	Synedra rumpens	15	6.8	5440	3.6
5	Dinobryon bavaricum	10	4.9	2984	2.0
6	Rhodomonas minuta	8	3.9	166	0.1
7	Unident. dinoflagellate	8	3.9	4145	2.8
8	Chlamydomonas sp.	4	1.9	1347	0.9
9	Synedra cyclopum	4	1.9	3503	2.3
10	Navicula pseudoscutiformis	2	1.0	366	0.2
11	Fragilaria construens	2	1.0	232	0.2
12	Achnanthes peragalli	2	1.0	290	0.2
13	Epithemia turgida	2	1.0	78651	52.6
14	Fragilaria pinnata	2	1.0	497	0.3
15	Asterionella formosa	2	1.0	369	0.2
16	Unident. green alga	2	1.0	311	0.2
17	Scenedesmus sp.	2	1.0	414	0.3

Table 25. Phytoplankton Sample Analysis for Hayden Lake Sampling Station 281 on July 22, 1986.

TOTAL DENSITY (#/ml): 139

TOTAL BIOVOLUME (cu.uM/ml): 52756

DIVERSITY INDEX: 2.17

	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Synedra radians	83	59.8	32885	62.3
2	Cryptomonas erosa	14	9.8	7079	13.4
3	Cyclotella stelligera	11	7.8	926	1.8
4	Asterionella formosa	10	6.9	4597	8.7
5	Synedra rumpens	5	3.9	2042	3.9
6	Dinobryon bavaricum	4	2.9	490	0.9
7	Rhodomonas minuta	3	2.0	54	0.1
8	Unident. dinoflagellate	3	2.0	1361	2.6
9	Synedra cyclopum	3	2.0	2301	4.4
10	Scenedesmus sp.	3	2.0	545	1.0
11	Stephanodiscus astraea minutula	1	1.0	476	0.9

Table 26. Phytoplankton Sample Analysis for Hayden Lake Sampling Station 282 on July 22, 1986.

TOTAL DENSITY (#/ml): 217

TOTAL BIOVOLUME (cu.uM/ml): 308459

DIVERSITY INDEX: 3.01

	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Rhodomonas minuta	54	24.5	1067	0.3
2	Anabaena circinalis	45	20.9	75831	24.6
3	Anabaena flos-aquae	38	17.3	49573	16.1
4	Cryptomonas sp.	26	11.8	10278	3.3
5	Sphaerocystis schroeteri	16	7.3	8223	2.7
6	Cryptomonas erosa	14	6.4	7195	2.3
7	Oocystis pusilla	4	1.8	277	0.1
8	Epithemia turgida	4	1.8	150025	48.6
9	Microcystis aeruginosa	4	1.8	495	0.1
10	Ankistrodesmus falcatus	4	1.8	148	0.0
11	Pleodorina sp.	4	1.8	3953	1.3
12	Scenedesmus quadricauda	2	0.9	514	0.2
13	Staurastrum pinque	2	0.9	692	0.2
14	Unident. desmid	2	0.9	326	0.1

Table 27. Phytoplankton Sample Analysis for Hayden Lake Sampling Station 279 on September 9, 1986.

TOTAL DENSITY (#/ml): 508

TOTAL BIOVOLUME (cu.uM/ml): 116519

DIVERSITY INDEX: 2.48

	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Synedra radians	238	46.9	90100	77.3
2	Rhodomonas minuta	109	21.5	2188	1.9
3	Cyclotella stelligera	59	11.5	4982	4.3
4	Ankistrodesmus falcatus	20	3.8	684	0.6
5	Asterionella formosa	16	3.1	4173	3.6
6	Ochromonas sp.	12	2.3	996	0.9
7	Dictyosphaerium ehrenbergianum	12	2.3	2110	1.8
8	Mallomonas sp.	8	1.5	2970	2.5
9	Cryptomonas erosa	8	1.5	4064	3.5
10	Navicula minima	8	1.5	344	0.3
11	Achnanthes lewisiana	4	0.8	488	0.4
12	Chlamydomonas sp.	4	0.8	1270	1.1
13	Achnanthes sp.	4	0.8	469	0.4
14	Unident. desmid	4	0.8	1289	1.1
15	Scenedesmus sp.	4	0.8	391	0.3

Table 28. Phytoplankton Sample Analysis for Hayden Lake Sampling Station 280 on September 9, 1986.

TOTAL DENSITY (#/ml): 550 .

TOTAL BIOVOLUME (cu.uM/ml): 126598

DIVERSITY INDEX: 2.83

	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Synedra radians	171	31.1	61586	48.6
2	Rhodomonas minuta	140	25.5	2799	2.2
3	Cyclotella stelligera	93	17.0	7932	6.3
4	Cryptomonas sp.	36	6.6	14515	11.5
5	Ochromonas sp.	31	5.7	2644	2.1
6	Cryptomonas erosa	10	1.9	5391	4.3
7	Chromulina sp.	10	1.9	207	0.2
8	Chroococcus sp.	10	1.9	7258	5.7
9	Unident. dinoflagellate	10	1.9	5184	4.1
10	Synura uvella	5	0.9	9160	7.2
11	Chroococcus prescottii	5	0.9	3188	2.5
12	Unident. desmid	5	0.9	855	0.7
13	Oocystis lacustris	5	0.9	622	0.5
14	Synedra cyclopum	5	0.9	4380	3.5
15	Fragilaria construens venter	5	0.9	746	0.6
16	Ankistrodesmus falcatus	5	0.9	130	0.1

Table 29. Phytoplankton Sample Analysis for Hayden Lake Sampling Station 281 on September 9, 1986.

TOTAL DENSITY (#/ml): 479

TOTAL BIOVOLUME (cu.uM/ml): 127061

DIVERSITY INDEX: 3.02

	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Synedra radians	191	39.8	72141	56.8
2	Cyclotella stelligera	75	15.7	6416	5.0
3	Rhodomonas minuta	71	14.8	1420	1.1
4	Chromulina sp.	27	5.6	533	0.4
5	Cryptomonas erosa	18	3.7	9232	7.3
6	Asterionella formosa	13	2.8	4740	3.7
7	Cryptomonas sp.	9	1.9	3551	2.8
8	Synedra cyclopum	9	1.9	7501	5.9
9	Fragilaria construens venter	9	1.9	1917	1.5
10	Chroococcus minimus	9	1.9	124	0.1
11	Gymnodinium sp.	4	0.9	11984	9.4
12	Mallomonas sp.	4	0.9	1687	1.3
13	Fragilaria construens	4	0.9	1491	1.2
14	Ochromonas sp.	4	0.9	377	0.3
15	Achnanthes lanceolata	4	0.9	799	0.6
16	Scenedesmus quadricauda	4	0.9	577	0.5
17	Oocystis pusilla	4	0.9	799	0.6
18	Chroococcus sp.	4	0.9	377	0.3
19	Cocconeis disculus	4	0.9	333	0.3
20	Fragilaria pinnata	4	0.9	533	0.4
21	Nitzschia sp.	4	0.9	533	0.4

Table 30. Phytoplankton Sample Analysis for Hayden Lake Sampling Station 282 on September 9, 1986.

TOTAL DENSITY (#/ml): 1412

TOTAL BIOVOLUME (cu.uM/ml): 1549599

DIVERSITY INDEX: 2.49

	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Cryptomonas erosa	382	27.0	198566	12.8
2	Rhodomonas minuta	301	21.3	6017	0.4
3	Anabaena circinalis	139	9.8	236613	15.3
4	Cryptomonas sp.	93	6.6	37029	2.4
5	Microcystis aeruginosa	81	5.7	8100	0.5
6	Synedra radians	58	4.1	20829	1.3
7	Trachelomonas volvocina	46	3.3	87249	5.6
8	Nitzschia paleacea	35	2.5	3402	0.2
9	Selenastrum minutum	35	2.5	2083	0.1
10	Ankistrodesmus falcatus	35	2.5	868	0.1
11	Scenedesmus quadricauda	35	2.5	9026	0.6
12	Dictyosphaerium ehrenbergianum	23	1.6	4166	0.3
13	Chlamydomonas sp.	23	1.6	7521	0.5
14	Epithemia turgida	23	1.6	878271	56.7
15	Chroococcus prescottii	12	0.8	28466	1.8
16	Oocystis sp.	12	0.8	868	0.1
17	Cymbella microcephala	12	0.8	613	0.0
18	Mallomonas sp.	12	0.8	4397	0.3
19	Nitzschia amphibia	12	0.8	1111	0.1
20	Unident. desmid	12	0.8	1909	0.1
21	Nitzschia sp.	12	0.8	2777	0.2
22	Gloeocystis sp.	12	0.8	3009	0.2
23	Euglena sp.	12	0.8	6711	0.4

Appendix D

Water Quality Data Collection Notes for Hayden Lake..

Water Quality Data Collection Notes for Hayden Lake

Notes: less than values (<) assumed to be 1/2 of the detection limit value.

Soltero data:

- NO2-N detection limit=.001
- NO3-N detection limit=.01
- NH3-N detection limit=.01
- Kjeldahl-N = Total organic NH3-N+NH3
- Ortho PO4 and PO4 detection limit=.01
- PO4 and Ortho PO4 converted to P (.33).
- PO4 and Ortho PO4 conversions below detection limit were assigned to 1/2 detection limit value.
- HCO3 converted to Alkalinity by milliequivalent factor of 50
- Ca and Mg converted to Hardness by milliequivalent factor of 50
- Deep sample data extracted from deepest point in profile information.

DEQ and CVMP data:

- NO2-N and NO3-N detection limit=.001
- Kjeldahl N detection limit=.05
- NH3-N detection limit=.001
- Ortho PO4 and PO4 detection limit=.002
- CVMP euphotic sample at secchi depth, not vertically integrated.