

Lake Water Quality Assessment for Upper Des Lacs Lake Ward and Burke Counties North Dakota

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**North Dakota Department of Health
Division of Water Quality**

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for Upper Des Lacs Lake
Ward and Burke Counties, North Dakota

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Table 1. Upper Des Lacs Lake

Location	
State:	North Dakota
County:	Ward, Burke
Nearest Municipality:	Kenmare
Ownership:	US Fish & Wildlife Service
<u>Physical Description</u>	
Surface Area:	94,292 acres
Major Tributary:	Des Lacs River
Major Basin:	Hudson Bay
Drainage Area:	602 square miles
Average Depth:	3 feet
Maximum Depth:	13 feet
Type of Waterbody:	Reservoir
Fishery Type:	Intermittent northern pike, yellow perch, bullhead
Trophic Condition:	Hypereutrophic
Facilities	
Public Facilities:	One lake access point with boat ramp and parking, two picnic areas, fishing areas, hunting access, auto tour, hiking paths, information center and refuge headquarters. Note: All public use and access rights are limited and controlled by the Des Lacs National Wildlife Refuge. For open periods and list of restrictions, contact the Des Lacs National Wildlife Refuge.
Beneficial Uses	
Classified beneficial uses:	Recreation/agricultural/aquatic life/municipal/water supply ¹

¹Based on classified uses as defined in the *Standards of Water Quality for the State of North Dakota*, February 1, 1991.

Introduction

Following is a summary of the data collected on Upper Des Lacs Lake as part of North Dakota's Lake Water Quality Assessment Project. The project is designed to characterize the baseline chemical, physical and biological condition of Upper Des Lacs Lake. The assessment is not intended to pinpoint sources or causes of lake condition and lacks the complexity to do so. Data was collected from Upper Des Lacs Lake at two locations (Figure 1) and on four discrete dates (May 21, August 12, September 7, 1997 and February 23, 1998).

The Upper Des Lacs Lake is located in north-central North Dakota near the town of Kenmare in Ward and Burke Counties. It is a U.S. Fish and Wildlife Service (USFW) dam built for water supply, wildlife propagation and waterfowl staging and resting. Nearly all of the reservoir lies within the boundary of the Des Lacs National Wildlife Refuge (NWR) with a small portion extending into Saskatchewan, Canada.

Upper Des Lacs Lake is one of three man-made reservoirs on the NWR. The lake is long and narrow with a surface area of 4,292 acres and a maximum depth of 14 feet. Upper Des Lacs Lake's drainage area is approximately 602 square miles of which 365 lie in North Dakota and the remaining 237 in Saskatchewan, Canada. A significant amount of the Upper Des Lacs watershed is composed of noncontributing terminal drainages typical of the Prairie Pothole Region of the Northern Glaciated Plains.

Due to its shallow depth and frequent fish kills, the North Dakota Department of Health (NDDoH) does not classify the Upper Des Lacs Lake as a fishery; however, there is most likely a permanent or semi-permanent population of small species such as shiners, minnows, white suckers and bullheads, and during periods of high water a temporary population of northern pike and yellow perch.

Public facilities on the Upper Des Lacs Lake include one lake access point with day-use picnic areas, auto routes and hiking trails. Boating and refuge access are controlled by the NWR with restrictive operational times and seasons. For additional information on restrictions and recreational opportunities, contact the NWR headquarters.

Water Quality

Lake water quality assessment data was collected on Upper Des Lacs Lake during the summer of 1997 and winter of 1997-1998. Data collected included water quality chemistry (Table 2), phytoplankton species identification and population enumeration and sediment analysis. The data was used to evaluate Upper Des Lacs Lake's physical, chemical and biological condition over the sampling period of May 21, 1997 through February 24, 1998.

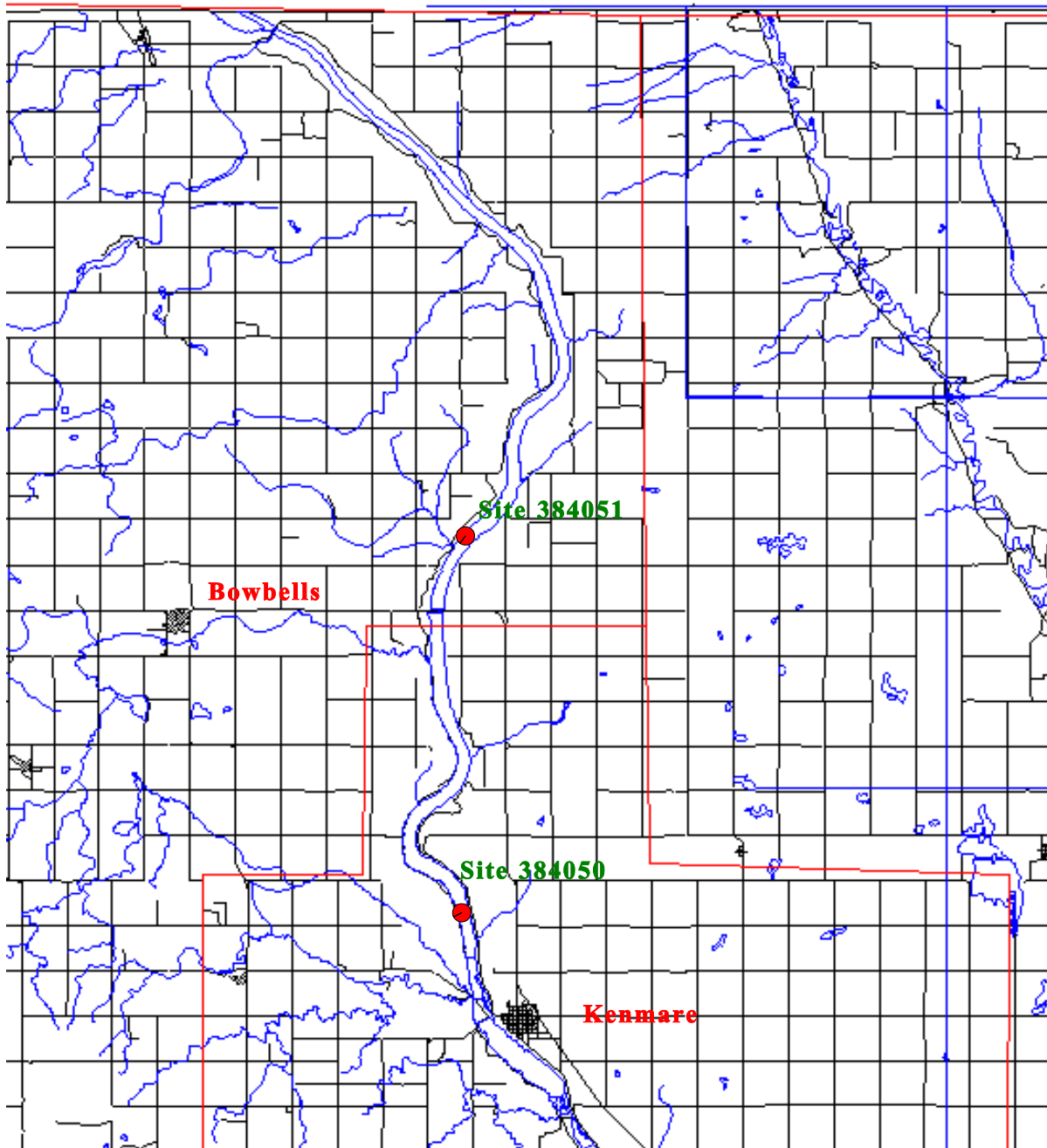


Figure 1. Upper Des Lacs Lake

Table 2. Water Quality Parameters

Analyte	Units	Analyte	Unit
Temperature	C	Specific Conductance	Umhos/cm
Carbonate	mg/L	Bicarbonates	mg/L
Total Kjeldahl Nitrogen	mg/L	Nitrate + Nitrite as N	mg/L
Total phosphorus as P	mg/L	Dissolved Phosphorus as P	mg/L
Total Hardness	mg/L	Calcium	mg/L
Magnesium	mg/L	Potassium	mg/L
Potassium	mg/L	Manganese	mg/L
Iron	µg/L	Sulfates	mg/L
Chlorides	µg/L	Boron	µg/L
Total Dissolved Solids	µg/L	Potassium	µg/L
Aluminum	µg/L	Chromium	µg/L
Beryllium	µg/L	Copper	µg/L
Nickel	µg/L	Arsenic	µg/L
Zinc	µg/L	Silver	µg/L
Selenium	µg/L	Antimony	µg/L
Cadmium	µg/L	Thallium	µg/L
Barium	µg/L	pH	µg/L
Lead	µg/L		

Water quality samples were collected from Upper Des Lacs Lake on four separate occasions and at two locations. Sampling times were May 21, August 12, and September 7, 1997 and February 23, 1998. Sampling locations were approximately ½ mile upstream from the control structure (site 384050) and approximately 1½ miles north of North Dakota Highway 5 (site 384051) (Figure 1). Water samples were collected over the thalway and at two discrete depths of ½ meter below the surface and ½ meter above the lake floor.

At no time during the investigation was Upper Des Lacs Lake thermally stratified (Figures 2, 4, 6 and 8). With only a single exception, dissolved oxygen concentrations remained above the state's water quality standards of 5.0 milligrams per liter (mg/L). The single exception occurred on February 23 above Highway 5 at site 384051 when concentrations dipped to 1.83 mg/L at two meters of depth (Figures 3, 5, 7, 9).

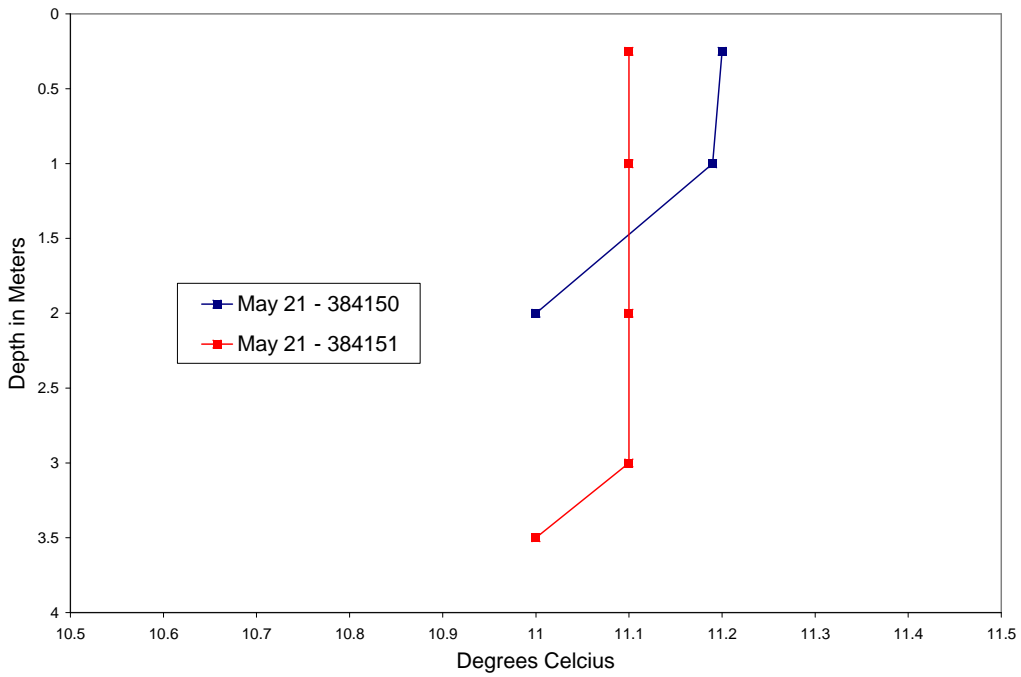


Figure 2. May 21, 1997 Temperature Profiles

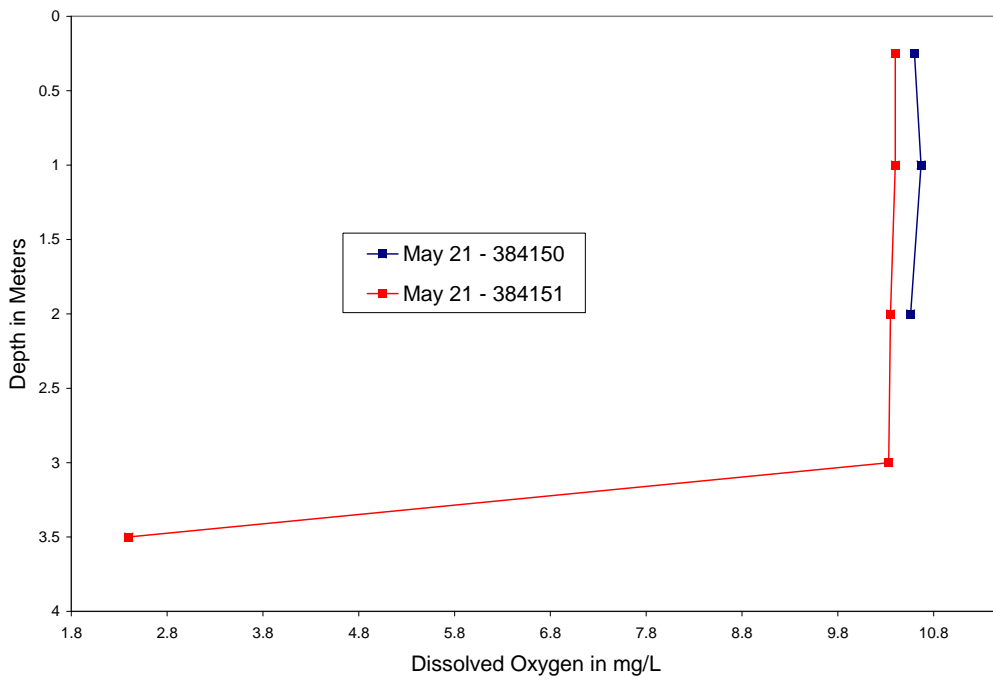


Figure 3. May 21, 1997 Dissolved Oxygen Profiles

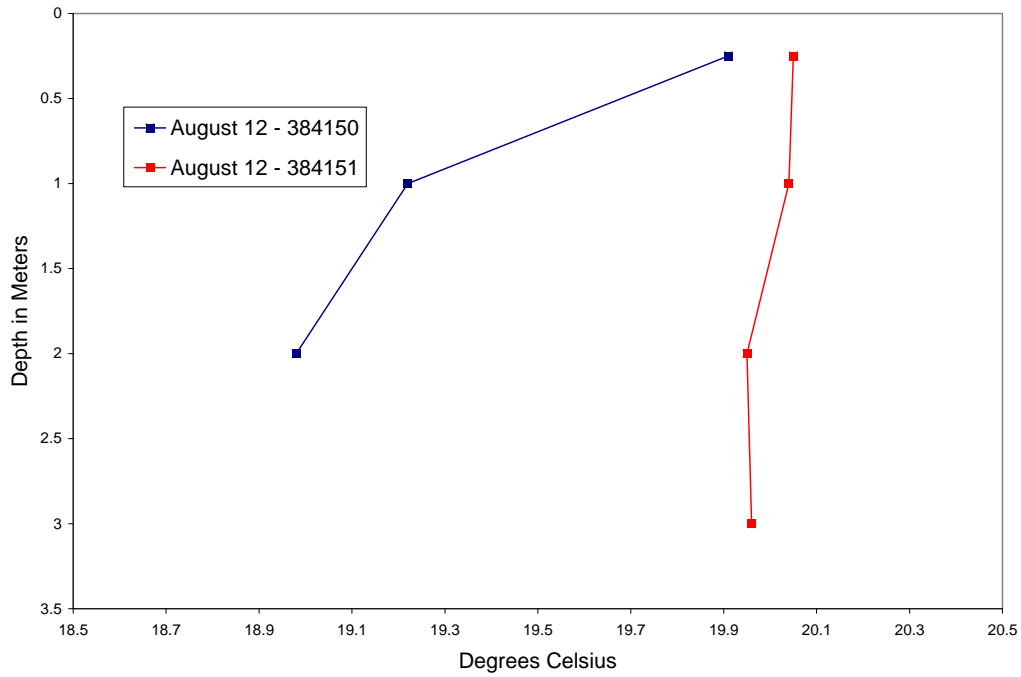


Figure 4. August 12, 1997 Temperature Profiles

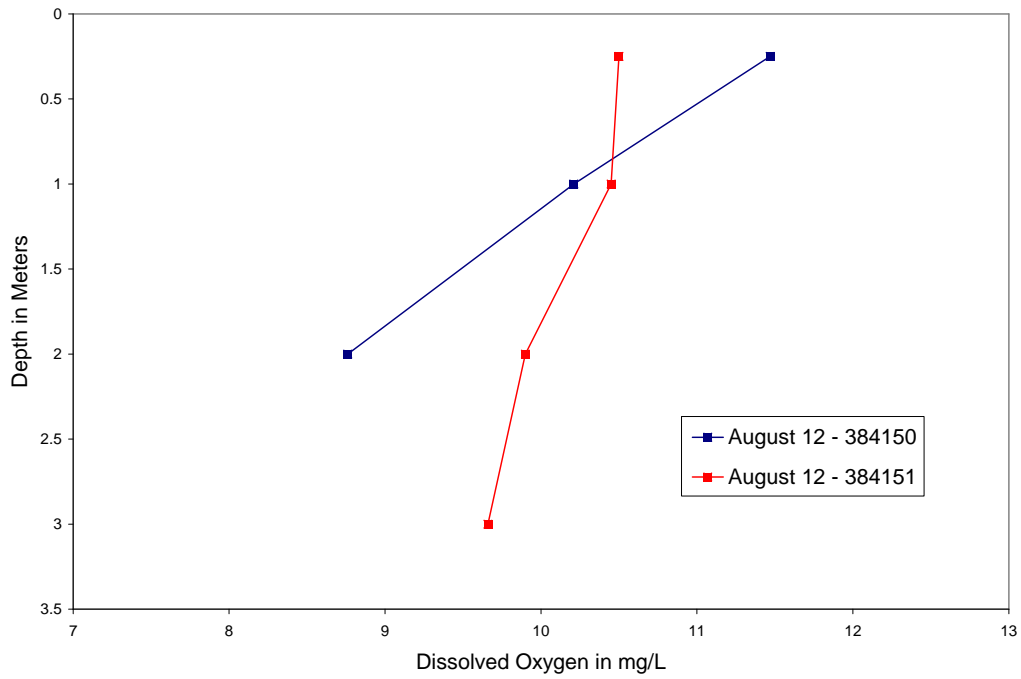


Figure 5. August 12, 1997 Dissolved Oxygen Profiles

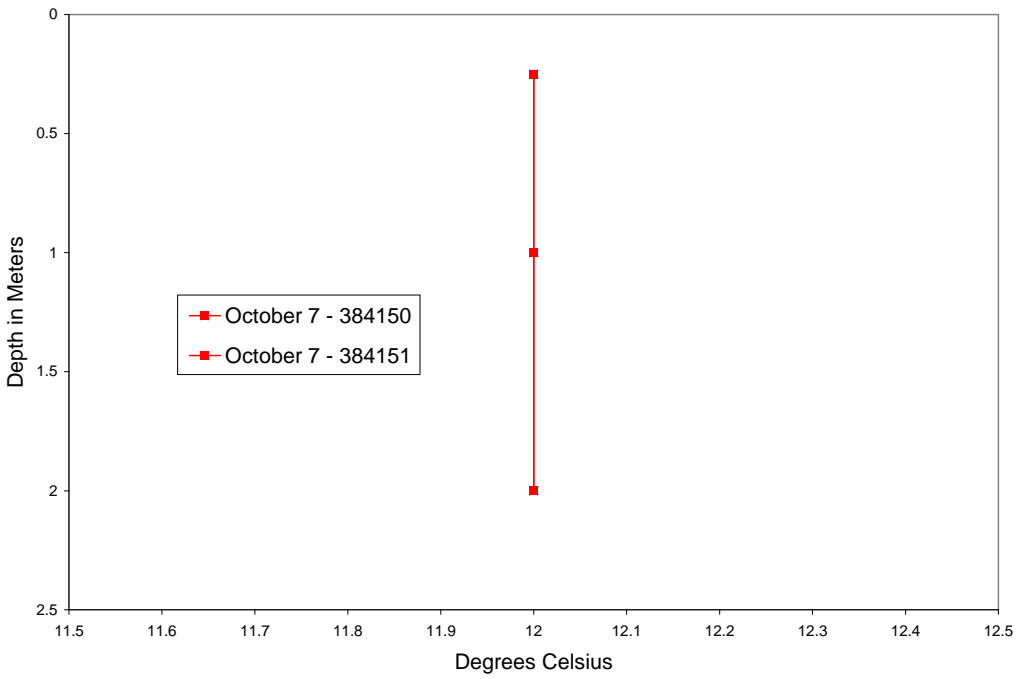


Figure 6. October 17, 1997 Temperature Profiles

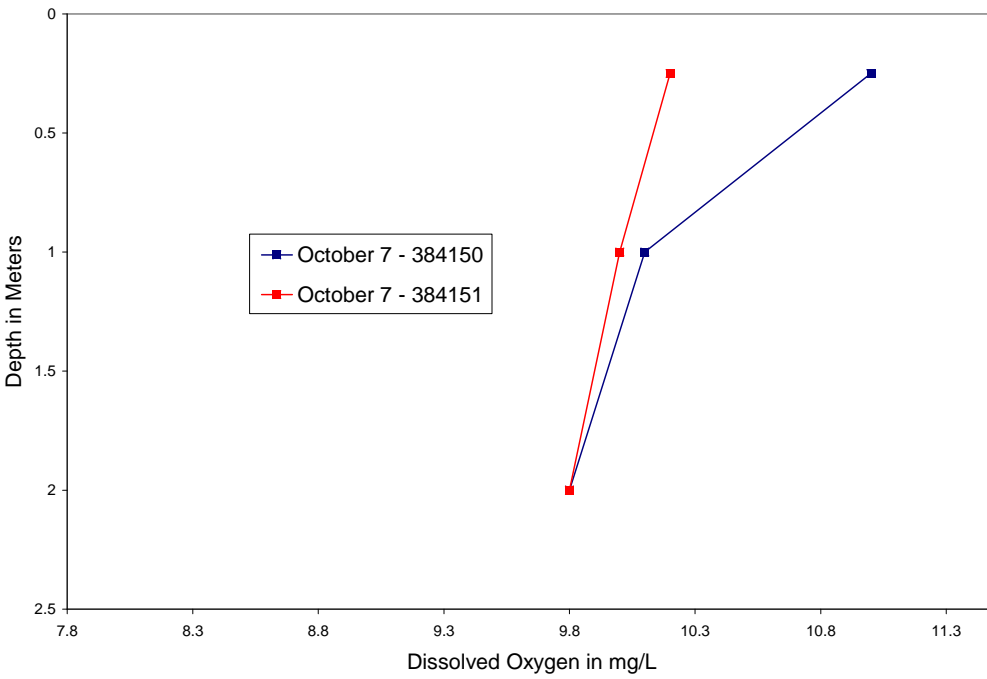


Figure 7. October 17, 1997 Dissolved Oxygen Profiles

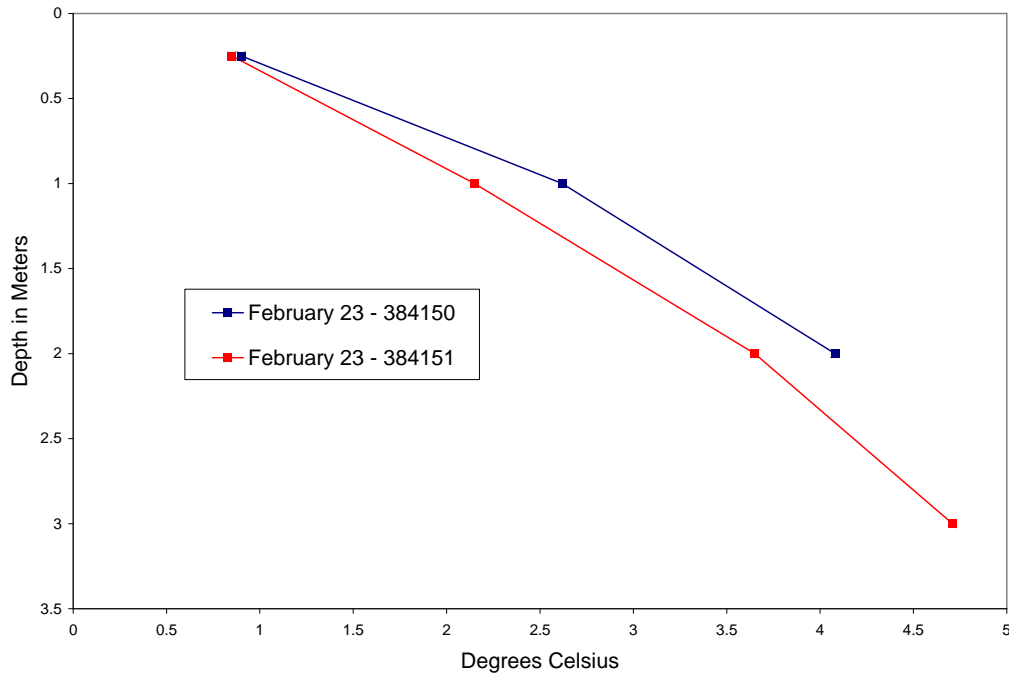


Figure 8. February 23, 1998 Temperature Profiles

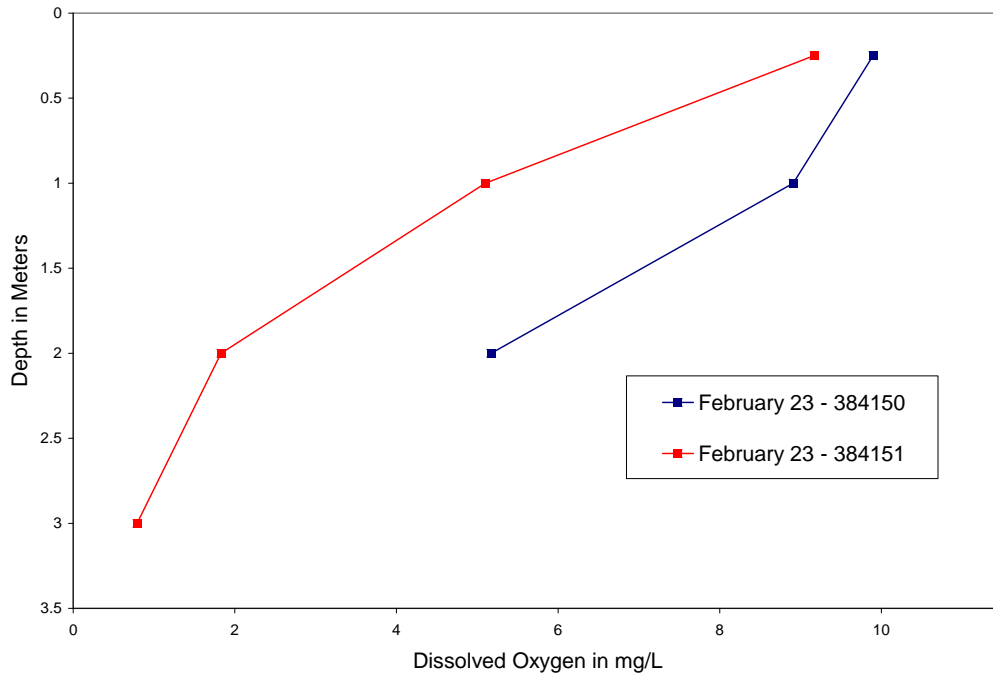


Figure 9. February 23, 1998 Dissolved Oxygen Profiles

Water quality samples collected from Upper Des Lacs Lake describe a well-buffered hypereutrophic reservoir. Total alkalinity as calcium ranged from 152 mg/L to 266 mg/L with a mean of 214 mg/L. The dominant anions within the water column are bicarbonates and sulfates. Bicarbonates ranged from 188 mg/L to 324 mg/L with a mean concentration of 205 mg/L, while sulfates ranged between 202 mg/L to 293 mg/L with a mean of 234 mg/L. Table 3 contains ranges for selected parameters within Upper Des Lacs Lake during the assessment project and North Dakota's arithmetic mean or all lakes and reservoirs sampled between 1985 and 1995.

Table 3. Concentration Ranges for Select Parameters within Upper Des Lacs Lake and the North Dakota Arithmetic Mean for all Lakes Sampled Between 1985 and 1995

Parameter	Des Lacs Lake Range	1995-2002 Mean	Unit
Total Dissolved Solids	475-715	1545	mg/L
Hardness as Calcium	168-253	474	mg/L
Sulfate as SO ₄	202-293	785	mg/L
Chlorides	5.9-21.2	64	mg/L
Total Alkalinity as Calcium	152-266	229	mg/L
Bicarbonate as HCO ₃	188-324	274	mg/L
Conductivity	787-1120	1984	omhos/cm
Total Phosphorus as Phosphate	0.110-0.385	0.152	mg/L
Nitrate + Nitrite as Nitrogen	0.020-0.030	0.117	mg/L
Total Ammonia as Nitrogen	0.010-0.637	0.272	mg/L
Total Kjeldahl Nitrogen	1.760-3.160	1.775	mg/L

Nutrients and Limiting Nutrients

Total nitrogen as nitrogen and total phosphorus as phosphate concentrations ranged from 0.010 mg/L to 0.030 mg/L, and 0.11 mg/L to 0.385 mg/L, respectively, with mean concentrations of 0.020 mg/L and 0.233 mg/L. Total nitrogen to total phosphorus ratios ranged from 4.5:1 at site 384151 on August 12, 1997 to 18:1 at site 384150 on September 7, 1997. The 1997-1998 annual total nitrogen to total phosphorus ratio for all samples is 11:1, indicating that for most of the year, and particularly during the productive times of the year, Upper Des Lacs Lake is nitrogen limited (Figure 10).

For purposes of this assessment, a waterbody is assumed to be in nutrient equilibrium when the total nitrogen to total phosphorus ratio is 15:1. Ratios greater than 15:1 indicate that phosphorus is the limiting nutrient, and ratios smaller than 15:1 indicate that nitrogen is the limiting nutrient. When nitrogen becomes the limiting nutrient, primary production is usually not limited but altered. The altered condition favors primary producers that are either able to affix nitrogen or are tolerant of low-nitrogen conditions.

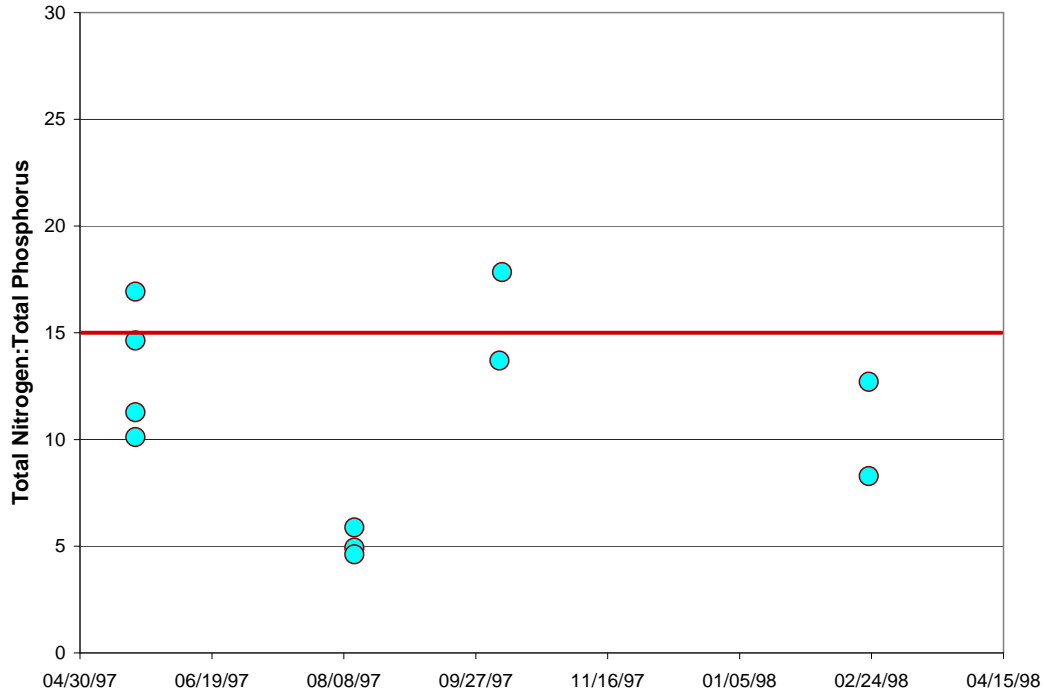


Figure 10. Des Lacs Lakes 1997-1998 Total Nitrogen to Total Phosphorus Ratios

Trophic Status

During the 1997-1998 investigation, Upper Des Lacs Lake’s trophic status was assessed as hypereutrophic. Trophic status is an estimation of a lake’s or reservoir’s productivity. Normally, as a lake ages it becomes more productive or eutrophic. When this maturing process reaches an advanced stage, it is usually identified by loss of lake depth through sedimentation and a marked decline in esthetics due to frequent algal blooms. When a lake reaches an extreme level of eutrophication, it is called hypereutrophic. At this point, a lake often gives off a foul odor, suffers frequent fish kills and experiences rapid oxygen depletion during periods of thermal stratification and under ice cover. Reservoirs which inundated fertile soils and associated plants are especially susceptible to rapid eutrophication and often begin life in an over-productive condition.

For purposes of this project, trophic status is measured using Carlson’s Trophic Status Index (TSI) (Carlson 1977). Carlson’s TSI was selected because of its common use among limnologists and because it was developed for lakes in Minnesota, a state close to North Dakota geographically.

Carlson's TSI uses a mathematical relationship based on secchi disk transparency, concentrations of total phosphorus at the surface and chlorophyll-a concentrations. This numerical value then corresponds to a trophic condition ranging from 0 to 100 with increasing values indicating a more eutrophic condition. Carlson's TSI ranges are displayed in Figure 11.

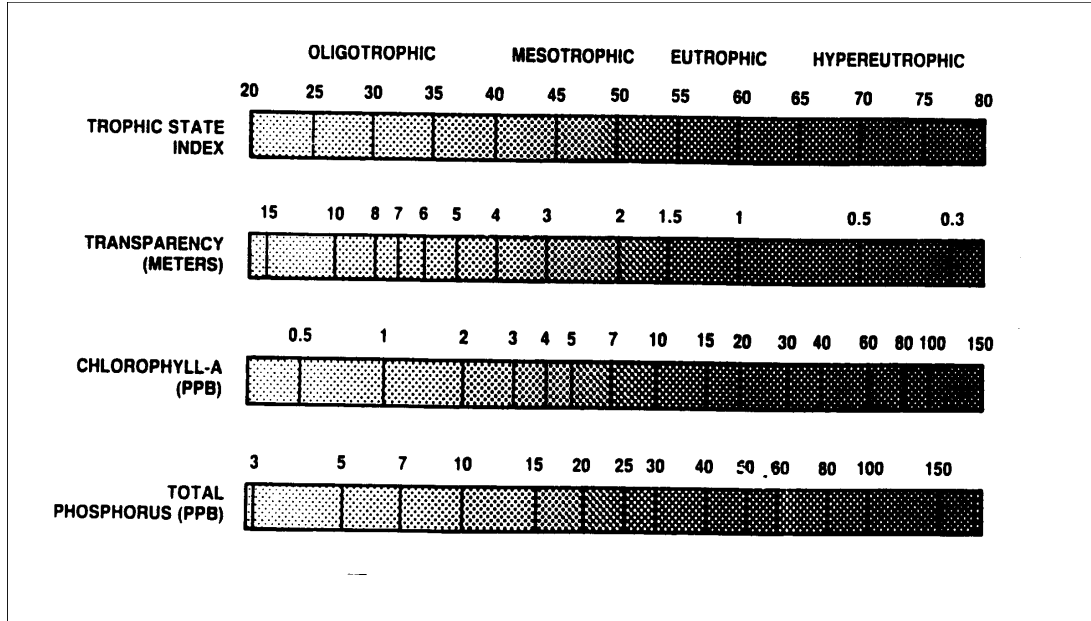


Figure 11. Graphical Depiction of Carlson's Trophic Status Index

An accurate trophic status assessment is important in making sound management decisions. In order to ensure an accurate assessment has been made, usually two consecutive years of monitoring are desired, and a multiple-indicators approach should be used. The term "indicator" is used because trophic status can be seasonally and annually variable, creating a situation where it can be easily misidentified. Because this project lacks the resources for a second year of investigation, the trophic status assessment should be viewed with cautious skepticism.

Trace Metals

Beyond general chemistry, Des Lacs Lake was sampled for an array of trace elements and metals. Of these, cadmium, copper, chromium, lead, nickel, silver and zinc have both chronic and acute limits set in the *Standards of Water Quality for the State of North Dakota*. The standard is hardness-dependent and is calculated using the equations in Table 4.

While none of the trace elements exceeded the state’s acute standard, copper exceeded the state’s chronic concentrations in seven of 11 water samples analyzed. The standard is hardness dependant and varied throughout the year. The exceedances ranged from 3.1 to 11 ug/L.

Table 4. Trace Element Acute and Chronic Water Quality Standards for State of North Dakota

Hardness Dependent Equation				
Acute	=	$\exp(\text{ma}(\ln(\text{hardness}))+\text{Ba})$		
Chronic	=	$\exp(\text{mc}(\ln(\text{hardness}))+\text{Bc})$ Where:		
Element	ma	Ba	mc	Bc
Cadmium	1.1280	-3.828	0.7852	-3.490
Copper	0.9422	-1.464	0.8545	-1.465
Chromium	0.8190	3.6881	0.8190	1.561
Lead	1.2780	-1.460	1.2780	-4.705
Nickel	0.8460	3.361	0.8460	1.165
Silver	1.7200	-6.520	NA	NA
Zinc	0.8473	0.860	0.8473	0.7614

Phytoplankton

Upper Des Lacs Lake’s phytoplankton community was sampled twice during the summer of 1997. The phytoplankton community is relatively diverse with representation from seven orders and 56 genera. The order cyanophyceae and bacillariophyceae dominated the population by density followed by chlorophyceae, cryptophyceae, chrysophyceae, euglenophyceae and dinophyceae (Table 5) Densities ranged from a low of none present for euglenophyceae and dinophyceae at the site above Highway 5 (site 384051) to a high of 175,917,500 cells/mL of cyanophyceae. In general, densities were highest above Highway 5 (Figure 12).

Table 5. Mean Algal Densities (Cells/mL) for Upper Des Lacs Lake (August 12 and September 7, 1997)

Division	Near Dam Site 384050	Above Hwy 5 Site 384041
Chlorophyta	4,372,000	8,523,200
Cryptophyta	500,733	854,600
Cyanophyta	124,800,484	175,917,500
Euglenophyta	1,000	0
Dinophyceae	1,000	0
Chrysophyceae	128,567	776,475
Bacillariophyta	44,956,902	2,659,800

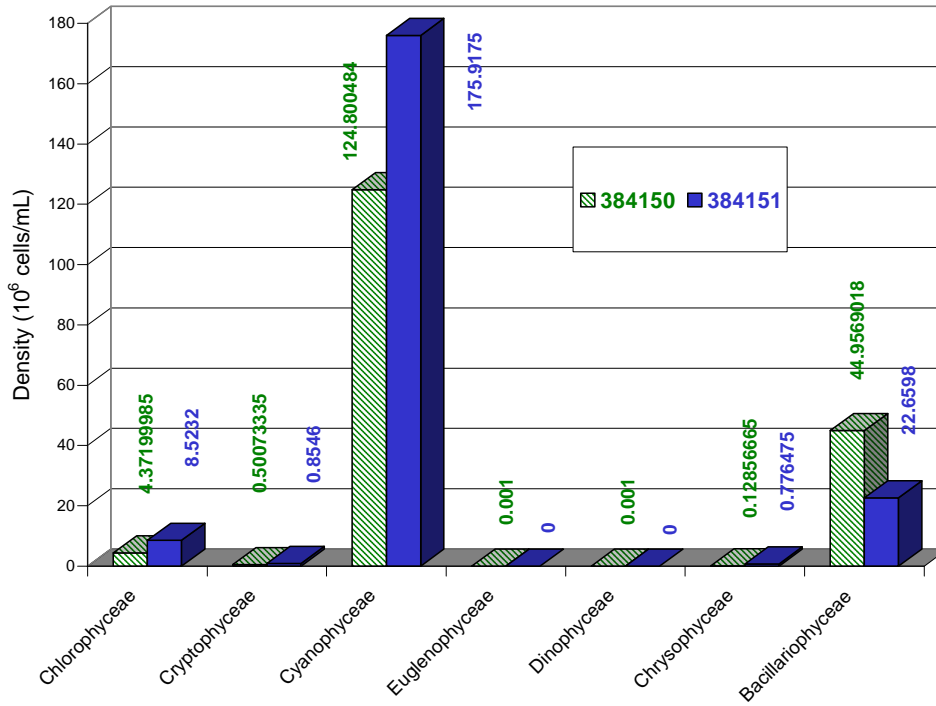


Figure 12. Phytoplankton Densities Expressed as Cells/mL

The phytoplankton population by volume, expressed as cubic micrometers of algae per mL is dominated by the order Bacillariophyceae followed by Cyanophyceae, Chlorophyceae, Cryptophyceae, Chrysophyceae, Dinophyceae and Euglenophyceae (Table 6, Figure 13). The order Bacillariophyceae occupies a significant portion of the phytoplankton population by volume, and Eyanophyceae occupies a relatively small portion in comparison to the population when expressed by density. This is due to the relatively large size of the organisms in the order Baccilariophyceae (diatoms) and the small size of the organisms in the order Cyanophyceae (blue-green algae).

Table 6. Mean Algal Volumes (Cubic Micrometers/mL) for Upper Des Lacs Lake (August 12 and September 7, 1997)

Division	Near Dam Site 384050	Above Hwy 5 Site 384041
Chlorophyta	771,897,090	1,113,661,025
Cryptophyta	177,532,910	34,558,948
Cyanophyta	2,771,097,230	1,741,366,680
Euglenophyta	653,000	0
Dinophyceae	16,363,000	0
Chrysophyta	10,319,167	67,979,625
Bacillariophyta	12,503,844,798	23,363,947,900

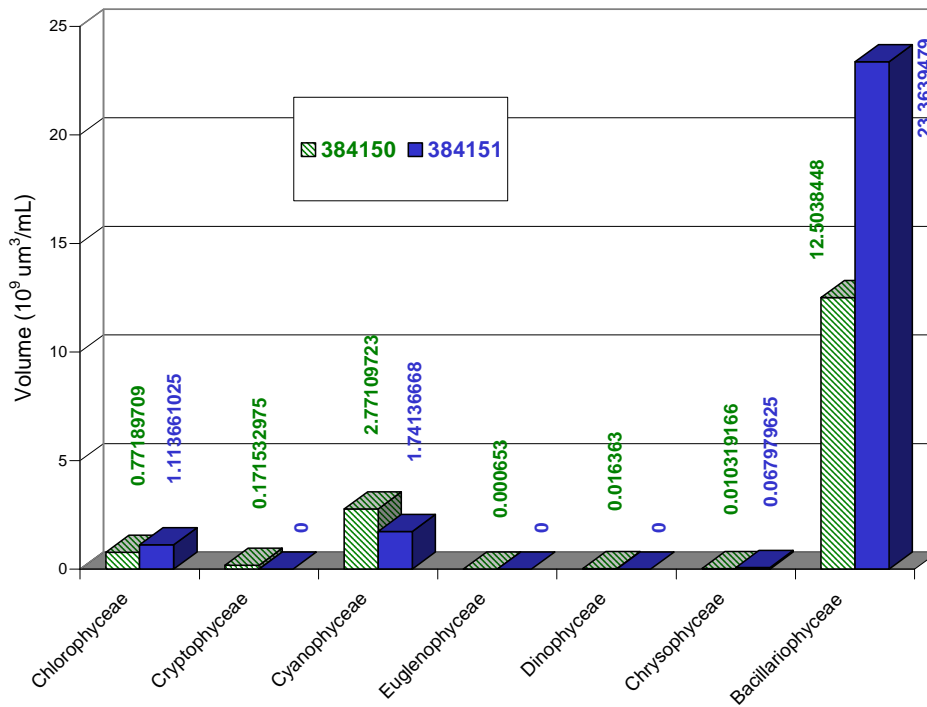


Figure 13. Phytoplankton Volumes Expressed as Cubic Micrometers/mL

Sediment Analysis

Sediment samples were collected from Upper Des Lacs Lake at both water quality monitoring sites (Figure 1). Sediments were collected using a 1-inch core sampler and sampling a minimum of the top 6 inches of sediments. Sediments have been analyzed for 12 elements and 14 pesticides (Table 7).

Reported concentrations of trace elements in Upper Des Lacs Lake’s deep water sediments are contained in Table 8. Sediment samples collected from Des Lacs Lake contained detectable levels of all elements analyzed. In order to evaluate the sediment data for Upper Des Lacs Lake, the results were compared to the deep-water sediment samples collected from 87 North Dakota lakes and reservoirs between 1991 and 1995.

Table 7. List of Analytes Completed for Sediment Samples Collected from the Upper Des Lacs Lake in 1997

Analyte	Analyte	Analyte
Aluminum (Al)	Manganese (Mn)	Iron (Fe)
Copper (Cu)	Zinc (Zn)	Barium (Ba)
Chromium (Cd)	Lead (Pb)	Mercury (Mg)
Hoelon	2-4-D	Dicamba
Dinoseb	MCPA	Tordon
2-4-5-T	Silvex	Pentachlorobenzoic Acid
Bromoxynil	Dichloprop	Bentazon

In summary, the reported concentrations are relatively high in comparison to the 50th and 100th percentiles of 87 deep-water sediments. The reported concentrations of copper, barium, arsenic, selenium, lead, cadmium and mercury all exceeded the 50th percentile, and zinc and chromium exceeded the 100th percentile in both samples collected (Table 8). No pesticides were detected in either sample collected.

Table 8. Reported Concentrations of Trace Elements in Upper Des Lacs Lake Sediment and the 100th and 50th Percentile from 87 Sediment Samples Collected from Select North Dakota Lakes and Reservoirs between 1991 and 1994. Concentrations are in micrograms/gram wet weight (ppb)

Elements	1991-1994 Percentiles n=87		Upper Des Lacs Lake Results	
	50TH	100TH	Near Dam 384050	Above Hwy 5 384051
Aluminum	Not Sampled	Not Sampled	11,600.00	10,200.00
Manganese	Not Sampled	Not Sampled	547.00	665.00
Iron	Not Sampled	Not Sampled	18,100.00	17,900.00
Copper	5.48	25.80	14.30	15.40
Zinc	22.20	41.00	58.90	61.80
Barium	56.60	165.00	128.00	163.00
Chromium	4.82	14.10	18.60	23.10
Arsenic	1.61	5.71	4.24	4.85
Selenium	0.16	1.88	1.19	1.56
Lead	4.49	33.80	10.10	12.80
Cadmium	0.21	0.97	0.47	0.524
Mercury	< 0.01	0.044	0.04	0.06