2008-2010
North Dakota Lake Water Quality Assessment Reports

Completed June 2011

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Acknowledgements

Numerous fisheries scientist and environmental technicians have made major contribution to the Lake Water Quality Assessment Project. A special thanks to Josh Obrigewich, Luke Welty, Tyler Merkel, Jason Sieler, Andy McDonald and Joshua Jensen for assisting in data collection and filling out hours of paper work. Additionally, I would like to thank the North Dakota Game and Fish Department's Fisheries District staff including but not limited to, Jeff Hendrickson, Fred Ryckman, Shane Shefstad, Jason Lee, Brian Frohlich, Dave Fryda, Russ Kinzler, Paul Baily, Randy Hiltner, Gene Van Eeckout, Scott Elstad and Pat John for their advice and guidance on lake access, great contour maps, and general support of the project. Appreciation also goes to the North Dakota Department of Health's Chemistry Division for their accurate and timely analysis of all the water quality samples. Lastly I would like to thank Joe Gross of the North Dakota Department of Health's, Division of Water Quality for his help in managing and reducing the large amounts of data needed to complete this project.

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INTRODUCTION

Project Description and Purpose

The 2008-2010 Lake Water Quality Assessment Project is part of the ongoing efforts of the North Dakota Department of Health's Division of Water Quality Surface Water Quality Management Program (SWQMP) to track the health and wellbeing of the States waters.

There are currently 246 lakes and reservoirs listed in the state that are managed for fishing and/or for public recreation. With its limited resources, it is not possible for the SWQMP to adequately sample all of these lakes and reservoirs in a timely matter resulting in 41 of managed lake lacking representation in the SWQMP's Sample Identification Database (SID).

The 2008-2010 Lake Water Quality Assessment Project's (LWQAP) primary goal was to collect water quality data on those 41 lakes. The initial sampling plan developed in 2008 was to collect two open water samples annually to represent spring and summer on 12 to 13 lakes over a 3 year period. In 2009 the plan was revised and expanded to include 15 lakes annually and three open water samples to represent spring, summer and fall condition.

The core purpose of the LWQAP monitoring protocol is to: 1) identify the general chemical, physical and biological characteristics of the lakes and reservoirs; 2) assess the current water quality condition and trophic status of monitored lakes and reservoirs; 3) determine spatial differences among lakes and reservoirs; and when applicable 4) determine temporal trends in lake water quality by comparing project data to Lake Water Quality Assessment data or other historic water quality data. Assessment information generated from this project will be used by both the North Dakota Game and Fish Department and the North Dakota Department of Health's Division of Water Quality to prioritize lakes, reservoirs and their watersheds for lake maintenance and improvement projects (i.e., Save Our Lakes, Total Maximum Daily Loads, section 319 Non-point Source Management Program).

The assessment is not intended to be an in-depth evaluation of the individual lake or reservoir but rather a simple and functional characterization of the major water quality parameters, limiting nutrients, and current trophic status of the lake or reservoir. If sufficient historic data are available for a lake or reservoir, trends (improving, declining, or stable) in water quality are also assessed.

Lakes and Reservoirs Assessed in 2008-2010

A total of forty-three (43) lakes and reservoirs were monitored (Figure 1, Table 1). Assessed lakes and reservoirs were selected by the North Dakota Department of Health SWQMP. Thirteen lakes were sampled during the open water period in 2008 and 15 in 2009 and 2010. All water quality samples are collected utilizing a 2-meter depth integrated water column tube sampler. A complete monitoring plan and sampling procedures are contained the Quality Assurance Project Plan (NDDoH 2009).

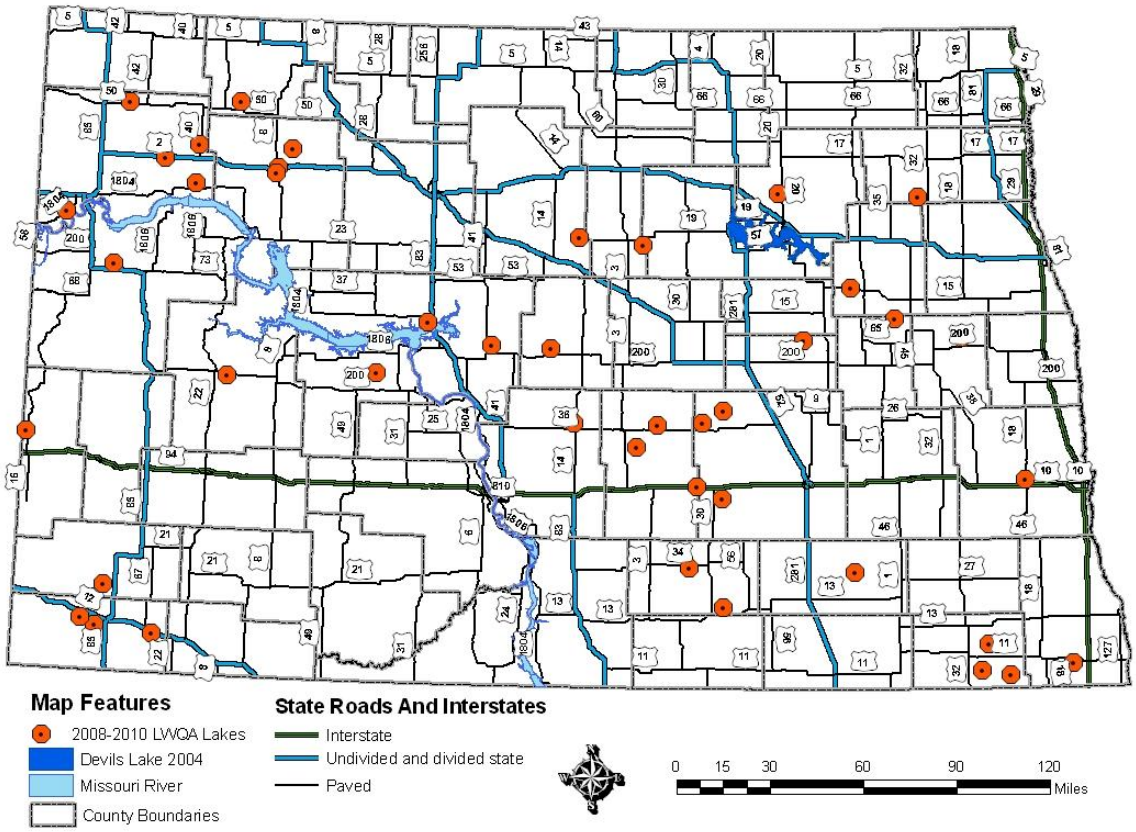

Figure 1. Location of 2008-2010 Lakes and Reservoirs in North Dakota

Sample Frequency

Sampling was conducted on each lake or reservoir twice in 2008 and three times in 2009 and 2010. In 2008 two samples were collected annually, one during the late spring early summer (June) and one in late summer (August). In 2009 and 2010 three samples were collected annually in the spring (May) one in mid-summer (July) and one in the fall (September).

Water Quality Variables

Water Quality data collected for each assessment included field measurements of Secchi disk transparency, a specific conductance, temperature, dissolved oxygen and pH profile, and a water sample analyzed for a suite of chemical analytes and chlorophyll-a (Table 2). All water quality samples collected were analyzed by the North Dakota Department of Health's Division of Laboratory Services for general chemistry.

Table 1. Summary of Lakes and Reservoirs Included in 2008-2010 Lake Water Quality Assessment Project (by County)

Lake Name	County	Lake Name	County
Gascoyne Lake	Bowman	Stanley City Pond	Mountrail
Kalina Dam	Bowman	Stanley Reservoir	Mountrail
Lutz Dam	Bowman	Tolna Dam	Nelson
Smishek Lake	Burke	Buffalo Lake	Pierce
Mitchell Lake	Burleigh	Cavanaugh Lake	Ramsey
Casselton Reservoir	Cass	Lake Elsie	Richland
Lake Ilo	Dunn	Buffalo Lake	Sargent
Juanita Lake	Foster	Lake Tewaukon	Sargent
Odland Dam	Golden Valley	Sprague Lake	Sargent
Carlson-Tande Dam	Griggs	South McCusky Lake	Sheriden
Cherry Lake	Kidder	Stewart Lake	Slope
Frettum Lake	Kidder	South Golden Lake	Steele
Crystal springs	Kidder/Stutsman	Bader Lake	Stutsman
Limesand-Seefedlt Dam	LaMoure	Barnes lake	Stutsman
Mundt Lake	Logan	Clark Lake	Stutsman
Rudolph Lake	Logan	Matejcek Dam	Walsh
Round Lake	McHenry	Cottonwood Lake	Williams
Clear Water	McIntosh	Kota Ray Dam	Williams
Arnegard Dam	McKenzie	McLeod (Ray) Reservoir	Williams
Custer Mine Pond	McLean	Tioga Dam	Williams
Lightning Lake	McLean	Trenton Lake	Williams
Harmony Lake	Mercer		

Table 2. Summary of Lake Water Quality Assessment Water Quality Variables

Field Measurements	General	Nutrients	Biological
Secchi Disk Transparency	Sodium	Total Nitrogen	Chlorophyll-a
Dissolved Oxygen	Potassium	Total Phosphorus	
Temperature	Magnesium	Total Kjeldahl Nitrogen	
	Calcium	Nitrate + Nitrite	
	Iron	Total Ammonia	
	Hardness		
	Alkalinity		
	Bicarbonate		
	Carbonate		
	Hydroxide		
	Chloride		
	Sulfate		
	Conductivity		
	pH		

Historical Water Quality and Trends Analysis

When available, historical water quality data was compared to the 2008-2010 data in an attempt to determine water quality trends. Since most of the historical water quality data was collected at multiple depths, only water samples collected between one and two meters of depth was used in the comparison analysis. Historical water quality data for trend assessment was further restricted to data collected by the SWQMP between 1991 and 2010 and stored in SID. Trends assessments were conducted for each lake or reservoir by comparing historical descriptive statistics (e.g., mean, minimum, maximum and standard deviation) and graphical comparisons of Carlson's Trophic Status Index (TSI) scores over time.

Temperature and Dissolved Oxygen Profiles

Temperature and dissolved oxygen (DO) play an important role in a lake or reservoir's overall health and ability to sustain appropriately diverse populations of aquatic life. In general, cooler water temperatures and the higher oxygen concentrations will result in increased diversity and populations of aquatic species.

During periods of summer stratification, the majority of the cool water in a lake or reservoir is in a region referred to as the hypolimnion. The hypolimnion is defined as the water below the thermocline. The depth of the thermocline is defined by a 1 degree shift in temperature occurring within a 1-meter change in depth. The thermocline results in two layers of water; a warmer upper layer (epilimnion) and a cooler bottom layer (hypolimnion). While the epilimnion is exposed to wind action and the photosynthetic activity of algae, the hypolimnion is often isolated.

The water in the hypolimnion is typically an area of increased oxygen consumption, where accumulated organic matter (e.g., settling algae) is decomposed. The decomposition processes require oxygen which is obtained from the water column in the hypolimnion. The rate at which oxygen is consumed in the hypolimnion, termed the hypolimnetic oxygen depletion rate, is directly related to the amount of organic matter deposited in the hypolimnion which is directly related to the lake or reservoir's trophic status. This relationship makes the tracking of temperature and dissolved oxygen profiles an excellent measure of increasing or decreasing eutrophication.

Trophic Status Assessment

Trophic status is the primary indicator used to assess whether a lake or reservoir is meeting or likely to meet its intended beneficial uses (e.g., fishery class, recreation use). Trophic status is a measure of the primary productivity of a lake or reservoir and is directly related to the level of nutrients (i.e., phosphorus and nitrogen) entering the lake or reservoir from its watershed and/or from the internal recycling. Highly productive lakes, termed "hypereutrophic," contain excessive phosphorus and are characterized by large growths of macrophytes, blue-green algal blooms, low transparency, and low dissolved oxygen (DO) concentrations. These lakes typically experience frequent fish kills that often results in excessive rough fish populations (carp, bullhead, and sucker) and poor sport fisheries. Due to the frequent algal blooms and excessive weed growth, these lakes are also undesirable for recreational uses such as swimming and boating.

Mesotrophic and eutrophic lakes, on the other hand, have lower phosphorus concentrations, low to moderate levels of algae and aquatic plant growth, high transparency and adequate DO concentrations throughout the year. Mesotrophic lakes do not regularly experience algal blooms, while eutrophic lakes experience occasional moderate to severe algal blooms for durations of a few days to a few weeks.

Due to the relationship between trophic status indicators and the aquatic community or between trophic status indicators and the frequency of algal blooms, trophic status becomes an effective indicator of aquatic life and recreation use support in lakes and reservoirs. For purposes of this assessment it is assumed that hypereutrophic lakes are either at risk of not supporting or do not fully support a sustainable sport fishery and are limited in recreational uses, whereas mesotrophic lakes fully support both aquatic life and recreation use. Eutrophic lakes may be assessed as fully supporting, fully supporting but threatened, or not supporting their uses for aquatic life or recreation.

Since trophic status indicators specific to North Dakota waters have not been developed, Carlson's trophic status index (TSI) (Carlson, 1977) has been chosen to assess the trophic status of lakes or reservoirs. To create a numerical TSI value, Carlson's TSI uses a mathematical relationship based on three indicators: 1) Secchi Disk Transparency in meters (m); 2) surface total phosphorus as P concentration expressed as µg/ L; and 3) chlorophyll-a concentration expressed as µg/L.

This numerical value, ranging from 0-100, corresponds to a trophic condition with increasing values indicating a more eutrophic (degraded) condition. Carlson's TSI estimates are calculated using the following equations and is also depicted graphically in Figure 2.

- Trophic status based on Secchi Disk Transparency (TSIS):
  $TSIS = 60 - 14.41 \ln (SD)$
  Where SD = Secchi disk transparency in meters.

- Trophic status based on total phosphorus (TSIP):
  $TSIP = 14.20 \ln (TP) + 4.15$
  Where TP = Total phosphorus concentration in $\mu g\ L^{-1}$.

- Trophic status based on chlorophyll-a (TSIC):
  $TSIC = 9.81 \ln (TC) + 30.60$
  Where TC = Chlorophyll-a concentrations in $\mu g\ L^{-1}$.

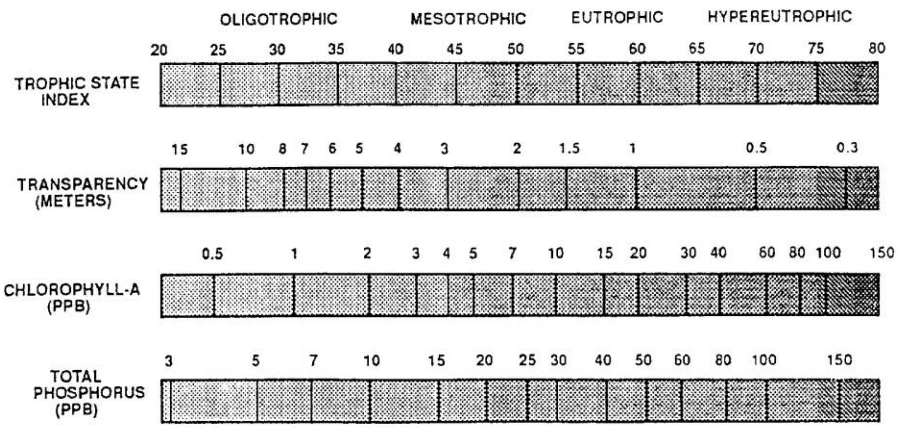

Figure 2. A Graphic Representation of Carlson's TSI

Of the three indicators chlorophyll-a is the best indicator of trophic status as it is a direct measure of lake productivity. Secchi disk transparency should be used next, followed by phosphorus concentration. In theory, for a given lake or reservoir, the measures of chlorophyll-a, secchi disk transparency, and phosphorus concentration are all interrelated and should yield similar trophic status index values, however this is often not the case. Many lakes and reservoirs in the state are shallow and windswept causing non-algal turbidity to limit light penetration. This situation may result in a lake having a high phosphorus concentration, low Secchi disk transparency, and low chlorophyll-a concentration. In other instances, other micronutrients may be limiting algal growth even though excessive phosphorus is present.

Comparison of Results

In an attempt to better understand the significance of the results, each water body was compared to similar water bodies within the same region. For purposes of this comparison the water body types are limited to natural lakes and manmade reservoirs.

Lake types were chosen as natural lakes are older, usually do not have a control structure, and generally have longer residence times. Reservoirs by contrast are manmade, usually have a control structure and have shorter hydraulic residence times. These factors can have a significant effect on the water quality of a lake or reservoir which should be considered when making regional comparisons.

Regionality was selected as geology, landscape, and climatic can have a dramatic influence on water quality. For example, lakes and reservoirs in the eastern part of the state will have naturally different water quality than lakes or reservoirs in the west as a result of the variations in soils, natural vegetation, land use patterns, and precipitation.

One way to group or classify broad regional area based factors is to use ecorgions that have similar land forms, geological history, soils and ecological function. There are four different Level III Ecoregions in North Dakota. From east to west they are the Lake Agassiz Plain (48), Northern Glaciated Plains (46), Northwestern Glaciated Plains (42), and the Northwestern Great Plains (43) (Figure 2).

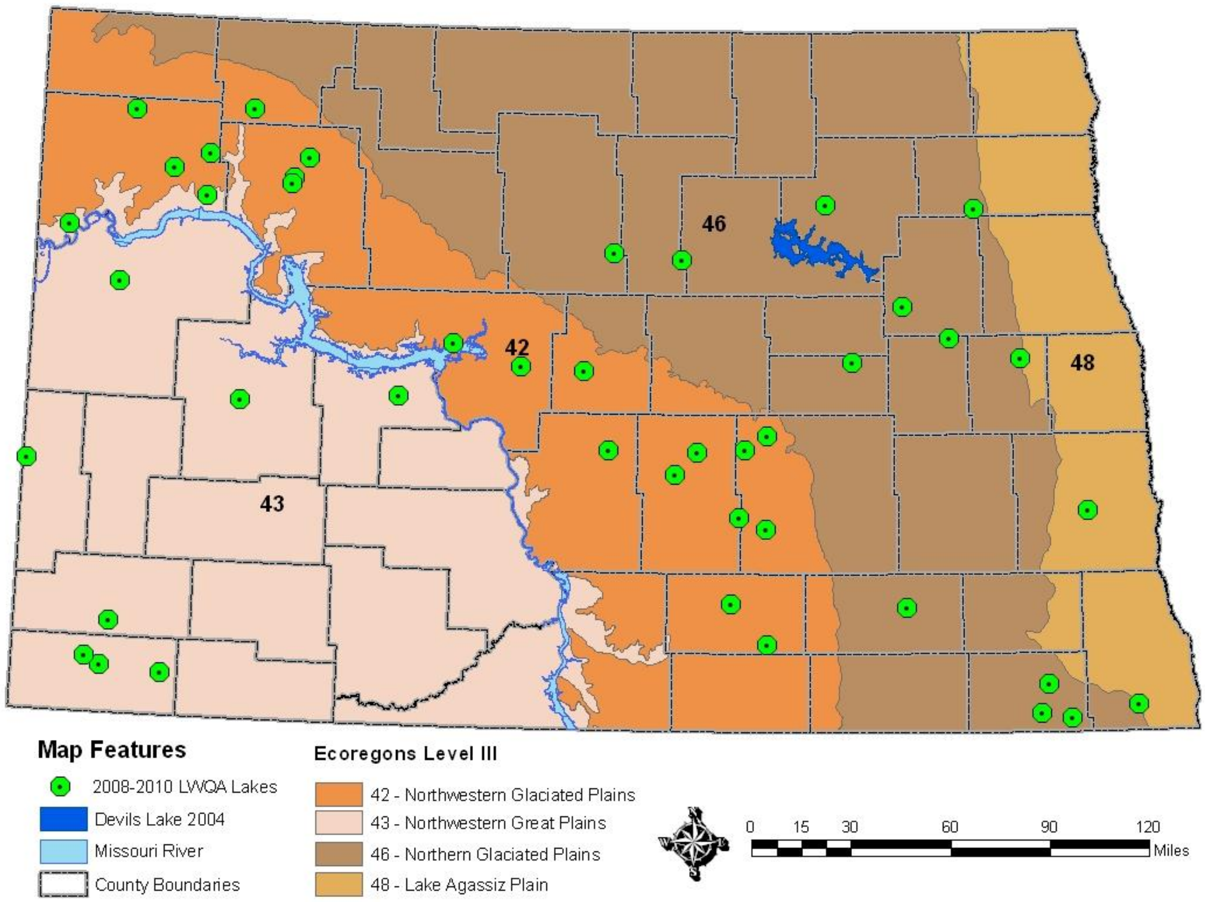

Figure 2. Level III Ecoregions and 2008-2010 Lake Water Quality Assessment Lakes and Reservoirs

While it is most helpful to compare each lake or reservoir in relationship to as specific an ecological region as possible, it is also necessary to have an adequate sample size of lakes and reservoirs to compare. Therefore, to ensure an adequate sample size of lakes and reservoirs the four level III ecoregions in the state were combine into two broader ecoregions. The Lake Agassiz Plain (48) and Northern Glaciaed Plains (46) ecoregions were combined to form the Cultivated Plains region and the Northwestern Glaciated Plains (42) and Northwestern Great Plains (43) ecoregions were combined to form the Rangeland Plains region (Figure 3).

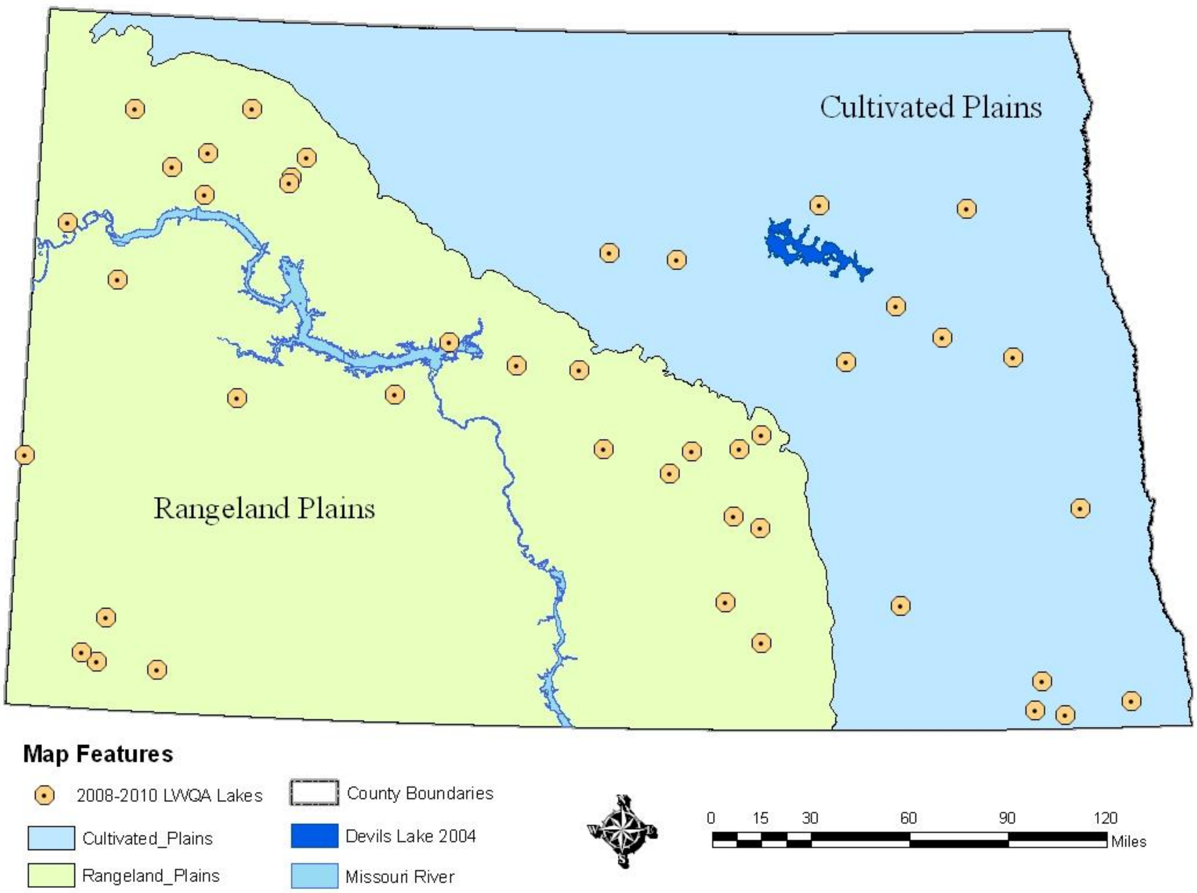

Figure 3. Cultivated Plains and Rangeland Plains Regions in North Dakota

Gascoyne Lake, Bowman County

BACKGROUND

Location: Gascoyne Lake is a wide shallow windswept natural lake on the north side of Highway 12 between Scranton and Gascoyne, North Dakota (Figure 1). The fishery is managed by the North Dakota Game and Fish. Fish species managed for are northern pike and yellow perch.

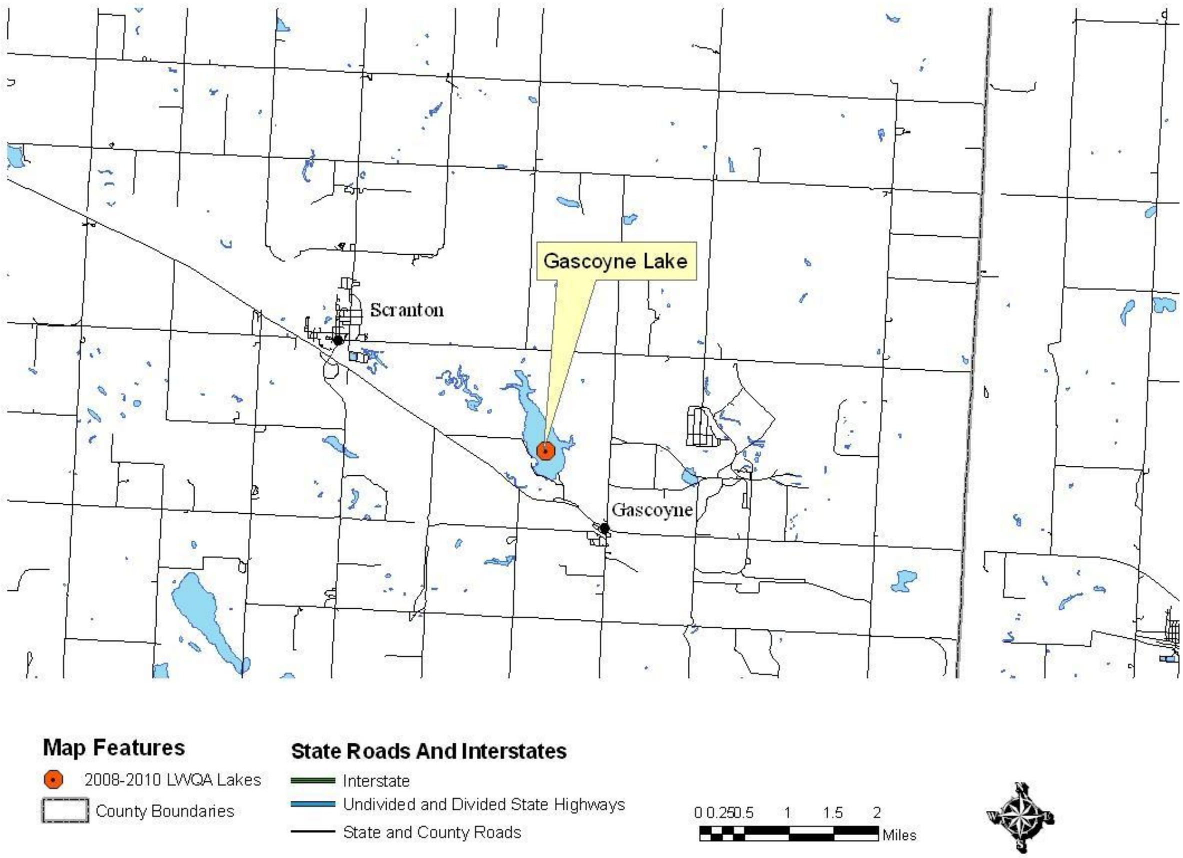

Figure 1. Location of Gascoyne Lake

Physiographic/Ecological Setting: Gascoyne Lake has a surface area of 180.1 acres, a maximum depth of 9 ft and an average depth 5.5 ft (Figure 2). The lake is located within the Northwestern Great Plains Level III Ecoregion, which is part of the broader Rangeland Plains Ecoregion (Figures 3 and 4).

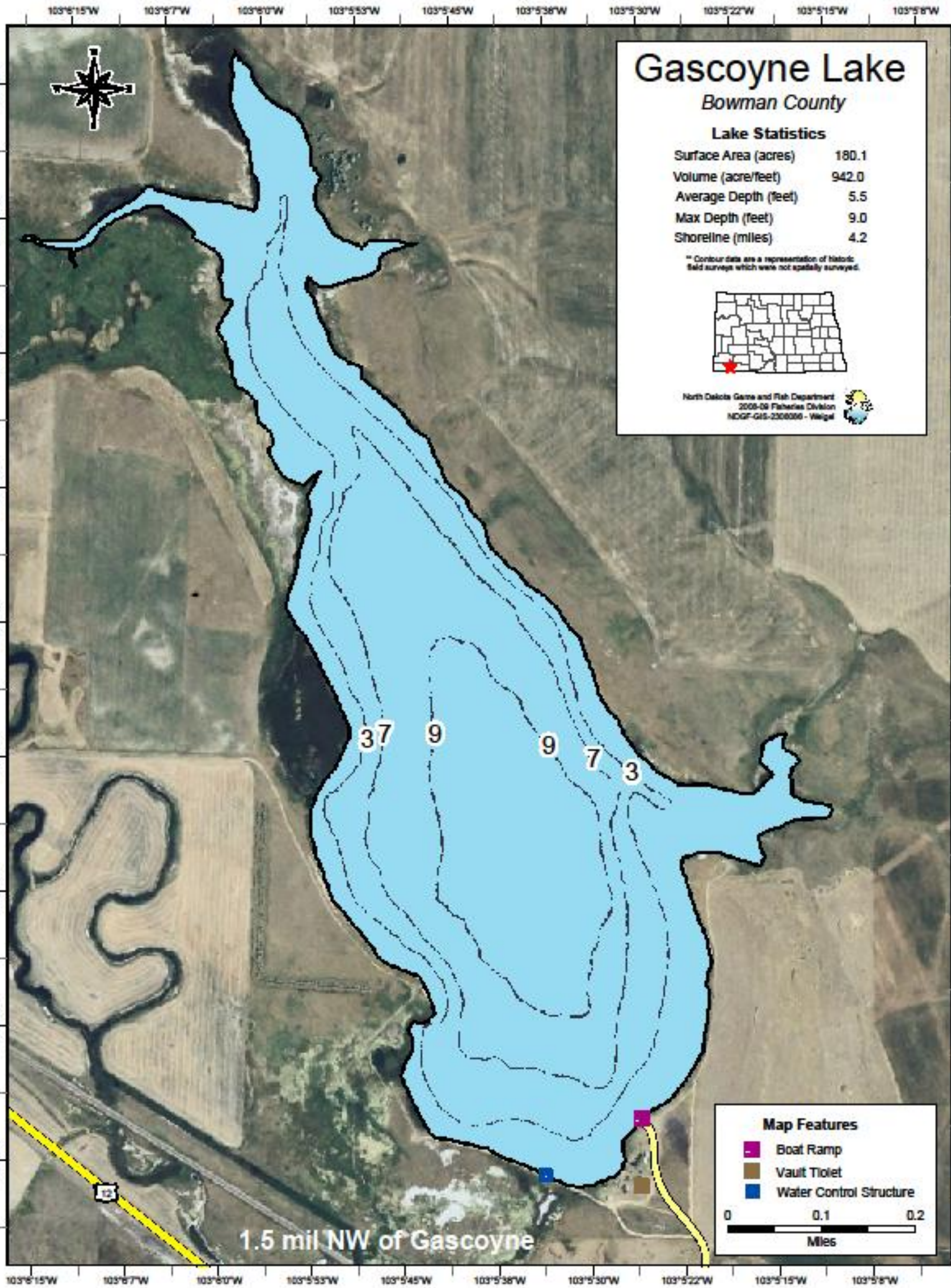

Figure 2. Contour Map of Gascoyne Lake (Map Courtesy of North Dakota Game and Fish Department)

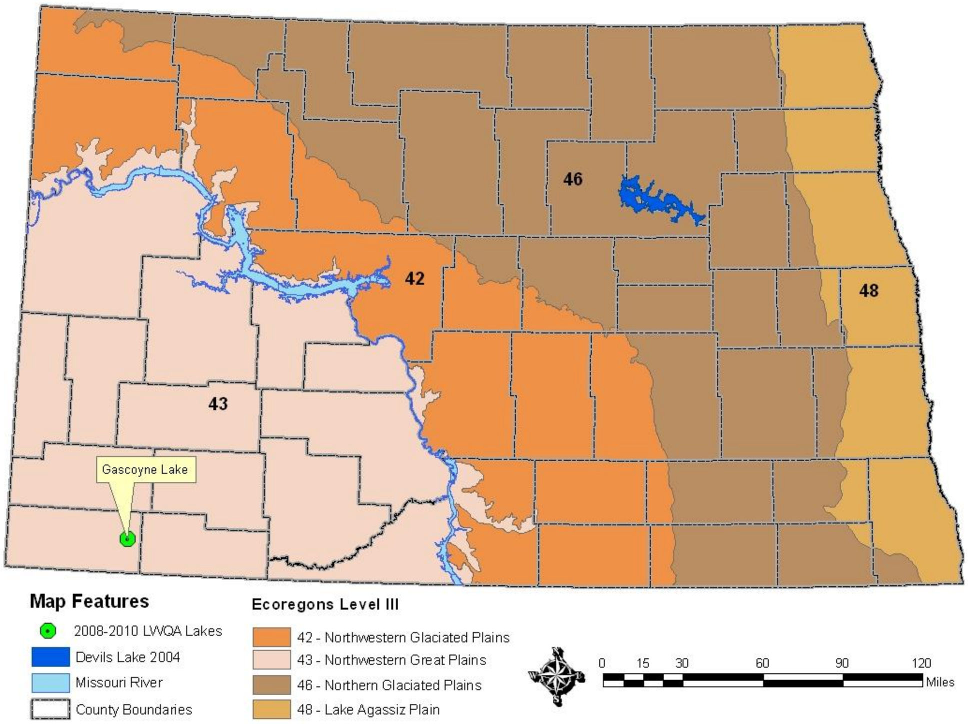

Figure 3. Gascoyne Lake's Location and the Level III Ecoregions

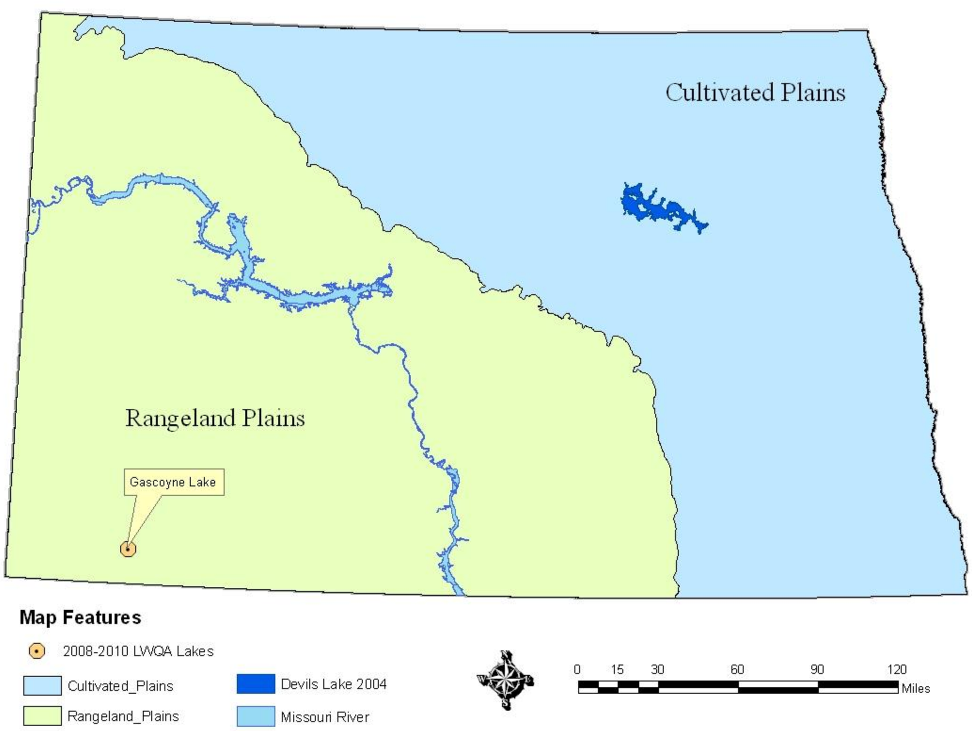

Figure 4. Gascoyne Lake Location and the Cultivated and Rangeland Plans Regions

Recreational Facilities: Recreational facilities at Gascoyne Lake include a cement boat ramp, boat and vehicle parking, a small park with shelters, picnic tables, garbage pickup, and outdoor toilets.

Water Quality Standards Classification: Gascoyne Lake is classified in the state "Standards of Quality for Waters of the State" (NDDoH, 2011) as a class 3 lake. Class 3 lakes or reservoirs are defined as a "warm water fishery" or "waters capable of supporting natural reproduction and growth of warm water fishes (e.g., largemouth bass and bluegill) and associated aquatic biota. Some cool water species may also be present."

Historical Water Quality Sampling: No historical water quality data.

WATER QUALITY MONITORING RESULTS

The water quality assessment for Gascoyne Lake is presented in four general categories: 1) temperature and dissolved oxygen profile results; 2) general water quality characterization; 3) nutrient limitation; and 4) trophic status. Where appropriate, results have been compared to the regional data for natural lakes in the Rangeland Plains region.

Temperature and Dissolved Oxygen Profile Results: There are three temperature and dissolved oxygen profiles for Gascoyne Lake collected in 2009 (Figures 5 and 6). The profile data shows that Gascoyne Lake was not thermally stratification during the open water period of 2009. Also the profiles showed that during the open water period the lake remained well enough oxygenated to support aquatic life.

General Water Quality: Gascoyne Lake is a well buffered lake with total alkalinity as $CaCO_3$ concentrations ranging from 222 to 384 mg/L (Table 1). The lake is sodium sulfate dominated with an average sodium concentration of 300 mg/L and an average sulfate concentration of 771 mg/L. The average total dissolved solids concentration and specific conductance measurement for 2009 sampling period were 1437 mg/L and 1650 µmhos/cm respectively. Average total nitrogen as N and total phosphorus as P concentrations were 1.523 mg/L and 0.145 mg/L respectively.

When compared to the regional average water quality for natural lakes in the Rangeland Plans, Gascoyne Lake is fairly representative (Table 3). For example, the regional average TDS, total nitrogen, and total phosphorus concentrations are 1466 mg/L, 1.794 mg/L, and 0.233 mg/L respectively, compared to Gascoyne Lake's average TDS, total nitrogen, and total phosphorus concentrations of 1437 mg/L, 1.523 mg/L and 0.145 mg/L respectively.

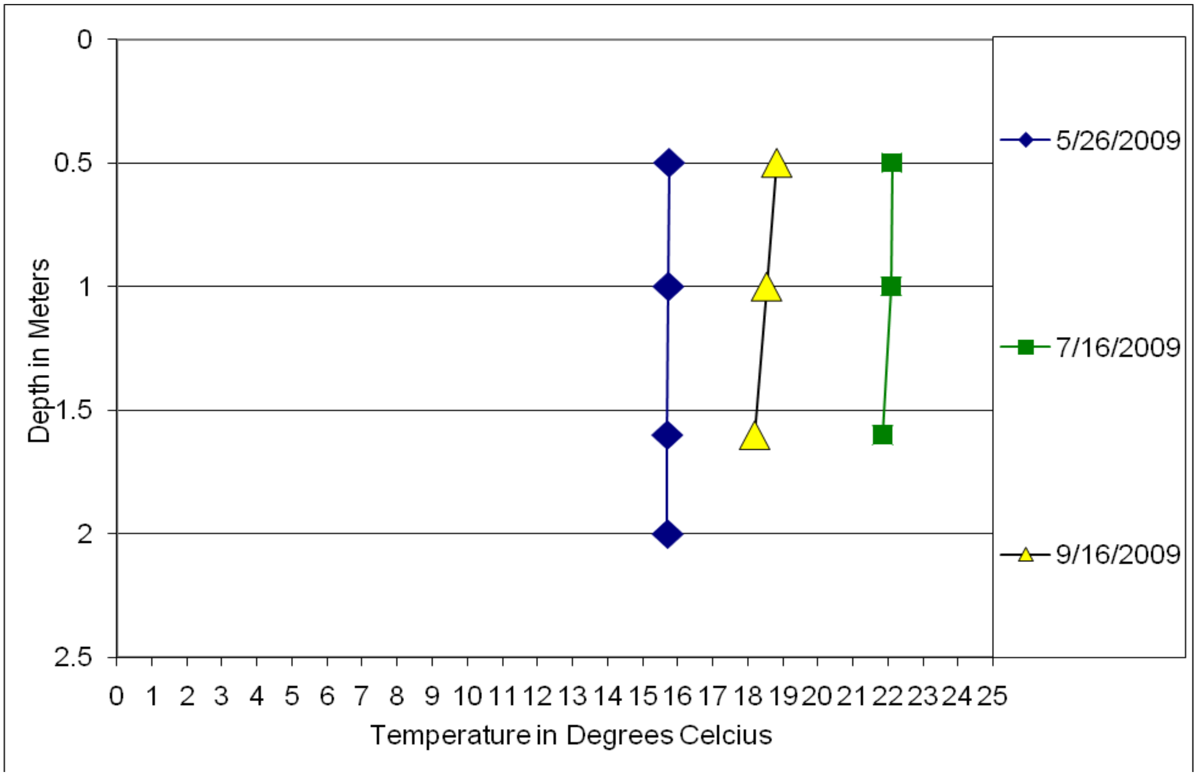

Figure 5. Temperature Profiles for Gascoyne Lake

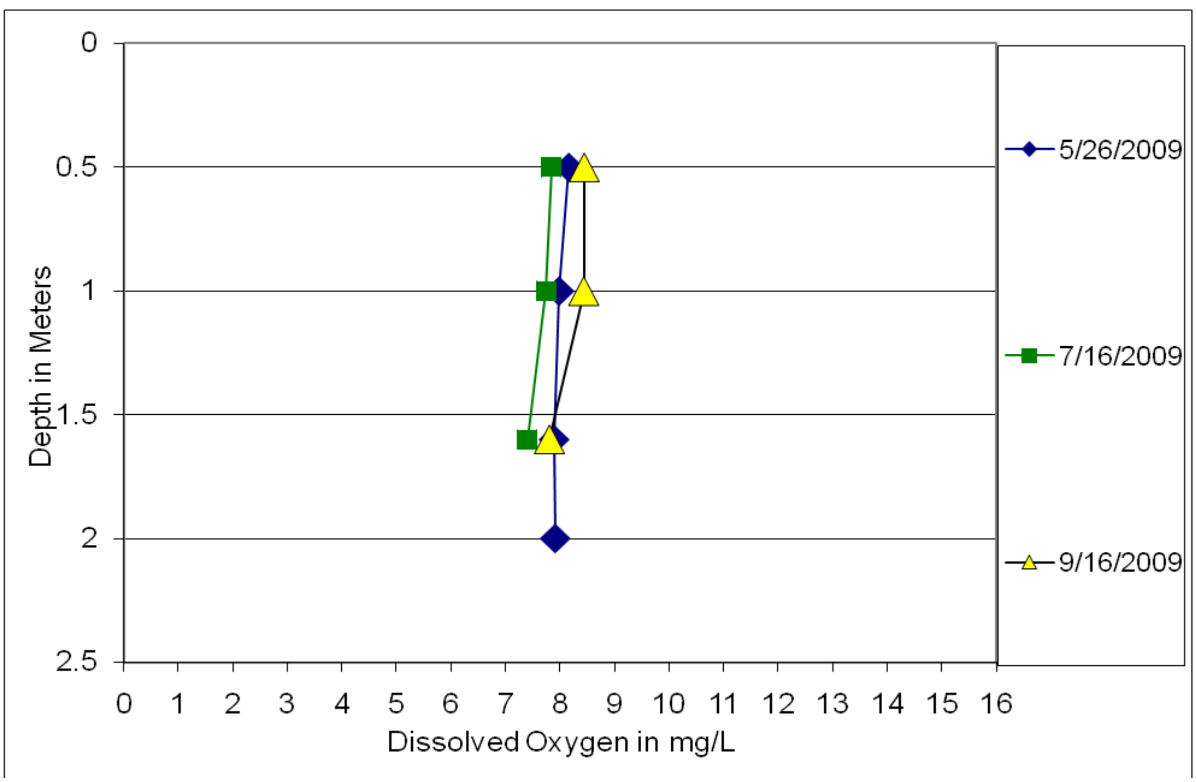

Figure 6. Dissolved Oxygen Profiles for Gascoyne Lake

Table 1. Statistical Summary of Gascoyne Lake's 2009 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	3	313	222	384	83
Total Ammonia as N	mg/L	3	0.087	0.058	0.127	0.036
Bicarbonate (HCO_3)	mg/L	3	309	205	367	90
Calcium (Ca)	mg/L	3	51.6	43.0	56.3	7.4
Carbonate (CO_3)	mg/L	3	36	25	50	13
Chloride (Cl)	mg/L	3	11	9	12	2
Chlorophyll-a	µg/L	3	8.6	3.0	12.0	4.9
Specific Conductance	µmhos	3	2023	1650	2390	370
Total Dissolved Solids	mg/L	3	1437	1120	1710	297
Total Hardness as ($CaCO_3$)	mg/L	3	486	393	554	83
Hydroxide (OH)	mg/L	3	1.0[1]	1.0[1]	1.0[1]	0.0
Iron (Fe)	mg/L	3	0.257	0.099	0.366	0.140
Magnesium (Mg)	mg/L	3	86.8	69.5	101.0	16.0
Nitrate + Nitrite as N	mg/L	3	0.160	0.060	0.350	0.165
Total Kjeldahl Nitrogen as N	mg/L	3	1.363	1.190	1.520	0.166
Total Nitrogen as N	mg/L	3	1.523	1.250	1.730	0.247
pH		3	8.80	8.68	8.91	0.12
Total Phosphorus as P	mg/L	3	0.145	0.115	0.189	0.039
Potassium (K)	mg/L	3	22.6	18.2	26.4	4.1
Sodium (Na)	mg/L	3	300.0	229.0	352.0	63.7
Sulfate (SO4)	mg/L	3	771	612	928	158

[1]Equal to the lower reporting limit

Limiting Nutrients: The three water quality samples indicate that Gascoyne Lake is nitrogen limited (Figure 7). The limiting nutrient assessment is based on the assumption that either nitrogen or phosphorus is limiting algal growth and that the ratio of total nitrogen as N to total phosphorus as P (N:P), by weight in the average algae is approximately 15 to 1. When the N:P ratio is less than 15:1, nitrogen is assumed to be the limiting nutrient and when it exceeds 15:1, the limiting nutrient is assumed to be phosphorus.

Trophic Status Assessment: Based on the chlorophyll-a, secchi disk transparency, and total phosphorus data collected in 2009, Gascoyne Lake's trophic status estimate is eutrophic. The trophic Status Index scores ranged from a low of 41 based on chlorophyll-a to a high of 80 based on total phosphorus (Figure 8).

Table 2. Statistical Summary of Water Quality Data[2] Collected from Natural and Enhanced Lakes in the Rangeland Plains Ecological Region of North Dakota

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	383	513	111	4770	487
Total Ammonia as N	mg/L	494	0.105	0.001[1]	2.230	0.229
Bicarbonate (HCO_3)	mg/L	383	469	60	2990	320
Calcium (Ca)	mg/L	384	41.1	0.5	282.0	34.4
Carbonate (CO_3)	mg/L	377	79	1[1]	1420	148
Chloride (Cl)	mg/L	383	44	3[1]	1070	103
Chlorophyll-a	µg/L	346	22.5	1.5[1]	292.0	37.4
Specific Conductance	µmhos	383	2028	424	20100	1976
Total Dissolved Solids	mg/L	383	1466	227	18200	1717
Total Hardness as ($CaCO_3$)	mg/L	384	529	74	2370	295
Hydroxide (OH)	mg/L	322	1.0	0.0[1]	1.0	0.2
Iron (Fe)	mg/L	385	0.245	0.001[1]	7.070	0.543
Magnesium (Mg)	mg/L	384	103.6	8.5	567.0	70.9
Nitrate + Nitrite as N	mg/L	491	0.040	0.001[1]	0.54	0.054
Total Kjeldahl Nitrogen as N	mg/L	463	1.876	0.080	8.500	1.073
Total Nitrogen as N	mg/L	401	1.794	0.240	5.520	0.897
pH		383	8.80	7.40	9.87	0.36
Total Phosphorus as P	mg/L	501	0.233	0.002[1]	1.940	0.336
Potassium (K)	mg/L	384	34.0	3.1	356.0	37.0
Sodium (Na)	mg/L	384	299.6	16.9	4680.0	514.5
Sulfate (SO4)	mg/L	383	625	34	10500	885

[1]Equal to the lower reporting limit
[2]Data collected from 64 natural and enhanced Lakes between 1991 and 2010

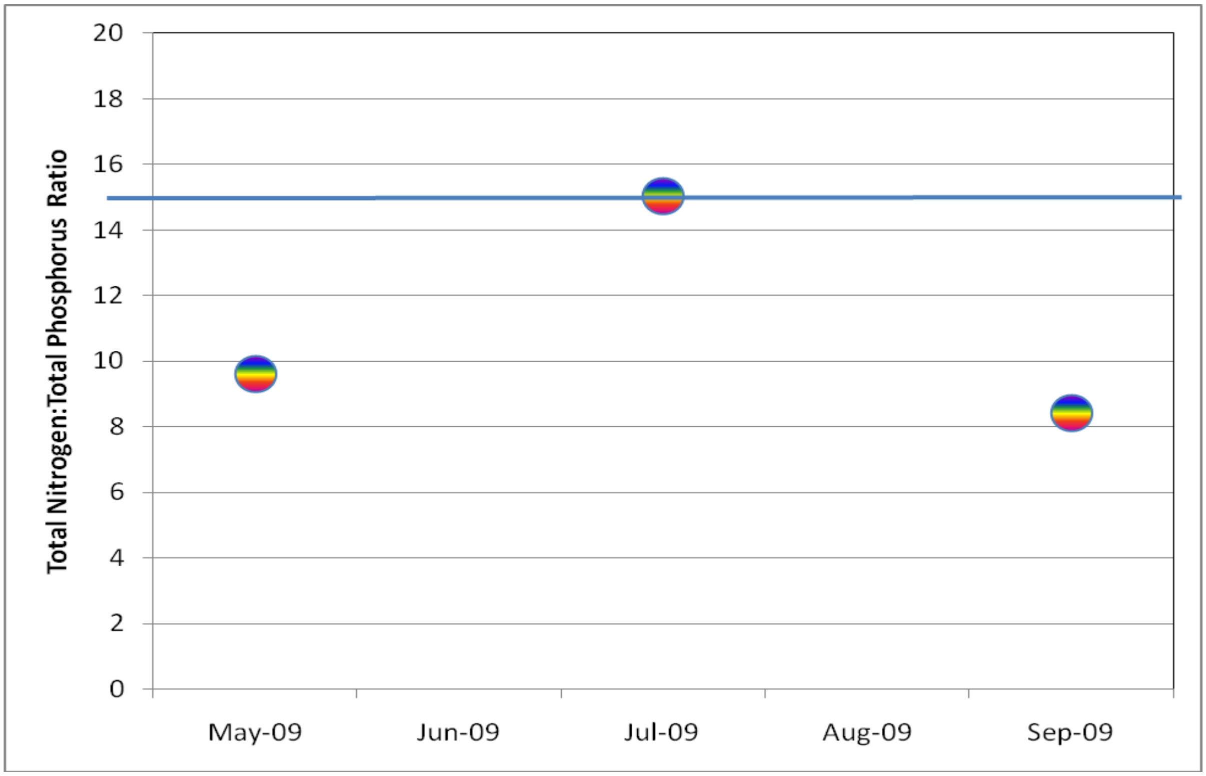

Figure 7. Gascoyne Lake's Total Nitrogen to Total Phosphorus Ratio

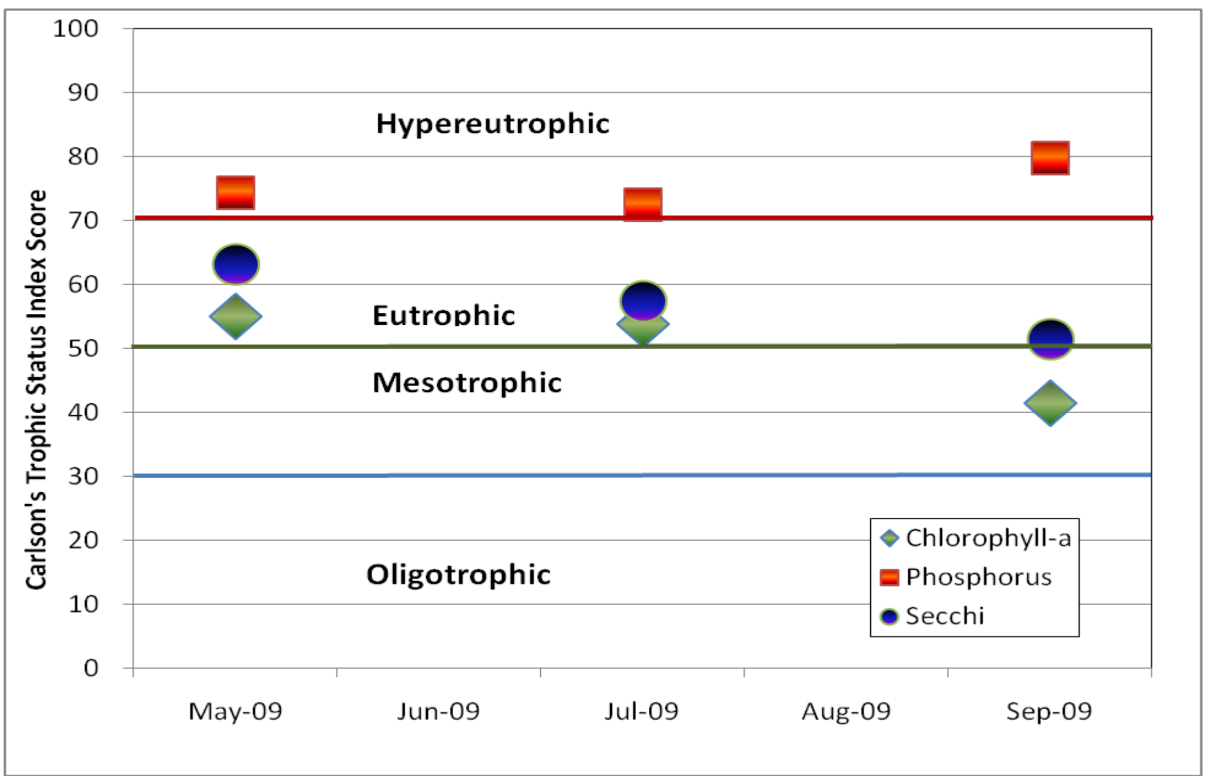

Figure 8. Gascoyne Lake's TSI Scores

Kalina Dam, Bowman County

BACKGROUND

Location: Kalina Dam is a pretty little reservoir on an un-named drainage just southwest of Bowman North Dakota (Figure 1). The fishery is managed by the North Dakota Game and Fish Department. Fish species managed for are northern pike, yellow perch and bluegill.

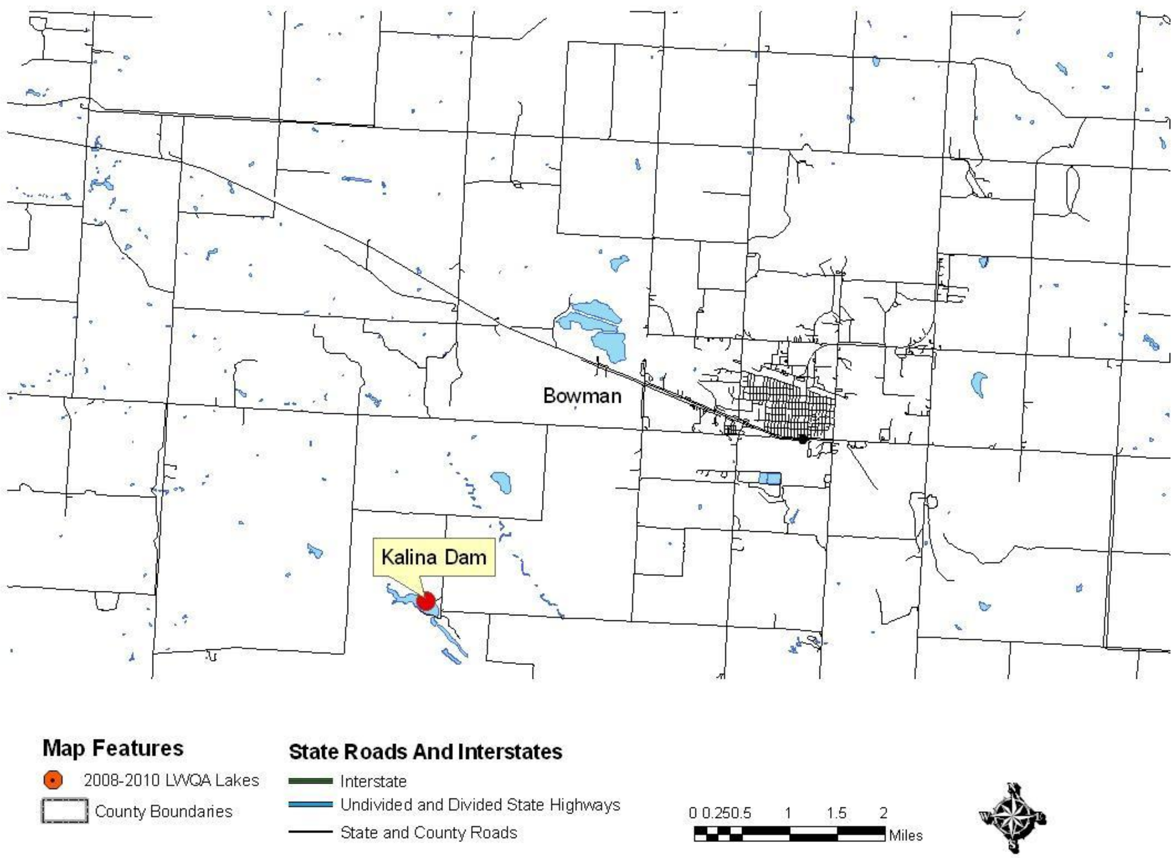

Figure 1. Location of Kalina Dam

Physiographic/Ecological Setting: Kalina Dam has a surface area of approximately 32 acres and a maximum depth of 9 ft. It is a sheltered reservoir with a fair amount of shading from shoreline trees and cattails (Figure 2). The reservoir is located in the Northwestern Great Plains Level III Ecoregion, which is part of the broader Rangeland Plains Region (Figures 3 and 4).

Figure 2. Aerial View of Kalina Dam

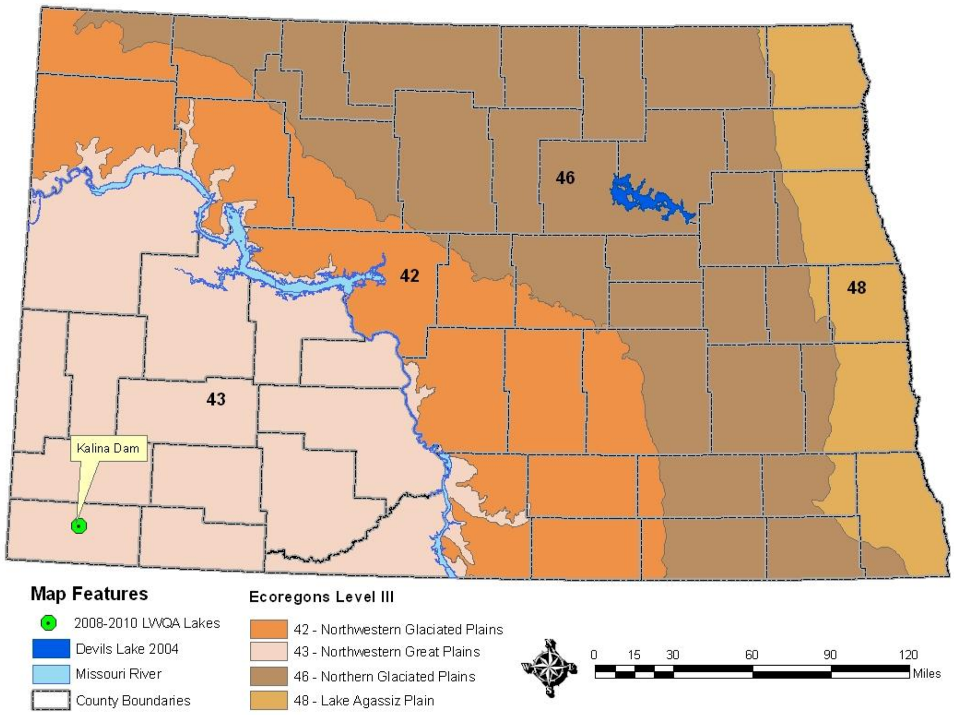

Figure 3. Kalina Dam's Location and the Level III Ecoregions

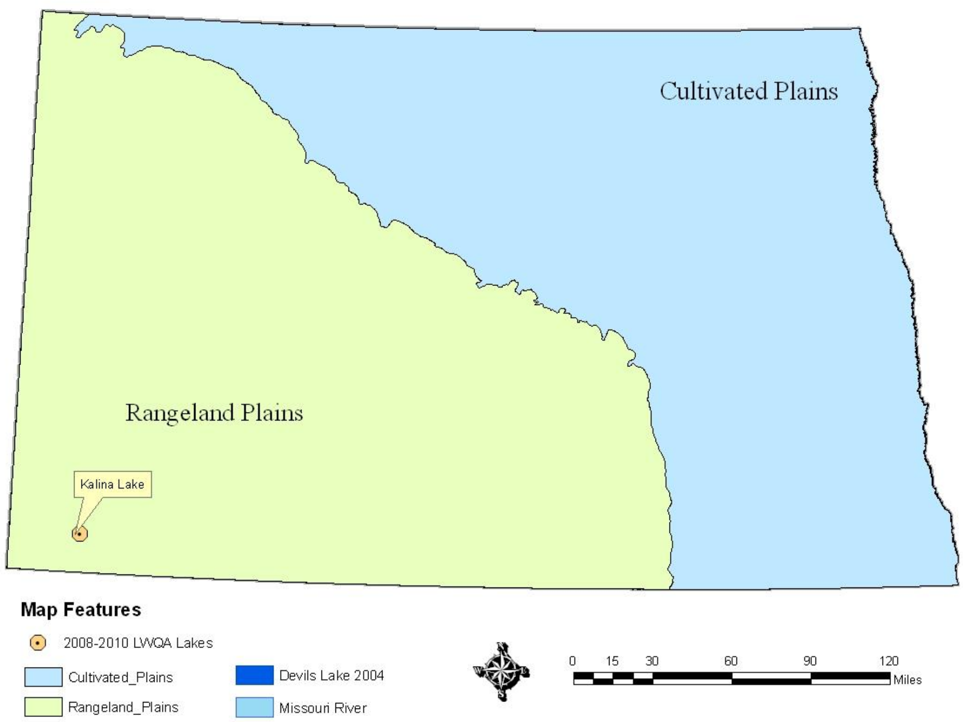

Figure 4. Kalina Dam's Location and the Cultivated and Rangeland Plans Regions

Recreational Facilities: Recreational facilities at Kalina Dam are an access road, parking spots and a small gravel ramp.

Water Quality Standards Classification: Kalina Dam is classified in the state "Standards of Quality for Waters of the State" (NDDoH, 2011) as a class 3 reservoir. Class 3 lakes or reservoirs are defined as a "warm water fishery" or "waters capable of supporting natural reproduction and growth of warm water fishes (e.g., largemouth bass and bluegill) and associated aquatic biota. Some cool water species may also be present."

Historical Water Quality Sampling: No historical water quality data.

WATER QUALITY MONITORING RESULTS

The water quality assessment for Kalina Dam is presented in four general categories: 1) temperature and dissolved oxygen profile results; 2) general water quality characterization; 3) nutrient limitation; and 4) trophic status. Where appropriate, results have been compared to the regional data for reservoirs in the Rangeland Plains region.

Temperature and Dissolved Oxygen Profile Results: There are three temperature and dissolved oxygen profiles for Kalina Dam collected in 2009 (Figures 5 and 6). The profile data indicates that Kalina Dam does not thermally stratification during the open water period, even though the reservoir is relatively narrow and protected from the wind. Data also indicates that during the open water period the reservoir remains well enough oxygenated to support aquatic life.

General Water Quality: Data collected in 2009 indicates that Kalina Dam is well buffered with total alkalinity as $CaCO_3$ concentrations ranging from 111 to 142 mg/L (Table 1) and that the reservoir is sodium bicarbonate dominated with an average sodium concentration of 92 mg/L and an average bicarbonate concentration of 170 mg/L. The average total dissolved solids concentration and specific conductance measurements for the 2009 sampling period were 292 mg/L and 479 µmhos/cm, respectively. The average total nitrogen as N and total phosphorus as P concentrations were 1.048 mg/L and 0.269 mg/L respectively.

When compared to regional water quality for reservoirs in the Rangeland Plans, Kalina Dam is fairly fresh, nitrogen poor, but phosphorus rich (Table 3). For example, the regional average TDS, total nitrogen, and total phosphorus concentrations are 1107 mg/L, 1.314 mg/L, and 0.128 mg/L respectively, compared to Kalina Dam's average TDS, total nitrogen, and total phosphorus concentrations of 292 mg/L, 1.043 mg/L and 0.269 mg/L respectively.

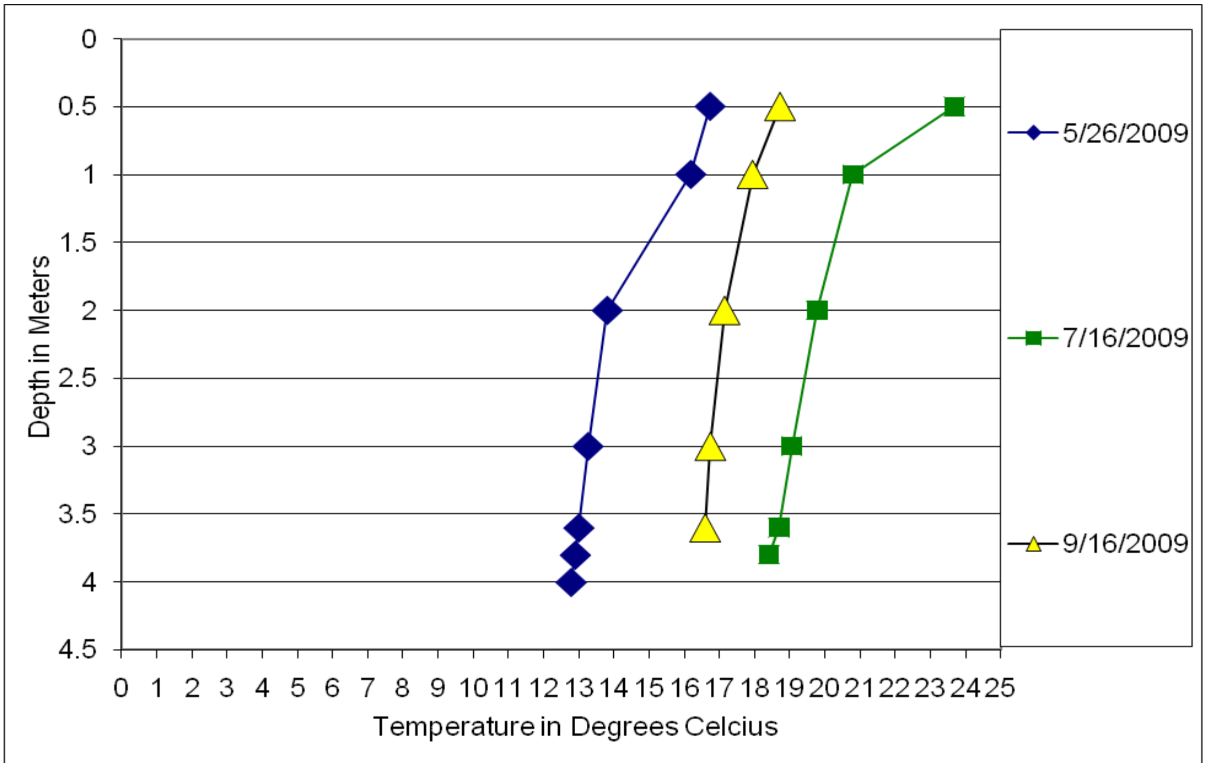

Figure 5. Temperature Profiles for Kalina Dam

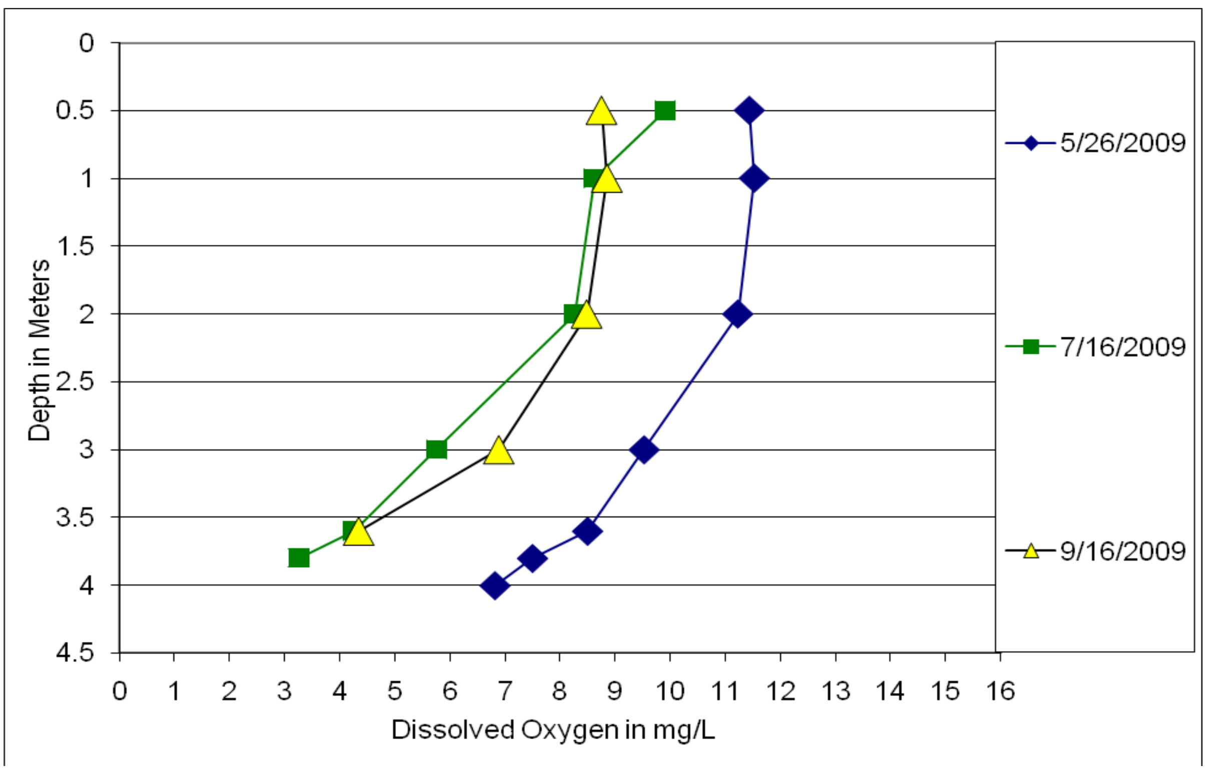

Figure 6. Dissolved Oxygen Profiles for Kalina Dam

Table 1. Statistical Summary of Kalina Dam's 2009 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	3	142	111	175	32
Total Ammonia as N	mg/L	3	0.075	0.030[1]	0.165	0.078
Bicarbonate (HCO_3)	mg/L	3	170	135	213	40
Calcium (Ca)	mg/L	3	17.8	15.8	20.0	2.1
Carbonate (CO_3)	mg/L	3	2	1[1]	3	1
Chloride (Cl)	mg/L	3	2	2	2	0
Chlorophyll-a	µg/L	3	11.1	3.0	19.2	8.1
Specific Conductance	µmhos	3	479	424	540	58
Total Dissolved Solids	mg/L	3	292	264	323	30
Total Hardness as ($CaCO_3$)	mg/L	3	81	74	90	8
Hydroxide (OH)	mg/L	3	1.0[1]	1.0[1]	1.0[1]	0.0
Iron (Fe)	mg/L	3	0.758	0.156	1.660	0.796
Magnesium (Mg)	mg/L	3	8.9	8.5	9.6	0.6
Nitrate + Nitrite as N	mg/L	3	0.090	0.030[1]	0.140	0.056
Total Kjeldahl Nitrogen as N	mg/L	3	0.958	0.824	1.070	0.124
Total Nitrogen as N	mg/L	3	1.048	0.964	1.100	0.073
pH		3	8.11	7.59	8.50	0.47
Total Phosphorus as P	mg/L	3	0.269	0.168	0.372	0.102
Potassium (K)	mg/L	3	6.7	6.4	6.9	0.3
Sodium (Na)	mg/L	3	77.8	69.7	83.3	7.1
Sulfate (SO4)	mg/L	3	92	89	95	3

[1]Equal to the lower reporting limit

Limiting Nutrients: The three water quality samples indicate that Kalina Dam is nitrogen limited (Figure 7). The limiting nutrient assessment is based on the assumption that either nitrogen or phosphorus is limiting algal growth and that the ratio of total nitrogen as N to total phosphorus as P (N:P), by weight in the average algae is approximately 15 to 1. When the N:P ratio is less than 15:1, nitrogen is assumed to be the limiting nutrient and when it exceeds 15:1, the limiting nutrient is assumed to be phosphorus.

Trophic Status Assessment: Based on the chlorophyll-a, secchi disk transparency, and total phosphorus data collected in 2009, Kalina Dam's trophic status is estimated as eutrophic. The trophic status index (TSI) scores ranged from a low of 41 based on chlorophyll-a to a high of 89 based on total phosphorus (Figure 8).

Table 2. Statistical Summary of Water Quality Data[2] Collected from Reservoirs and Impoundments in the Rangeland Plains Ecological Region of North Dakota

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	522	283	54	982	131
Total Ammonia as N	mg/L	593	0.092	0.001[1]	2.440	0.183
Bicarbonate (HCO_3)	mg/L	522	295	14	1040	145
Calcium (Ca)	mg/L	522	52.3	4.7	163.0	27.3
Carbonate (CO_3)	mg/L	520	25	1[1]	197	29
Chloride (Cl)	mg/L	522	13	3[1]	75	9
Chlorophyll-a	µg/L	415	20.1	1.5[1]	218.0	27.0
Specific Conductance	µmhos	542	1621	173	5880	988
Total Dissolved Solids	mg/L	523	1107	100	5110	782
Total Hardness as ($CaCO_3$)	mg/L	522	396	45	2100	279
Hydroxide (OH)	mg/L	465	1.0	0.0[1]	1.0	0.2
Iron (Fe)	mg/L	523	0.193	0.007	4.110	0.349
Magnesium (Mg)	mg/L	522	64.5	5.6	412.0	54.0
Nitrate + Nitrite as N	mg/L	592	0.060	0.001[1]	0.790	0.102
Total Kjeldahl Nitrogen as N	mg/L	483	1.375	0.108	7.720	0.789
Total Nitrogen as N	mg/L	426	1.314	0.178	4.840	0.605
pH		542	8.55	6.73	9.87	0.55
Total Phosphorus as P	mg/L	599	0.128	0.004[1]	3.160	0.190
Potassium (K)	mg/L	522	13.8	2.6	39.2	6.5
Sodium (Na)	mg/L	522	217.2	3.0	932.0	171.6
Sulfate (SO4)	mg/L	520	573	1[1]	3210	519

[1]Equal to the lower reporting limit
[2]Data collected from 76 reservoirs between 1991 and 2010

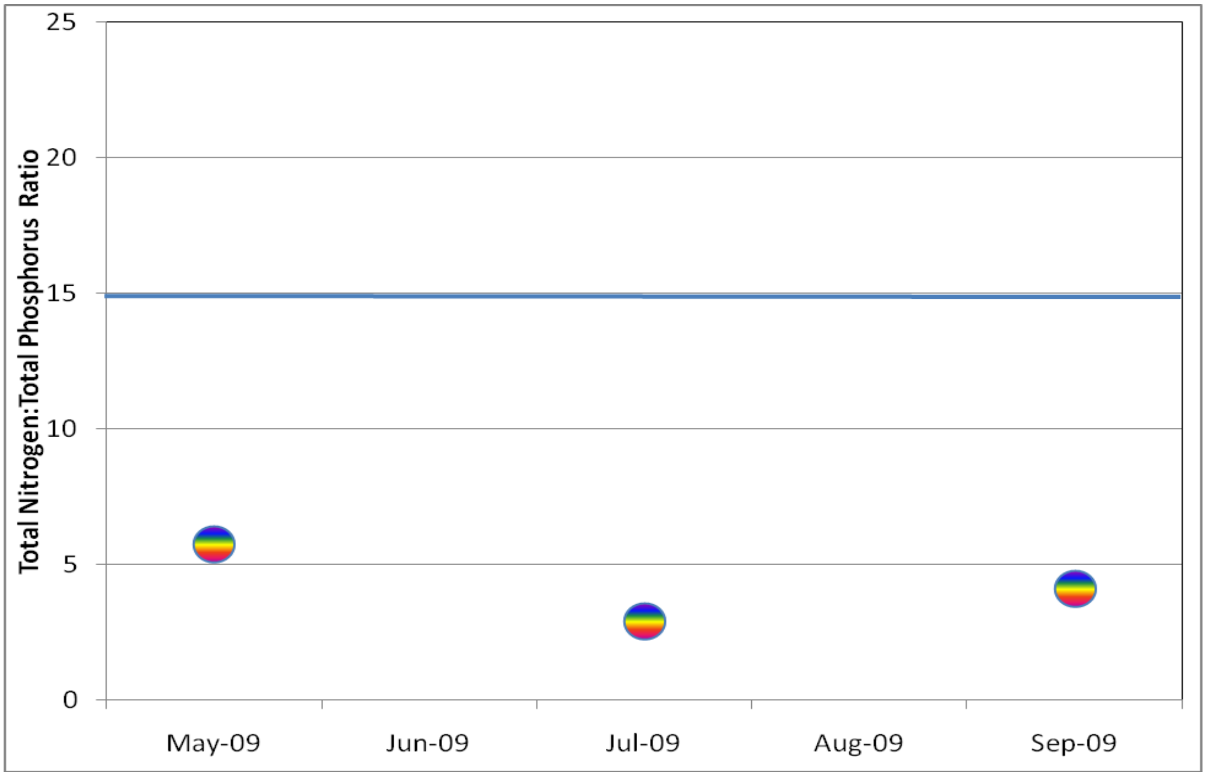

Figure 7. Kalina Dam's Total Nitrogen to Total Phosphorus Ratio

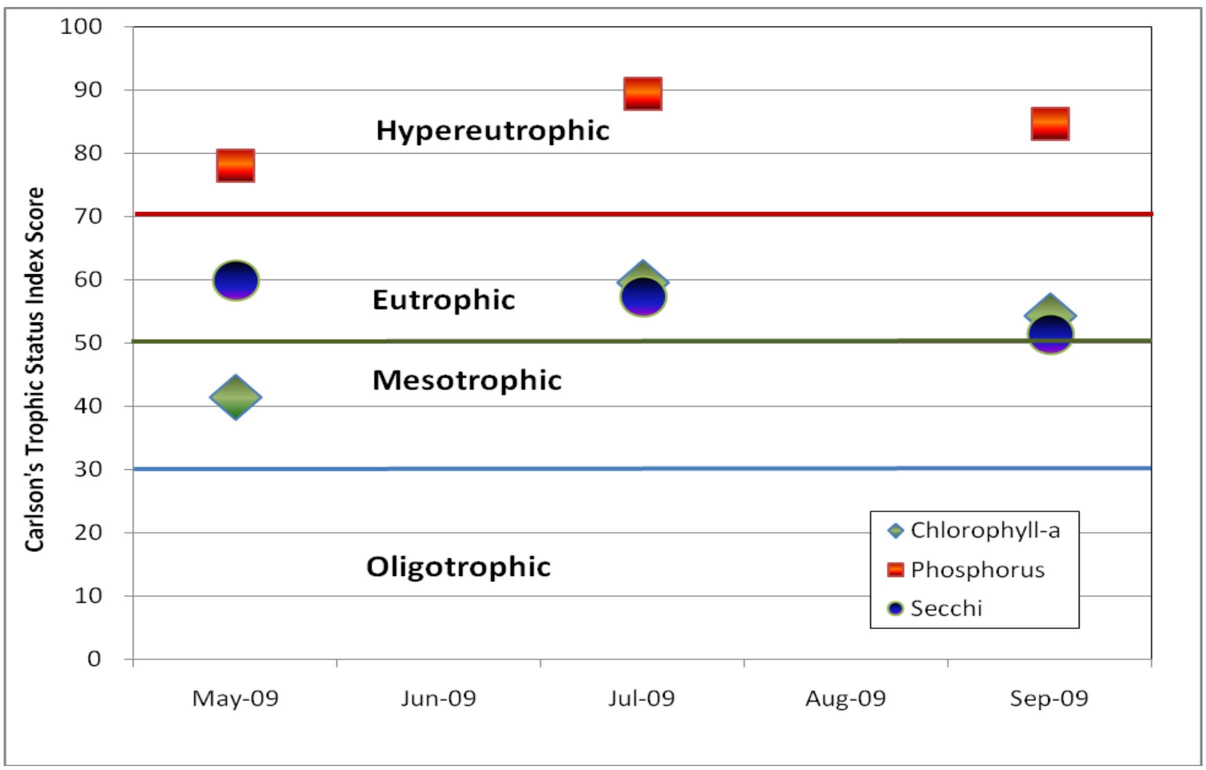

Figure 8. Kalina Dam's TSI Scores

Lutz Dam, Bowman County

BACKGROUND

Location: Lutz Dam is a small hidden away reservoir on an un-named drainage west of Bowman North Dakota (Figure 1). The fishery is managed by the North Dakota Game and Fish Department. Fish species managed for are rainbow trout, bluegill, and largemouth bass.

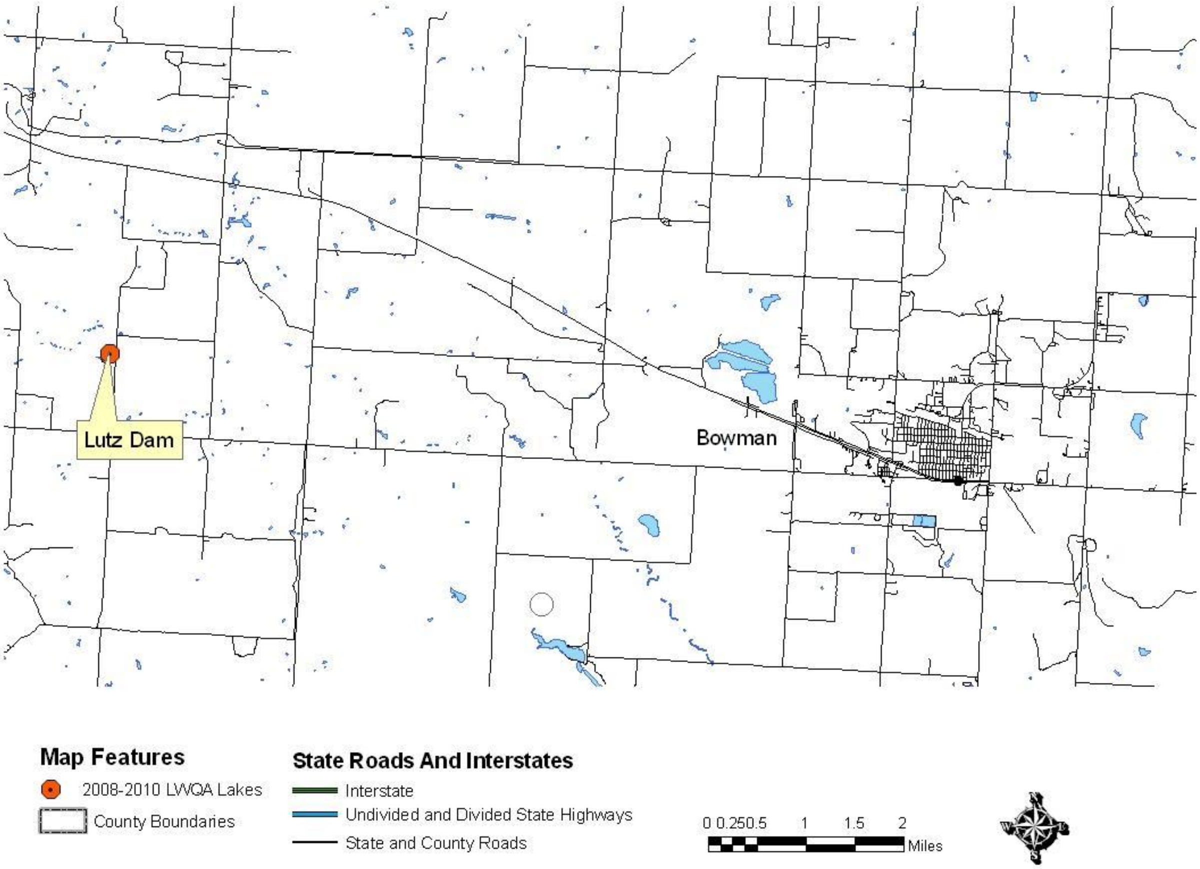

Figure 1. Location of Lutz Dam

Physiographic/Ecological Setting: Lutz Dam has a surface area of approximately 3.4 acres, a maximum depth of 14.1 ft, and an average depth of 6.9 feet (Figure 2). The reservoir is located in the Northwestern Great Plains Level III Ecoregion, which is part of the broader Rangeland Plains Region (Figures 3 and 4).

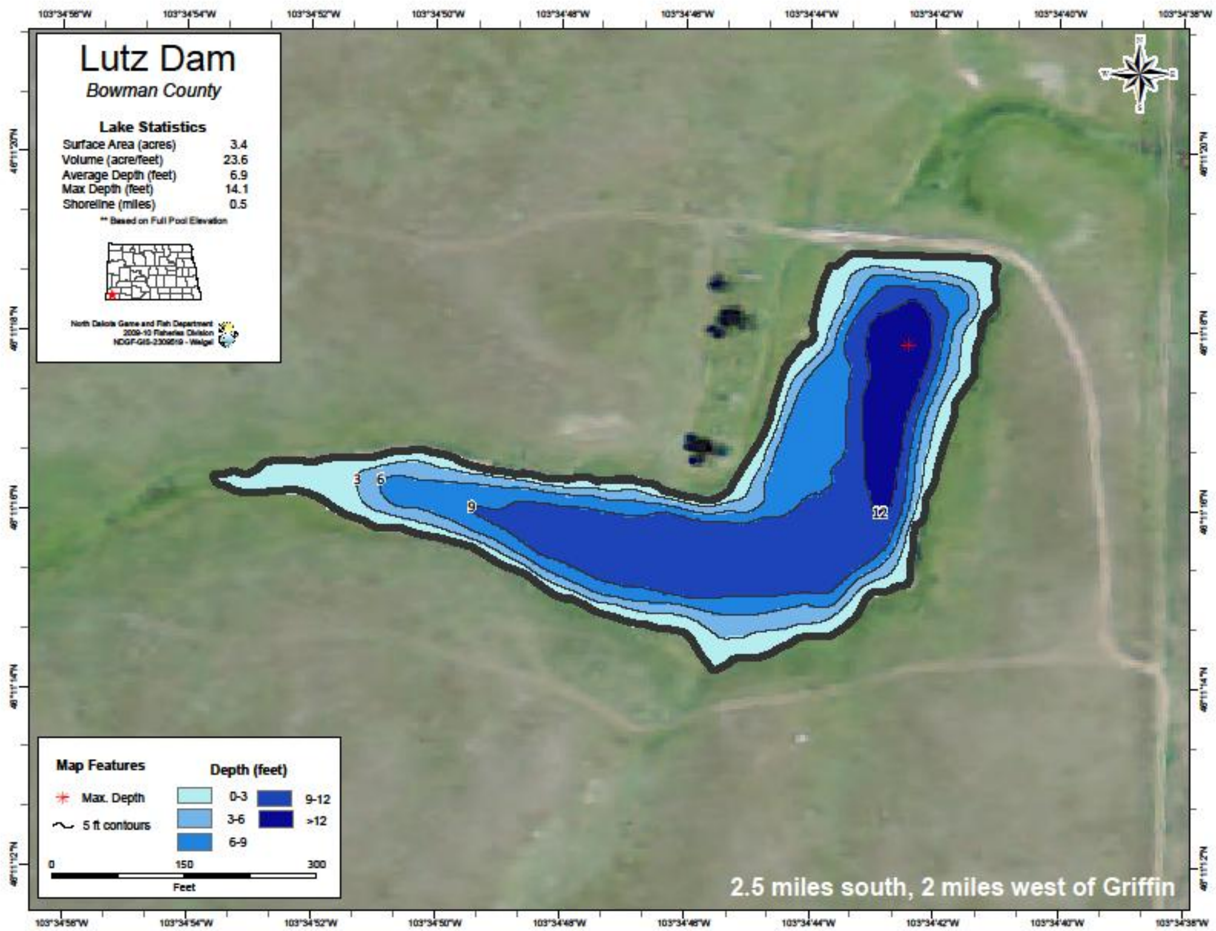

Figure 2. Contour Map of Lutz Dam (Map Courtesy of North Dakota Game and Fish Department)

Recreational Facilities: There are no recreational facilities at Lutz Dam beyond an access road.

Water Quality Standards Classification: Lutz Dam is classified in the state "Standards of Quality for Waters of the State" (NDDoH, 2011) as a class 2 reservoir. Class 2 lakes or reservoirs are defined as a "cool water fishery" or "waters capable of supporting natural reproduction and growth of cool water fishes (e.g., northern pike and walleye) and associated aquatic biota. These waters are also capable of supporting the growth and marginal survival of cold water species and associated biota"

Historical Water Quality Sampling: No historical water quality data.

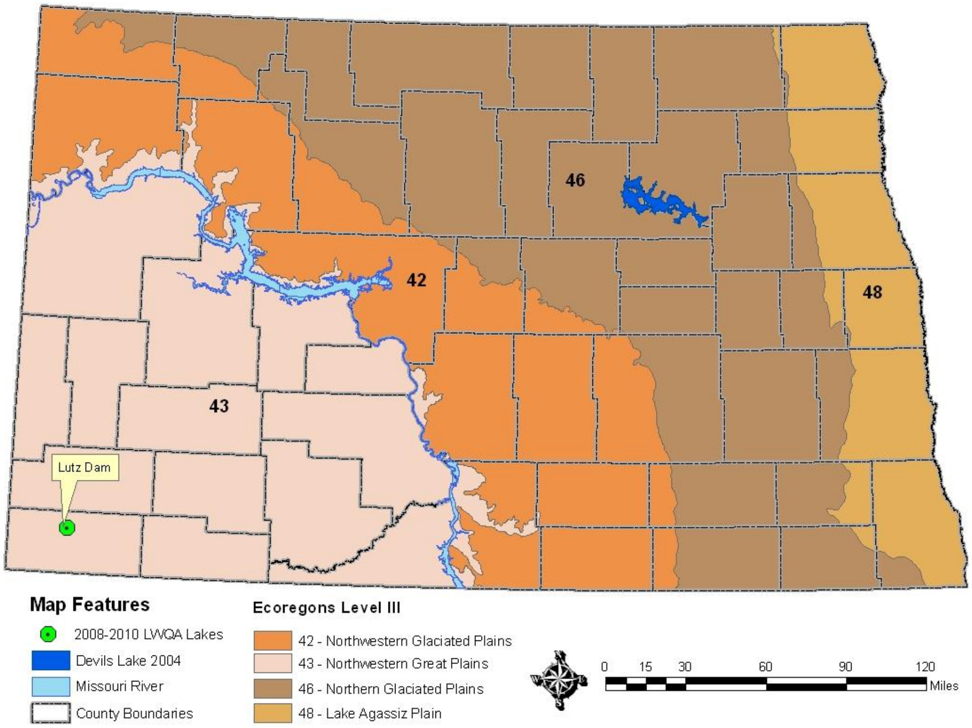

Figure 3. Lutz Dam's Location and the Level III Ecoregions

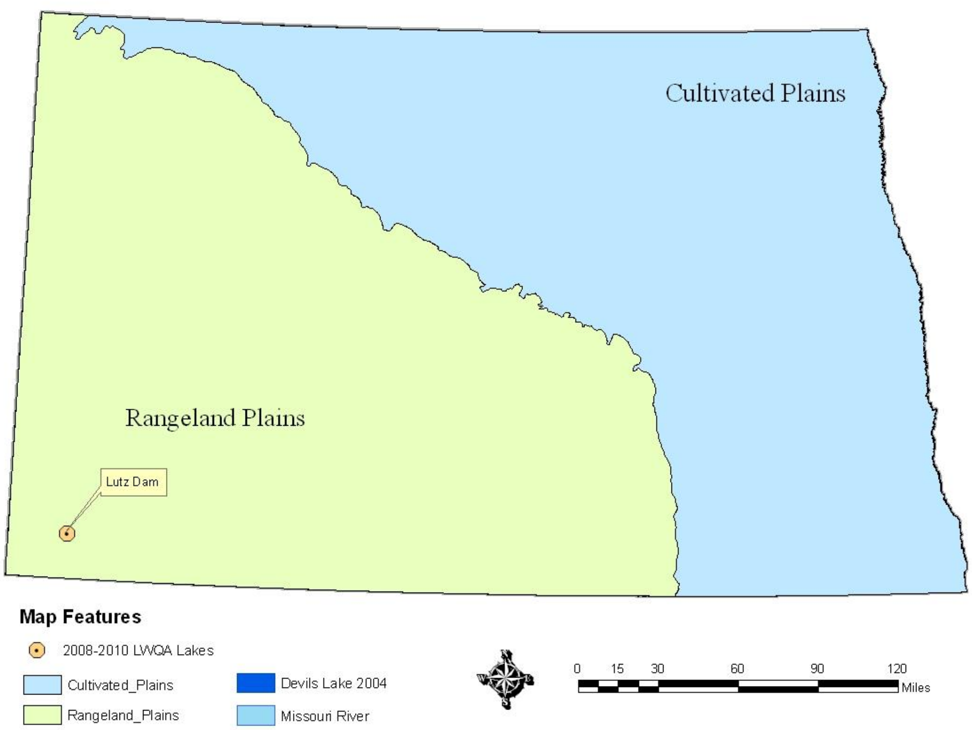

Figure 4. Lutz Dam's Location and the Cultivated and Rangeland Plans Regions

WATER QUALITY MONITORING RESULTS

The water quality assessment for Lutz Dam is presented in four general categories: 1) temperature and dissolved oxygen profile results; 2) general water quality characterization; 3) nutrient limitation; and 4) trophic status. Additionally, where appropriate, results have been compared to the regional data for reservoirs in the Rangeland Plains region.

Temperature and Dissolved Oxygen Profile Results: There are three temperature and dissolved oxygen profiles for Lutz Dam collected in 2009. The profile data indicates that Lutz Dam does not thermally stratification during the open water period and remains well enough oxygenated to support aquatic life (Figures 5 and 6).

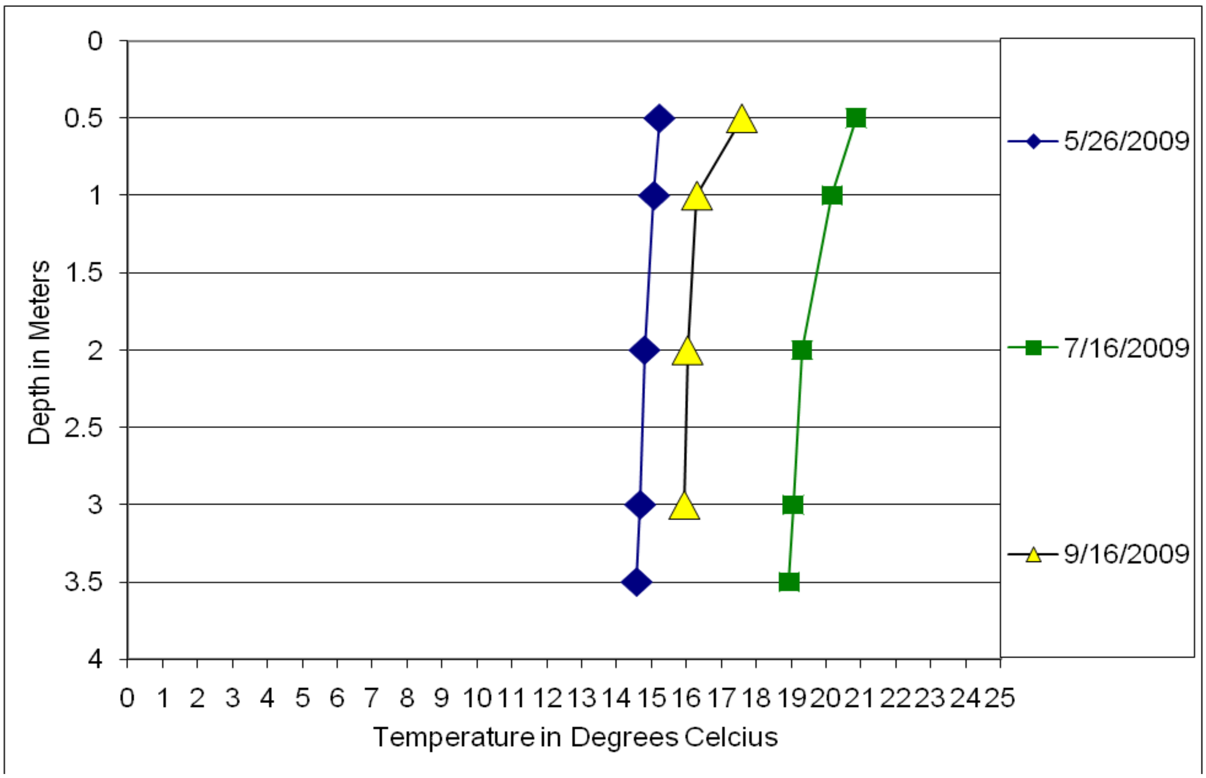

Figure 5. Temperature Profiles for Lutz Dam

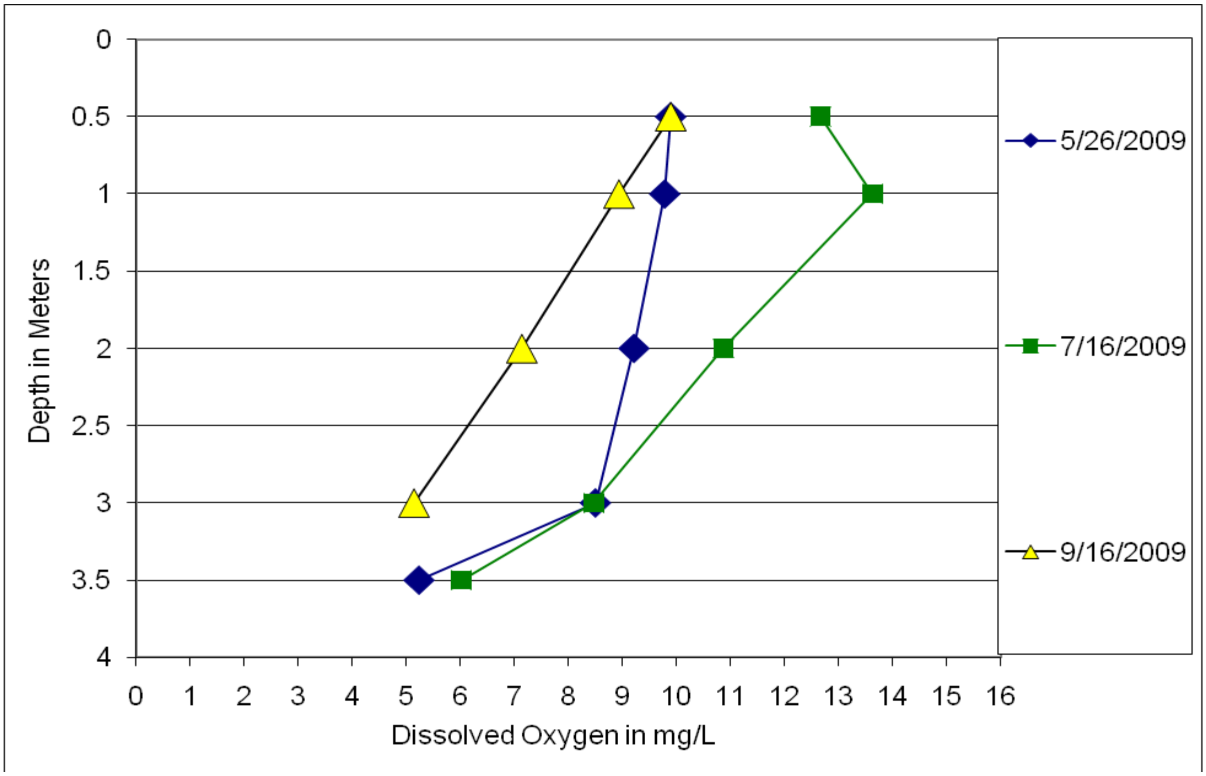

Figure 6. Dissolved Oxygen Profiles for Lutz Dam

General Water Quality: Data collected in 2009 indicate that Lutz Dam is well buffered with total alkalinity as $CaCO_3$ concentrations ranging from 192 to 223 mg/L (Table 1). The reservoir is sodium bicarbonate dominated with an average sodium concentration of 18.4 mg/L and an average bicarbonate concentration of 146 mg/L. The average total dissolved solids concentration and specific conductance measurements for the 2009 sampling period were 307 mg/L and 504 µmhos/cm, respectively. Average total nitrogen as N and total phosphorus as P concentrations were 1.080 mg/L and 0.039 mg/L respectively.

When compared to regional water quality for reservoirs in the Rangeland Plans Lutz Dam is fairly fresh and nutrient poor (Table 3). For example, the regional average TDS, total nitrogen, and total phosphorus concentrations are 1107 mg/L, 1.314 mg/L, and 0.128 mg/L respectively, compared to Lutz Dam's average TDS, total nitrogen, and total phosphorus concentrations of 307 mg/L, 1.080 mg/L and 0.039 mg/L respectively.

Table 1. Statistical Summary of Lutz Dam's 2009 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	3	207	192	223	16
Total Ammonia as N	mg/L	3	0.030[1]	0.030[1]	0.030[1]	0.000
Bicarbonate (HCO_3)	mg/L	3	146	60	264	106
Calcium (Ca)	mg/L	3	26.8	20.2	38.0	9.8
Carbonate (CO_3)	mg/L	3	52	4	86	43
Chloride (Cl)	mg/L	3	3	3	4	1
Chlorophyll-a	µg/L	3	14.1	3.0	23.2	10.2
Specific Conductance	µmhos	3	504	469	561	50
Total Dissolved Solids	mg/L	3	307	298	325	15
Total Hardness as ($CaCO_3$)	mg/L	3	269	262	283	12
Hydroxide (OH)	mg/L	3	1.0[1]	1.0[1]	1.0[1]	0.0
Iron (Fe)	mg/L	3	0.052	0.050	0.057	0.004
Magnesium (Mg)	mg/L	3	49.1	45.8	51.4	2.9
Nitrate + Nitrite as N	mg/L	3	0.137	0.030[1]	0.350	0.185
Total Kjeldahl Nitrogen as N	mg/L	3	0.943	0.770	1.050	0.151
Total Nitrogen as N	mg/L	3	1.080	1.040	1.120	0.040
pH		3	9.29	8.38	9.78	0.79
Total Phosphorus as P	mg/L	3	0.039	0.037	0.042	0.003
Potassium (K)	mg/L	3	5.4	4.8	6.5	1.0
Sodium (Na)	mg/L	3	18.4	16.9	19.7	1.4
Sulfate (SO4)	mg/L	3	78	74	82	4

[1]Equal to the lower reporting limit

Limiting Nutrients: The three water quality samples indicate that Lutz Dam is phosphorus limited (Figure 7). The limiting nutrient assessment is based on the assumption that either nitrogen or phosphorus is limiting algal growth and that the ratio of total nitrogen as N to total phosphorus as P (N:P), by weight in the average algae is approximately 15 to 1. When the N:P ratio is less than 15:1, nitrogen is assumed to be the limiting nutrient and when it exceeds 15:1, the limiting nutrient is assumed to be phosphorus.

Trophic Status Assessment: Based on the chlorophyll-a, secchi disk transparency, and total phosphorus data collected in 2009, Lutz Dam's trophic status is estimated as eutrophic. The trophic status index (TSI) scores ranged from a low of 41 based on chlorophyll-a to a high of 89 based on total phosphorus (Figure 8).

Table 2. Statistical Summary of Water Quality Data[2] Collected from Reservoirs and Impoundments in the Rangeland Plains Ecological Region of North Dakota

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	522	283	54	982	131
Total Ammonia as N	mg/L	593	0.092	0.001[1]	2.440	0.183
Bicarbonate (HCO_3)	mg/L	522	295	14	1040	145
Calcium (Ca)	mg/L	522	52.3	4.7	163.0	27.3
Carbonate (CO_3)	mg/L	520	25	1[1]	197	29
Chloride (Cl)	mg/L	522	13	3[1]	75	9
Chlorophyll-a	µg/L	415	20.1	1.5[1]	218.0	27.0
Specific Conductance	µmhos	542	1621	173	5880	988
Total Dissolved Solids	mg/L	523	1107	100	5110	782
Total Hardness as ($CaCO_3$)	mg/L	522	396	45	2100	279
Hydroxide (OH)	mg/L	465	1.0	0.0[1]	1.0	0.2
Iron (Fe)	mg/L	523	0.193	0.007	4.110	0.349
Magnesium (Mg)	mg/L	522	64.5	5.6	412.0	54.0
Nitrate + Nitrite as N	mg/L	592	0.060	0.001[1]	0.790	0.102
Total Kjeldahl Nitrogen as N	mg/L	483	1.375	0.108	7.720	0.789
Total Nitrogen as N	mg/L	426	1.314	0.178	4.840	0.605
pH		542	8.55	6.73	9.87	0.55
Total Phosphorus as P	mg/L	599	0.128	0.004[1]	3.160	0.190
Potassium (K)	mg/L	522	13.8	2.6	39.2	6.5
Sodium (Na)	mg/L	522	217.2	3.0	932.0	171.6
Sulfate (SO4)	mg/L	520	573	1[1]	3210	519

[1]Equal to the lower reporting limit
[2]Data collected from 76 reservoirs between 1991 and 2010

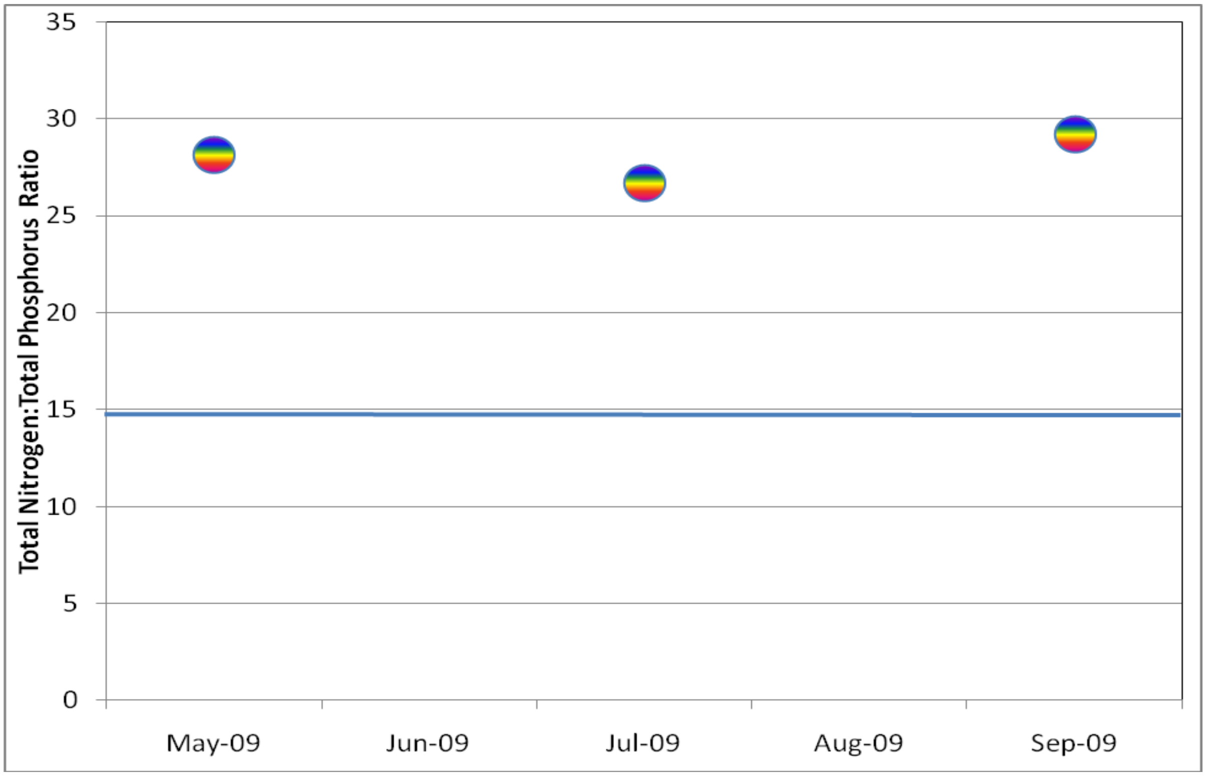

Figure 7. Lutz Dam's Total Nitrogen to Total Phosphorus Ratio

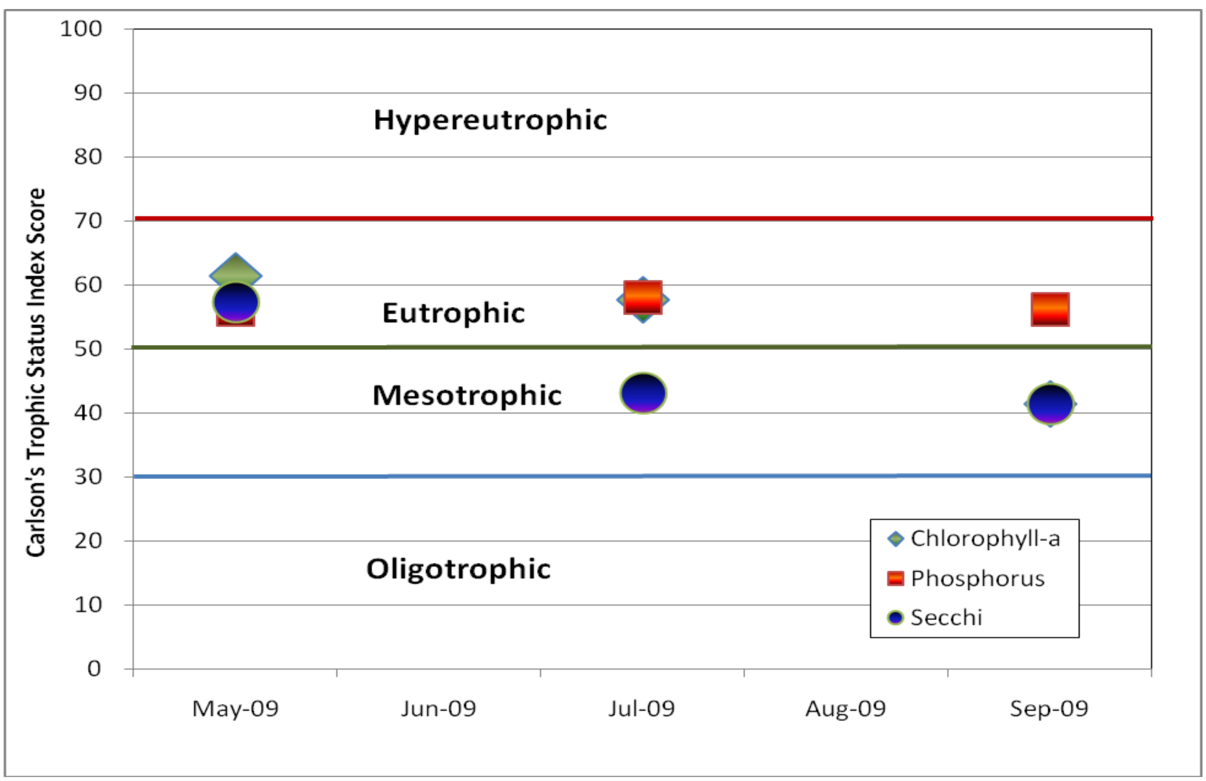

Figure 8. Lutz Dam's TSI Scores

Smishek Lake, Burke County

BACKGROUND

Location: Smishek Lake is an enhanced natural lake located approximately three miles north of Powers Lake North Dakota (Figure 1). The fishery is managed by the North Dakota Game and Fish Department. Fish species managed for are northern pike and yellow perch.

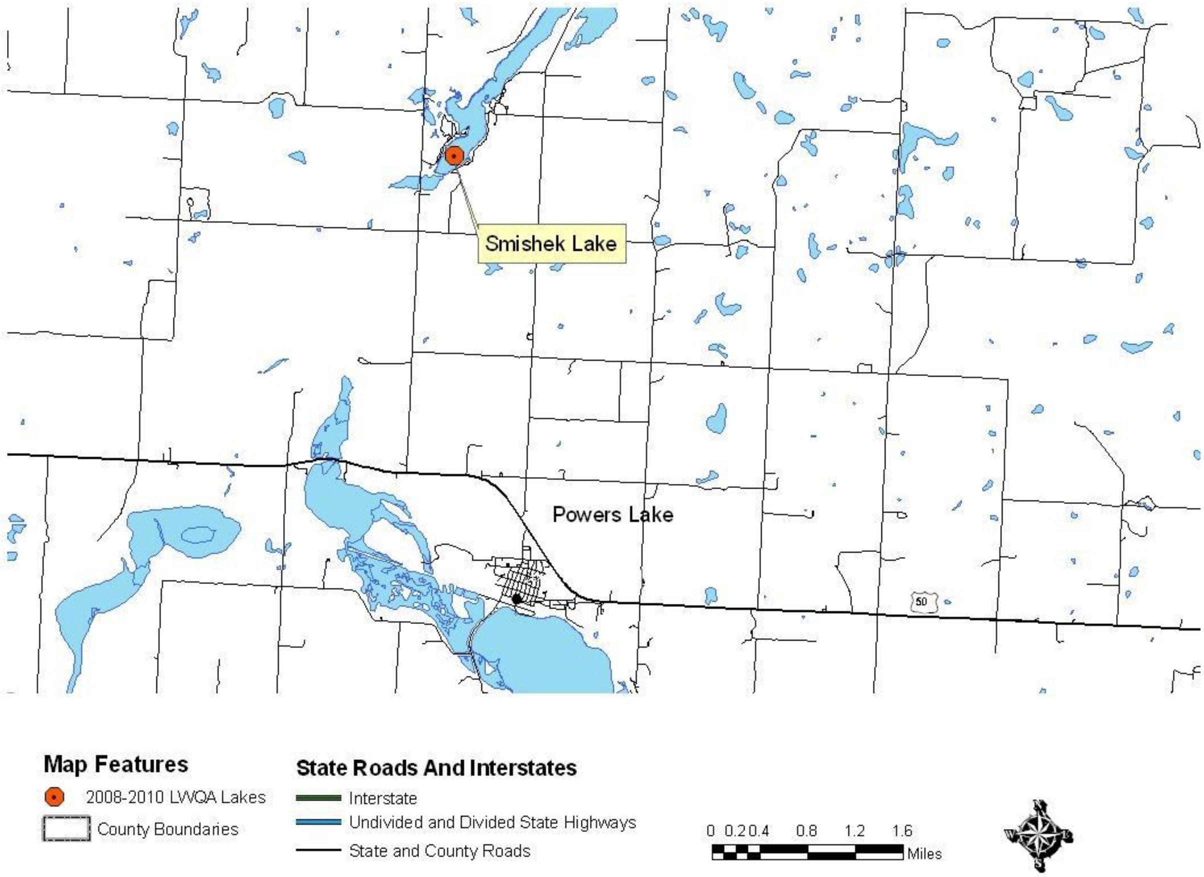

Figure 1. Location of Smishek Lake

Physiographic/Ecological Setting: Smishek Lake has a surface area of 190.2 acres, and average depth of 9.2 ft and a maximum depth of 26.7 ft. It is a long windswept lake with little to no shading or shelter from the ever present sun and northwest wind (Figure 2). The lake is located in the Northwestern Glaciated Plains Level III Ecoregion, which is part of the broader Rangeland Plains region (Figures 3 and 4).

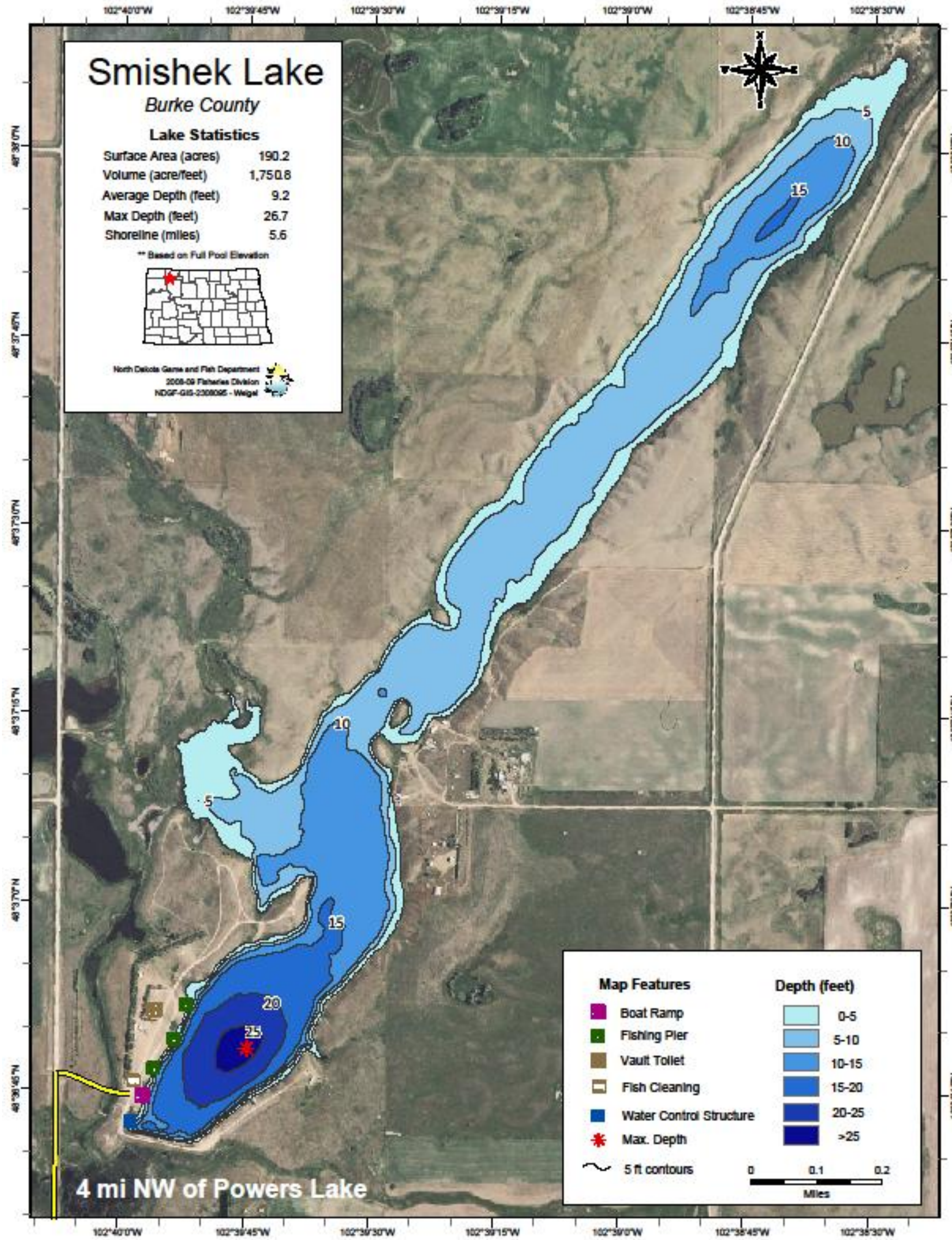

Figure 2. Contour Map of Smishek Lake (Map Courtesy of North Dakota Game and Fish Department)

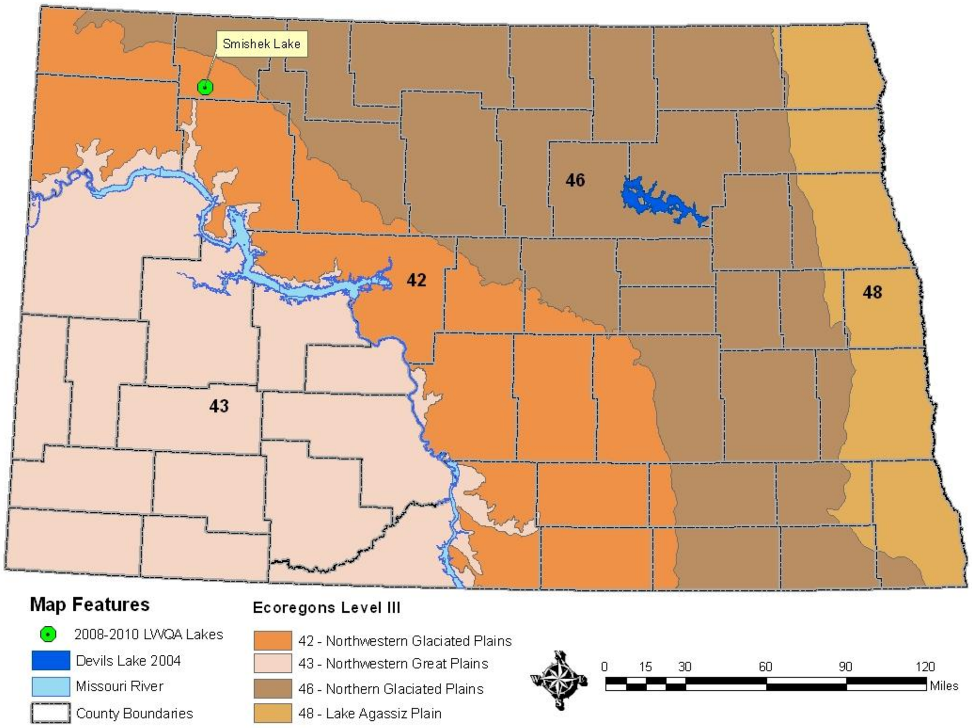

Figure 3. Smishek Lake's Location and the Level III Ecoregions

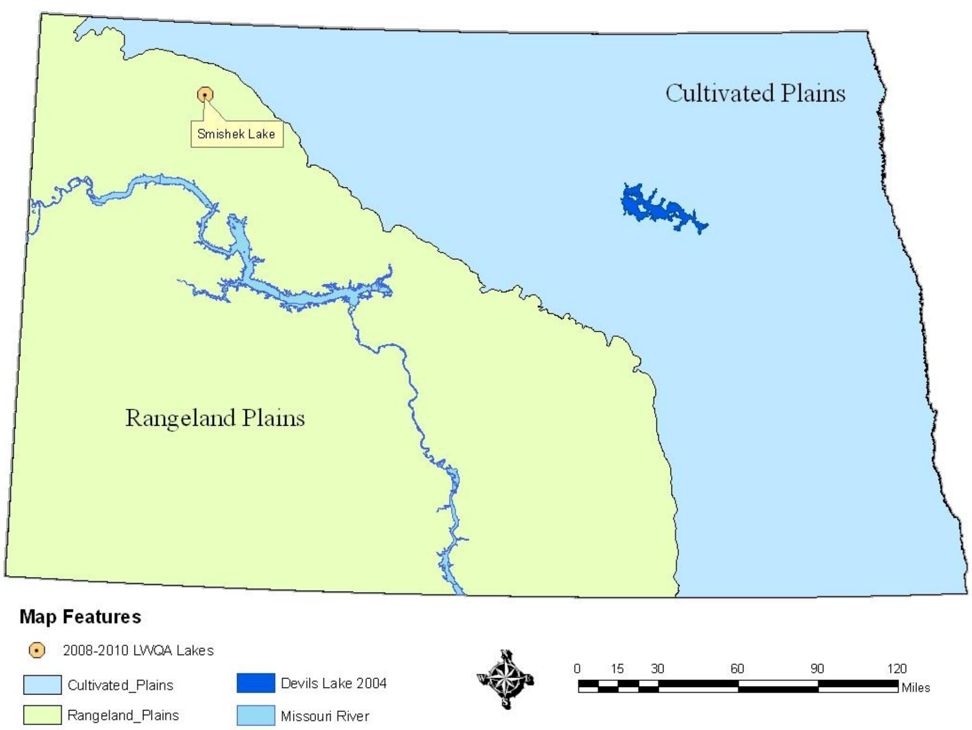

Figure 4. Smishek Lake's Location and the Cultivated and Rangeland Plans Regions

Recreational Facilities: Public facilities are managed by the local park board and include, camping, toilets, garbage pickup, fish cleaning station, and concrete boat ramp.

Water Quality Standards Classification: Smishek Lake is classified in the state "Standards of Quality for Waters of the State" (NDDoH, 2011) as a class 2 reservoir. Class 2 lakes or reservoirs are defined as a "cool water fishery" or "waters capable of supporting natural reproduction and growth of cool water fishes (e.g., northern pike and walleye) and associated aquatic biota. These waters are also capable of supporting the growth and marginal survival of cold water species and associated biota"

Historical Water Quality Sampling: Historical water quality data includes results from three samples collected from 1992 through 1993.

WATER QUALITY MONITORING RESULTS

The water quality assessment for Smishek Lake is presented in four general categories: 1) temperature and dissolved oxygen profile results; 2) general water quality characterization; 3) nutrient limitation; and 4) trophic status. Additionally, where appropriate, results have been compared to the regional and historical data.

Temperature and Dissolved Oxygen Profile Results: There were six temperature and dissolved oxygen profiles for Smishek Lake collected between 1992 and 2009. The profiles represent two time periods of 1992-1993 and 2009 (Figures 3 and 4).

The temperature and dissolved oxygen profiles show that during thermal stratification Smishek Lake experiences oxygen decay, and can drop below the state's water quality standard of 5 mg/L at depths greater than 20 feet. Of the profiles collected only two (7-15-1992 and 2-23-1993) experienced thermal stratification and resulting dissolved oxygen decay. While the decline of dissolved oxygen during these periods is concerning, dissolved oxygen concentrations remained high enough to maintain aquatic life in the upper 20 feet of the water column.

General Water Quality: Data collected in 2009 indicate that Smishek Lake is well buffered with total alkalinity as $CaCO_3$ concentrations ranging from 318 to 371 mg/L (Table 1). The lake is sodium bicarbonate dominated with an average sodium concentration of 225 mg/L and an average bicarbonate concentration of 357 mg/L. The average total dissolved solids concentration and specific conductance measurements for the 2009 sampling period were 1027 mg/L and 1507 µmhos/cm, respectively and the average total nitrogen as N and total phosphorus as P concentrations were 0.679 mg/L and 0.013 mg/L, respectively.

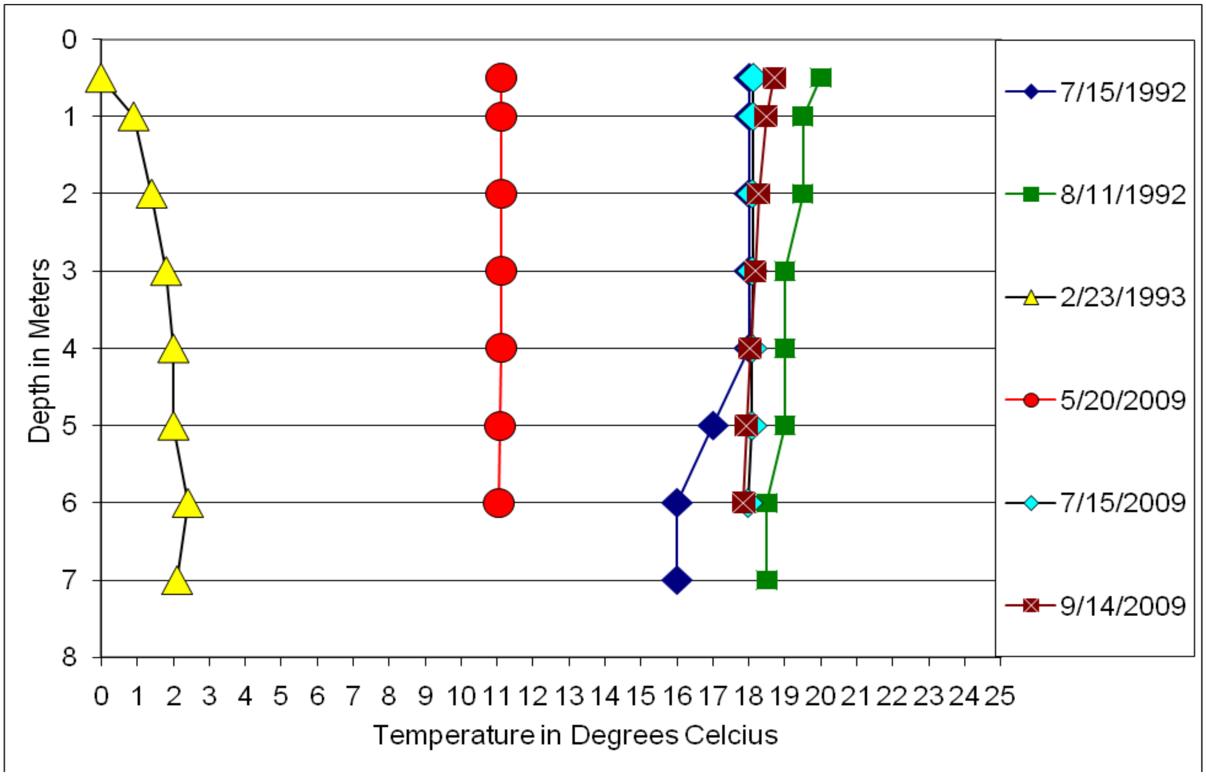

Figure 5. Temperature Profiles for Smishek Lake

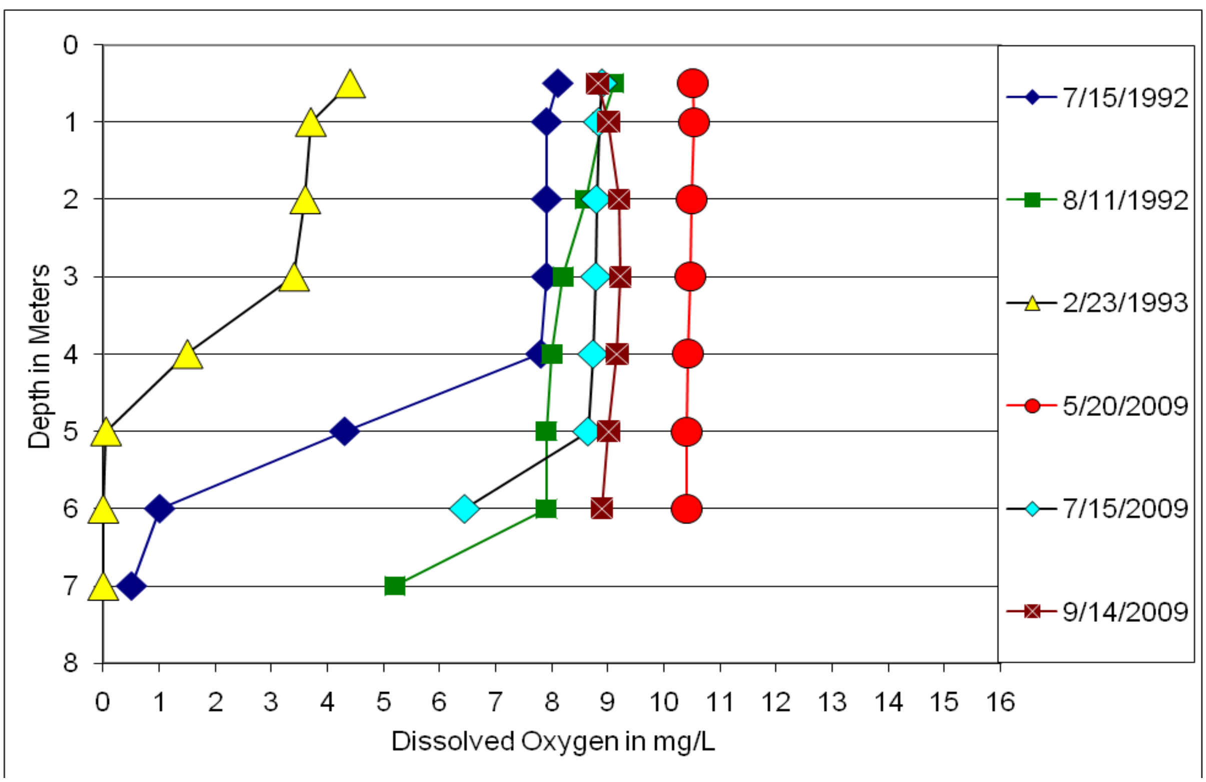

Figure 6. Dissolved Oxygen Profiles for Smishek Lake

Table 1. Statistical Summary of Smishek Lake's 2009 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	3	338	318	371	29
Total Ammonia as N	mg/L	3	0.030[1]	0.030[1]	0.030[1]	0.000
Bicarbonate (HCO_3)	mg/L	3	357	305	418	57
Calcium (Ca)	mg/L	3	40.3	27.9	58.3	16.0
Carbonate (CO_3)	mg/L	3	28	17	41	12
Chloride (Cl)	mg/L	3	7	7	8	0
Chlorophyll-a	µg/L	2	7.8	6.4	9.1	1.9
Specific Conductance	µmhos	3	1507	1470	1530	32
Total Dissolved Solids	mg/L	3	1027	1000	1050	25
Total Hardness as ($CaCO_3$)	mg/L	3	393	365	442	42
Hydroxide (OH)	mg/L	3	1.0[1]	1.0[1]	1.0[1]	0.0
Iron (Fe)	mg/L	3	0.110	0.050	0.215	0.091
Magnesium (Mg)	mg/L	3	71.1	67.7	73.6	3.0
Nitrate + Nitrite as N	mg/L	3	0.030[1]	0.030[1]	0.030[1]	0.000
Total Kjeldahl Nitrogen as N	mg/L	3	0.649	0.573	0.708	0.069
Total Nitrogen as N	mg/L	3	0.679	0.603	0.738	0.069
pH		3	8.65	8.54	8.75	0.11
Total Phosphorus as P	mg/L	3	0.013	0.004[1]	0.024	0.010
Potassium (K)	mg/L	3	9.7	9.4	10.2	0.4
Sodium (Na)	mg/L	3	225.0	223.0	228.0	2.6
Sulfate (SO4)	mg/L	3	469	456	488	17

[1]Equal to the lower reporting limit

When comparing historical water quality data (1992-1993) to the 2009 water quality data, it appears that general water quality constituents have decreased. For example, the historical average bicarbonate and sodium concentrations were 481 mg/L and 270 mg/L, respectively, compared to the 2009 averages of 357 mg/L and 225 mg/L (Tables 1 and 2). Nutrient concentrations appear to be following a similar trend with total nitrogen and total phosphorus concentrations declining from 0.820 mg/L and 0.021 mg/L, respectively, to 0.679 mg/L and for total nitrogen and 0.013 mg/L for total phosphorus.

Compared to the average natural lake in the Rangeland Plans region, Smishek Lake is fresher and less eutrophic than most (Tables 1 and 3). For example, the regional average TDS, total nitrogen, and total phosphorus concentrations are 1466 mg/L, 1.794 mg/L, and 0.233 mg/L respectively, compared to Smishek Lake's 2009 average TDS, total nitrogen, and total phosphorus concentrations of 1027 mg/L, 0.679 mg/L and 0.013 mg/L, respectively.

L**imiting Nutrients:** The six water quality samples collected between 1992 and 2009 indicate that Smishek Lake is phosphorus limited (Figure 7). The difference between the ratios in 1992-93 and 2009 also indicate that the trend is towards greater phosphorus limitation.

Table 2. Statistical Summary of Smishek Lake's 1992-1993 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	3	420	377	501	70
Total Ammonia as N	mg/L	3	0.082	0.015	0.196	0.099
Bicarbonate (HCO_3)	mg/L	3	481	411	612	114
Calcium (Ca)	mg/L	3	35.9	32.3	42.5	5.8
Carbonate (CO_3)	mg/L	3	16	1[1]	27	14
Chloride (Cl)	mg/L	3	13	11	15	2
Chlorophyll-a	µg/L	2	7.8	4.6	11.0	4.5
Specific Conductance	µmhos	3	1860	1685	2190	286
Total Dissolved Solids	mg/L	3	1233	1040	1490	232
Total Hardness as ($CaCO_3$)	mg/L	3	440	388	510	63
Hydroxide (OH)	mg/L	1	1.0[1]	1.0[1]	1.0[1]	0.0
Iron (Fe)	mg/L	3	0.040	0.025	0.052	0.014
Magnesium (Mg)	mg/L	3	85.2	74.7	98.1	11.9
Nitrate + Nitrite as N	mg/L	2	0.030	0.006	0.053	0.033
Total Kjeldahl Nitrogen as N	mg/L	2	0.790	0.780	0.800	0.014
Total Nitrogen as N	mg/L	2	0.820	0.786	0.853	0.047
pH		3	8.47	8.22	8.73	0.26
Total Phosphorus as P	mg/L	3	0.021	0.001[1]	0.038	0.019
Potassium (K)	mg/L	3	10.4	9.9	11.0	0.6
Sodium (Na)	mg/L	3	270.3	244.0	306.0	32.0
Sulfate (SO4)	mg/L	3	570	443	721	141

[1]Equal to the lower reporting limit

The limiting nutrient assessment is based on the assumption that either nitrogen or phosphorus is limiting algal growth and that the ratio of total nitrogen as N to total phosphorus as P (N:P), by weight in algae is approximately 15 to 1. When the N:P ratio is less than 15:1, nitrogen is assumed to be the limiting nutrient and when it exceeds 15:1, the limiting nutrient is assumed to be phosphorus.

Trophic Status Assessment: Based on the chlorophyll-a, secchi disk transparency, and total phosphorus data collected in 2009, Smishek Lake's trophic status is estimated as eutrophic. The trophic status index (TSI) scores ranged from a low of 14 based on phosphorus to a high of 59 based on secchi disk (Figure 8).

A total of six total phosphorus samples, five chlorophyll-a samples and five secchi disk transparency measurements collected during the open water periods from 1992-93 and 2009 were available to evaluate trends in the trophic status of Smishek Lake. While not conclusive the limited data indicates Smishek Lake is stable and healthy.

Table 3. Statistical Summary of Water Quality Data[2] Collected from Natural and Enhanced Lakes in the Rangeland Plains Ecological Region of North Dakota

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	383	513	111	4770	487
Total Ammonia as N	mg/L	494	0.105	0.001[1]	2.230	0.229
Bicarbonate (HCO_3)	mg/L	383	469	60	2990	320
Calcium (Ca)	mg/L	384	41.1	0.5	282.0	34.4
Carbonate (CO_3)	mg/L	377	79	1[1]	1420	148
Chloride (Cl)	mg/L	383	44	3[1]	1070	103
Chlorophyll-a	µg/L	346	22.5	1.5[1]	292.0	37.4
Specific Conductance	µmhos	383	2028	424	20100	1976
Total Dissolved Solids	mg/L	383	1466	227	18200	1717
Total Hardness as ($CaCO_3$)	mg/L	384	529	74	2370	295
Hydroxide (OH)	mg/L	322	1.0	0.0[1]	1.0	0.2
Iron (Fe)	mg/L	385	0.245	0.001[1]	7.070	0.543
Magnesium (Mg)	mg/L	384	103.6	8.5	567.0	70.9
Nitrate + Nitrite as N	mg/L	491	0.040	0.001[1]	0.54	0.054
Total Kjeldahl Nitrogen as N	mg/L	463	1.876	0.080	8.500	1.073
Total Nitrogen as N	mg/L	401	1.794	0.240	5.520	0.897
pH		383	8.80	7.40	9.87	0.36
Total Phosphorus as P	mg/L	501	0.233	0.002[1]	1.940	0.336
Potassium (K)	mg/L	384	34.0	3.1	356.0	37.0
Sodium (Na)	mg/L	384	299.6	16.9	4680.0	514.5
Sulfate (SO4)	mg/L	383	625	34	10500	885

[1]Equal to the lower reporting limit
[2]Data collected from 64 natural and enhanced Lakes between 1991 and 2010

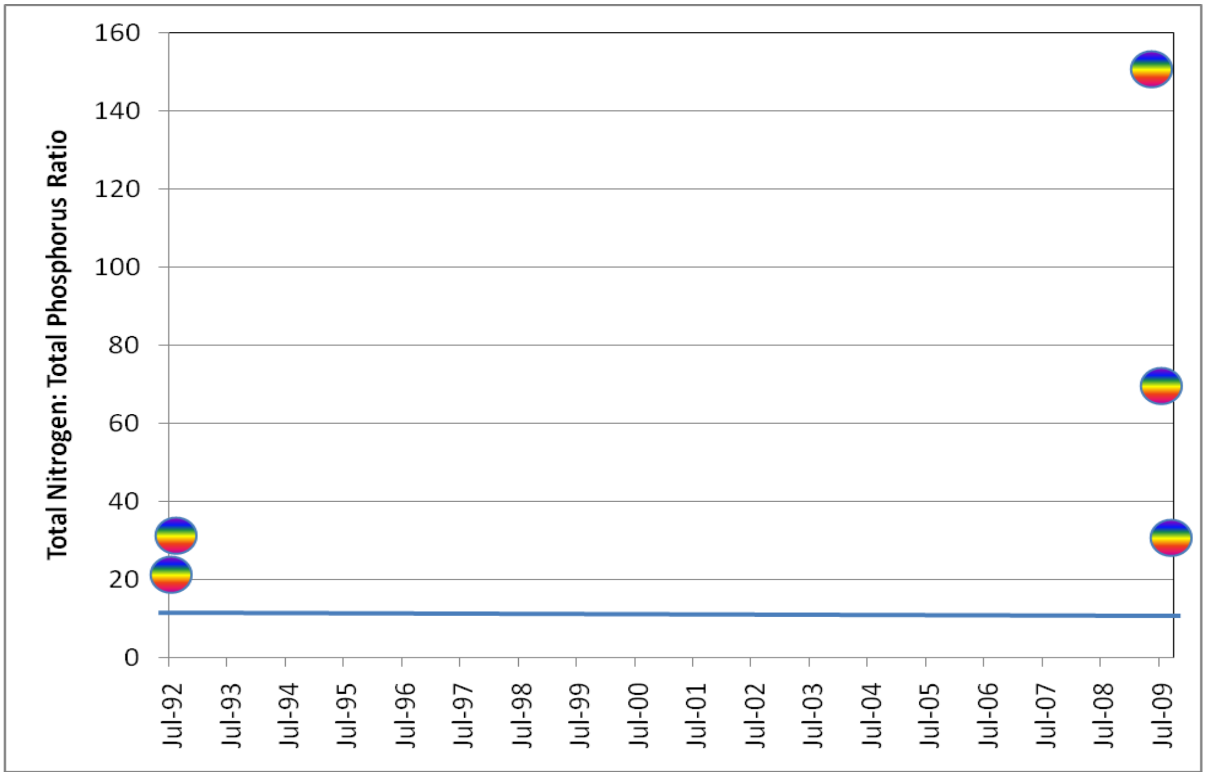

Figure 7. Smishek Lake's Total Nitrogen to Total Phosphorus Ratio

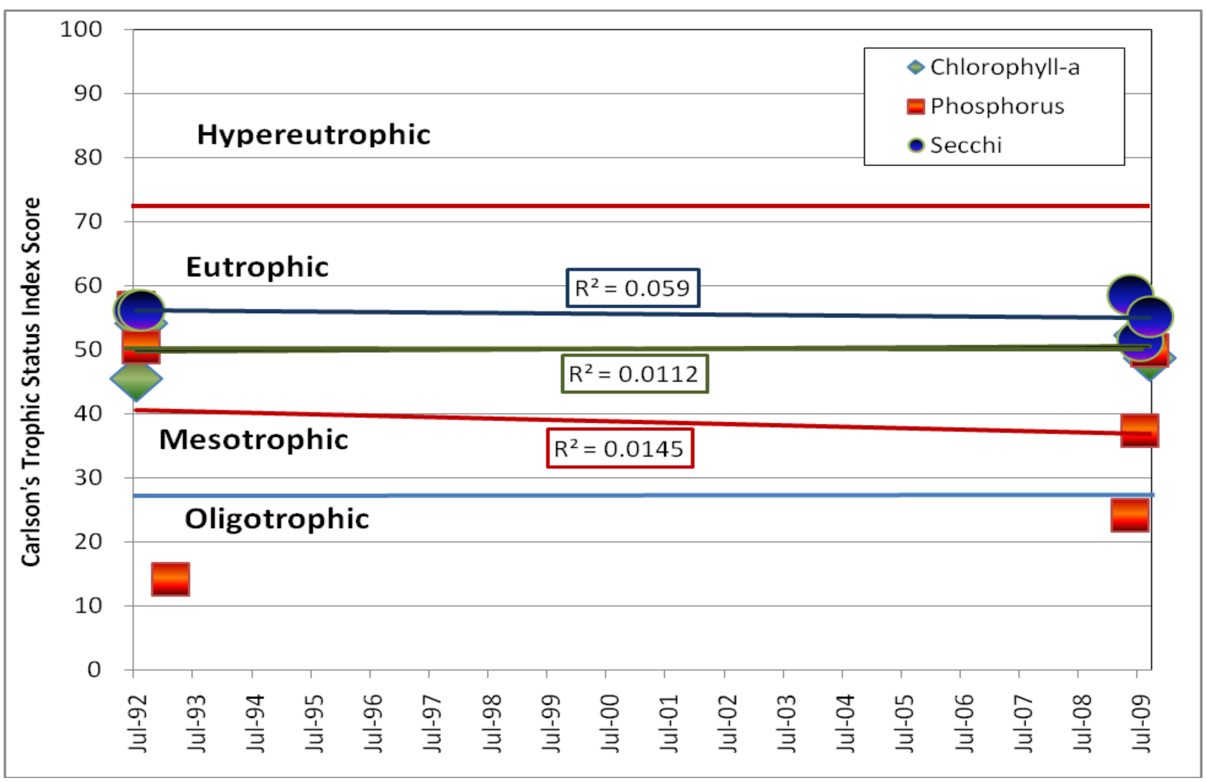

Figure 8. Smishek Lake's TSI Scores

Mitchell Lake, Burleigh County

BACKGROUND

Location: Mitchell Lake is a shallow natural lake located two couple miles northwest of Wing, North Dakota (Figure 1). The fishery is managed by the North Dakota Game and Fish. Fish species managed for are northern pike and yellow perch.

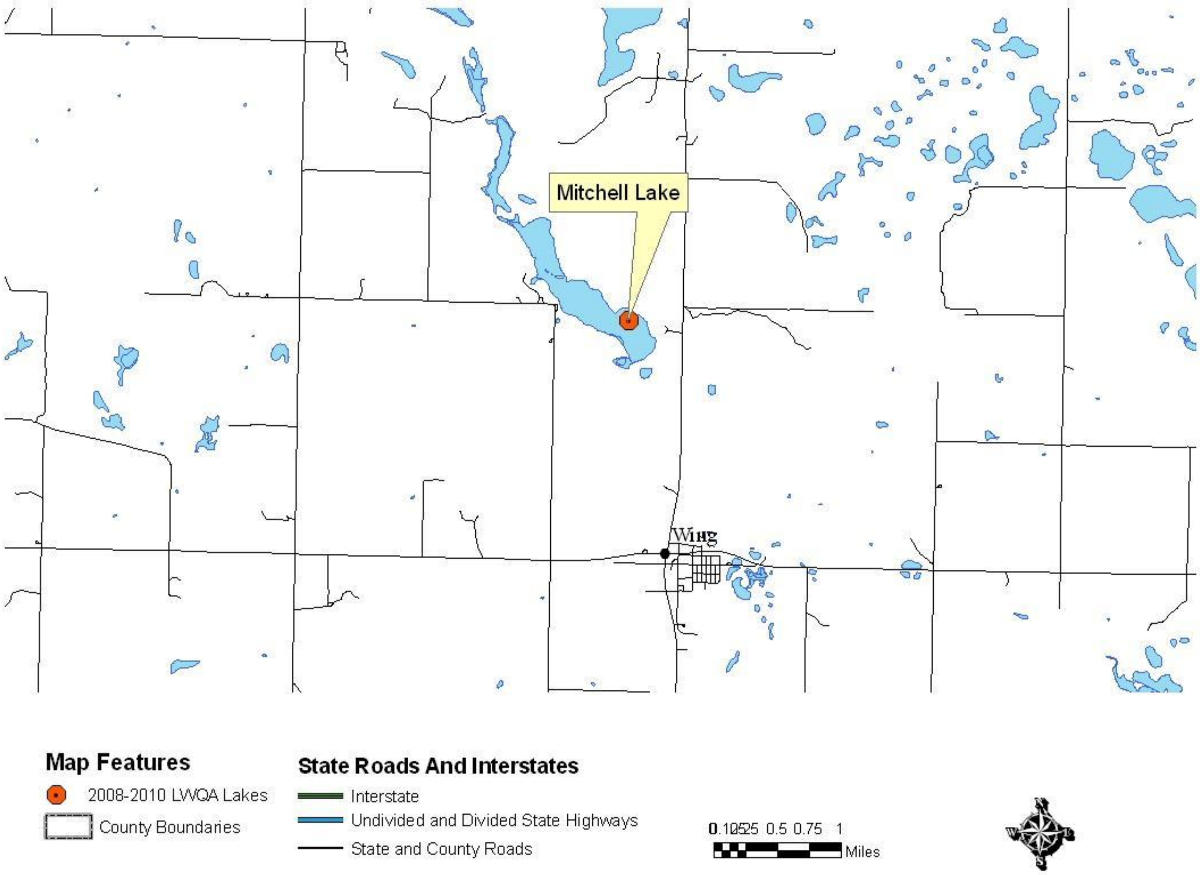

Figure 1. Location of Mitchell Lake

Physiographic/Ecological Setting: Mitchell Lake has a surface area of 196 acres, a maximum depth of 12 ft and an average depth 6.9 ft (Figure 2). The lake is located within the Northwestern Glaciated Plains (NWGP) Level III Ecoregion, which is part of the broader Rangeland Plains region (Figures 3 and 4).

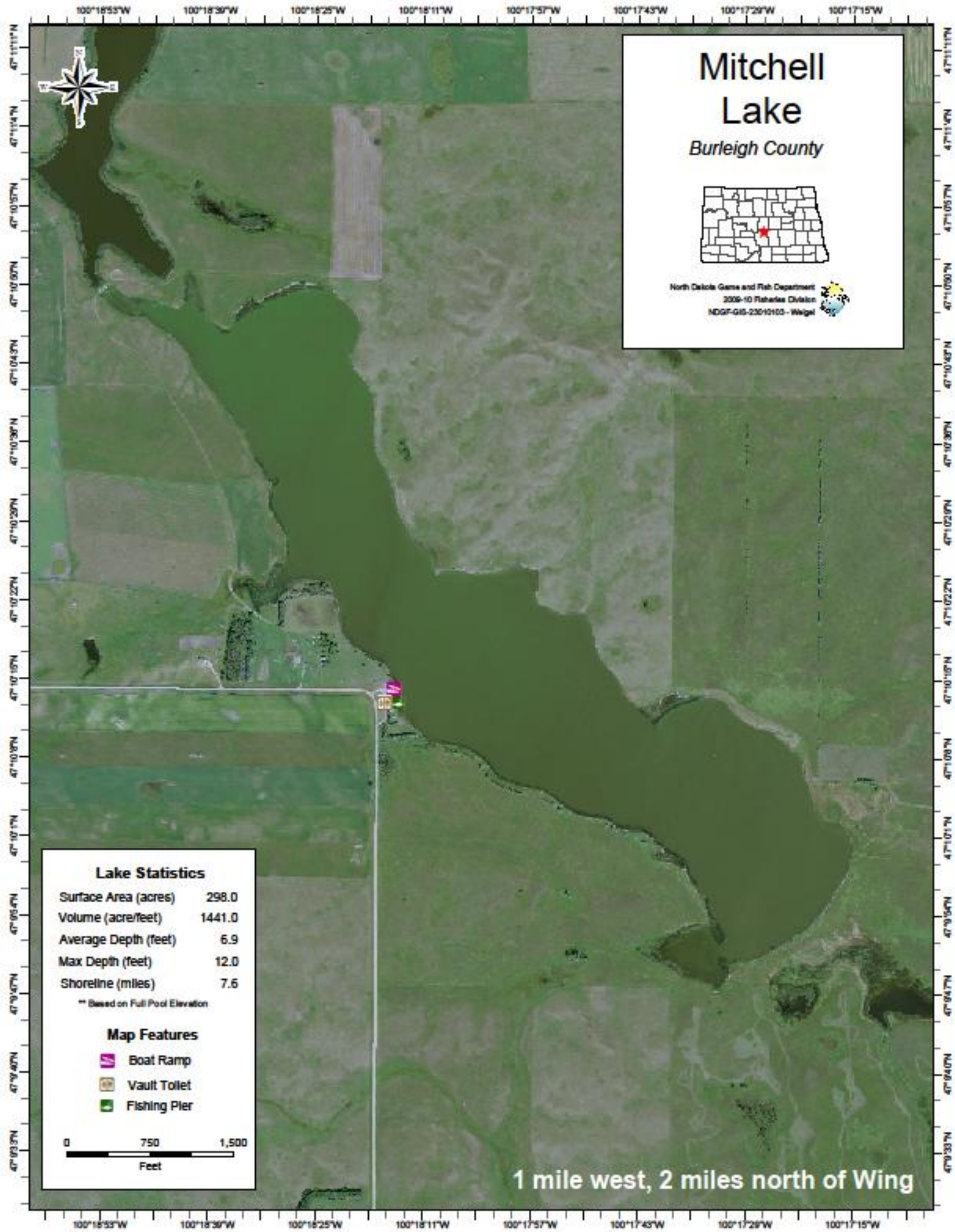

Figure 2. Aerial View of Mitchell Lake (Map Courtesy of North Dakota Game and Fish Department)

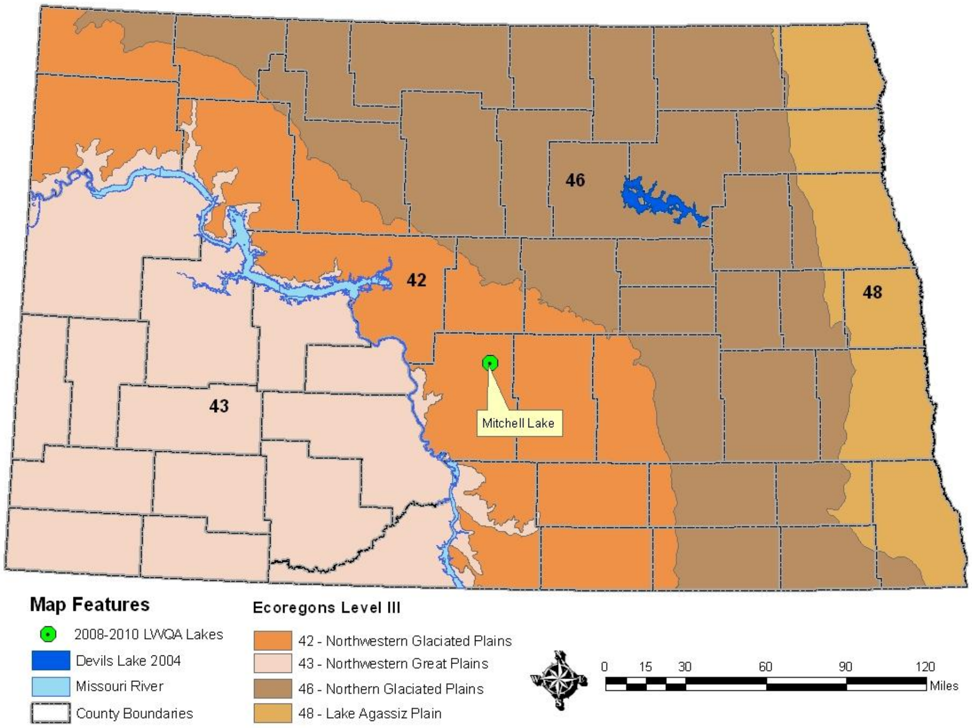

Figure 3. Mitchell Lake's Location and the Level III Ecoregions

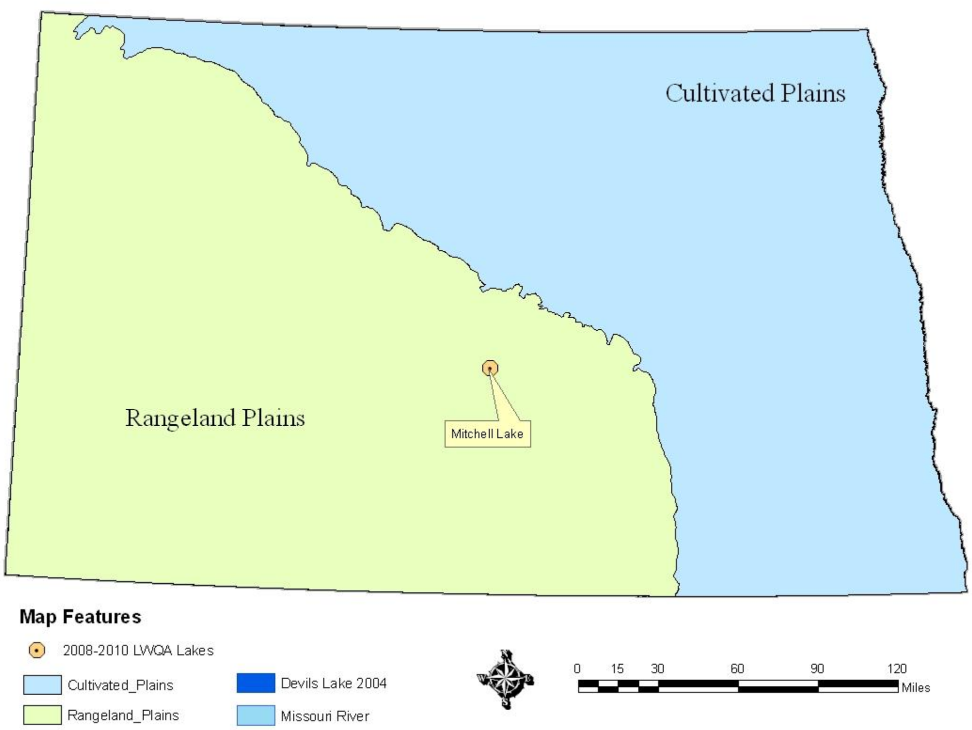

Figure 4. Mitchell Lake Location and the Cultivated and Rangeland Plans Regions

Recreational Facilities: Recreational facilities at Mitchell Lake include a cement boat ramp, boat and vehicle parking, a couple primitive camping spots, fishing pier, and outdoor toilets.

Water Quality Standards Classification: Mitchell Lake is classified in the state "Standards of Quality for Waters of the State" (NDDoH, 2011) as a class 3 lake. Class 3 lakes or reservoirs are defined as a "warm water fishery" or "waters capable of supporting natural reproduction and growth of warm water fishes (e.g., largemouth bass and bluegill) and associated aquatic biota. Some cool water species may also be present."

Historical Water Quality Sampling: No historical water quality data.

WATER QUALITY MONITORING RESULTS

The water quality assessment for Mitchell Lake is presented in four general categories: 1) temperature and dissolved oxygen profile results; 2) general water quality characterization; 3) nutrient limitation; and 4) trophic status. Additionally, where appropriate, results have been compared to regional data.

Temperature and Dissolved Oxygen Profile Results: There are two temperature and dissolved oxygen profiles for Mitchell Lake collected in 2008 (Figures 5 and 6). The profile data shows that Mitchell Lake was not thermally stratification during the open water period. Additionally the during the open water period the lake remained well enough oxygenated to support aquatic life.

General Water Quality: Data collected in 2008 indicate that Mitchell Lake is well buffered with total alkalinity as $CaCO_3$ concentrations ranging from 802 to 812 mg/L (Table 1). The lake is sodium sulfate dominated with an average sodium concentration of 629 mg/L and an average sulfate concentration of 1043 mg/L. The average total dissolved solids concentration and specific conductance measurement for 2008 sampling period were 2370 mg/L and 3320 µmhos/cm, respectively, and average total nitrogen as N and total phosphorus as P concentrations were 3.86 mg/L and 0.3 mg/L, respectively.

When compared to the regional average water quality for natural lakes in the Rangeland Plans, Mitchell Lake is more mineralized and eutrophic then most (Table 3). For example, the regional average TDS, total nitrogen, and total phosphorus concentrations are 1466 mg/L, 1.794 mg/L, and 0.233 mg/L respectively, compared to Mitchell Lake's average TDS, total nitrogen, and total phosphorus concentrations of 2370 mg/L, 3.86 mg/L and 0.30 mg/L respectively.

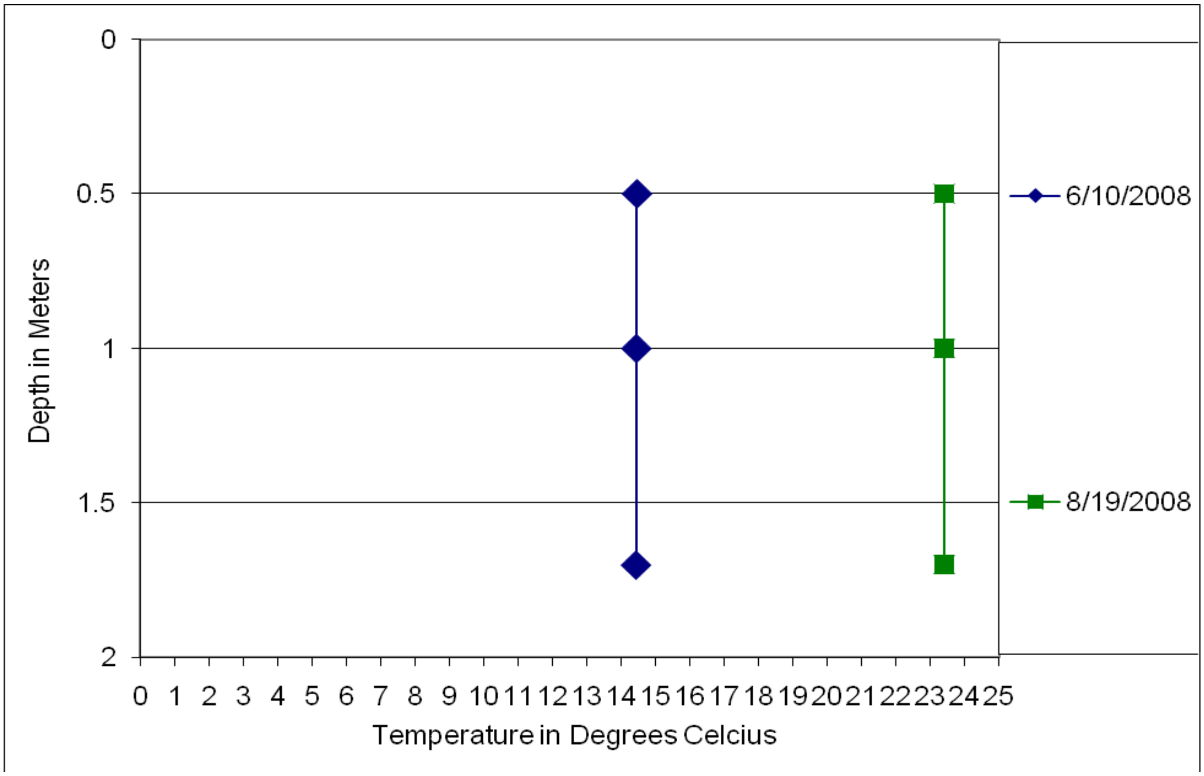

Figure 5. Temperature Profiles for Mitchell Lake

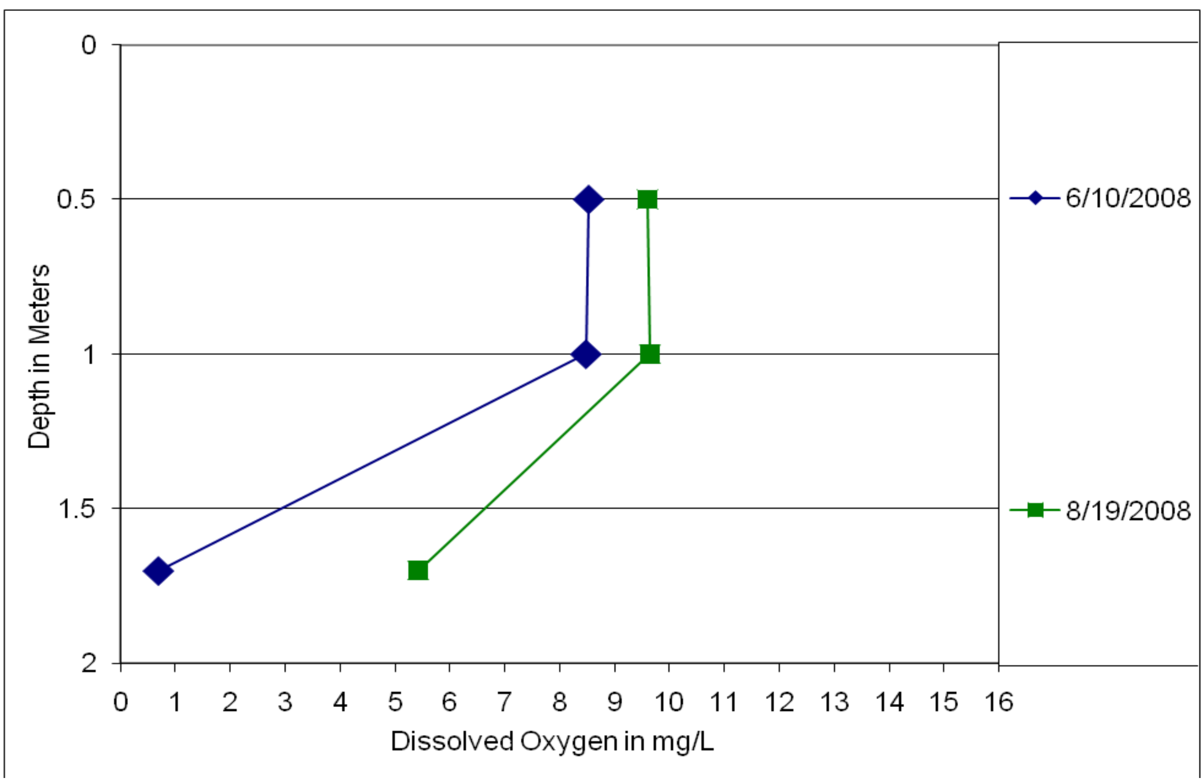

Figure 6. Dissolved Oxygen Profiles for Mitchell Lake

1. Statistical Summary of Mitchell Lake's 2008 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	2	807	802	812	7
Total Ammonia as N	mg/L	2	0.404	0.030[1]	0.778	0.529
Bicarbonate (HCO_3)	mg/L	2	754	652	856	144
Calcium (Ca)	mg/L	2	23.3	19.1	27.4	5.9
Carbonate (CO_3)	mg/L	2	113	60	166	75
Chloride (Cl)	mg/L	2	28	26	31	4
Chlorophyll-a	µg/L	2	32.2	4.5	59.8	39.1
Specific Conductance	µmhos	2	3320	3240	3400	113
Total Dissolved Solids	mg/L	2	2370	2280	2460	127
Total Hardness as ($CaCO_3$)	mg/L	2	515	501	529	20
Hydroxide (OH)	mg/L	2	1.0[1]	1.0[1]	1.0[1]	0.0
Iron (Fe)	mg/L	2	3.840	0.609	7.070	4.569
Magnesium (Mg)	mg/L	2	111.0	105.0	117.0	8.5
Nitrate + Nitrite as N	mg/L	2	0.125	0.030[1]	0.220	0.134
Total Kjeldahl Nitrogen as N	mg/L	2	3.735	3.300	4.170	0.615
Total Nitrogen as N	mg/L	2	3.860	3.330	4.390	0.750
pH		2	8.91	8.64	9.17	0.37
Total Phosphorus as P	mg/L	2	0.300	0.137	0.463	0.231
Potassium (K)	mg/L	2	49.9	44.9	54.8	7.0
Sodium (Na)	mg/L	2	629.0	604.0	654.0	35.4
Sulfate (SO4)	mg/L	2	1043	986	1100	81

[1]Equal to the lower reporting limit

Limiting Nutrients: The two water quality samples results for Mitchell Lake are inconclusive in determining nutrient is limitation (Figure 7). Basically, there is so much nitrogen and phosphorus in the system that only sunlight and temperature could limit primary productivity.

The limiting nutrient assessment is based on the assumption that either nitrogen or phosphorus is limiting algal growth, and that the ratio of total nitrogen as N to total phosphorus as P (N:P), by weight in the average algae, is approximately 15 to 1. When the N:P ratio is less than 15:1, nitrogen is assumed to be the limiting nutrient and when it exceeds 15:1, the limiting nutrient is assumed to be phosphorus.

Trophic Status Assessment: Based on the chlorophyll-a, secchi disk transparency, and total phosphorus data collected in 2008, Mitchell Lake's trophic condition is estimated as hypereutrophic. The trophic Status Index scores ranged from a low of 45 based on chlorophyll-a to a high of 93 based on total phosphorus (Figure 8).

Table 2. Statistical Summary of Water Quality Data[2] Collected from Natural and Enhanced Lakes in the Rangeland Plains Ecological Region of North Dakota

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	383	513	111	4770	487
Total Ammonia as N	mg/L	494	0.105	0.001[1]	2.230	0.229
Bicarbonate (HCO_3)	mg/L	383	469	60	2990	320
Calcium (Ca)	mg/L	384	41.1	0.5	282.0	34.4
Carbonate (CO_3)	mg/L	377	79	1[1]	1420	148
Chloride (Cl)	mg/L	383	44	3[1]	1070	103
Chlorophyll-a	µg/L	346	22.5	1.5[1]	292.0	37.4
Specific Conductance	µmhos	383	2028	424	20100	1976
Total Dissolved Solids	mg/L	383	1466	227	18200	1717
Total Hardness as ($CaCO_3$)	mg/L	384	529	74	2370	295
Hydroxide (OH)	mg/L	322	1.0	0.0[1]	1.0	0.2
Iron (Fe)	mg/L	385	0.245	0.001[1]	7.070	0.543
Magnesium (Mg)	mg/L	384	103.6	8.5	567.0	70.9
Nitrate + Nitrite as N	mg/L	491	0.04046	0.001[1]	0.54	0.054
Total Kjeldahl Nitrogen as N	mg/L	463	1.876	0.080	8.500	1.073
Total Nitrogen as N	mg/L	401	1.794	0.240	5.520	0.897
pH		383	8.80	7.40	9.87	0.36
Total Phosphorus as P	mg/L	501	0.233	0.002[1]	1.940	0.336
Potassium (K)	mg/L	384	34.0	3.1	356.0	37.0
Sodium (Na)	mg/L	384	299.6	16.9	4680.0	514.5
Sulfate (SO4)	mg/L	383	625	34	10500	885

[1]Equal to the lower reporting limit
[2]Data collected from 64 natural and enhanced Lakes between 1991 and 2010

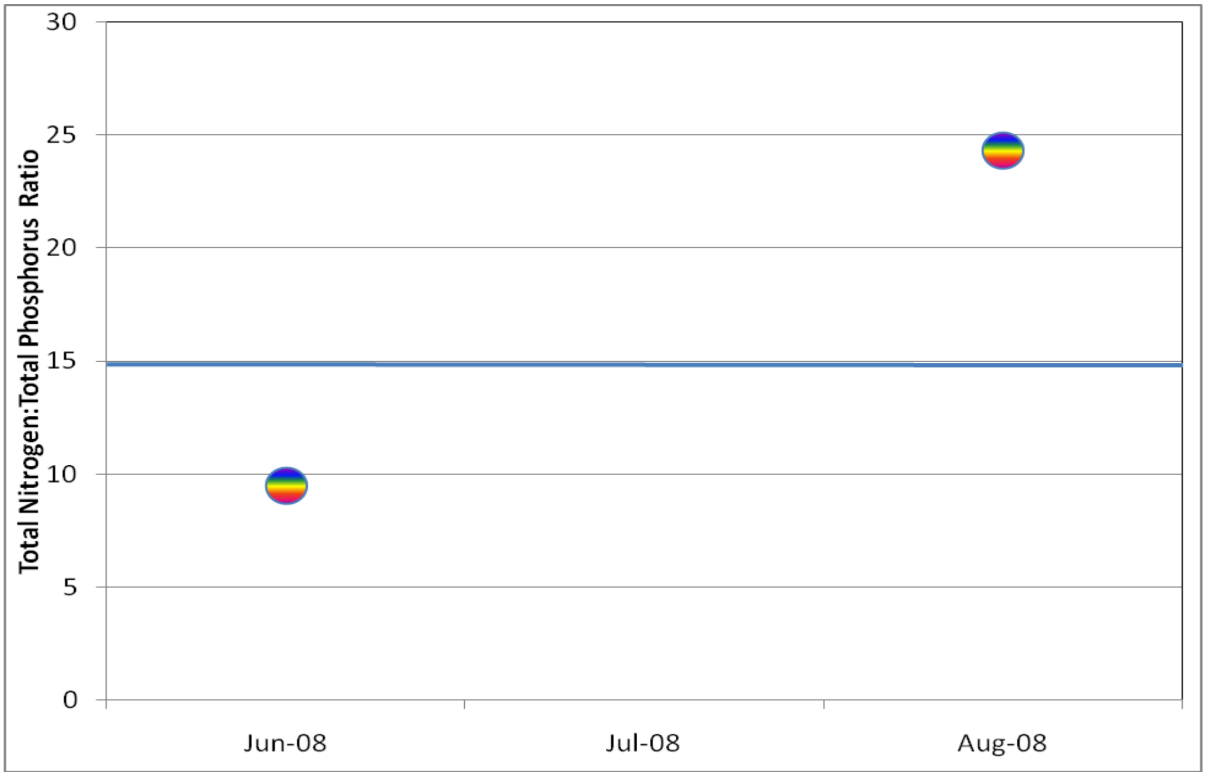

Figure 7. Mitchell Lake's Total Nitrogen to Total Phosphorus Ratio

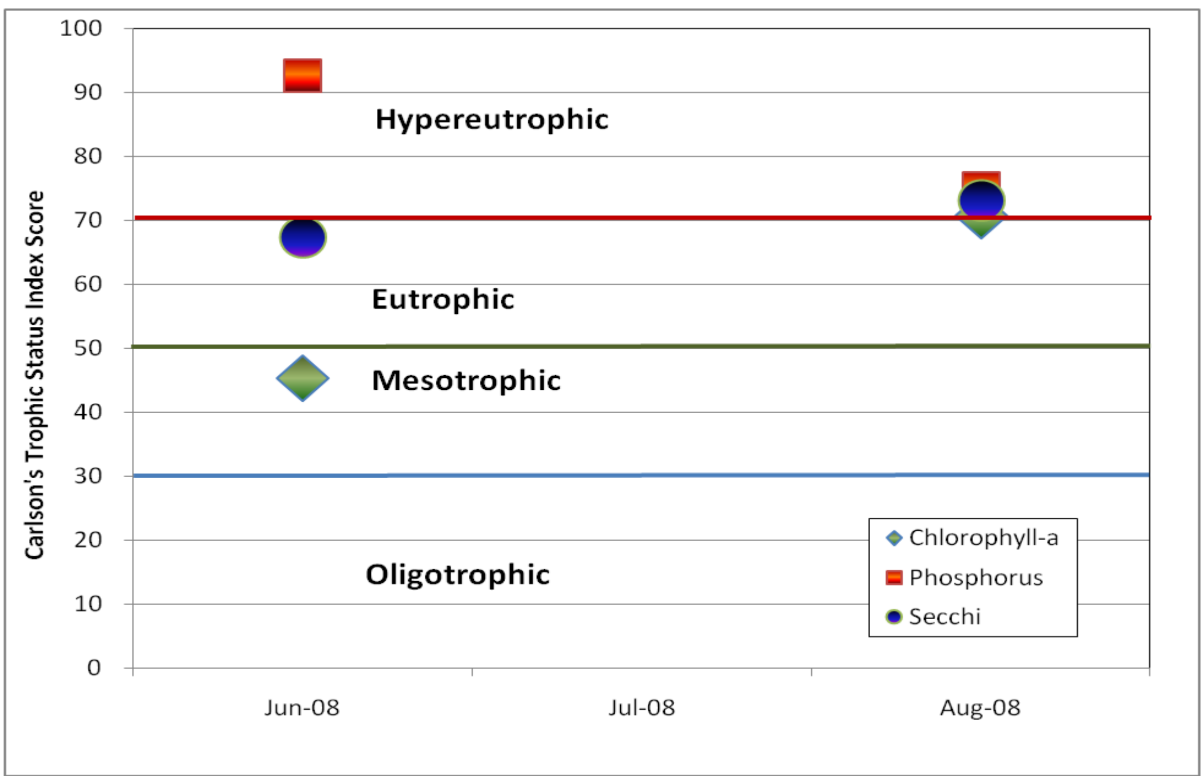

Figure 8. Mitchell Lake's TSI Scores

Casselton Reservoir, Cass County

BACKGROUND

Location: The Casselton Reservoir is a small impoundment on western edge of Casselton, North Dakota (Figure 1). Originally a railroad water reservoir the pond now serves as the principle water based recreation resource for the community. The fishery is managed by the North Dakota Game and Fish Department (NDG&F). Fish species recently stocked by the NDG&F are walleye, rainbow trout, bluegill, largemouth bass, and yellow perch.

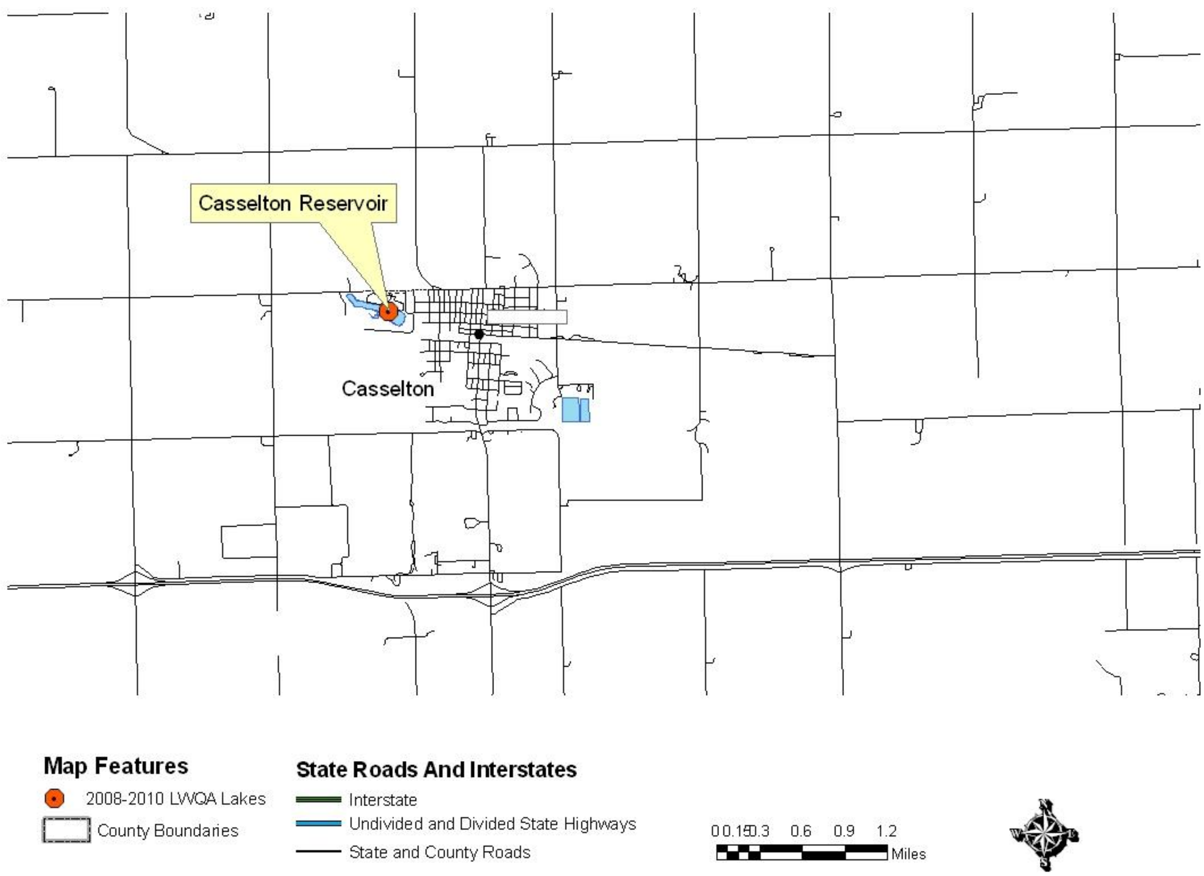

Figure 1. Location of Casselton Reservoir

Physiographic/Ecological Setting: Casselton Reservoir has a surface area of 16.8 acres, a maximum depth of 13.2 ft, and an average depth of 9.4 feet (Figure 2). The reservoir is located in the Lake Agassiz Plains Level III Ecoregion, which is part of the broader Cultivated Plains region (Figures 3 and 4).

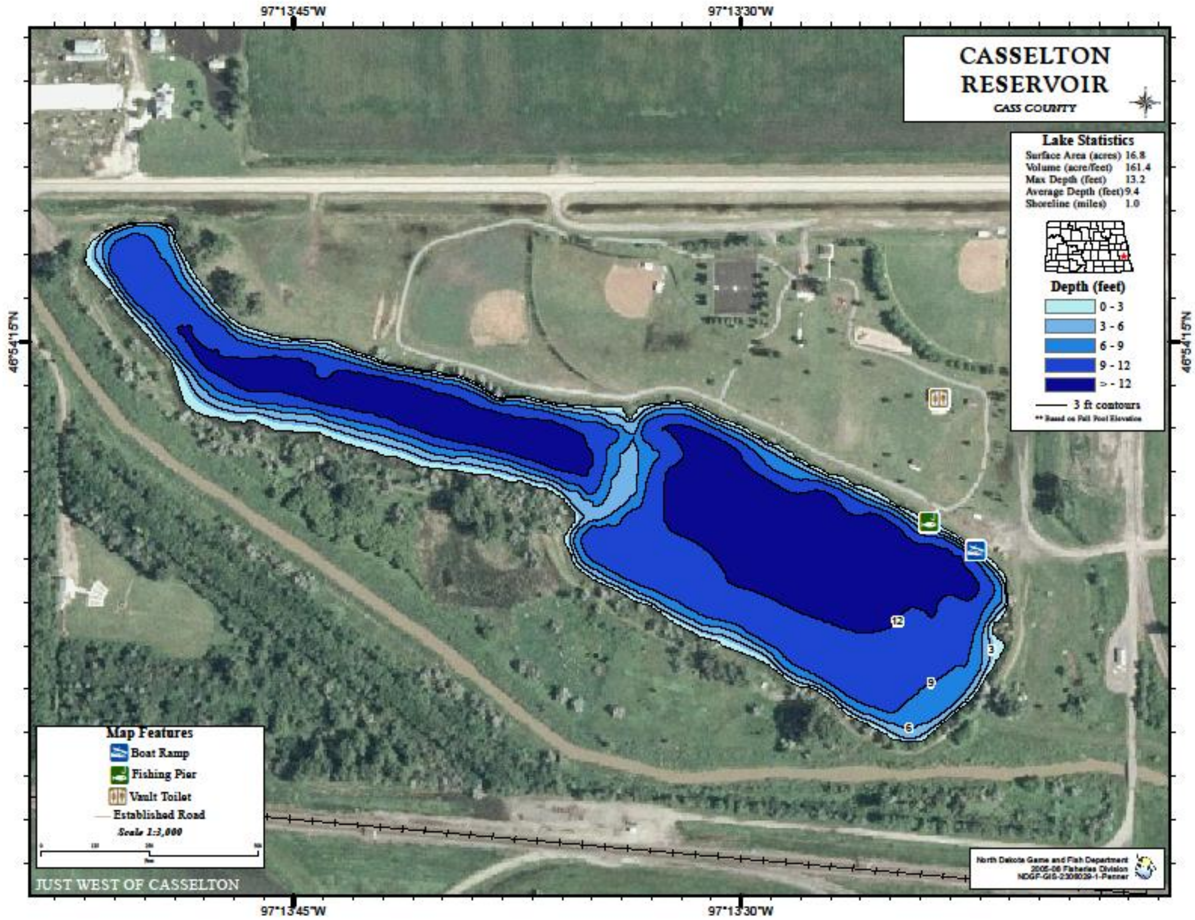

Figure 2. Contour Map of Casselton Reservoir (Map Courtesy of North Dakota Game and Fish Department)

Recreational Facilities: Recreational facilities at Casselton Reservoir include a boat ramp and courtesy dock, fishing pier, parking, outdoor toilets and dumpster.

Water Quality Standards Classification: Casselton Reservoir is classified in the state "Standards of Quality for Waters of the State" (NDDoH, 2011) as a class 3 lake. Class 3 lakes or reservoirs are defined as a "warm water fishery" or "waters capable of supporting natural reproduction and growth of warm water fishes (e.g., largemouth bass and bluegill) and associated aquatic biota. Some cool water species may also be present."

Historical Water Quality Sampling: No historical water quality data.

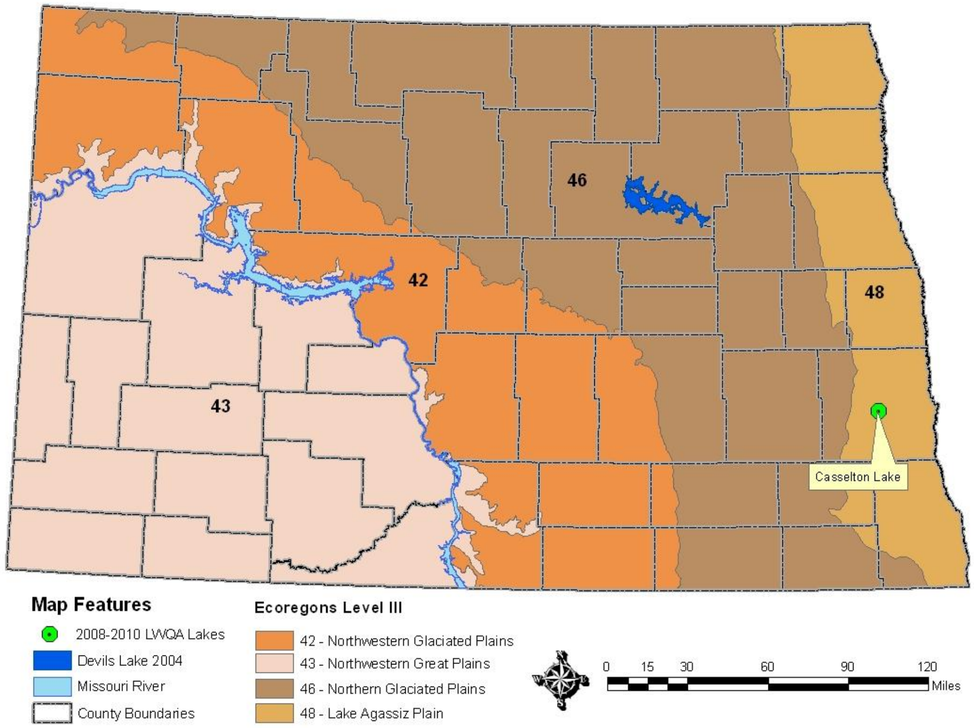

Figure 3. Casselton Reservoir's Location and the Level III Ecoregions

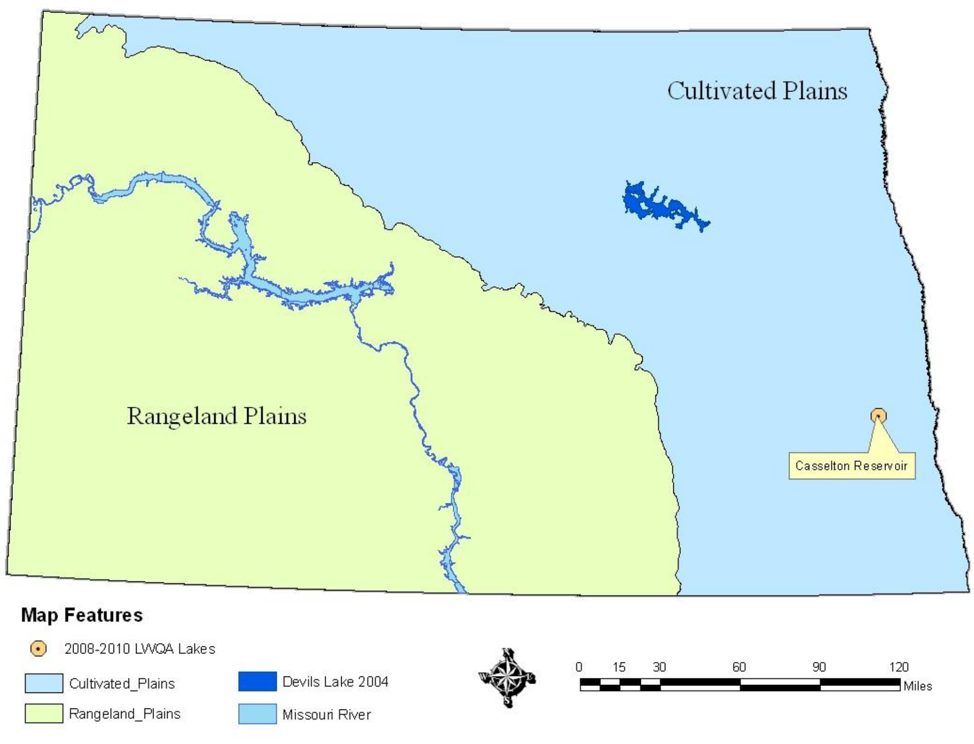

Figure 4. Casselton Reservoir's Location and the Cultivated and Rangeland Plans Regions

WATER QUALITY MONITORING RESULTS

The water quality assessment for Casselton Reservoir is presented in four general categories: 1) temperature and dissolved oxygen profile results; 2) general water quality characterization; 3) nutrient limitation; and 4) trophic status. Additionally, where appropriate, results have been compared to the regional data on reservoirs in the Cultivated Plains.

Temperature and Dissolved Oxygen Profile Results: There are three temperature and dissolved oxygen profiles for Casselton Reservoir collected in 2010. The profile data shows that the lake weakly thermally stratifies. During periods of thermal stratification (7/21 and 9/22) the reservoir experiences measurable oxygen decay. Even with this decay the reservoir remained well enough oxygenated to support aquatic life throughout the majority of the water column (Figures 5 and 6).

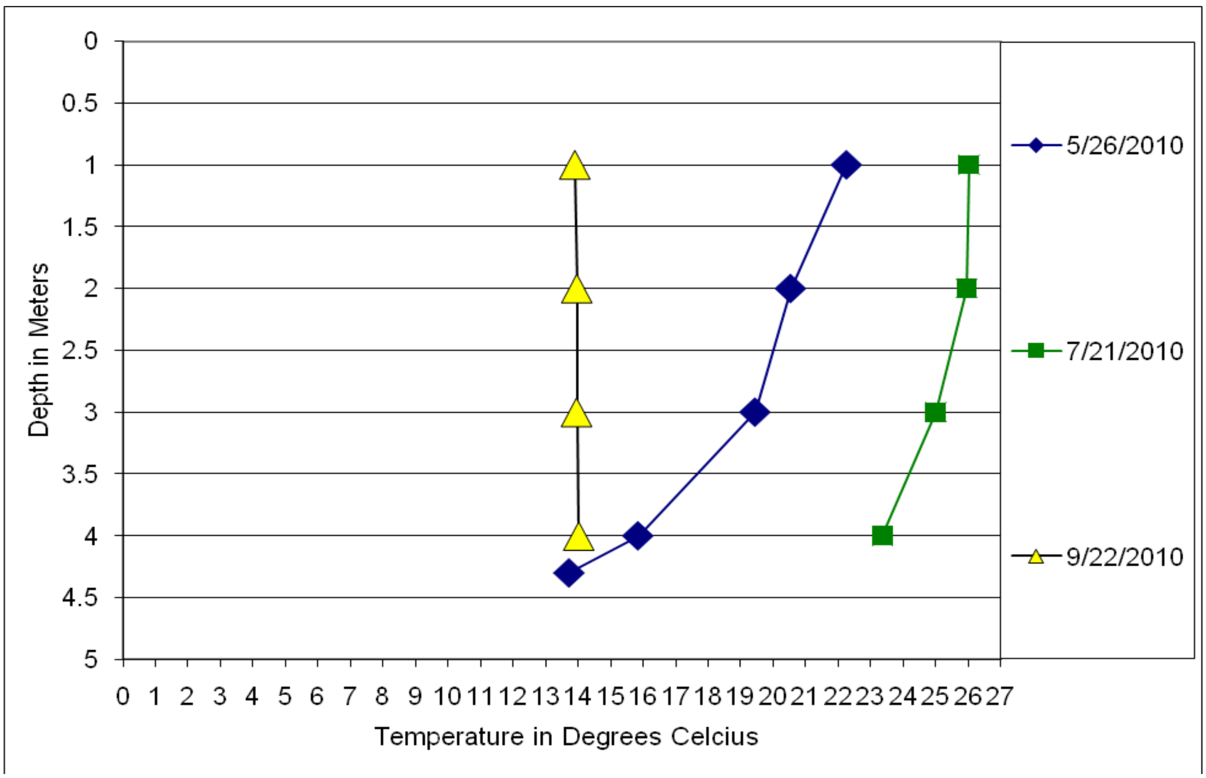

Figure 5. Temperature Profiles for Casselton Reservoir

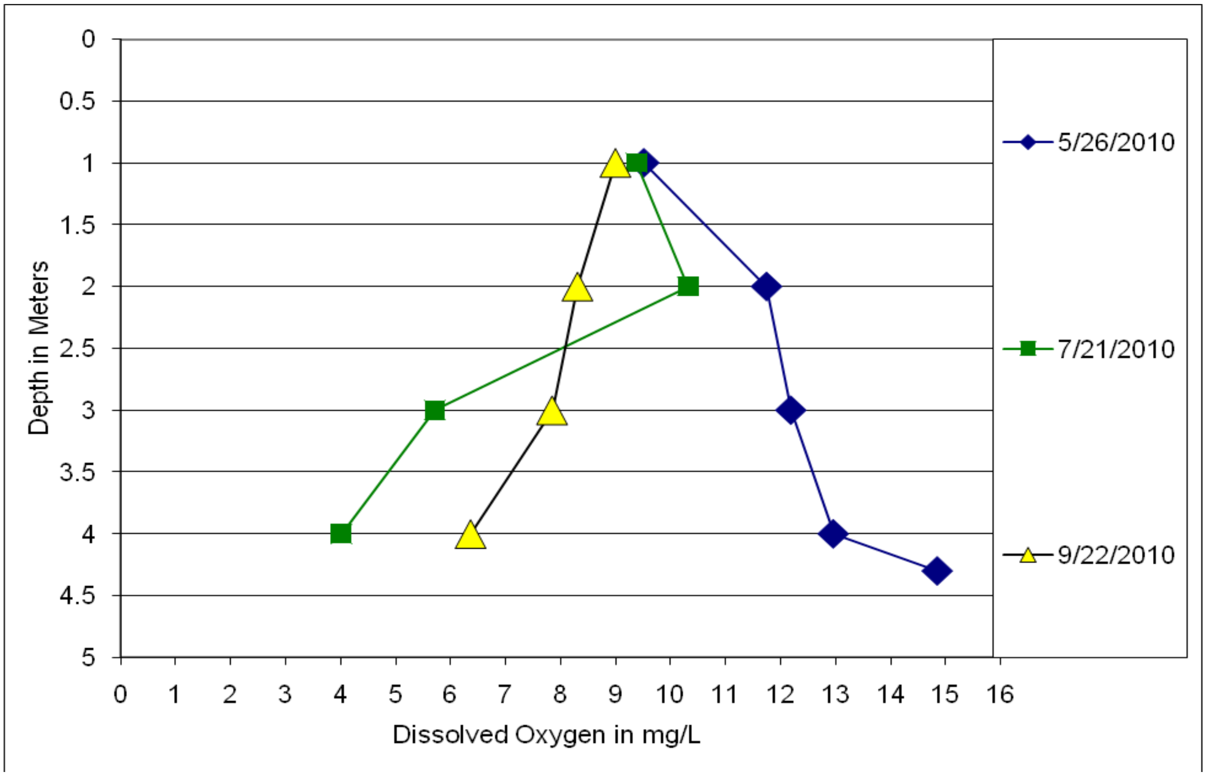

Figure 6. Dissolved Oxygen Profiles for Casselton Reservoir

General Water Quality: Data collected in 2010 indicate that Casselton Reservoir is well buffered with total alkalinity as $CaCO_3$ concentrations ranging from 133 to 172 mg/L (Table 1). The reservoir is sodium sulfate dominated with an average sodium concentration of 53.8 mg/L and an average sulfate concentration of 172 mg/L. The average total dissolved solids concentration and specific conductance measurements for the 2010 sampling period were 423 mg/L and 703 µmhos/cm, respectively, and the average total nitrogen as N and total phosphorus as P concentrations were 1.154 mg/L and 0.033 mg/L, respectively.

When compared to the regional average water quality for reservoirs in the Rangeland Plans, Casselton Reservoir is fairly fresh, and less eutrophic (Table 3). For example, the regional average TDS, total nitrogen, and total phosphorus concentrations are 671 mg/L, 1.520 mg/L, and 0.327 mg/L respectively, compared to Casselton Reservoir's average TDS, total nitrogen, and total phosphorus concentrations of 151 mg/L, 1.156 mg/L and 0.033 mg/L.

Table 1. Statistical Summary of Casselton Reservoir's 2010 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	3	151	133	172	20
Total Ammonia as N	mg/L	3	0.123	0.030[1]	0.170	0.081
Bicarbonate (HCO_3)	mg/L	3	154	108	179	40
Calcium (Ca)	mg/L	3	32.9	27.6	39.3	5.9
Carbonate (CO_3)	mg/L	3	15	1[1]	27	13
Chloride (Cl)	mg/L	3	23	23	24	1
Chlorophyll-a	µg/L	3	21.6	6.0	31.0	13.6
Specific Conductance	µmhos	3	703	671	733	31
Total Dissolved Solids	mg/L	3	423	406	448	22
Total Hardness as ($CaCO_3$)	mg/L	3	247	239	253	7
Hydroxide (OH)	mg/L	3	1.0[1]	1.0[1]	1.0[1]	0.0
Iron (Fe)	mg/L	3	0.093	0.050	0.160	0.059
Magnesium (Mg)	mg/L	3	40.0	37.7	41.4	2.0
Nitrate + Nitrite as N	mg/L	3	0.030[1]	0.030[1]	0.030[1]	0.000
Total Kjeldahl Nitrogen as N	mg/L	3	1.124	0.963	1.210	0.140
Total Nitrogen as N	mg/L	3	1.154	0.993	1.240	0.140
pH		3	8.73	8.23	9.22	0.50
Total Phosphorus as P	mg/L	3	0.033	0.018	0.042	0.013
Potassium (K)	mg/L	3	9.3	8.8	10.1	0.7
Sodium (Na)	mg/L	3	53.8	50.7	59.2	4.7
Sulfate (SO4)	mg/L	3	172	160	183	12

[1]Equal to the lower reporting limit

Limiting Nutrients: The three water quality samples collected in 2010 indicate that Casselton Reservoir is phosphorus limited (Figure 7). The limiting nutrient assessment is based on the assumption that either nitrogen or phosphorus is limiting algal growth and that the ratio of total nitrogen as N to total phosphorus as P (N:P), by weight in the average algae is approximately 15 to 1. When the N:P ratio is less than 15:1, nitrogen is assumed to be the limiting nutrient and when it exceeds 15:1, the limiting nutrient is assumed to be phosphorus.

Trophic Status Assessment: Based on the chlorophyll-a, secchi disk transparency, and total phosphorus data collected in 2010, Casselton Reservoir's trophic status is estimated as eutrophic. The trophic status index (TSI) scores ranged from a low of 46 based on phosphorus to a high of 64 based on chlorophyll-a (Figure 8).

Table 2. Statistical Summary of Water Quality Data[2] Collected from Reservoirs and Impoundments in the Cultivated Plains Ecological Region of North Dakota

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	400	261	88	891	99
Total Ammonia as N	mg/L	567	0.145	0.001[1]	2.070	0.208
Bicarbonate (HCO_3)	mg/L	400	294	91	951	110
Calcium (Ca)	mg/L	402	66.7	19.4	169.0	22.7
Carbonate (CO_3)	mg/L	382	13	1[1]	93	16
Chloride (Cl)	mg/L	400	21	3[1]	113	17
Chlorophyll-a	µg/L	445	19.9	1.5[1]	388.0	30.2
Specific Conductance	µmhos	400	1025	217	3140	501
Total Dissolved Solids	mg/L	392	671	127	2300	375
Total Hardness as ($CaCO_3$)	mg/L	402	341	95	1090	119
Hydroxide (OH)	mg/L	339	1.0	0.0[1]	1.0	0.2
Iron (Fe)	mg/L	400	0.143	0.007	3.190	0.220
Magnesium (Mg)	mg/L	402	42.3	11.2	161.0	19.6
Nitrate + Nitrite as N	mg/L	560	0.112	0.001[1]	2.060	0.213
Total Kjeldahl Nitrogen as N	mg/L	480	1.470	0.206	4.410	0.648
Total Nitrogen as N	mg/L	419	1.520	0.418	3.950	0.617
pH		401	8.34	1.76	9.40	0.54
Total Phosphorus as P	mg/L	569	0.327	0.002[1]	2.270	0.290
Potassium (K)	mg/L	402	11.6	2.7	34.5	5.4
Sodium (Na)	mg/L	402	96.8	2.2	582.0	102.9
Sulfate (SO4)	mg/L	400	272	1[1]	1350	210

[1]Equal to the lower reporting limit
[2]Data collected from 45 reservoirs between 1991 and 2010

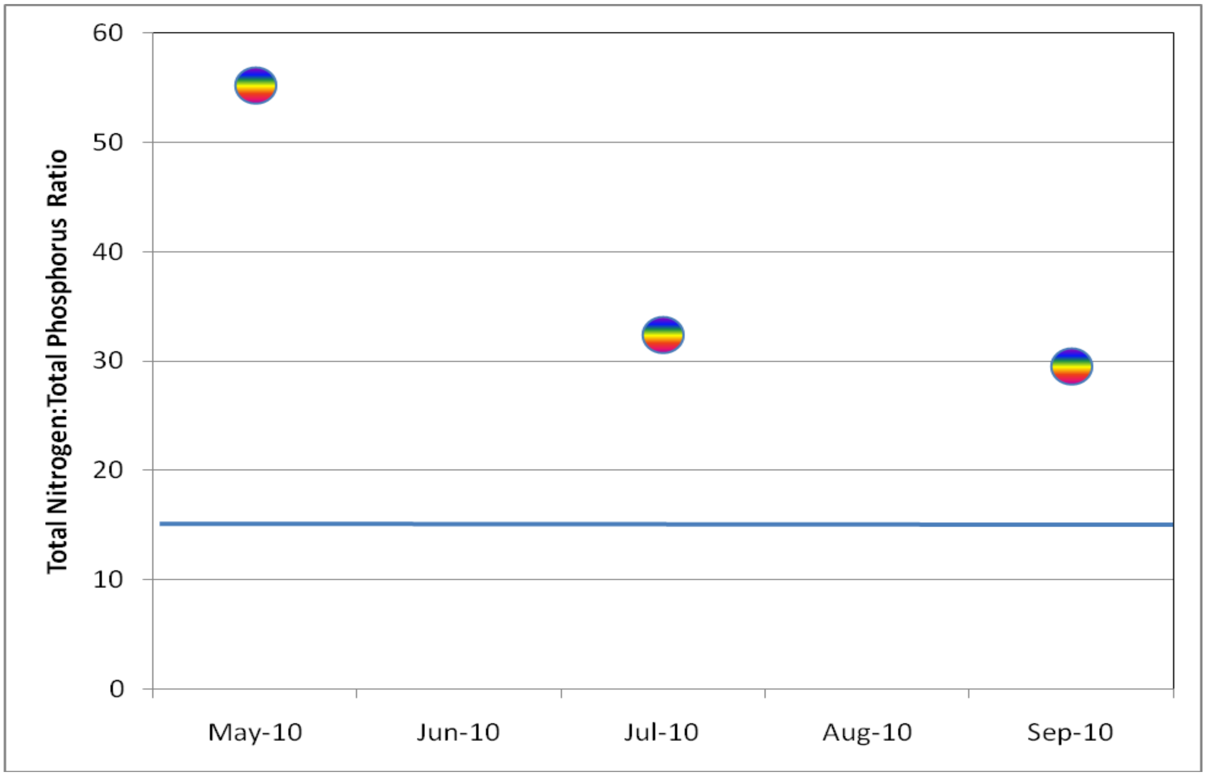

Figure 7. Casselton Reservoir's Total Nitrogen to Total Phosphorus Ratio

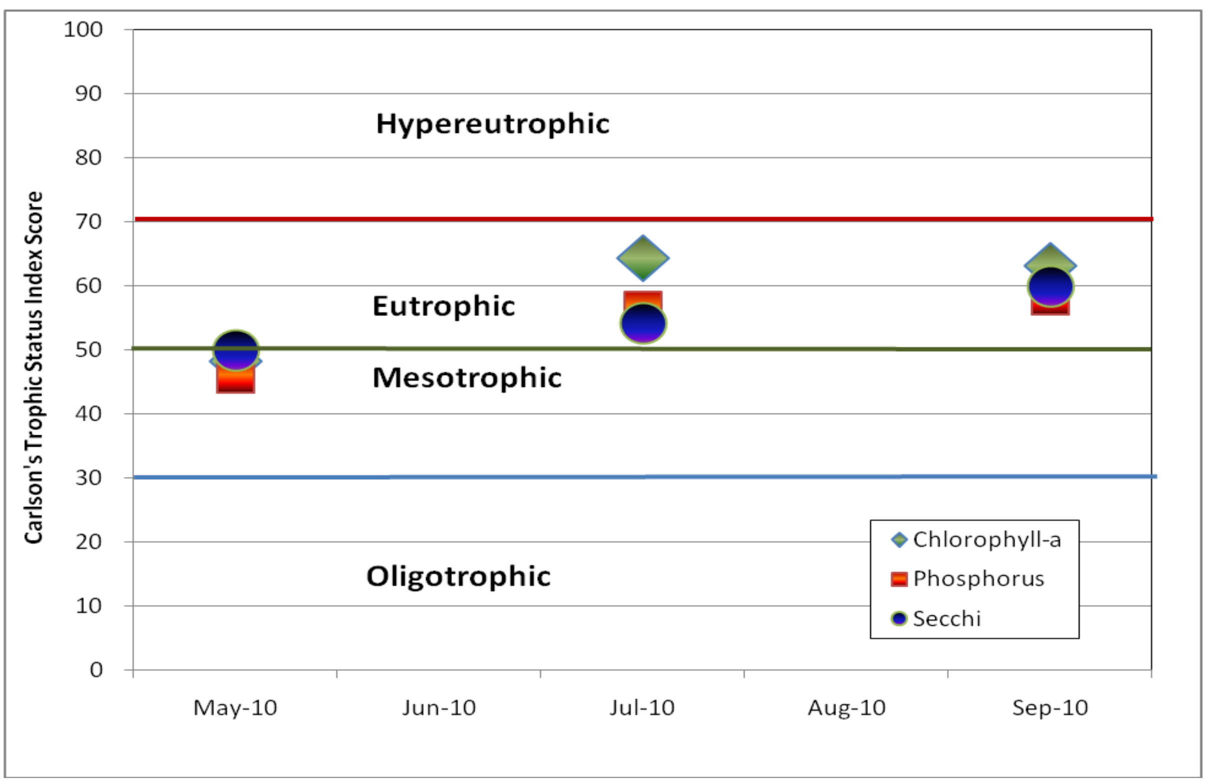

Figure 8. Casselton Reservoir's TSI Scores

Lake Ilo, Dunn County

BACKGROUND

Location: Lake Ilo is a US fish and Wildlife Service Dam on Spring Creek just west of Dunn Center, North Dakota (Figure 1). The Lake is managed by the US Fish and Wild Service and fishery by the North Dakota Game and Fish Department. Fish species stocked in recent years are northern pike, yellow perch and bluegill.

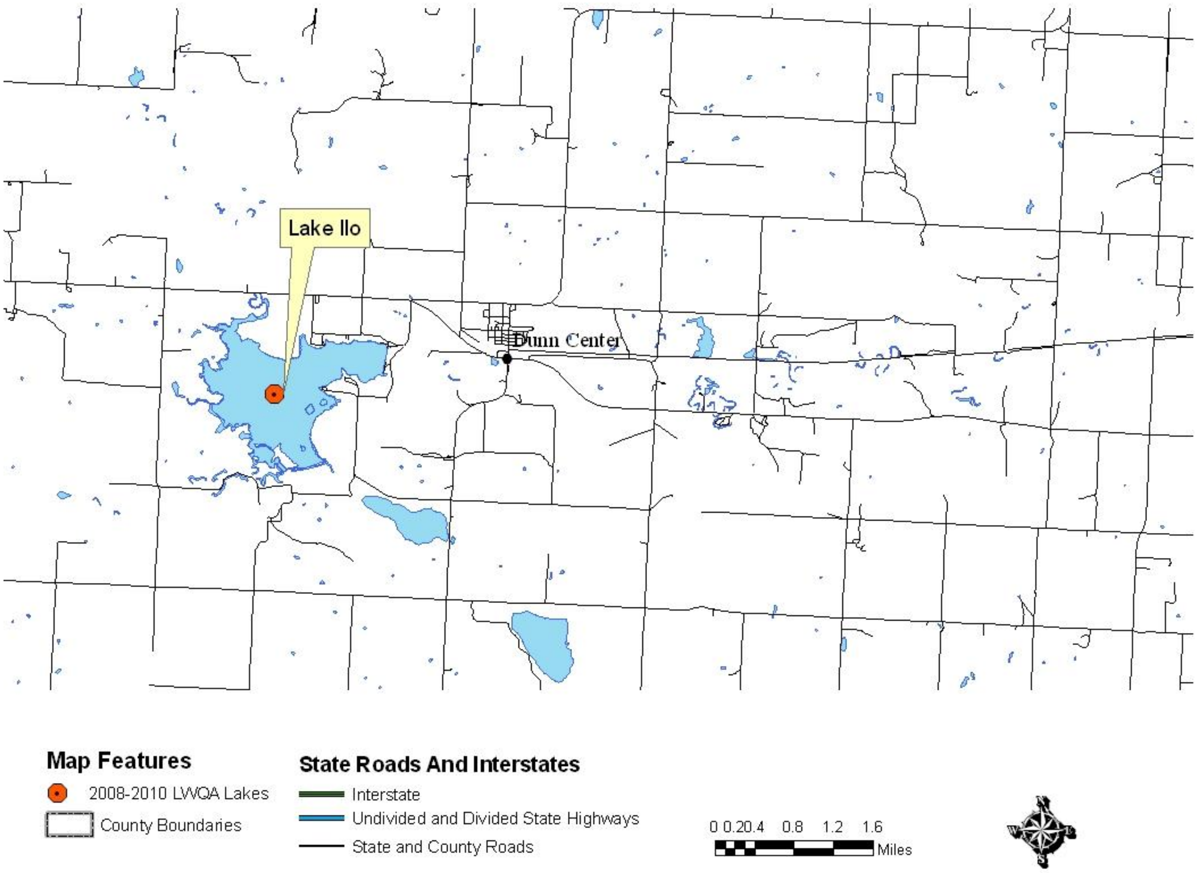

Figure 1. Location of Lake Ilo

Physiographic/Ecological Setting: Lake Ilo has a surface area of 858.6 acres, a maximum depth of 13.7 ft, and an average depth of 4.4 ft. It is a shallow windswept muddy reservoir with some low density urban development on its north shore (Figure 2). The reservoir is located in the Northwestern Great Plains Level III Ecoregion, which is part of the broader Rangeland Plains region (Figures 3 and 4).

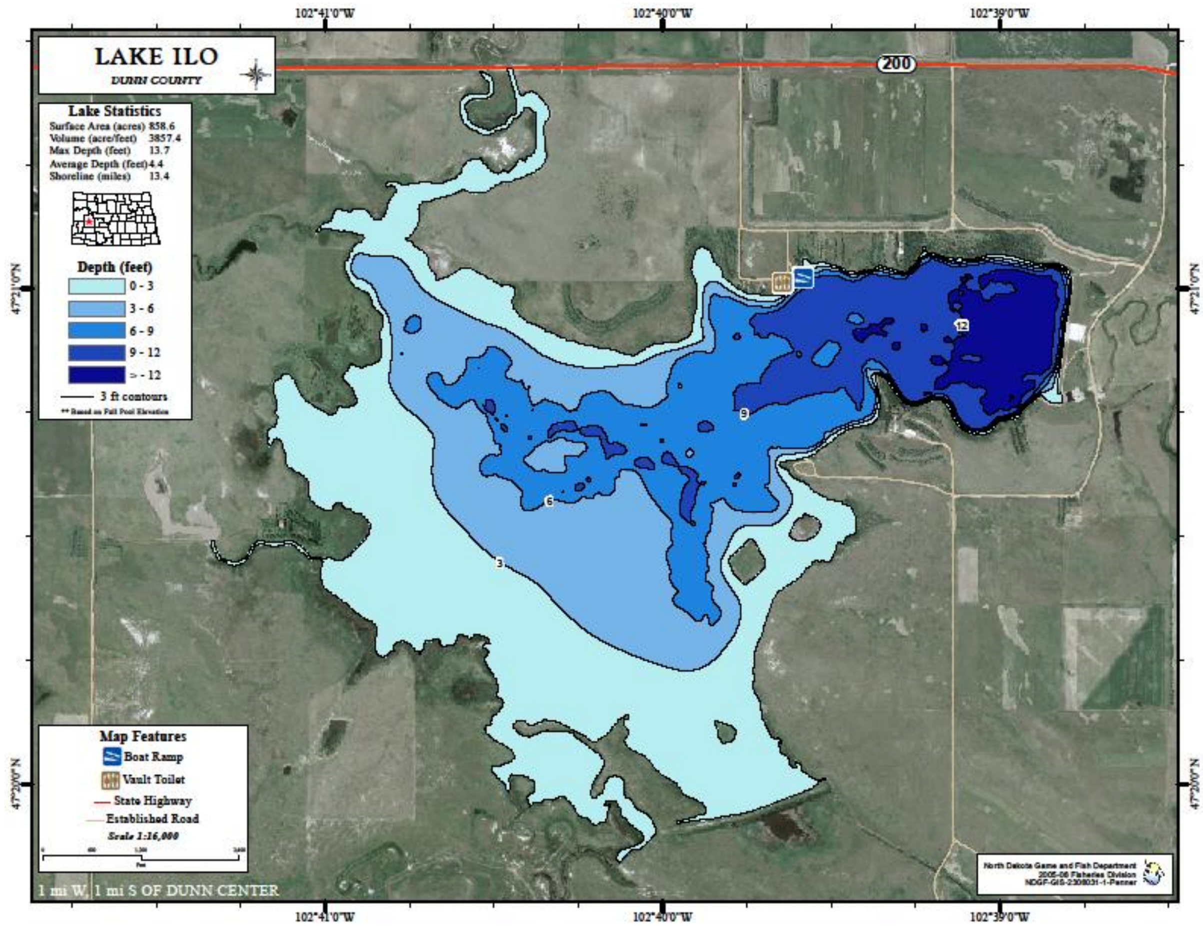

Figure 2. Contour Map of Lake Ilo (Courtesy of the North Dakota Game and Fish Department)

Recreational Facilities: Recreational facilities at Lake Ilo are access road, concrete boat ramp, courtesy dock and outdoor toilets.

Water Quality Standards Classification: Lake Ilo is classified in the state "Standards of Quality for Waters of the State" (NDDoH, 2011) as a class 3 reservoir. Class 3 lakes or reservoirs are defined as a "warm water fishery" or "waters capable of supporting natural reproduction and growth of warm water fishes (e.g., largemouth bass and bluegill) and associated aquatic biota. Some cool water species may also be present."

Historical Water Quality Sampling: No historical water quality data.

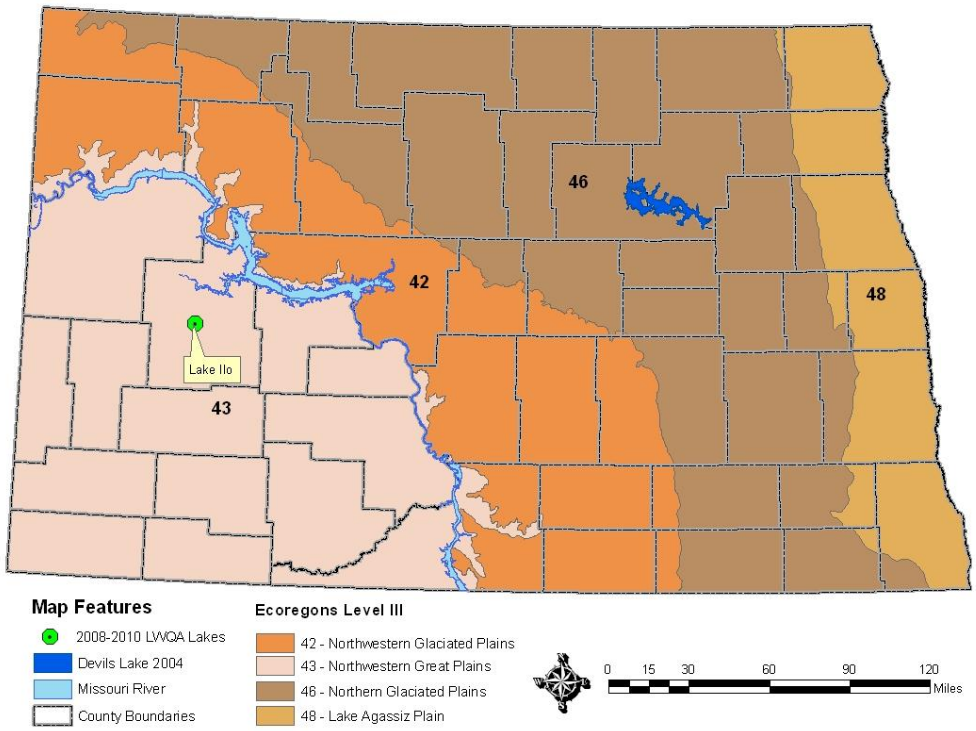

Figure 3. Lake Ilo's Location and the Level III Ecoregions

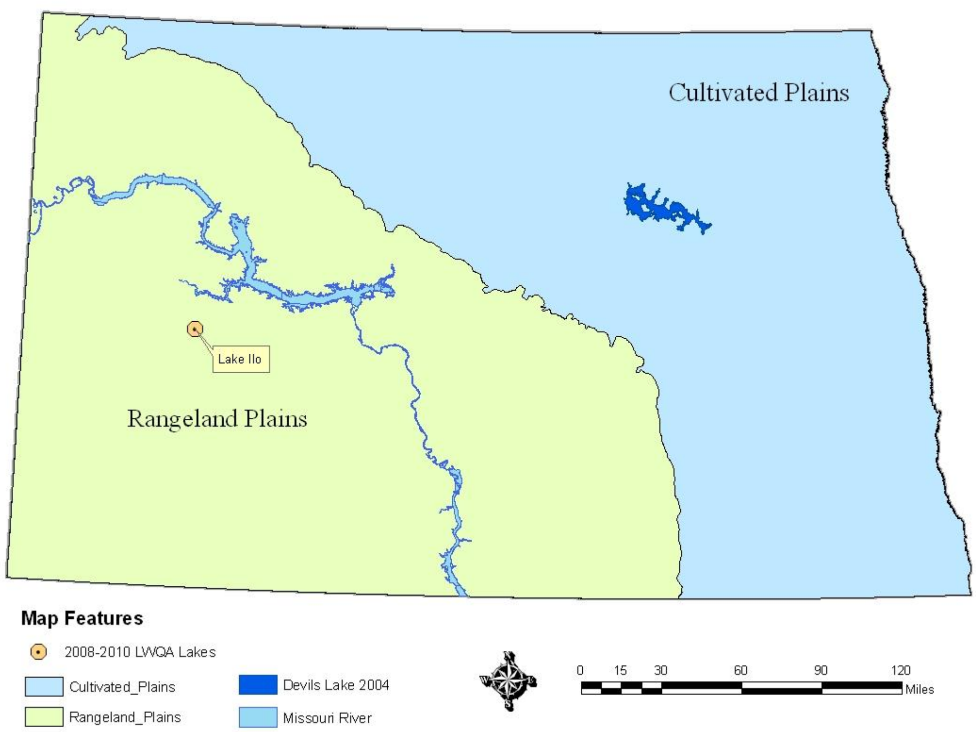

Figure 4. Lake Ilo's Location and the Cultivated and Rangeland Plans Regions

WATER QUALITY MONITORING RESULTS

The water quality assessment for Lake Ilo is presented in four general categories: 1) temperature and dissolved oxygen profile results; 2) general water quality characterization; 3) nutrient limitation; and 4) trophic status. Where appropriate, results have been compared to the regional data for reservoirs in the Rangeland Plains.

Temperature and Dissolved Oxygen Profile Results: There are three temperature and dissolved oxygen profiles for Lake Ilo collected in 2009 (Figures 5 and 6). The profile data shows that Lake Ilo does not thermally stratification. Dissolved oxygen concentrations were between 6 and 9 mg/L, well above the concentrations required to support aquatic life and the state standard of 5 mg/L.

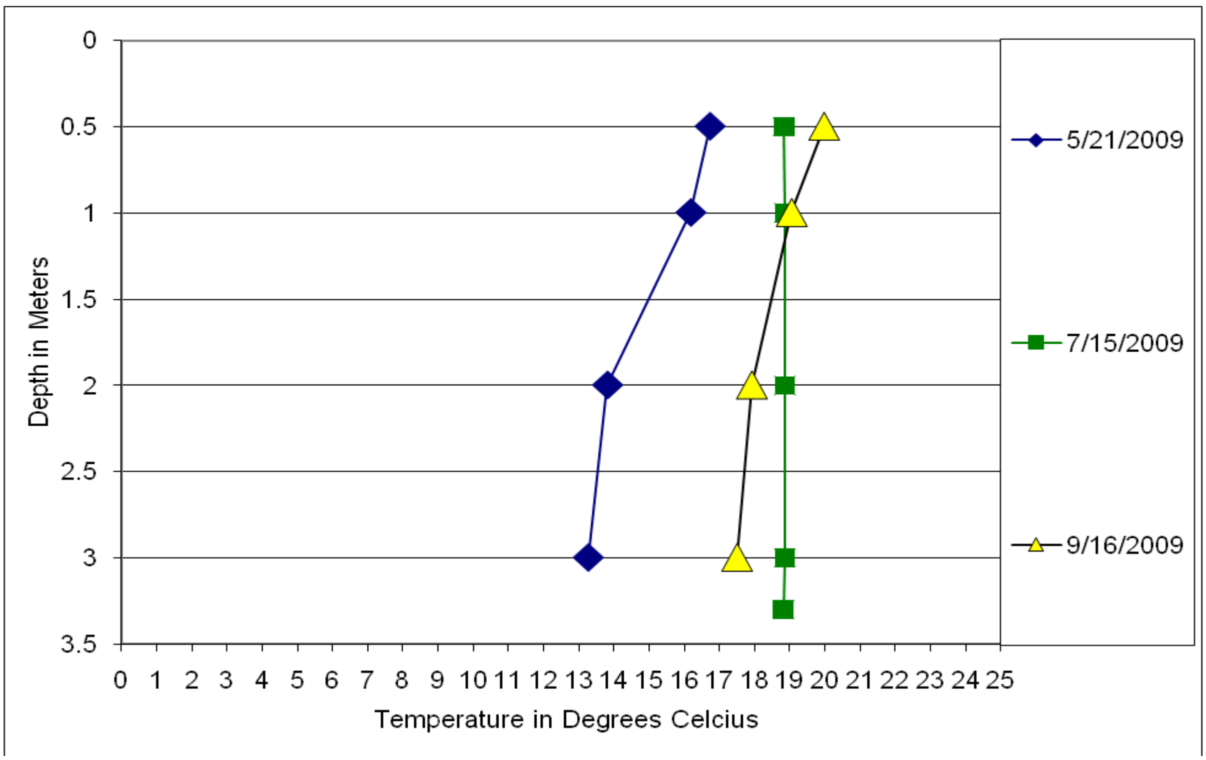

Figure 5. Temperature Profiles for Lake Ilo

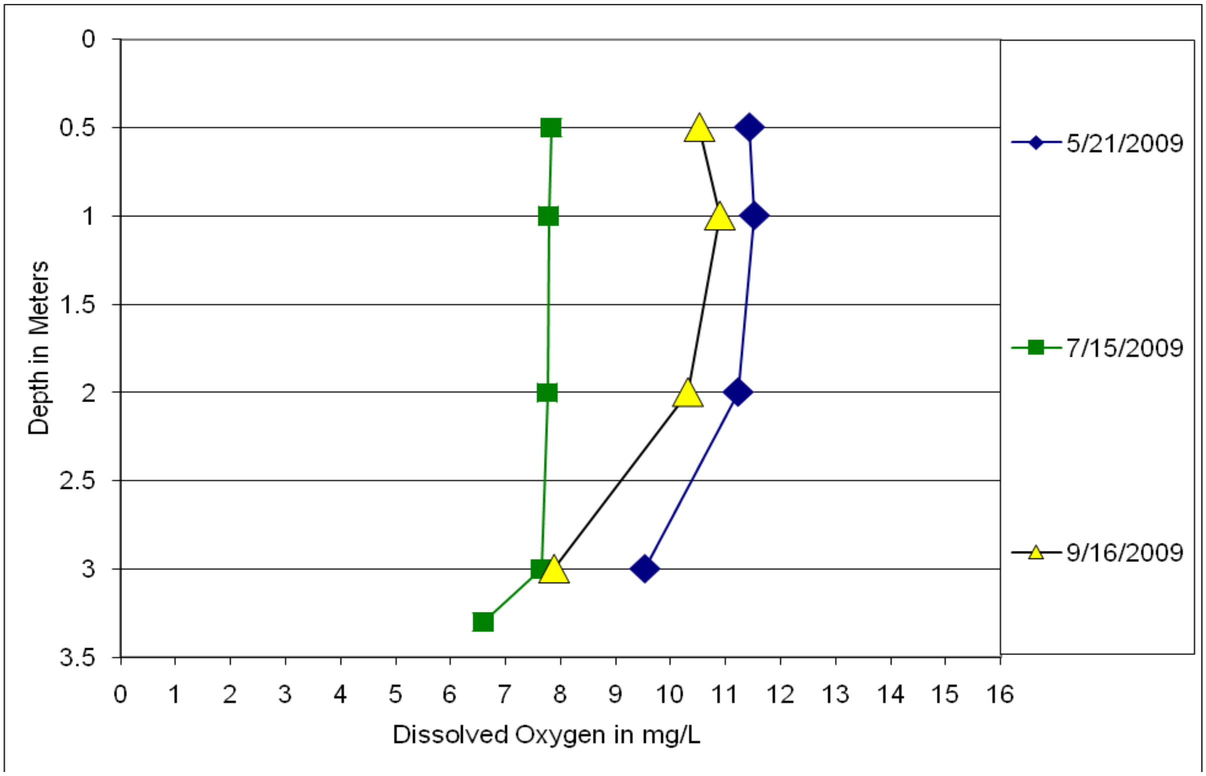

Figure 6. Dissolved Oxygen Profiles for Lake Ilo

General Water Quality: Data collected in 2009 indicate that Lake Ilo is well buffered with total alkalinity as $CaCO_3$ concentrations ranging from 133 to 209 mg/L (Table 1). The reservoir is sodium bicarbonate dominated with an average sodium concentration of 78.6 mg/L and an average bicarbonate concentration of 177 mg/L. The total dissolved solids concentration and specific conductance measurements for the 2009 sampling period averaged 307 mg/L and 510 µmhos/cm, and total nitrogen as N and total phosphorus as P concentrations 0.912 mg/L and 0.111 mg/L, respectively.

When compared to the water quality for reservoirs in the Rangeland Plans region, Lake Ilo is fairly fresh and less eutrophic (Table 3). For example, the average regional concentrations for TDS, total nitrogen, and total phosphorus concentrations are 1107 mg/L, 1.314 mg/L, and 0.128 mg/L respectively, compared to Lake Ilo's average TDS, total nitrogen, and total phosphorus concentrations of 307 mg/L, 0.912 mg/L and 0.111 mg/L respectively.

Table 1. Statistical Summary of Lake Ilo's 2009 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	3	167	120	209	45
Total Ammonia as N	mg/L	3	0.056	0.030[1]	0.094	0.034
Bicarbonate (HCO_3)	mg/L	3	177	133	216	42
Calcium (Ca)	mg/L	3	19.3	16.6	21.3	2.4
Carbonate (CO_3)	mg/L	3	13	6	19	7
Chloride (Cl)	mg/L	3	4	4	5	0
Chlorophyll-a	µg/L	2	3.8	1.5[1]	6.0	3.2
Specific Conductance	µmhos	3	510	395	614	110
Total Dissolved Solids	mg/L	3	307	233	370	69
Total Hardness as ($CaCO_3$)	mg/L	3	91	76	105	15
Hydroxide (OH)	mg/L	3	1.0[1]	1.0[1]	1.0[1]	0.0
Iron (Fe)	mg/L	3	2.008	0.555	2.780	1.259
Magnesium (Mg)	mg/L	3	10.5	8.3	12.6	2.2
Nitrate + Nitrite as N	mg/L	3	0.043	0.030[1]	0.050	0.012
Total Kjeldahl Nitrogen as N	mg/L	3	0.869	0.734	1.060	0.170
Total Nitrogen as N	mg/L	3	0.912	0.764	1.110	0.178
pH		3	8.73	8.64	8.78	0.08
Total Phosphorus as P	mg/L	3	0.111	0.088	0.149	0.033
Potassium (K)	mg/L	3	9.5	8.9	10.2	0.7
Sodium (Na)	mg/L	3	78.6	56.4	95.7	20.1
Sulfate (SO4)	mg/L	3	83	66	100	17

[1]Equal to the lower reporting limit

Limiting Nutrients: The three water quality samples collected in 2009 indicate that Lake Ilo is nitrogen limited (Figure 7). The limiting nutrient assessment is based on the assumption that either nitrogen or phosphorus is limiting algal growth and that the ratio of total nitrogen as N to total phosphorus as P (N:P), by weight in the average algae is approximately 15 to 1. When the N:P ratio is less than 15:1, nitrogen is assumed to be the limiting nutrient and when it exceeds 15:1, the limiting nutrient is assumed to be phosphorus.

Trophic Status Assessment: Based on the chlorophyll-a, secchi disk transparency, and total phosphorus data collected in 2009, Lake Ilo's trophic status is estimated as hypereutrophic. The trophic status index (TSI) scores ranged from a low of 35 based on chlorophyll-a to a high of 77 based on secchi disk (Figure 8).

Table 2. Statistical Summary of Water Quality Data[2] Collected from Reservoirs and Impoundments in the Rangeland Plains Ecological Region of North Dakota

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	522	283	54	982	131
Total Ammonia as N	mg/L	593	0.092	0.001[1]	2.440	0.183
Bicarbonate (HCO_3)	mg/L	522	295	14	1040	145
Calcium (Ca)	mg/L	522	52.3	4.7	163.0	27.3
Carbonate (CO_3)	mg/L	520	25	1[1]	197	29
Chloride (Cl)	mg/L	522	13	3[1]	75	9
Chlorophyll-a	µg/L	415	20.1	1.5[1]	218.0	27.0
Specific Conductance	µmhos	542	1621	173	5880	988
Total Dissolved Solids	mg/L	523	1107	100	5110	782
Total Hardness as ($CaCO_3$)	mg/L	522	396	45	2100	279
Hydroxide (OH)	mg/L	465	1.0	0.0[1]	1.0	0.2
Iron (Fe)	mg/L	523	0.193	0.007	4.110	0.349
Magnesium (Mg)	mg/L	522	64.5	5.6	412.0	54.0
Nitrate + Nitrite as N	mg/L	592	0.060	0.001[1]	0.790	0.102
Total Kjeldahl Nitrogen as N	mg/L	483	1.375	0.108	7.720	0.789
Total Nitrogen as N	mg/L	426	1.314	0.178	4.840	0.605
pH		542	8.55	6.73	9.87	0.55
Total Phosphorus as P	mg/L	599	0.128	0.004[1]	3.160	0.190
Potassium (K)	mg/L	522	13.8	2.6	39.2	6.5
Sodium (Na)	mg/L	522	217.2	3.0	932.0	171.6
Sulfate (SO4)	mg/L	520	573	1[1]	3210	519

[1]Equal to the lower reporting limit
[2]Data collected from 76 reservoirs between 1991 and 2010

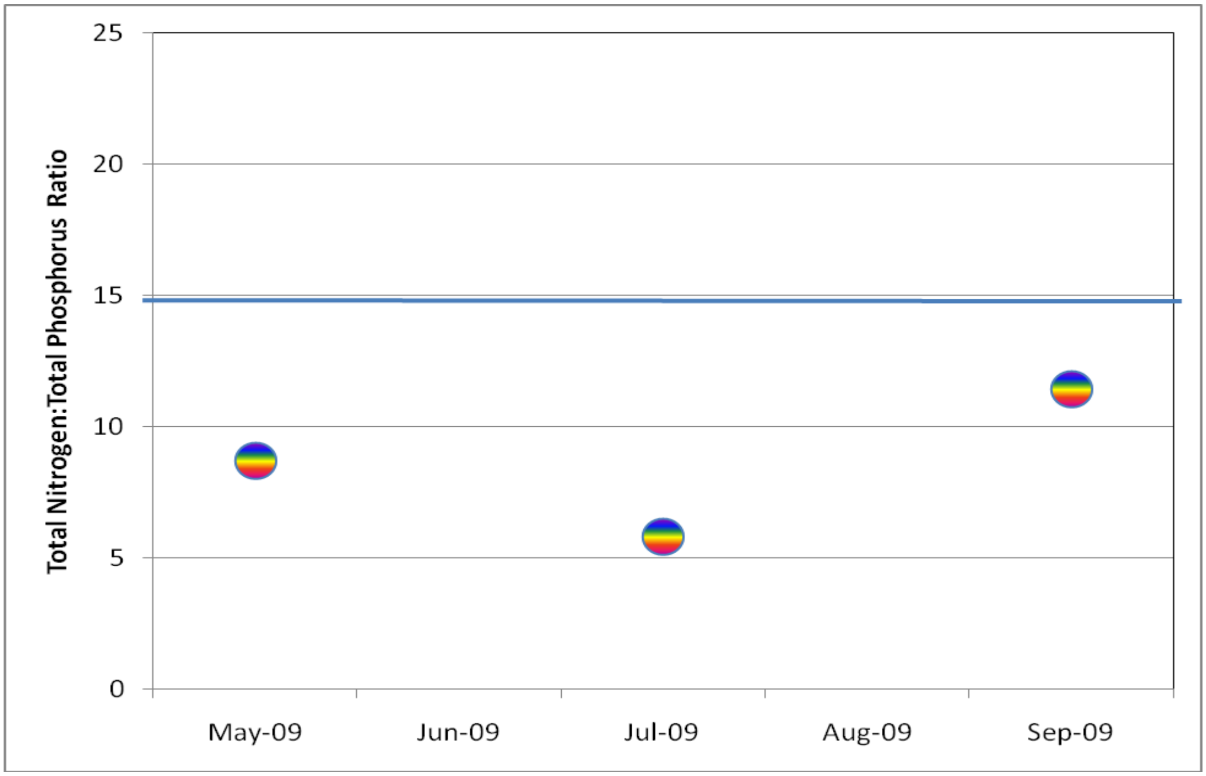

Figure 7. Lake Ilo's Total Nitrogen to Total Phosphorus Ratio

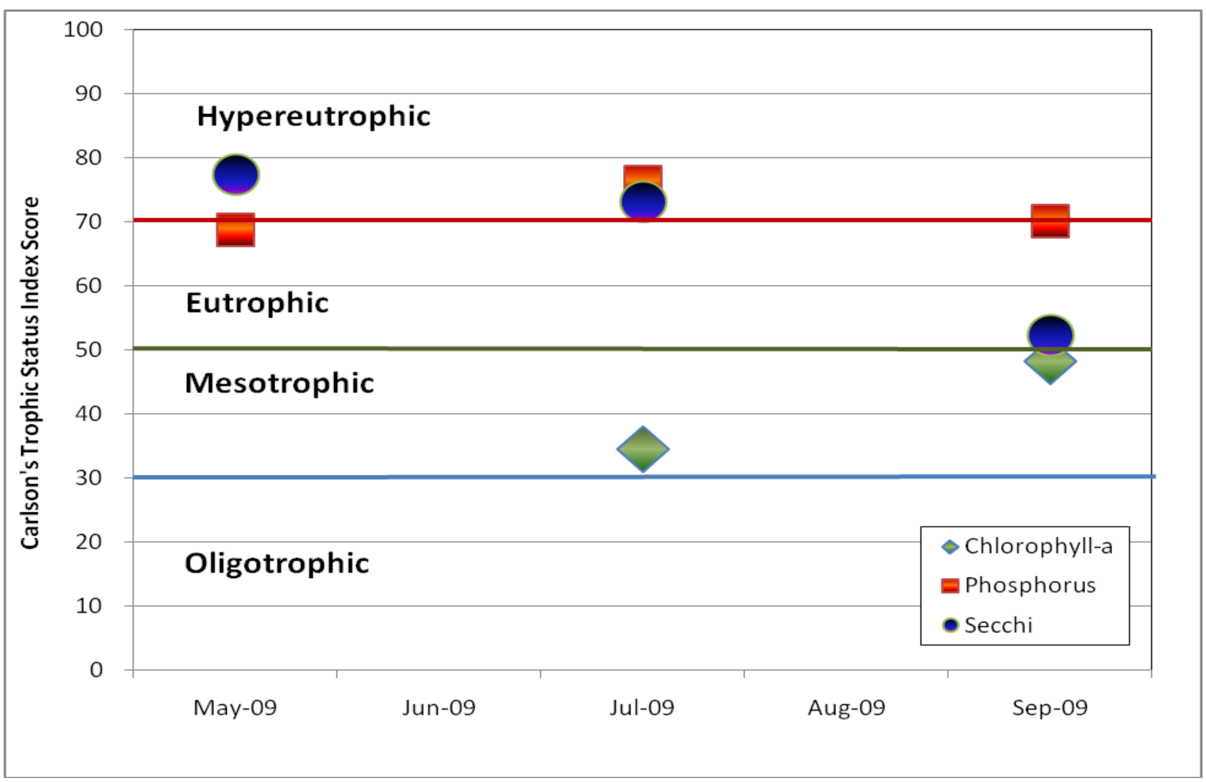

Figure 8. Lake Ilo's TSI Scores

Lake Juanita, Foster County

BACKGROUND

Location: Lake Juanita is a shallow glacial lake a few miles east of Grace City, North Dakota. It has limited low density urban development at both ends of the lake (Figure 1). The fishery is managed by the North Dakota Game and Fish. Fish species managed for are northern pike and yellow perch.

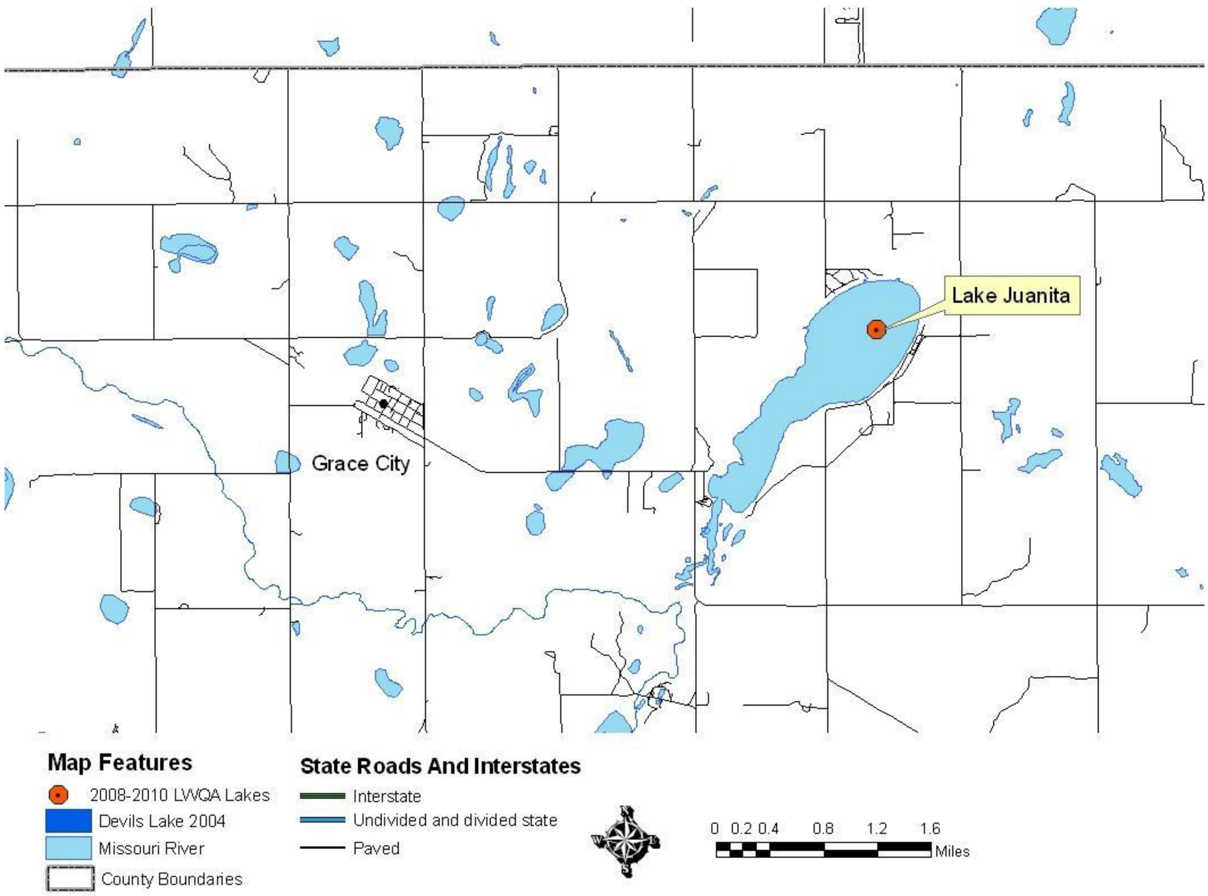

Figure 1. Location of Lake Juanita

Physiographic/Ecological Setting: Lake Juanita has a surface area of 678.6 acres, a maximum depth of 11.7 ft and an average depth 8.5 ft (Figure 2). It is a turbid, macrophyte poor lake with little to no protection from the seemingly ever present northwest wind. The lake is located within the Northern Glaciated Plains Level III Ecoregion, which is part of the broader Cultivated Plains region (Figures 3 and 4).

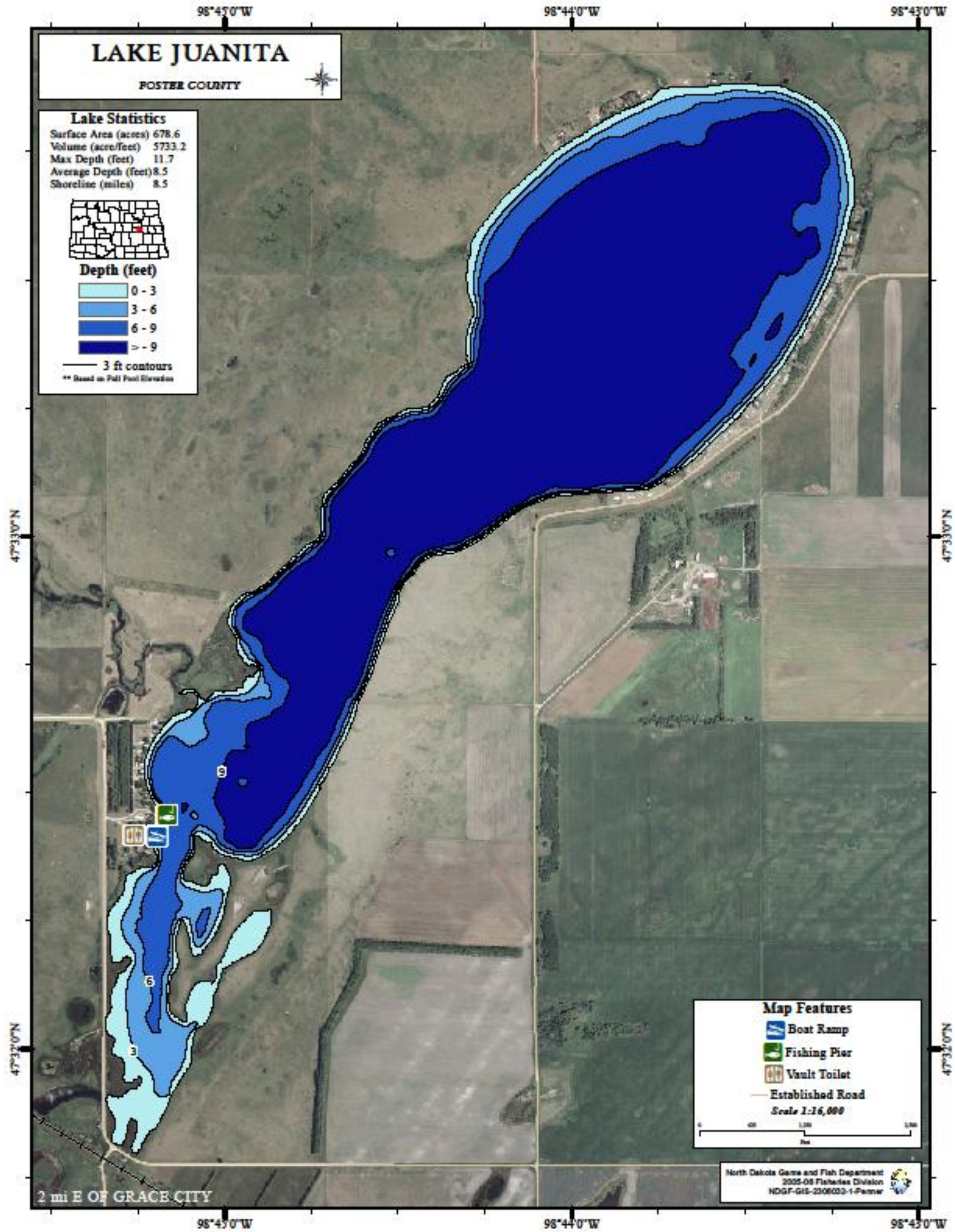

Figure 2. Contour Map of Lake Juanita (Map Courtesy of North Dakota Game and Fish Department)

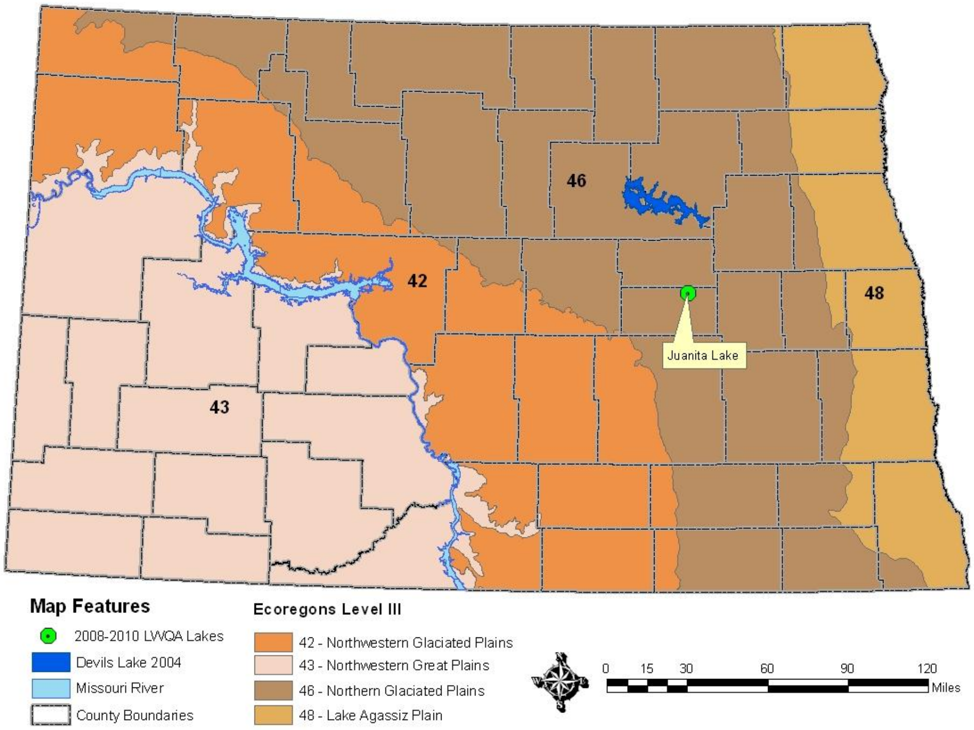

Figure 3. Lake Juanita's Location and the Level III Ecoregions

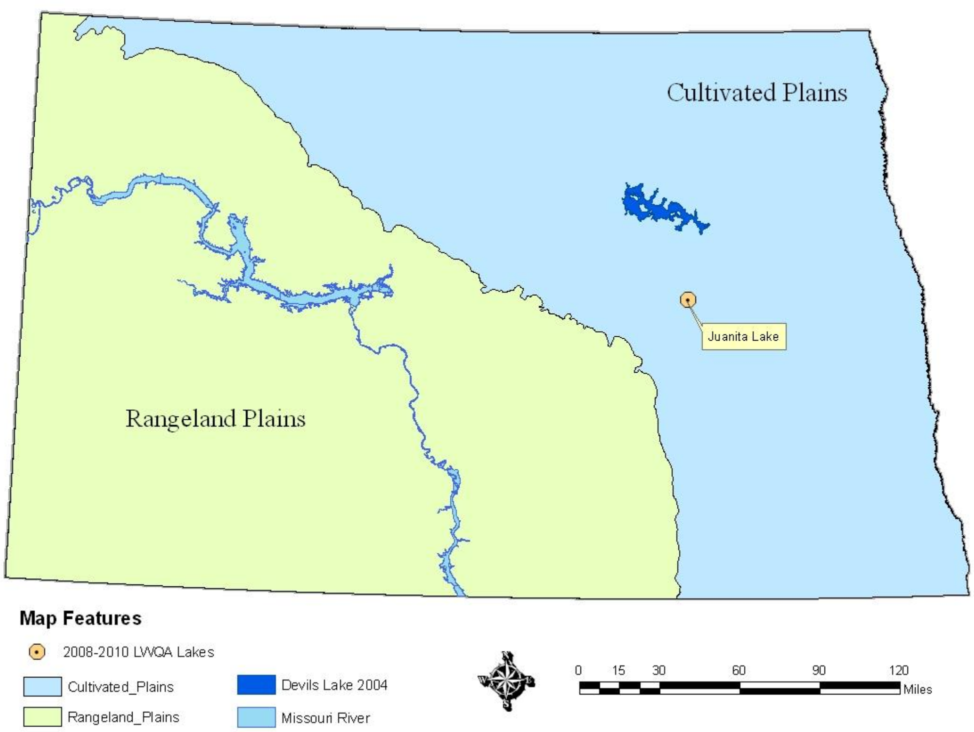

Figure 4. Lake Juanita's Location and the Cultivated and Rangeland Plans Regions

Recreational Facilities: Recreational facilities at Lake Juanita include a cement boat ramp and courtesy dock, boat and vehicle parking, a fishing pier and outdoor toilets.

Water Quality Standards Classification: Lake Juanita is classified in the state "Standards of Quality for Waters of the State" (NDDoH, 2011) as a class 3 lake. Class 3 lakes or reservoirs are defined as a "warm water fishery" or "waters capable of supporting natural reproduction and growth of warm water fishes (e.g., largemouth bass and bluegill) and associated aquatic biota. Some cool water species may also be present."

Historical Water Quality Sampling: No historical water quality data.

WATER QUALITY MONITORING RESULTS

The water quality assessment for Lake Juanita is presented in four general categories: 1) temperature and dissolved oxygen profile results; 2) general water quality characterization; 3) nutrient limitation; and 4) trophic status. Additionally, where appropriate, results have been compared to regional data.

Temperature and Dissolved Oxygen Profile Results: There are two temperature and dissolved oxygen profiles for Lake Juanita collected in 2008 (Figures 5 and 6). The profile data shows that Lake Juanita was not thermally stratification during the open water period. Additionally the during the open water period the lake remained well enough oxygenated to support aquatic life.

General Water Quality: Data collected in 2008 indicate that Lake Juanita is well buffered with total alkalinity as $CaCO_3$ concentrations ranging from 297 to 298 mg/L (Table 1). The lake is sodium bicarbonate dominated with an average sodium concentration of 76.4 mg/L and an average bicarbonate concentration of 307 mg/L. The average total dissolved solids concentration and specific conductance measurement for 2008 sampling period were 492 mg/L and 808 µmhos/cm respectively, and the average total nitrogen as N and total phosphorus as P concentrations were 1.415 mg/L and 0.074 mg/L respectively.

Lake Juanita is fairly average when compared to the water quality for natural lakes in the Cultivated Plans, (Table 3). For example, the regional average TDS, total nitrogen, and total phosphorus concentrations are 507 mg/L, 1.486 mg/L, and 0.090 mg/L respectively, compared to Lake Juanita's average TDS, total nitrogen, and total phosphorus concentrations of 492 mg/L, 1.415 mg/L and 0.074 mg/L respectively.

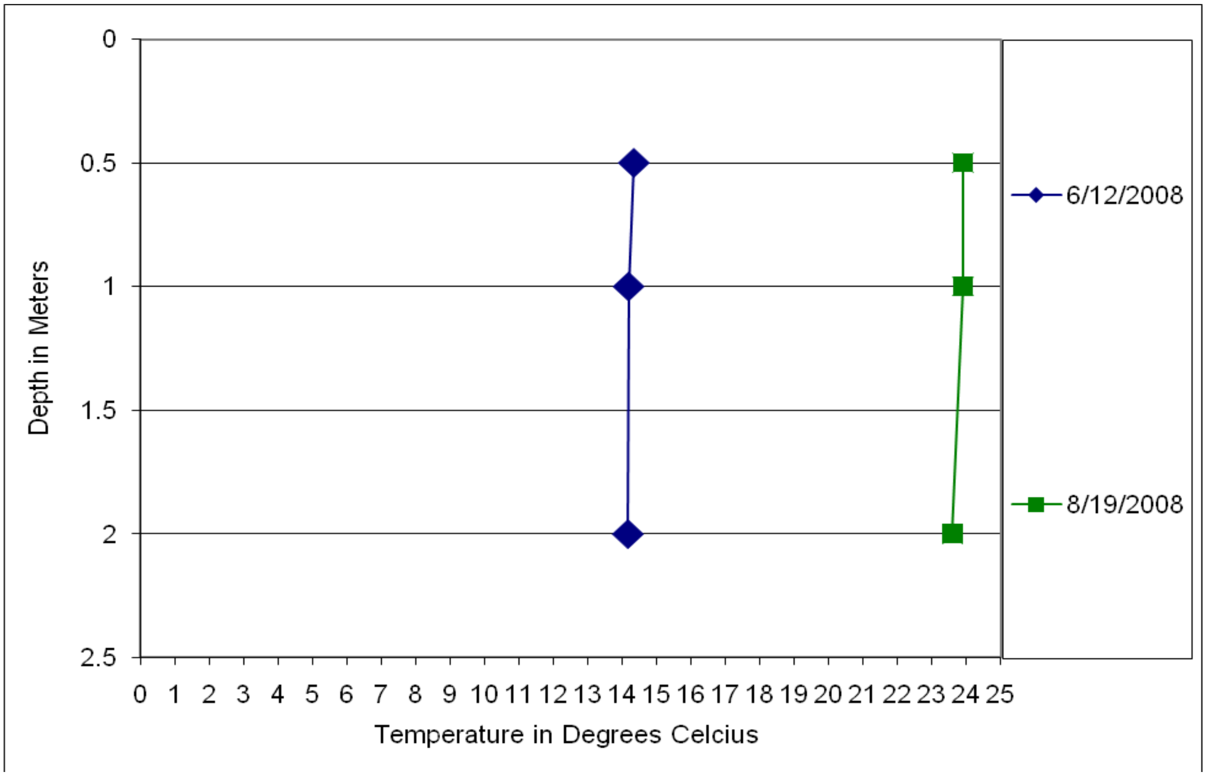

Figure 5. Temperature Profiles for Juanita Lake

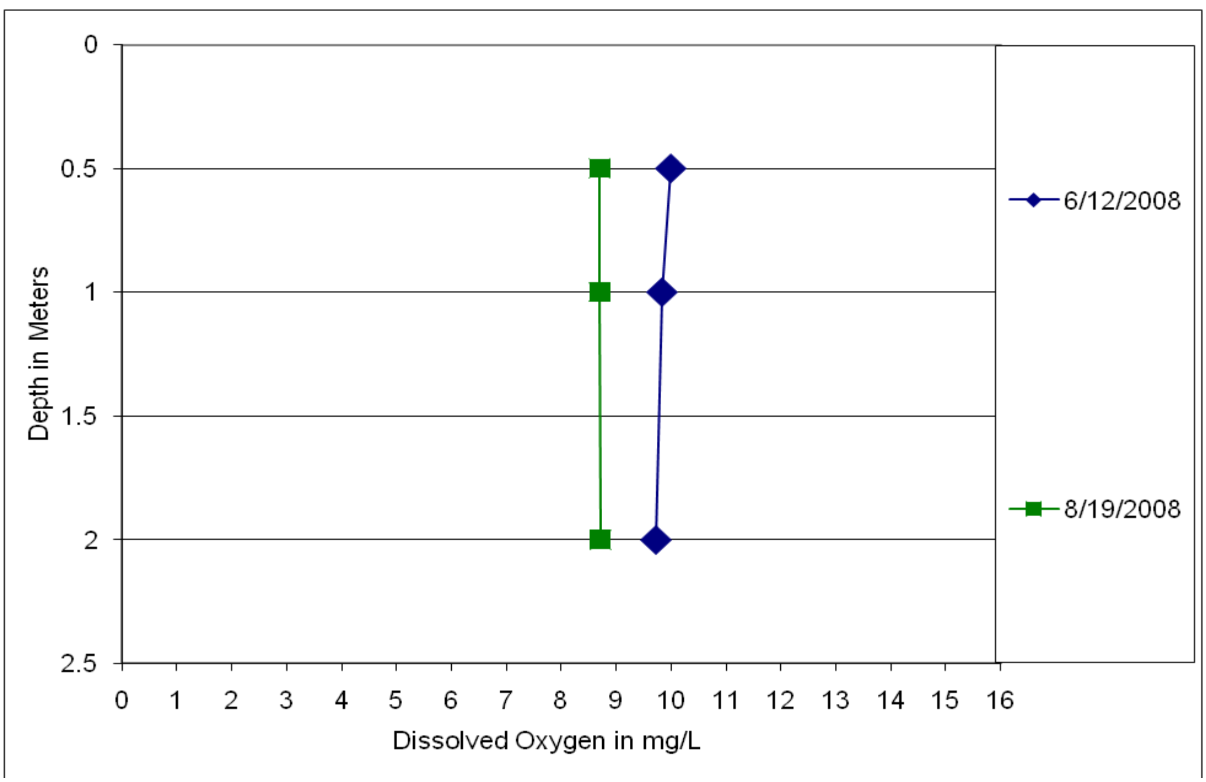

Figure 6. Dissolved Oxygen Profiles for Juanita Lake

Table 1. Statistical Summary of Lake Juanita's 2008 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	2	298	297	298	1
Total Ammonia as N	mg/L	2	0.030[1]	0.030[1]	0.030[1]	0.000
Bicarbonate (HCO_3)	mg/L	2	307	281	332	36
Calcium (Ca)	mg/L	2	42.6	42.0	43.1	0.8
Carbonate (CO_3)	mg/L	2	28	16	40	17
Chloride (Cl)	mg/L	2	23	22	23	1
Chlorophyll-a	µg/L	2	45.4	29.9	60.9	21.9
Specific Conductance	µmhos	2	808	806	809	2
Total Dissolved Solids	mg/L	2	492	488	495	5
Total Hardness as ($CaCO_3$)	mg/L	2	289	288	289	1
Hydroxide (OH)	mg/L	2	1.0[1]	1.0[1]	1.0[1]	0.0
Iron (Fe)	mg/L	2	0.620	0.418	0.822	0.286
Magnesium (Mg)	mg/L	2	44.3	43.9	44.7	0.6
Nitrate + Nitrite as N	mg/L	2	0.030[1]	0.030[1]	0.030[1]	0.000
Total Kjeldahl Nitrogen as N	mg/L	2	1.385	1.310	1.460	0.106
Total Nitrogen as N	mg/L	2	1.415	1.340	1.490	0.106
pH		2	8.75	8.54	8.95	0.29
Total Phosphorus as P	mg/L	2	0.074	0.056	0.091	0.025
Potassium (K)	mg/L	2	13.6	12.7	14.4	1.2
Sodium (Na)	mg/L	2	76.4	70.8	81.9	7.8
Sulfate (SO4)	mg/L	2	112	111	113	1

[1]Equal to the lower reporting limit

Limiting Nutrients: The two water quality samples results for Lake Juanita indicates that it is nitrogen limited (Figure 7). The limiting nutrient assessment is based on the assumption that either nitrogen or phosphorus is limiting algal growth with the lake, and that the ratio of total nitrogen as N to total phosphorus as P (N:P), by weight in the average algae, is approximately 15 to 1. When the N:P ratio is less than 15:1, nitrogen is assumed to be the limiting nutrient and when it exceeds 15:1, the limiting nutrient is assumed to be phosphorus.

Trophic Status Assessment: Based on the chlorophyll-a, secchi disk transparency, and total phosphorus data collected in 2008, Juanita Lake's trophic is hypereutrophic. The trophic Status Index scores ranged from a low of 45 based on chlorophyll-a to a high of 93 based on total phosphorus (Figure 8).

Table 2. Statistical Summary of Water Quality Data[2] Collected from Natural and Enhanced Natural Lakes in the Cultivated Plains Ecological Region of North Dakota

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	191	340	166	1120	181
Total Ammonia as N	mg/L	281	0.106	0.001	1.620	0.198
Bicarbonate (HCO_3)	mg/L	191	355	171	1040	154
Calcium (Ca)	mg/L	193	53.7	12.6	210.0	33.1
Carbonate (CO_3)	mg/L	188	30	1[1]	220	41
Chloride (Cl)	mg/L	191	90	3[1]	1260	206
Chlorophyll-a	µg/L	233	16.4	1.5[1]	908.0	61.8
Specific Conductance	µmhos	210	1742	361	11500	1879
Total Dissolved Solids	mg/L	192	1285	191	9880	1593
Total Hardness as ($CaCO_3$)	mg/L	193	507	173	1820	273
Hydroxide (OH)	mg/L	167	1.0	0.0[1]	1.0	0.2
Iron (Fe)	mg/L	189	0.162	0.007	1.620	0.226
Magnesium (Mg)	mg/L	193	90.6	28.4	413.0	63.1
Nitrate + Nitrite as N	mg/L	272	0.052	0.001[1]	0.680	0.086
Total Kjeldahl Nitrogen as N	mg/L	179	1.497	0.080	4.110	0.632
Total Nitrogen as N	mg/L	154	1.486	0.523	3.860	0.566
pH		193	8.48	1.78	9.56	0.76
Total Phosphorus as P	mg/L	283	0.090	0.002[1]	1.460	0.144
Potassium (K)	mg/L	193	27.7	2.2	179.0	35.6
Sodium (Na)	mg/L	193	227.8	4.5	2570.0	441.5
Sulfate (SO4)	mg/L	191	555	7	3880	728

[1]Equal to the lower reporting limit
[2]Data collected from 53 natural lakes between 1991 and 2010

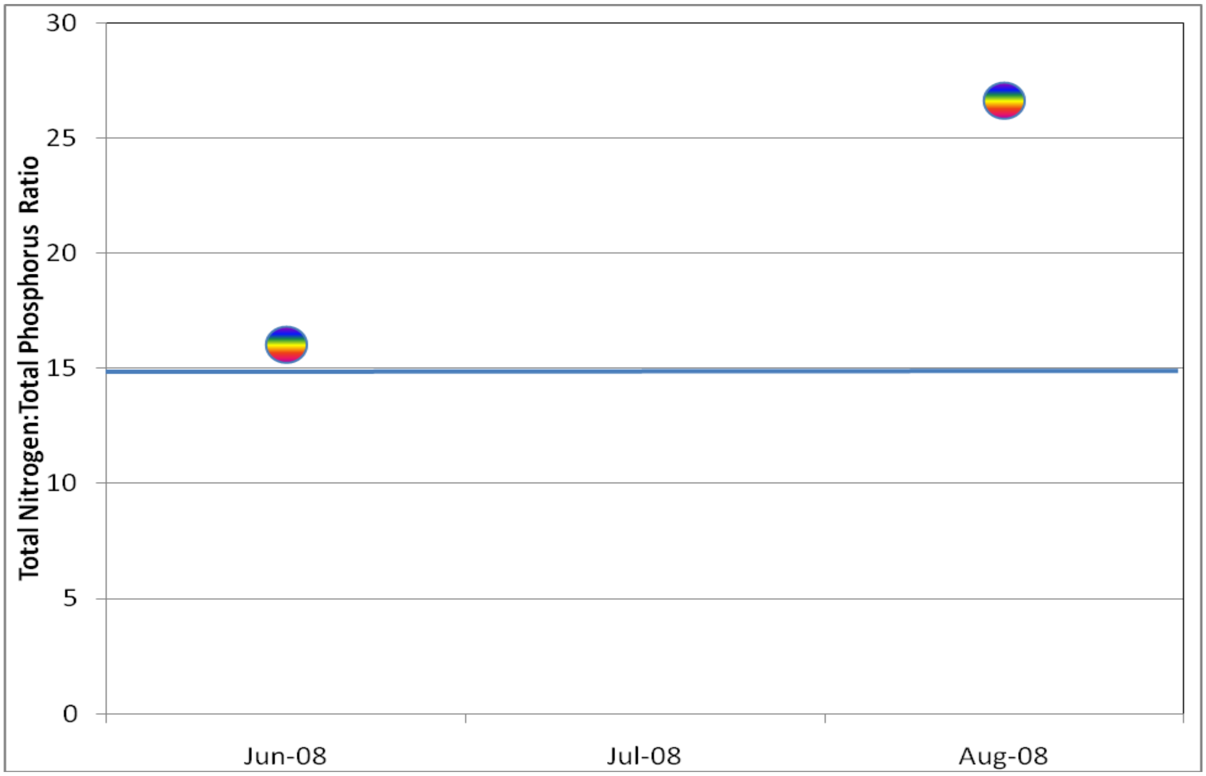

Figure 7. Lake Juanita's Total Nitrogen to Total Phosphorus Ratio

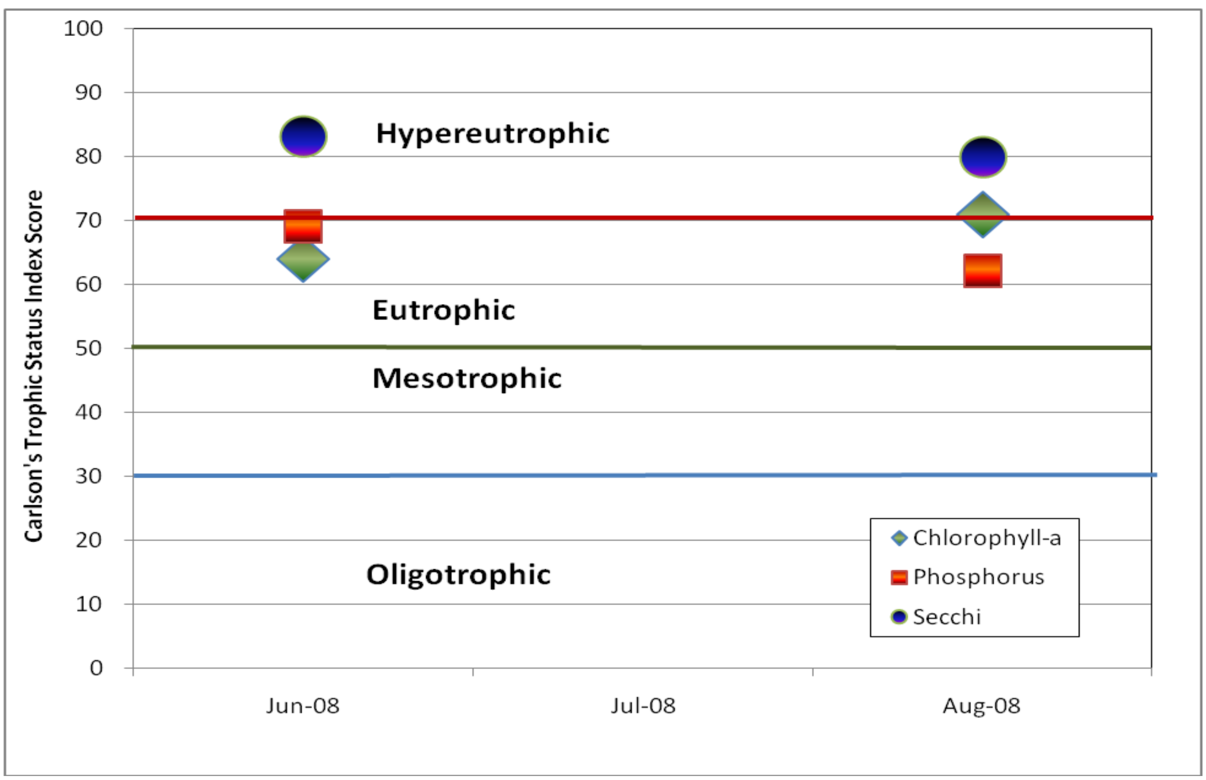

Figure 8. Lake Juanita's TSI Scores

Odland Dam, Golden Valley County

BACKGROUND

Location: Odland Dam is narrow winding reservoir on Little Beaver Creek just north of Beach, North Dakota (Figure 1). While small at only 116 acres, Odland Dam is an important recreational water body in this sparsely populated semi-arid region of North Dakota. The fishery is managed by the North Dakota Game and Fish Department. Fish species stocked in recent years are northern pike, walleye, yellow perch and bluegill.

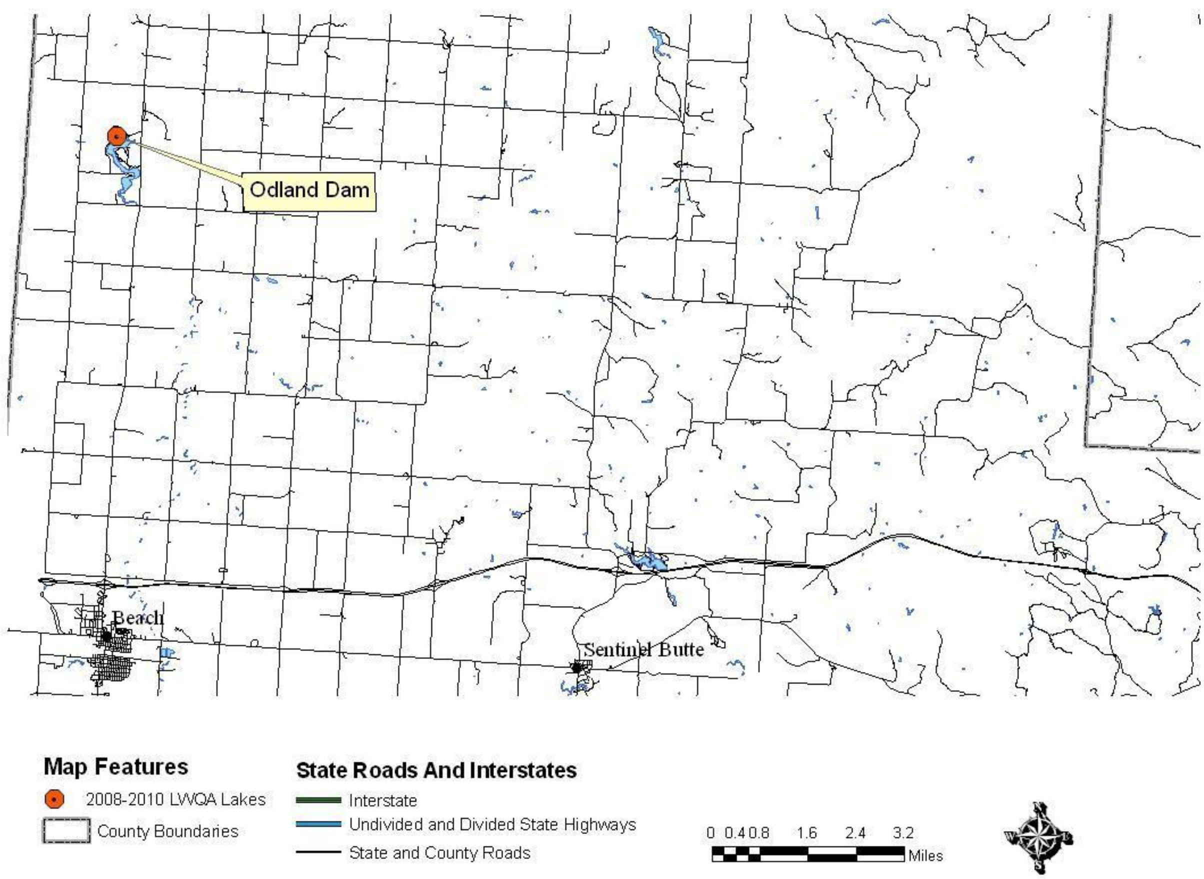

Figure 1. Location of Odland Dam

Physiographic/Ecological Setting: Odland Dam has a surface area of 116.9 acres, a maximum depth of 16.6 ft, and an average depth of 5.6 ft. The reservoir is narrow and shallow providing excellent access to a significant portion of the surface area from shore fisherman (Figure 2). The reservoir is located in the Northwestern Great Plains Level III Ecoregion, which is part of the broader Rangeland Plains region (Figures 3 and 4).

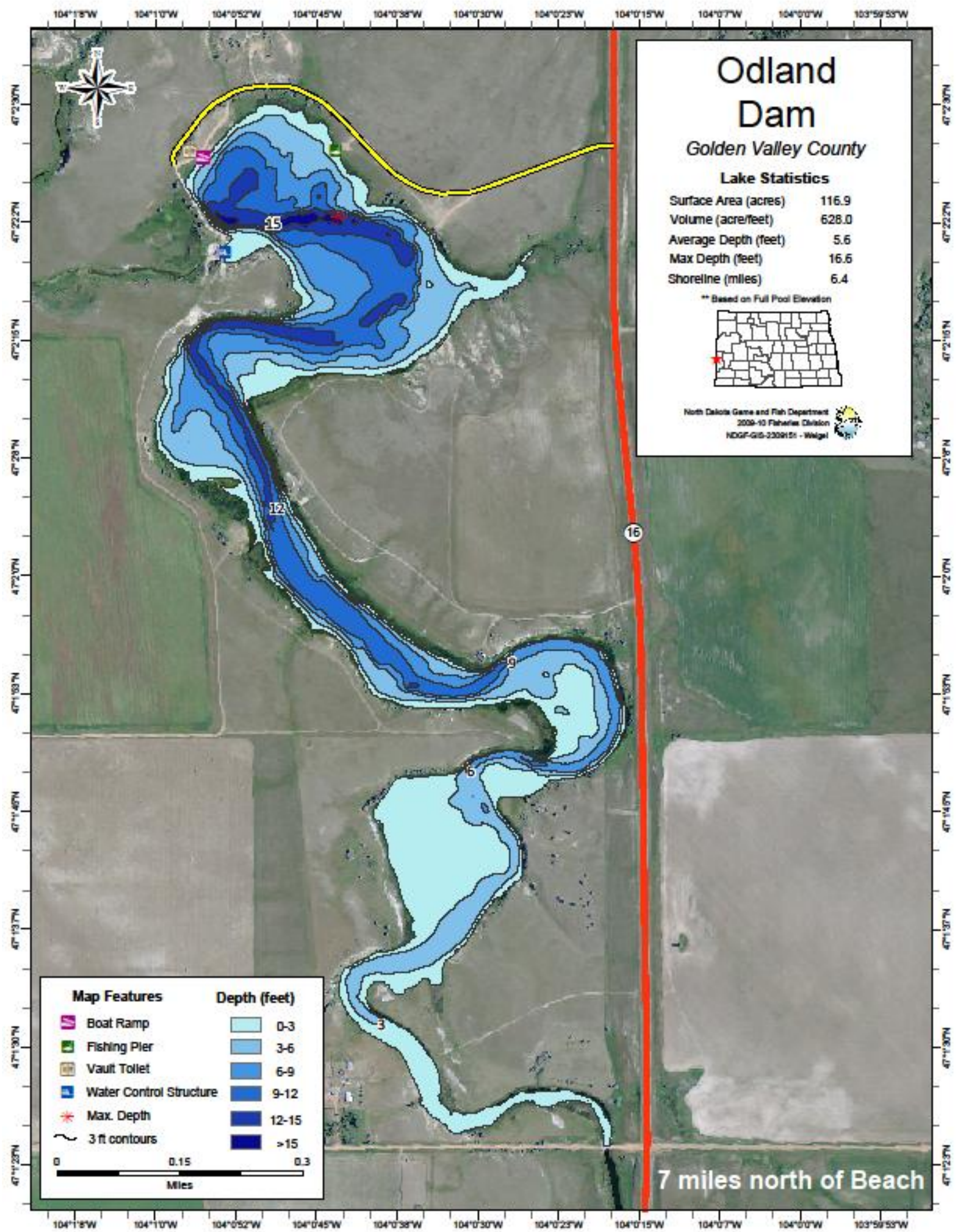

Figure 2. Contour Map of Odland Dam (Courtesy of the North Dakota Game and Fish Department)

Recreational Facilities: Recreational facilities at Odland Dam are access roads, concrete boat ramp with courtesy dock, fishing pier, and an outdoor toilet.

Water Quality Standards Classification: Odland Dam is classified in the state "Standards of Quality for Waters of the State" (NDDoH, 2011) as a class 3 reservoir. Class 3 lakes or reservoirs are defined as a "warm water fishery" or "waters capable of supporting natural reproduction and growth of warm water fishes (e.g., largemouth bass and bluegill) and associated aquatic biota. Some cool water species may also be present."

Historical Water Quality Sampling: No historical water quality data.

WATER QUALITY MONITORING RESULTS

The water quality assessment for Odland Dam is presented in four general categories: 1) temperature and dissolved oxygen profile results; 2) general water quality characterization; 3) nutrient limitation; and 4) trophic status. Where appropriate, results have been compared to the regional data for reservoirs in the Rangeland Plains region.

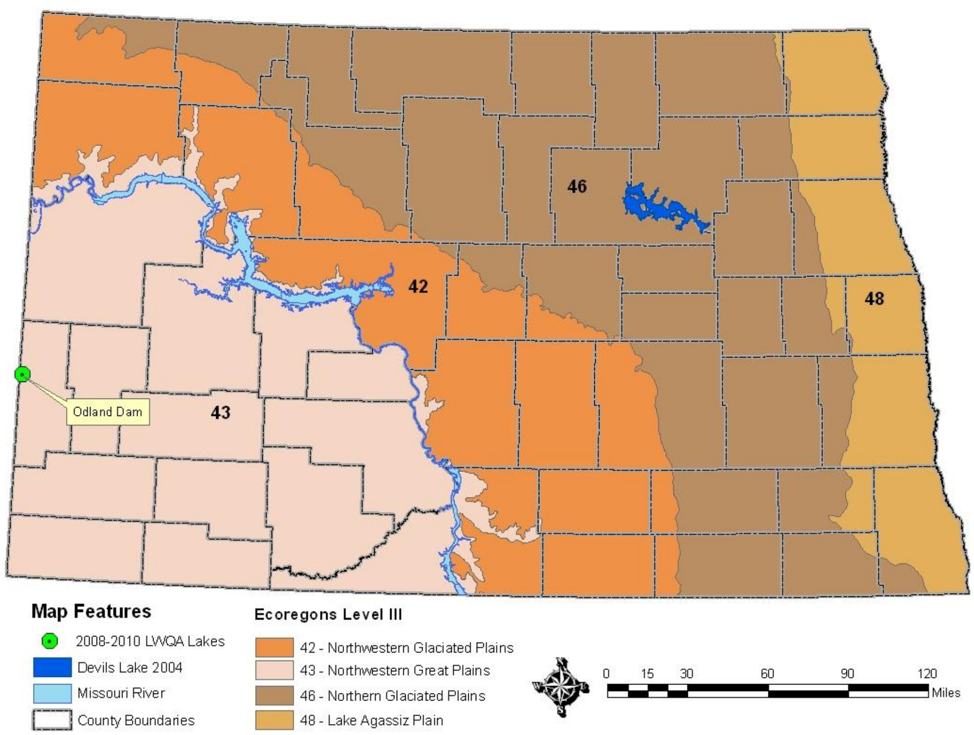

Figure 3. Odland Dam's Location and the Level III Ecoregions

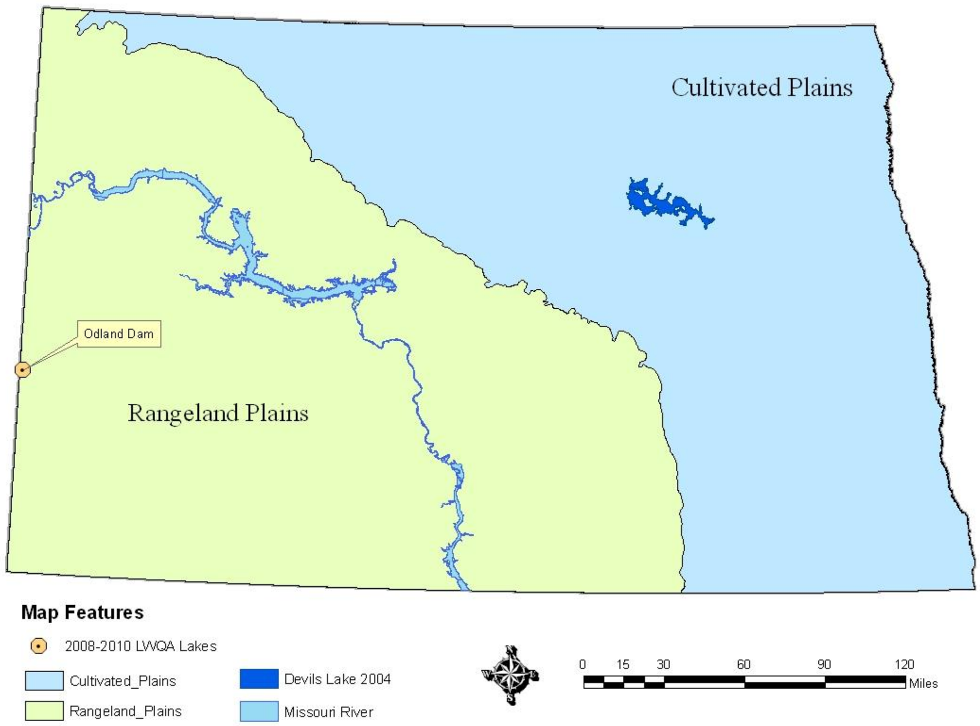

Figure 4. Odland Dams's Location and the Cultivated and Rangeland Plans Regions

Temperature and Dissolved Oxygen Profile Results: There are six temperature and dissolved oxygen profiles for Odland Dam collected in two periods 1992-93 and 2009 (Figures 5 and 6). The profile data shows that the water body does occasionally weakly thermally stratify. In response during thermal stratification dissolved oxygen concentrations decline, but for the most part remain above the 5.0 mg/L concentrations required to support aquatic life.

General Water Quality: Data collected in 2009 indicate that Odland Dam is well buffered with total alkalinity as $CaCO_3$ concentrations ranging from 288 to 400 mg/L (Table 1). The reservoir is sodium sulfate dominated with an average sodium concentration of 742 mg/L and an average sulfate concentration of 2773 mg/L. The average total dissolved solids concentration and specific conductance measurements for the 2009 sampling period were 4310 mg/L and 4940 µmhos/cm, respectively, and the average total nitrogen as N and total phosphorus as P concentrations were 2.280 mg/L and 0.171 mg/L respectively.

When compared to the average water quality for reservoirs in the Rangeland Plans region, Odland Dam contains higher concentrations of dissolved solids and is more eutrophic than most (Table 3). For example, the average regional concentrations for TDS, total nitrogen, and total phosphorus concentrations are 1107 mg/L, 1.314 mg/L, and 0.128 mg/L respectively, compared to Odland Dam's average TDS, total nitrogen, and total phosphorus concentrations of 4310 mg/L, 2.280 mg/L and 0.171 mg/L respectively.

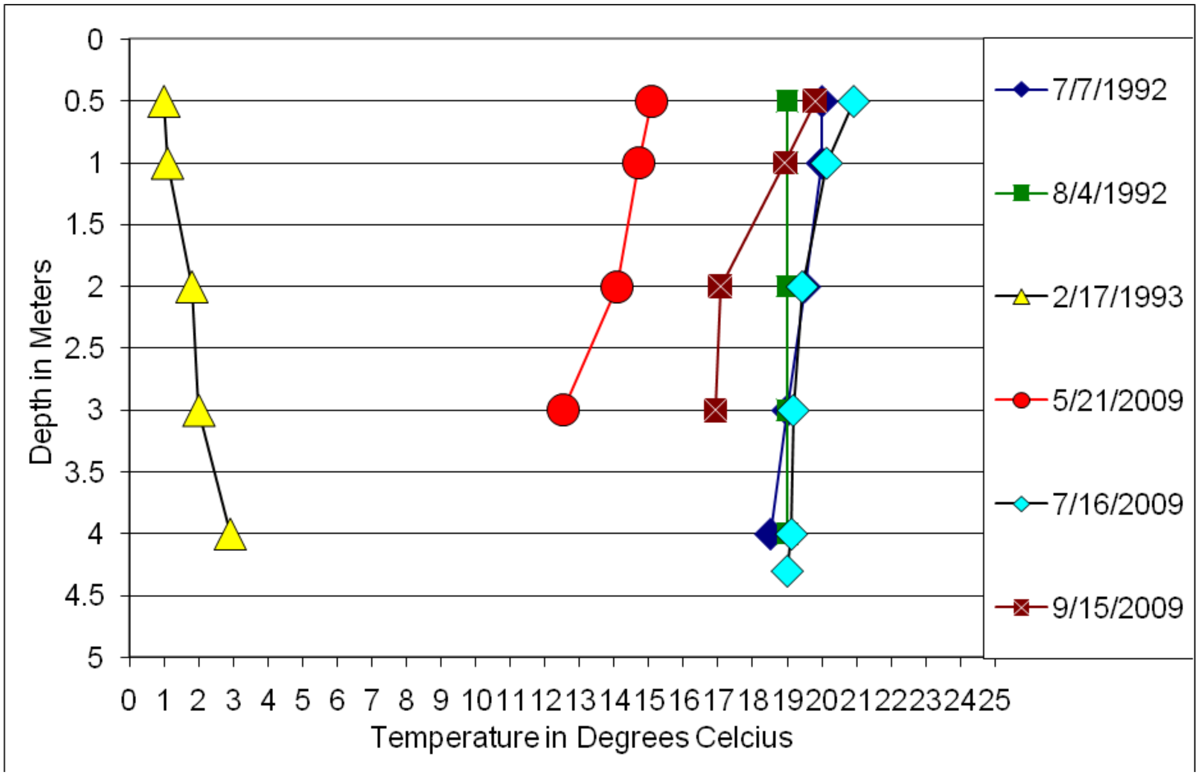

Figure 5. Temperature Profiles for Odland Dam

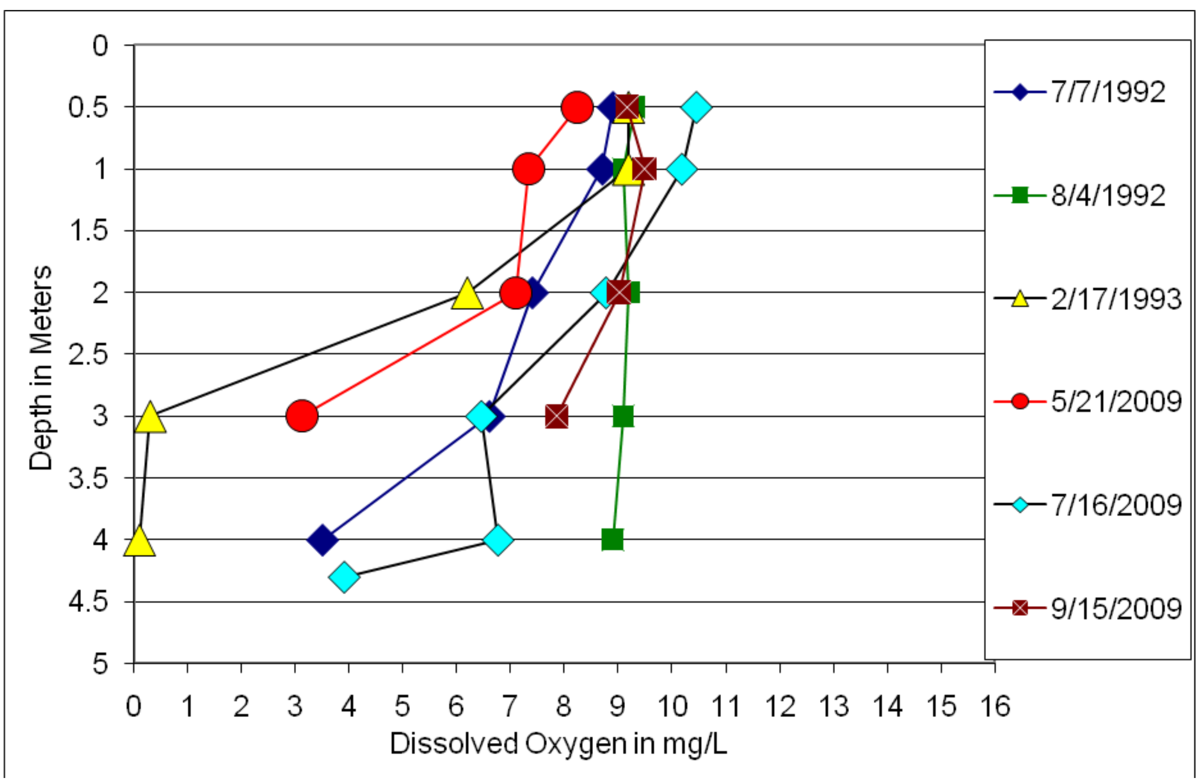

Figure 6. Dissolved Oxygen Profiles for Odland Dam

Table 1. Statistical Summary of Odland Dam's 2009 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	3	350	288	400	57
Total Ammonia as N	mg/L	3	0.121	0.030[1]	0.303	0.158
Bicarbonate (HCO_3)	mg/L	3	363	352	370	10
Calcium (Ca)	mg/L	3	147.0	121.0	163.0	22.7
Carbonate (CO_3)	mg/L	3	32	1[1]	59	29
Chloride (Cl)	mg/L	3	62	56	66	5
Chlorophyll-a	µg/L	2	11.2	4.8	17.5	9.0
Specific Conductance	µmhos	3	4940	4380	5490	555
Total Dissolved Solids	mg/L	3	4310	3720	4830	558
Total Hardness as ($CaCO_3$)	mg/L	3	1787	1610	2100	272
Hydroxide (OH)	mg/L	3	1.0[1]	1.0[1]	1.0[1]	0.0
Iron (Fe)	mg/L	3	0.396	0.189	0.500	0.180
Magnesium (Mg)	mg/L	3	345.0	296.0	412.0	60.1
Nitrate + Nitrite as N	mg/L	3	0.053	0.030[1]	0.100	0.040
Total Kjeldahl Nitrogen as N	mg/L	3	2.227	2.150	2.330	0.093
Total Nitrogen as N	mg/L	3	2.280	2.230	2.360	0.070
pH		3	8.50	8.10	8.75	0.35
Total Phosphorus as P	mg/L	3	0.171	0.134	0.217	0.042
Potassium (K)	mg/L	3	28.0	24.2	30.4	3.4
Sodium (Na)	mg/L	3	742.0	627.0	804.0	99.7
Sulfate (SO4)	mg/L	3	2773	2390	3120	366

[1]Equal to the lower reporting limit

When comparing historical water quality data (1992-1993) to the 2009 water quality data, it appears that some soluble water quality constituents have increased while nutrients have decreased. For example, the historical average sulfate and sodium concentrations were 2332 mg/L and 690 mg/L, respectively, compared to the 2009 averages of 2773 mg/L and 742 mg/L (Tables 1 and 2). However unlike the dissolved solids, nutrient concentrations appear to be trending downward with total nitrogen and total phosphorus concentrations decreasing from 2.735 mg/L and 0.220 mg/L, in 1992-93, to 2.28 mg/L and 0.171 mg/L in 2009.

Limiting Nutrients: The six water quality samples collected between 1992 and 2009 indicate that Odland Dam is nitrogen limited (Figure 7). The limiting nutrient assessment is based on the assumption that either nitrogen or phosphorus is limiting algal growth and that the ratio of total nitrogen as N to total phosphorus as P (N:P), by weight in the average algae is approximately 15 to 1. When the N:P ratio is less than 15:1, nitrogen is assumed to be the limiting nutrient and when it exceeds 15:1, the limiting nutrient is assumed to be phosphorus.

Table 2. Statistical Summary of Odland Dam's 1992-1993 Water Quality Data.

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	3	485	413	628	109
Total Ammonia as N	mg/L	3	0.055	0.021	0.109	0.041
Bicarbonate (HCO_3)	mg/L	3	549	424	747	153
Calcium (Ca)	mg/L	3	129.7	113.0	160.0	22.0
Carbonate (CO_3)	mg/L	3	21	10	40	14
Chloride (Cl)	mg/L	3	54	43	75	16
Chlorophyll-a	µg/L	2	7.5	3.0	12.0	6.4
Specific Conductance	µmhos	3	4574	3905	5880	1008
Total Dissolved Solids	mg/L	3	3787	2970	5110	989
Total Hardness as ($CaCO_3$)	mg/L	3	1405	1160	1850	327
Hydroxide (OH)	mg/L	2	1.0[1]	1.0[1]	1.0[1]	0.0
Iron (Fe)	mg/L	3	0.182	0.093	0.304	0.091
Magnesium (Mg)	mg/L	3	262.2	211.0	353.0	66.5
Nitrate + Nitrite as N	mg/L	3	0.058	0.003[1]	0.088	0.032
Total Kjeldahl Nitrogen as N	mg/L	3	2.678	1.540	3.900	1.103
Total Nitrogen as N	mg/L	3	2.735	1.543	3.988	1.135
pH		3	8.46	8.29	8.73	0.20
Total Phosphorus as P	mg/L	3	0.220	0.136	0.293	0.059
Potassium (K)	mg/L	3	26.9	21.4	35.0	6.2
Sodium (Na)	mg/L	3	690.0	536.0	932.0	184.8
Sulfate (SO4)	mg/L	3	2332	1790	3210	632

[1]Equal to the lower reporting limit

Trophic Status Assessment: Based on the chlorophyll-a, secchi disk transparency, and total phosphorus data collected in 2009, Odland Dam's trophic status is eutrophic. The trophic status index (TSI) scores ranged from a low of 14 based on total phosphorus concentrations to a high of 59 based on secchi disk transparency (Figure 8).

A total of six total phosphorus samples, four chlorophyll-a samples and five secchi disk transparency measurements collected during the sampling periods of 1992-93 and 2009 were available to evaluate trends in the trophic status of Odland Dam. While not conclusive the limited data indicates Odland Dam is stable to improving.

Table 3. Statistical Summary of Water Quality Data[2] Collected from Reservoirs and Impoundments in the Rangeland Plains Ecological Region of North Dakota

Parameter	Units	N	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	522	283	54	982	131
Total Ammonia as N	mg/L	593	0.092	0.001[1]	2.440	0.183
Bicarbonate (HCO_3)	mg/L	522	295	14	1040	145
Calcium (Ca)	mg/L	522	52.3	4.7	163.0	27.3
Carbonate (CO_3)	mg/L	520	25	1[1]	197	29
Chloride (Cl)	mg/L	522	13	3[1]	75	9
Chlorophyll-a	µg/L	415	20.1	1.5[1]	218.0	27.0
Specific Conductance	µmhos	542	1621	173	5880	988
Total Dissolved Solids	mg/L	523	1107	100	5110	782
Total Hardness as ($CaCO_3$)	mg/L	522	396	45	2100	279
Hydroxide (OH)	mg/L	465	1.0	0.0[1]	1.0	0.2
Iron (Fe)	mg/L	523	0.193	0.007	4.110	0.349
Magnesium (Mg)	mg/L	522	64.5	5.6	412.0	54.0
Nitrate + Nitrite as N	mg/L	592	0.060	0.001[1]	0.790	0.102
Total Kjeldahl Nitrogen as N	mg/L	483	1.375	0.108	7.720	0.789
Total Nitrogen as N	mg/L	426	1.314	0.178	4.840	0.605
pH		542	8.55	6.73	9.87	0.55
Total Phosphorus as P	mg/L	599	0.128	0.004[1]	3.160	0.190
Potassium (K)	mg/L	522	13.8	2.6	39.2	6.5
Sodium (Na)	mg/L	522	217.2	3.0	932.0	171.6
Sulfate (SO4)	mg/L	520	573	1[1]	3210	519

[1]Equal to the lower reporting limit
[2]Data collected from 76 reservoirs between 1991 and 2010

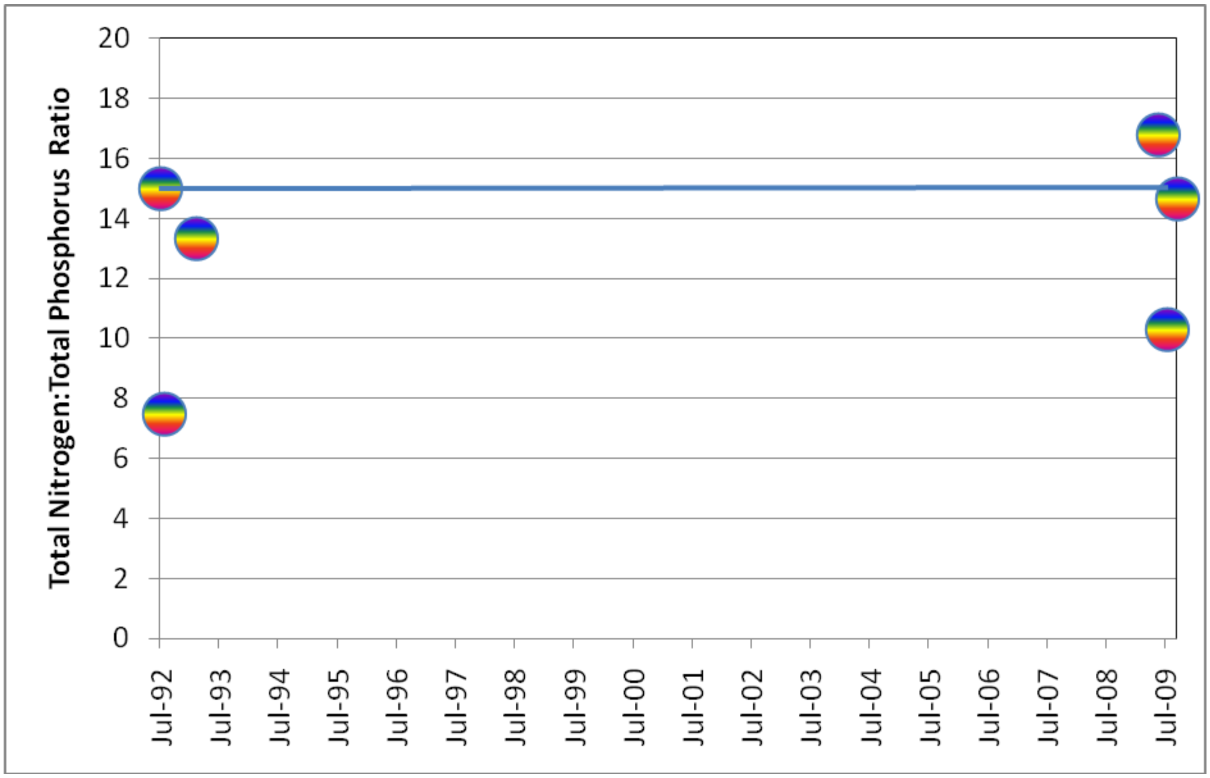

Figure 7. Odland Dam's Total Nitrogen to Total Phosphorus Ratio

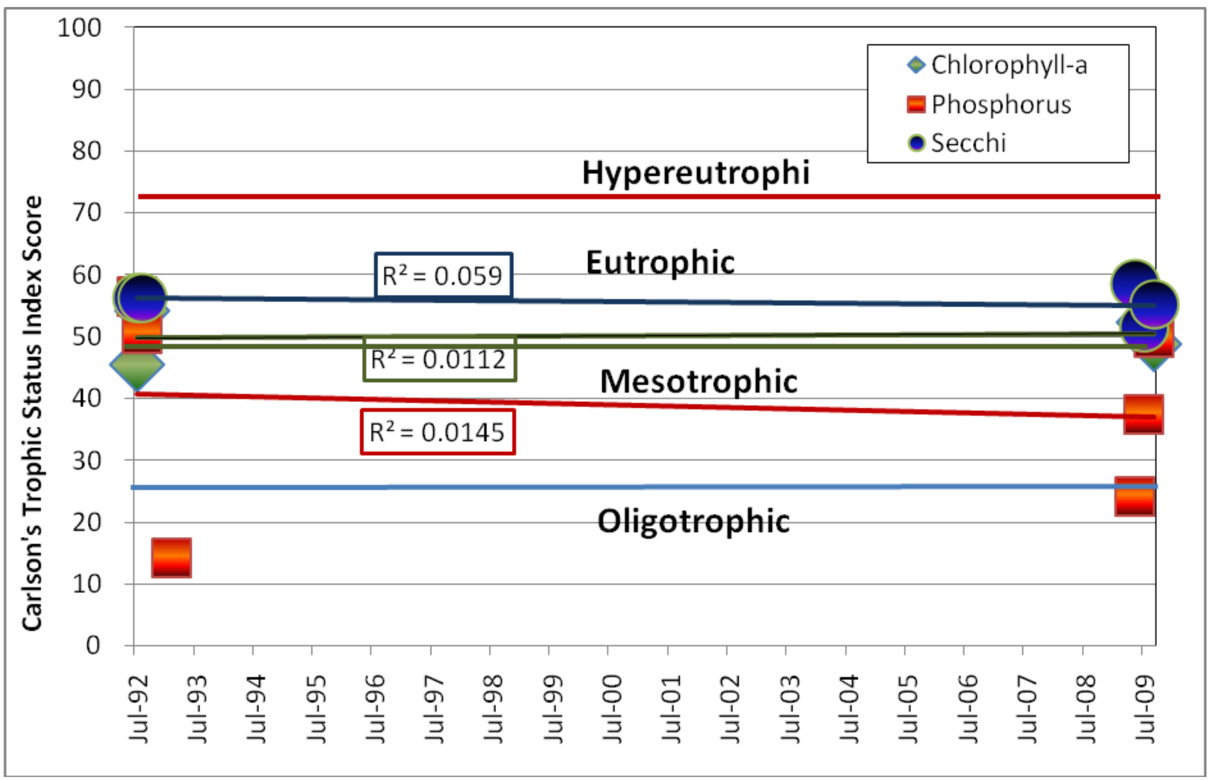

Figure 8. Odland Dam's TSI Scores

Carlson-Tande Dam, Griggs County

BACKGROUND

Location: Carlson-Tande Dam is a small impoundment on an un-named drainage of the Sheyenne River 5 miles west and one mile south of Aneta, North Dakota (Figure 1). It is at the end of a low maintenance road in a very pleasant valley setting. The fishery is managed by the North Dakota Game and Fish Department (NDG&F). Fish species recently stocked by the NDG&F are northern pike.

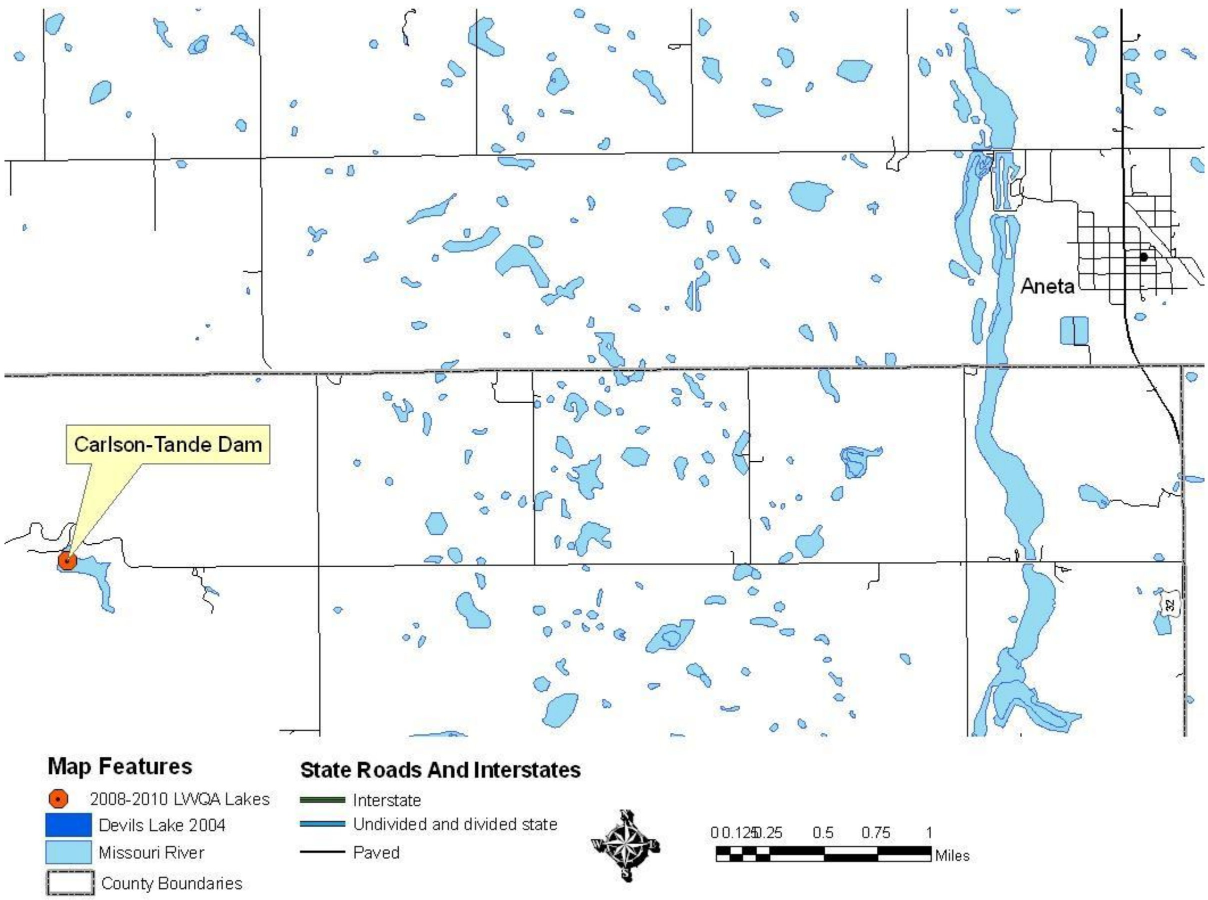

Figure 1. Location of Carlson-Tande Dam

Physiographic/Ecological Setting: Carlson-Tande Dam has a surface area of approximately 15 acres and a maximum depth of 24 ft (Figure 2). The reservoir is located in the Northern Glaciated Plains Level III Ecoregion, which is part of the broader Cultivated Plains region (Figures 3 and 4).

Figure 2. Aerial View of Carlson-Tande Dam

Recreational Facilities: Recreational facilities at Carlson-Tande Dam include a gravel boat ramp, fishing pier and parking.

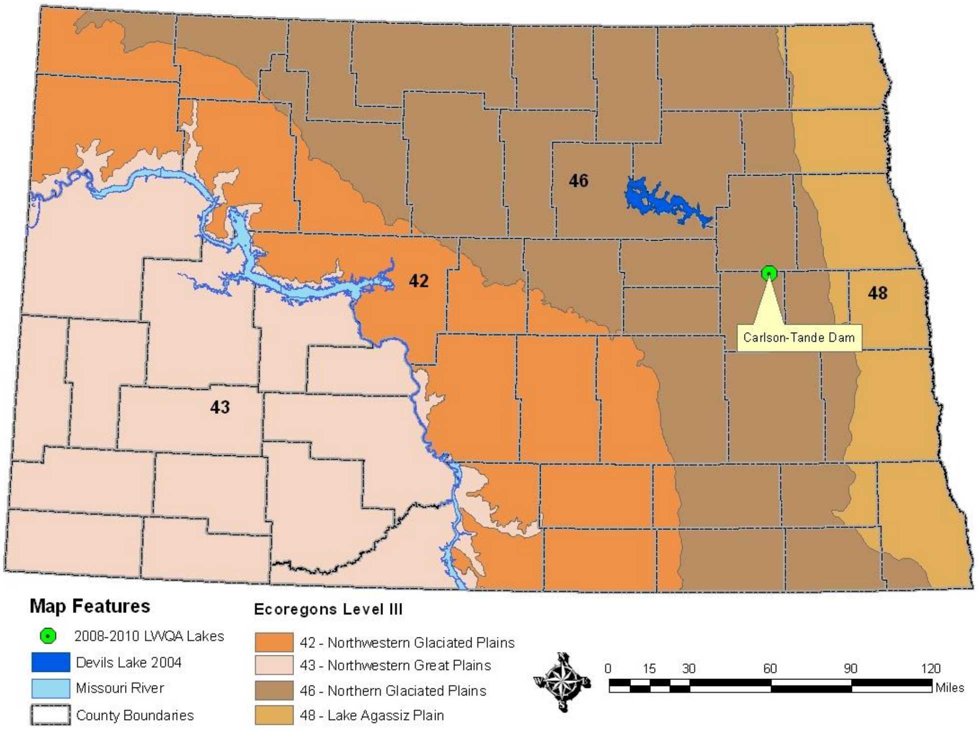

Figure 3. Carlson-Tande Dam's Location and the Level III Ecoregions

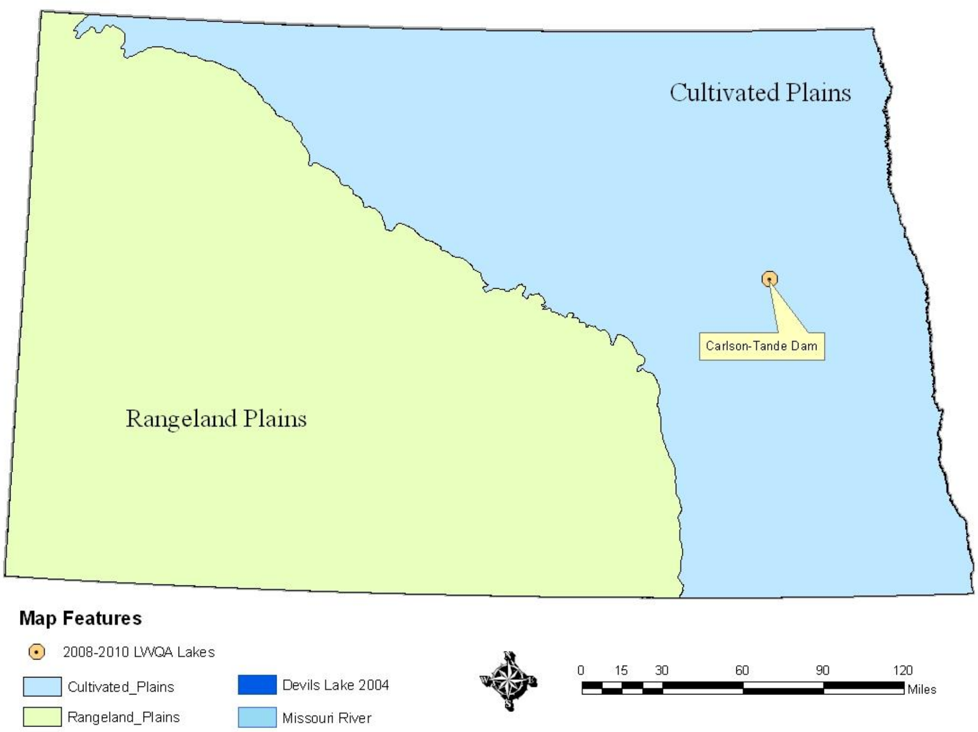

Figure 4. Carlson-Tande Dam's Location and the Cultivated and Rangeland Plans Regions

Water Quality Standards Classification: Carlson-Tande Dam is classified in the state "Standards of Quality for Waters of the State" (NDDoH, 2011) as a class 3 lake. Class 3 lakes or reservoirs are defined as a "warm water fishery" or "waters capable of supporting natural reproduction and growth of warm water fishes (e.g., largemouth bass and bluegill) and associated aquatic biota. Some cool water species may also be present."

Historical Water Quality Sampling: No historical water quality data.

WATER QUALITY MONITORING RESULTS

The water quality assessment for Carlson-Tande Dam is presented in four general categories: 1) temperature and dissolved oxygen profile results; 2) general water quality characterization; 3) nutrient limitation; and 4) trophic status. Additionally, where appropriate, results have been compared to the regional data on reservoirs in the Cultivated Plains region.

Temperature and Dissolved Oxygen Profile Results: There are three temperature and dissolved oxygen profiles for Carlson-Tande Dam collected in 2010. The profile data shows that the water body does weakly thermally stratify. During periods of thermal stratification the reservoir experienced rapid oxygen decay below the thermocline. However, even with this decay the reservoir remains well enough oxygenated to support aquatic life throughout the majority of the water column (Figures 5 and 6).

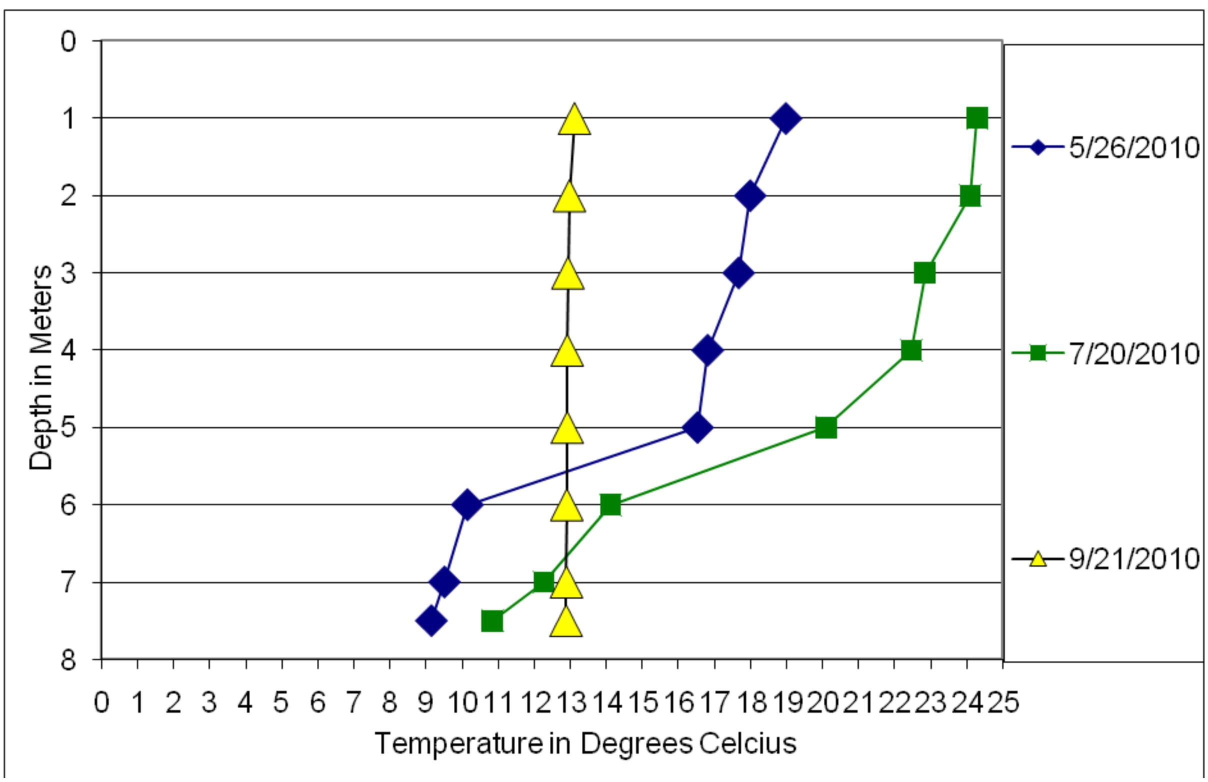

Figure 5. Temperature Profiles for Carlson-Tande Dam

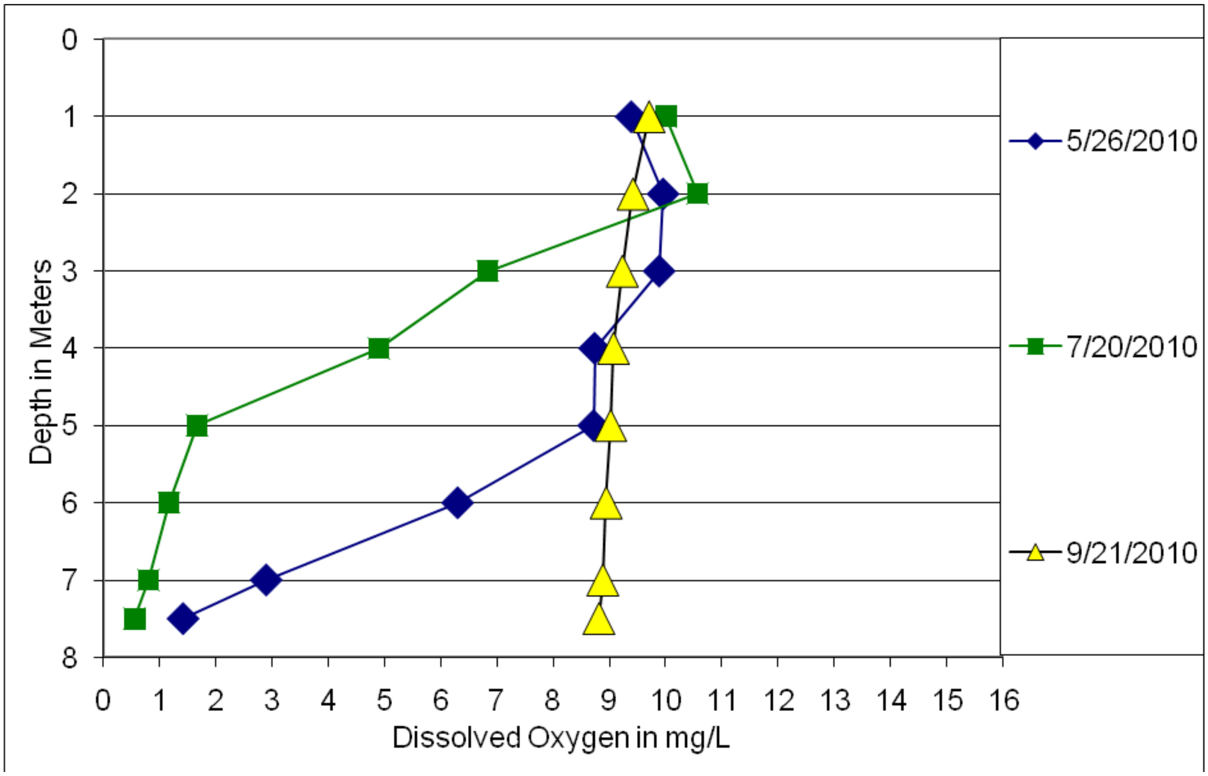

Figure 6. Dissolved Oxygen Profiles for Carlson-Tande Dam

General Water Quality: Data collected in 2010 indicate that Carlson Tande Dam is well buffered with total alkalinity as $CaCO_3$ concentrations ranging from 218 to 276 mg/L (Table 1). The reservoir is sodium sulfate dominated with an average sodium concentration of 88.7 mg/L and an average sulfate concentration of 335 mg/L. The average total dissolved solids concentration and specific conductance measurements for the 2010 sampling period were 718 mg/L and 1090 µmhos/cm, respectively, and the average total nitrogen as N and total phosphorus as P concentrations were 0.839 mg/L and 0.029 mg/L respectively.

When compared to water quality for reservoirs in the Cultivated Plans region, Carlson-Tande Dam is more mineralized but less eutrophic than most reservoirs (Table 3). For example, the regional average TDS, total nitrogen, and total phosphorus concentrations are 671 mg/L, 1.520 mg/L, and 0.327 mg/L respectively, compared to Carlson-Tande Dam's average TDS, total nitrogen, and total phosphorus concentrations of 718 mg/L, 0.839 mg/L and 0.029 mg/L respectively.

Table 1. Statistical Summary of Carlson-Tande Dam's 2010 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	2	247	218	276	41
Total Ammonia as N	mg/L	3	0.123	0.030[1]	0.170	0.081
Bicarbonate (HCO_3)	mg/L	2	302	266	337	50
Calcium (Ca)	mg/L	3	78.8	68.6	98.4	17.0
Carbonate (CO_3)	mg/L	2	1[1]	1[1]	1[1]	0
Chloride (Cl)	mg/L	2	9	8	10	1
Chlorophyll-a	µg/L	3	24.8	1.5[1]	58.7	30.0
Specific Conductance	µmhos	2	1090	1040	1140	71
Total Dissolved Solids	mg/L	2	718	658	777	84
Total Hardness as ($CaCO_3$)	mg/L	3	382	354	427	40
Hydroxide (OH)	mg/L	2	1.0[1]	1.0[1]	1.0[1]	0.0
Iron (Fe)	mg/L	3	0.200	0.050	0.500	0.260
Magnesium (Mg)	mg/L	3	45.0	44.1	46.4	1.3
Nitrate + Nitrite as N	mg/L	3	0.030[1]	0.030[1]	0.030[1]	0.000
Total Kjeldahl Nitrogen as N	mg/L	3	0.809	0.574	1.100	0.267
Total Nitrogen as N	mg/L	3	0.839	0.604	1.130	0.267
pH		2	8.23	8.23	8.23	0.00
Total Phosphorus as P	mg/L	3	0.029	0.026	0.032	0.003
Potassium (K)	mg/L	3	7.8	6.4	10.0	1.9
Sodium (Na)	mg/L	3	88.7	84.3	91.1	3.8
Sulfate (SO4)	mg/L	2	335	311	358	33

[1]Equal to the lower reporting limit

Limiting Nutrients: The three water quality samples collected in 2010 indicate that Carlson-Tande Dam is phosphorus limited (Figure 7). The limiting nutrient assessment is based on the assumption that either nitrogen or phosphorus is limiting algal growth and that the ratio of total nitrogen as N to total phosphorus as P (N:P), by weight in the average algae is approximately 15 to 1. When the N:P ratio is less than 15:1, nitrogen is assumed to be the limiting nutrient and when it exceeds 15:1, the limiting nutrient is assumed to be phosphorus.

Trophic Status Assessment: Based on the chlorophyll-a, secchi disk transparency, and total phosphorus data collected in 2010, Carlson-Tande Dam's trophic status is eutrophic. The trophic status index (TSI) scores ranged from a low of 35 based on chlorophyll-a to a high of 57 based on secchi disk (Figure 8).

Table 2. Statistical Summary of Water Quality Data[2] Collected from Reservoirs and Impoundments in the Cultivated Plains Ecological Region of North Dakota

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	400	261	88	891	99
Total Ammonia as N	mg/L	567	0.145	0.001[1]	2.070	0.208
Bicarbonate (HCO_3)	mg/L	400	294	91	951	110
Calcium (Ca)	mg/L	402	66.7	19.4	169.0	22.7
Carbonate (CO_3)	mg/L	382	13	1[1]	93	16
Chloride (Cl)	mg/L	400	21	3[1]	113	17
Chlorophyll-a	µg/L	445	19.9	1.5[1]	388.0	30.2
Specific Conductance	µmhos	400	1025	217	3140	501
Total Dissolved Solids	mg/L	392	671	127	2300	375
Total Hardness as ($CaCO_3$)	mg/L	402	341	95	1090	119
Hydroxide (OH)	mg/L	339	1.0	0.0[1]	1.0	0.2
Iron (Fe)	mg/L	400	0.143	0.007	3.190	0.220
Magnesium (Mg)	mg/L	402	42.3	11.2	161.0	19.6
Nitrate + Nitrite as N	mg/L	560	0.112	0.001[1]	2.060	0.213
Total Kjeldahl Nitrogen as N	mg/L	480	1.470	0.206	4.410	0.648
Total Nitrogen as N	mg/L	419	1.520	0.418	3.950	0.617
pH		401	8.34	1.76	9.40	0.54
Total Phosphorus as P	mg/L	569	0.327	0.002[1]	2.270	0.290
Potassium (K)	mg/L	402	11.6	2.7	34.5	5.4
Sodium (Na)	mg/L	402	96.8	2.2	582.0	102.9
Sulfate (SO4)	mg/L	400	272	1[1]	1350	210

[1]Equal to the lower reporting limit
[2]Data collected from 45 reservoirs between 1991 and 2010

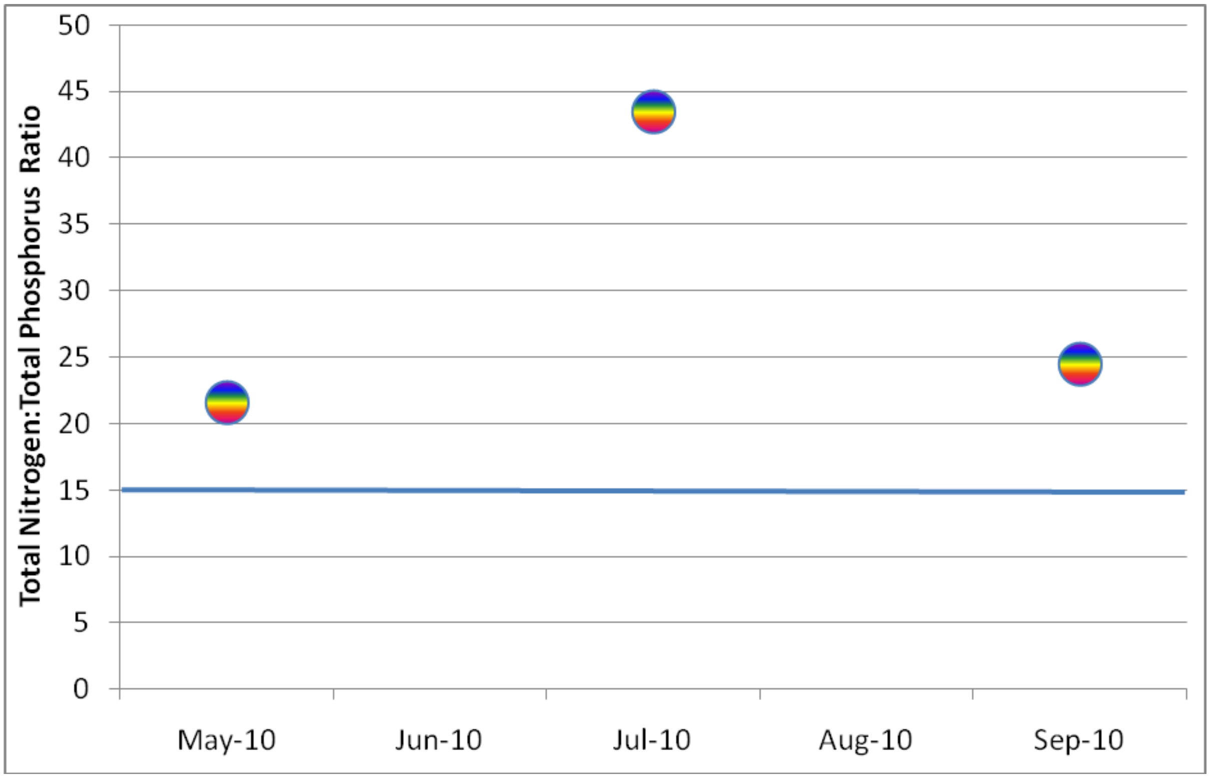

Figure 7. Carlson-Tande Dam's Total Nitrogen to Total Phosphorus Ratio

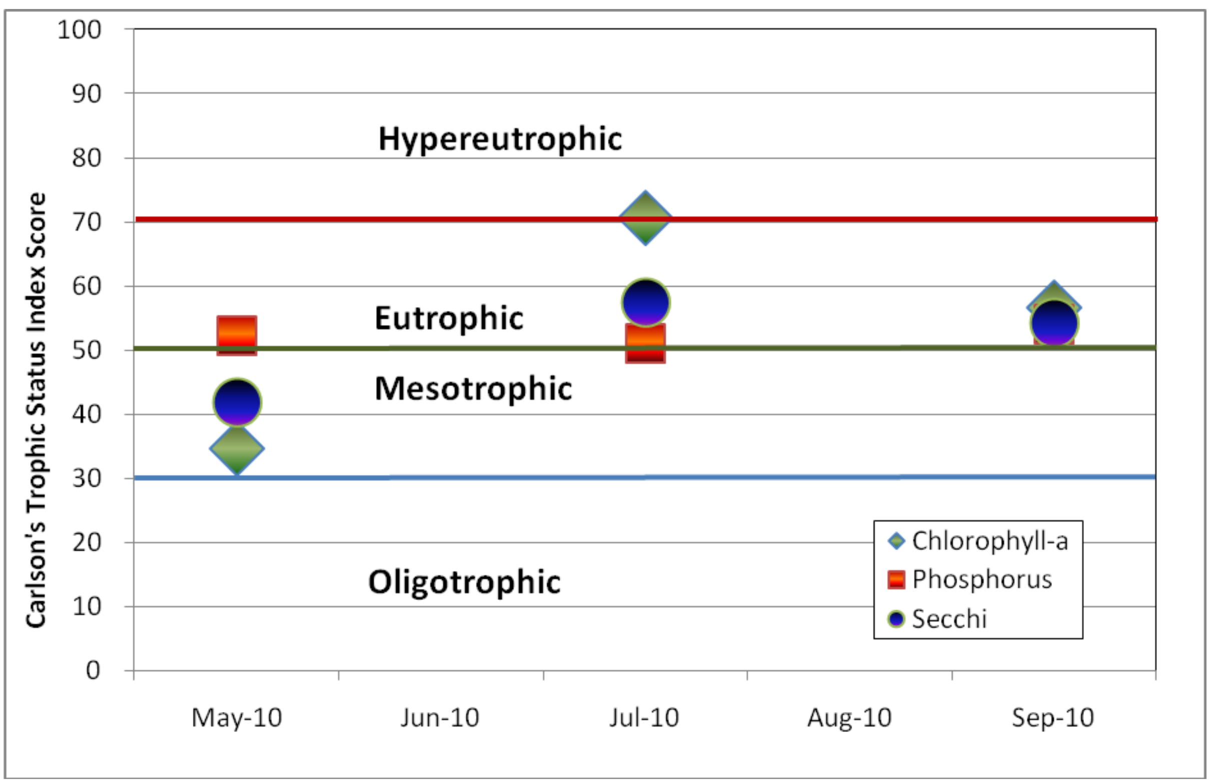

Figure 8. Carlson-Tande Dam's TSI Scores

Cherry Lake, Kidder County

BACKGROUND

Location: Cherry Lake is a shallow natural glacial lake a couple miles southeast of Tuttle, North Dakota (Figure 1). The fishery is managed by the North Dakota Game and Fish. Fish species managed for are northern pike and yellow perch.

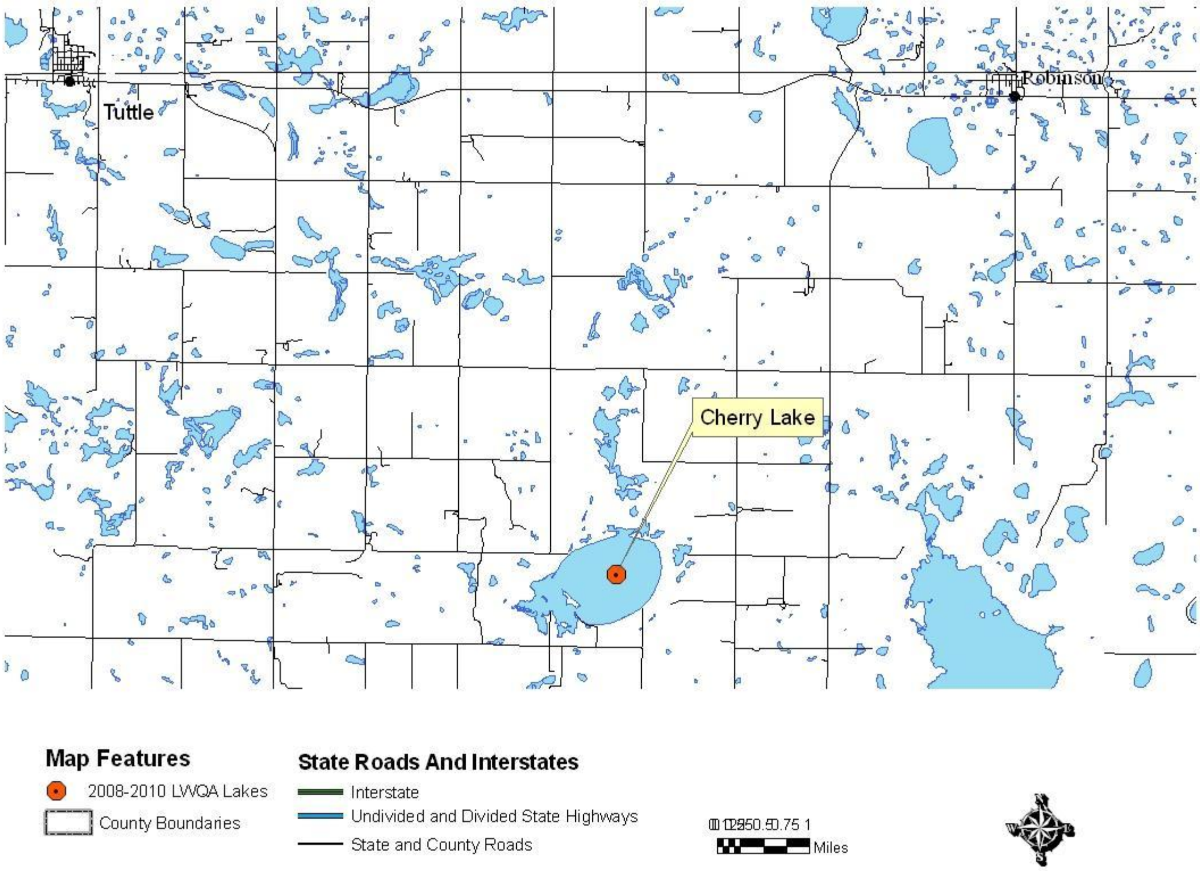

Figure 1. Location of Cherry Lake

Physiographic/Ecological Setting: Cherry Lake has a surface area of 658 acres, a maximum depth of 11.1 ft and an average depth 7.3 (Figure 2). The lake is located within the Northwestern Glaciated Plains Level III Ecoregion, which is part of the broader Rangeland Plains region (Figures 3 and 4).

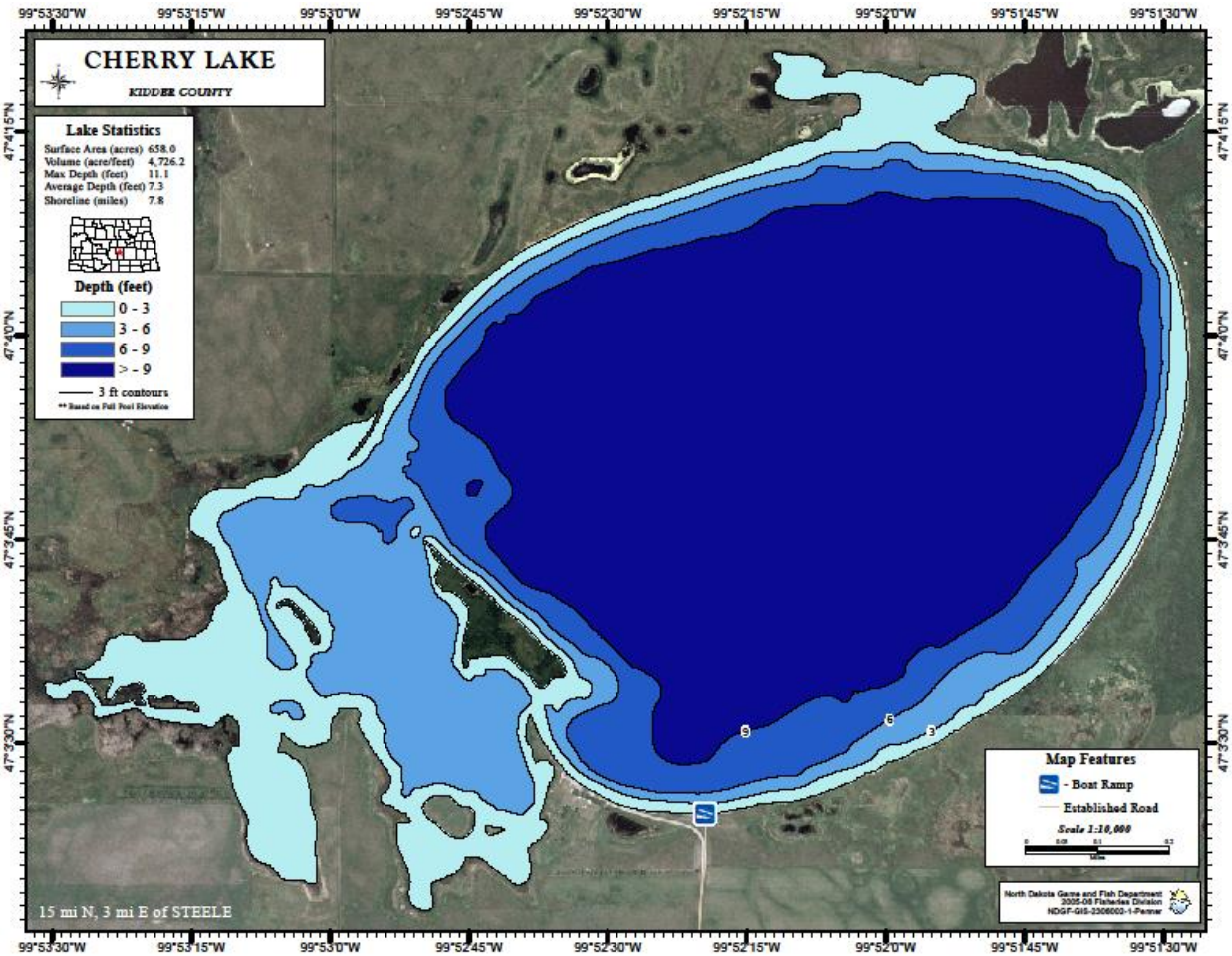

Figure 2. Contour Map of Cherry Lake (Map Courtesy of North Dakota Game and Fish Department)

Recreational Facilities: Recreational facilities at Cherry Lake include a cement boat ramp and vehicle parking.

Water Quality Standards Classification: Cherry Lake is classified in the state "Standards of Quality for Waters of the State" (NDDoH, 2011) as a class 3 lake. Class 3 lakes or reservoirs are defined as a "warm water fishery" or "waters capable of supporting natural reproduction and growth of warm water fishes (e.g., largemouth bass and bluegill) and associated aquatic biota. Some cool water species may also be present."

Historical Water Quality Sampling: No historical water quality data.

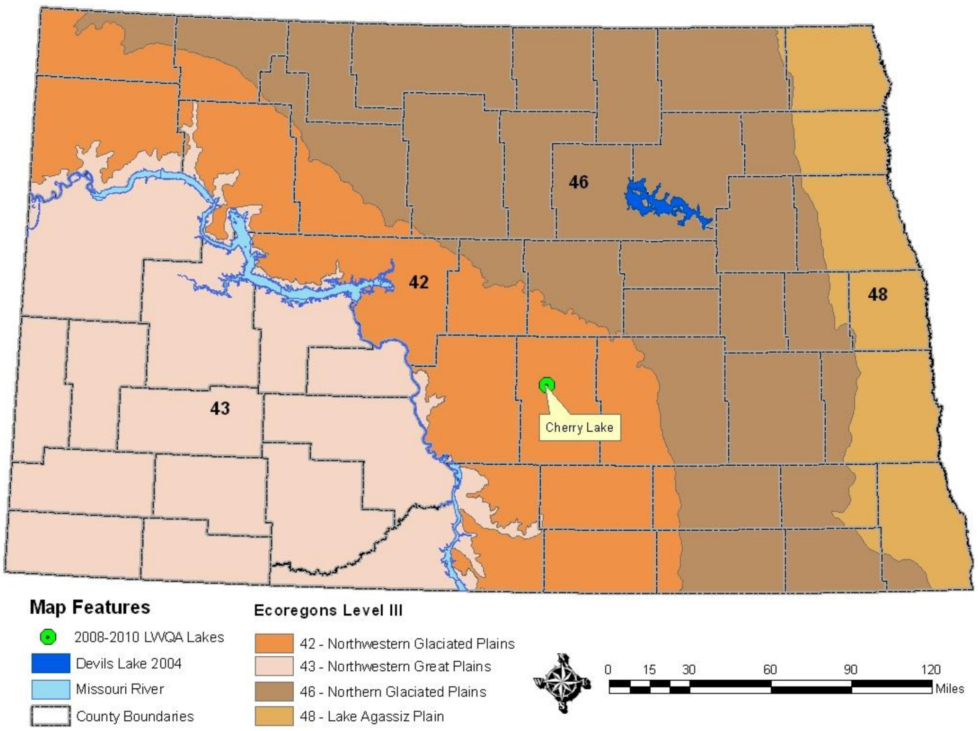

Figure 3. Cherry Lake's Location and the Level III Ecoregions

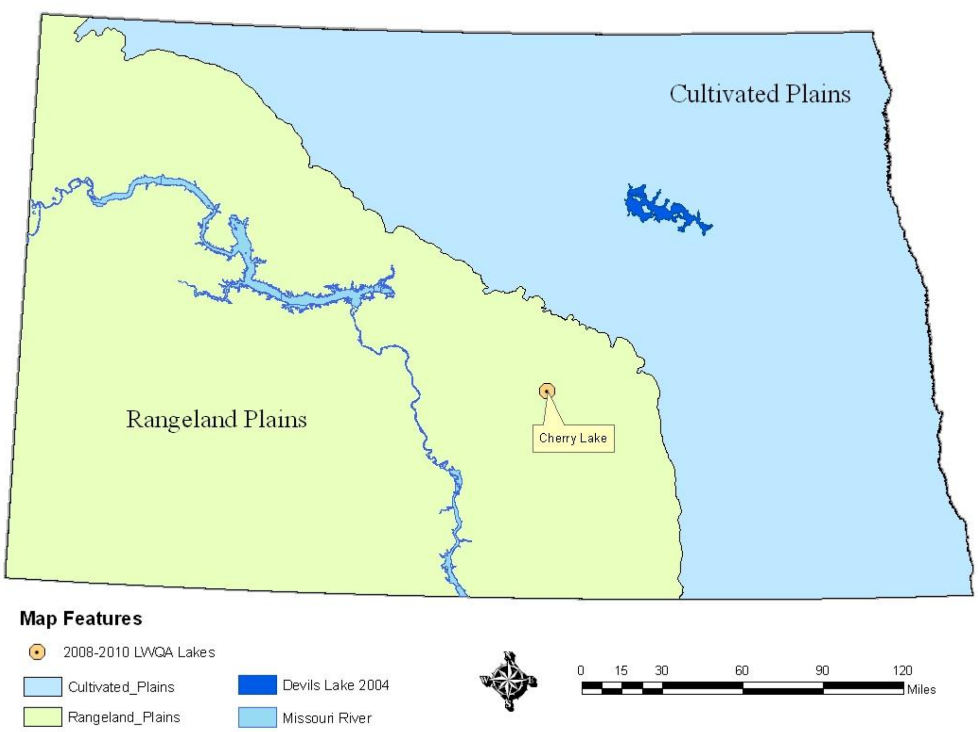

Figure 4. Cherry Lake'sLocation and the Cultivated and Rangeland Plans Regions

WATER QUALITY MONITORING RESULTS

The water quality assessment for Cherry Lake is presented in four general categories: 1) temperature and dissolved oxygen profile results; 2) general water quality characterization; 3) nutrient limitation; and 4) trophic status. Additionally, where appropriate, results have been compared to regional data.

Temperature and Dissolved Oxygen Profile Results: There are two temperature and dissolved oxygen profiles for Cherry Lake collected in 2008 (Figures 5 and 6). The profile data shows that Cherry Lake was not thermally stratification during the open water period. Additionally during the open water period the lake remained well enough oxygenated to support aquatic Life.

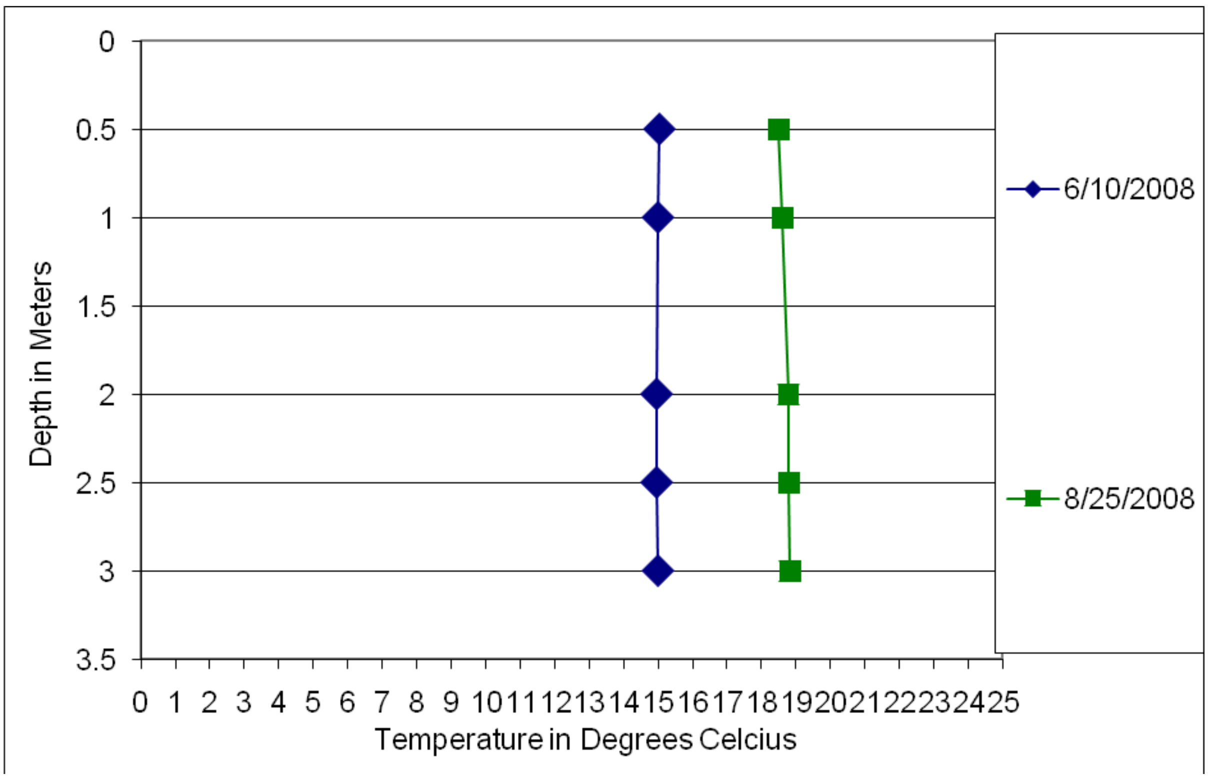

Figure 5. Temperature Profiles for Cherry Lake

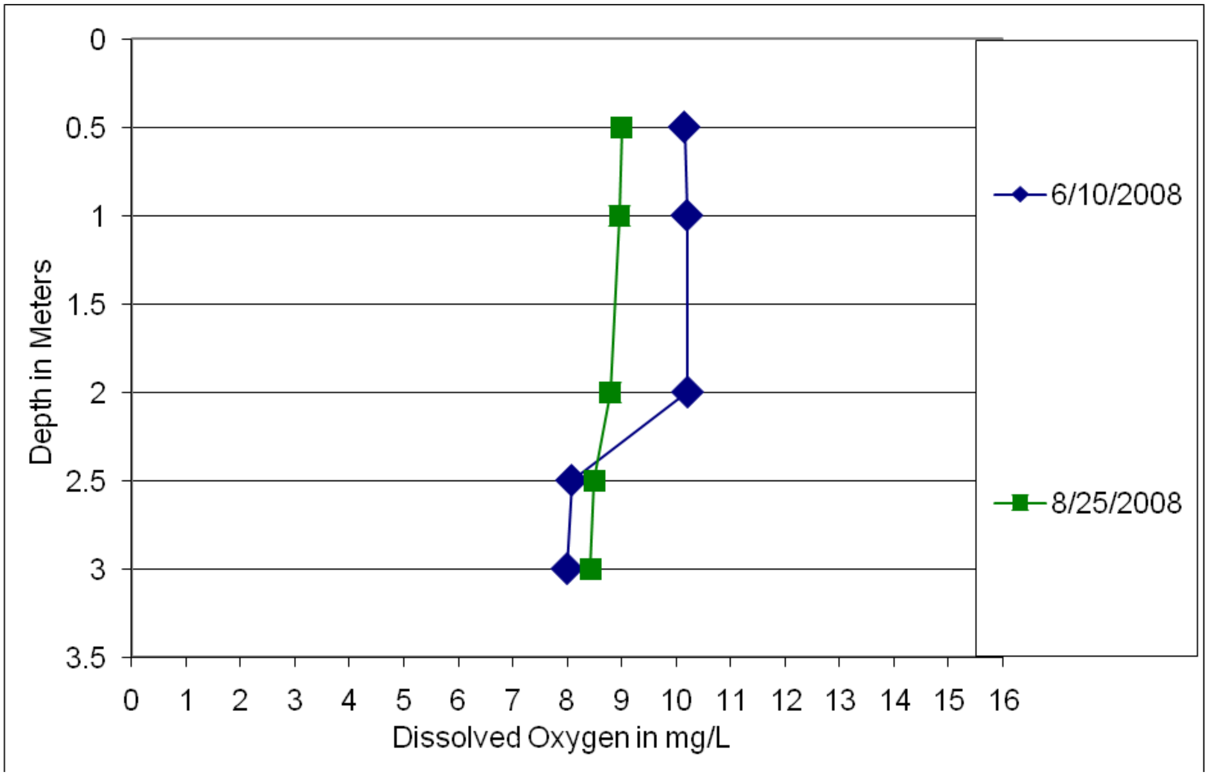

Figure 6. Dissolved Oxygen Profiles for Cherry Lake

General Water Quality: Data collected in 2008 indicate that Cherry Lake is well buffered with total alkalinity as $CaCO_3$ concentrations ranging from 849 to 855 mg/L (Table 1). The lake is sodium bicarbonate dominated with an average sodium concentration of 506.5 mg/L and an average bicarbonate concentration of 714 mg/L. The average total dissolved solids concentration and specific conductance measurement for 2008 sampling period were 1905 mg/L and 2750 µmhos/cm respectively, and the average total nitrogen as N and total phosphorus as P concentrations were 2.765 mg/L and 0.036 mg/L respectively.

When compared to the regional average water quality for natural lakes in the Rangeland Plans region, Cherry Lake is more mineralized and but less phosphorus rich then most (Table 3). For example, the regional average TDS and total phosphorus concentrations are 1466 mg/L and 0.233 mg/L respectively, compared to Cherry Lake's average TDS and total phosphorus concentrations of 1905 mg/L and 0.036 mg/L respectively.

Table 1. Statistical Summary of Cherry Lake's 2008 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	2	852	849	855	4
Total Ammonia as N	mg/L	2	0.030[1]	0.030[1]	0.030[1]	0.000
Bicarbonate (HCO_3)	mg/L	2	714	606	822	153
Calcium (Ca)	mg/L	2	14.4	11.8	17.0	3.7
Carbonate (CO_3)	mg/L	2	160	108	212	74
Chloride (Cl)	mg/L	2	82	80	83	2
Chlorophyll-a	µg/L	2	4.3	1.5	7.1	4.0
Specific Conductance	µmhos	2	2750	2700	2800	71
Total Dissolved Solids	mg/L	2	1905	1870	1940	49
Total Hardness as ($CaCO_3$)	mg/L	2	583	565	601	25
Hydroxide (OH)	mg/L	2	1.0[1]	1.0[1]	1.0[1]	0.0
Iron (Fe)	mg/L	2	0.064	0.059	0.068	0.006
Magnesium (Mg)	mg/L	2	133.0	127.0	139.0	8.5
Nitrate + Nitrite as N	mg/L	2	0.160	0.030[1]	0.290	0.184
Total Kjeldahl Nitrogen as N	mg/L	2	2.605	2.380	2.830	0.318
Total Nitrogen as N	mg/L	2	2.765	2.410	3.120	0.502
pH		2	9.11	8.89	9.33	0.31
Total Phosphorus as P	mg/L	2	0.036	0.020	0.052	0.023
Potassium (K)	mg/L	2	35.3	32.1	38.4	4.5
Sodium (Na)	mg/L	2	506.5	503.0	510.0	4.9
Sulfate (SO4)	mg/L	2	621	595	646	36

[1]Equal to the lower reporting limit

Limiting Nutrients: The two water quality samples results for Cherry Lake are defined the limiting nutrient as phosphorus (Figure 7). The limiting nutrient assessment is based on the assumption that either nitrogen or phosphorus is limiting algal growth with the water body, and that the ratio of total nitrogen as N to total phosphorus as P (N:P), by weight in the average algae, is approximately 15 to 1. When the N:P ratio is less than 15:1, nitrogen is assumed to be the limiting nutrient and when it exceeds 15:1, the limiting nutrient is assumed to be phosphorus.

Trophic Status Assessment: Based on the chlorophyll-a, secchi disk transparency, and total phosphorus data collected in 2008, Cherry Lake's trophic is eutrophic. The trophic Status Index scores ranged from a low of 35 based on chlorophyll-a to a high of 67 based on secchi disk (Figure 8).

Table 2. Statistical Summary of Water Quality Data[2] Collected from Natural and Enhanced Lakes in the Rangeland Plains Ecological Region of North Dakota

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	383	513	111	4770	487
Total Ammonia as N	mg/L	494	0.105	0.001[1]	2.230	0.229
Bicarbonate (HCO_3)	mg/L	383	469	60	2990	320
Calcium (Ca)	mg/L	384	41.1	0.5	282.0	34.4
Carbonate (CO_3)	mg/L	377	79	1[1]	1420	148
Chloride (Cl)	mg/L	383	44	3[1]	1070	103
Chlorophyll-a	µg/L	346	22.5	1.5[1]	292.0	37.4
Specific Conductance	µmhos	383	2028	424	20100	1976
Total Dissolved Solids	mg/L	383	1466	227	18200	1717
Total Hardness as ($CaCO_3$)	mg/L	384	529	74	2370	295
Hydroxide (OH)	mg/L	322	1.0	0.0[1]	1.0	0.2
Iron (Fe)	mg/L	385	0.245	0.001[1]	7.070	0.543
Magnesium (Mg)	mg/L	384	103.6	8.5	567.0	70.9
Nitrate + Nitrite as N	mg/L	491	0.04046	0.001[1]	0.54	0.054
Total Kjeldahl Nitrogen as N	mg/L	463	1.876	0.080	8.500	1.073
Total Nitrogen as N	mg/L	401	1.794	0.240	5.520	0.897
pH		383	8.80	7.40	9.87	0.36
Total Phosphorus as P	mg/L	501	0.233	0.002[1]	1.940	0.336
Potassium (K)	mg/L	384	34.0	3.1	356.0	37.0
Sodium (Na)	mg/L	384	299.6	16.9	4680.0	514.5
Sulfate (SO4)	mg/L	383	625	34	10500	885

[1]Equal to the lower reporting limit
[2]Data collected from 64 natural and enhanced Lakes between 1991 and 2010

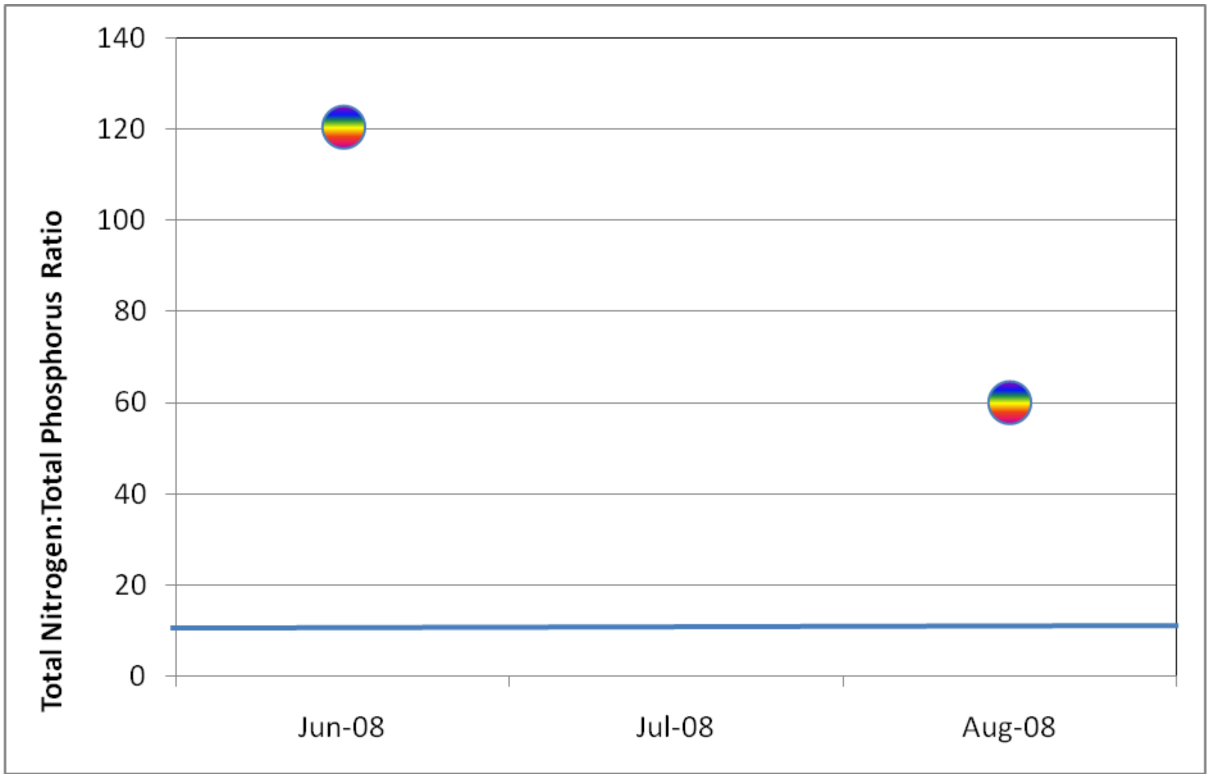

Figure 7. Cherry Lake's Total Nitrogen to Total Phosphorus Ratio

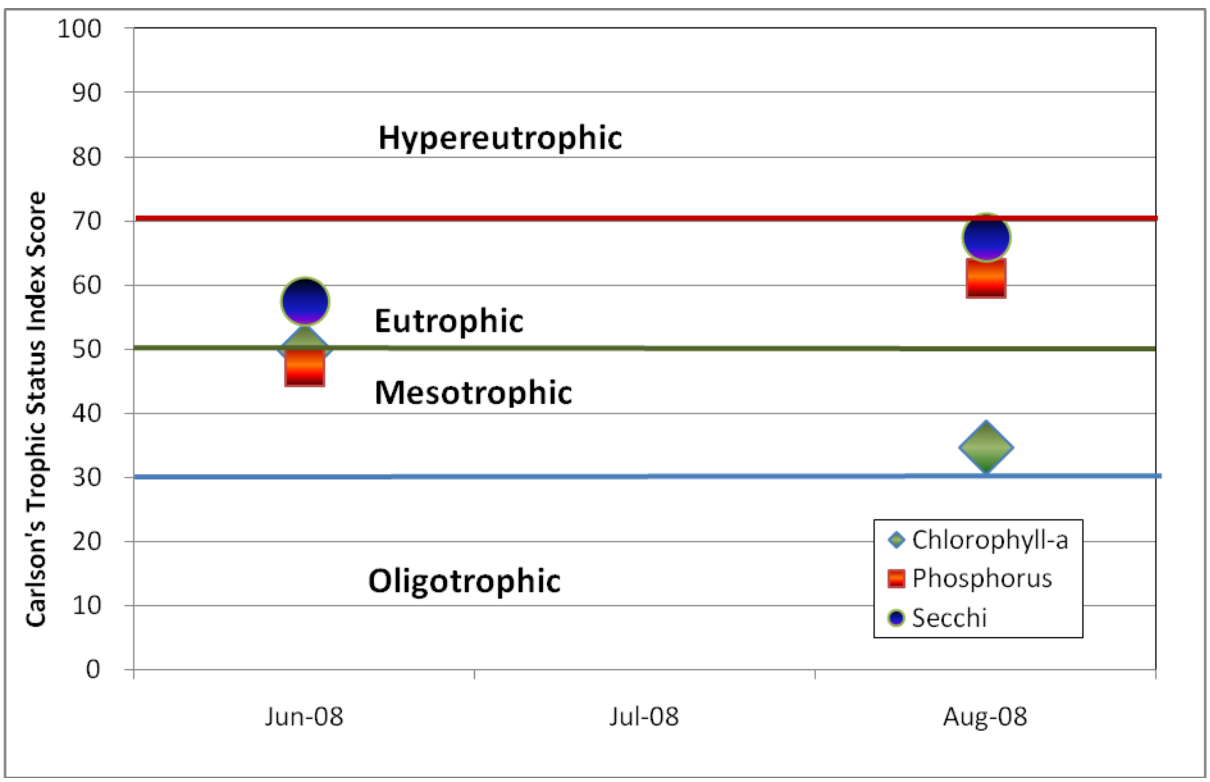

Figure 8. Cherry Lake's TSI Scores

Frettim Lake, Kidder County

BACKGROUND

Location: Frettim Lake is a wonderful example of just how pretty a small glacial lake can be. The lake is located in an expansive range of rolling glacial end moraines a short distance northeast of Robinson, North Dakota (Figure 1). The fishery is managed by the North Dakota Game and Fish. Fish species managed for are northern pike, smallmouth bass and yellow perch.

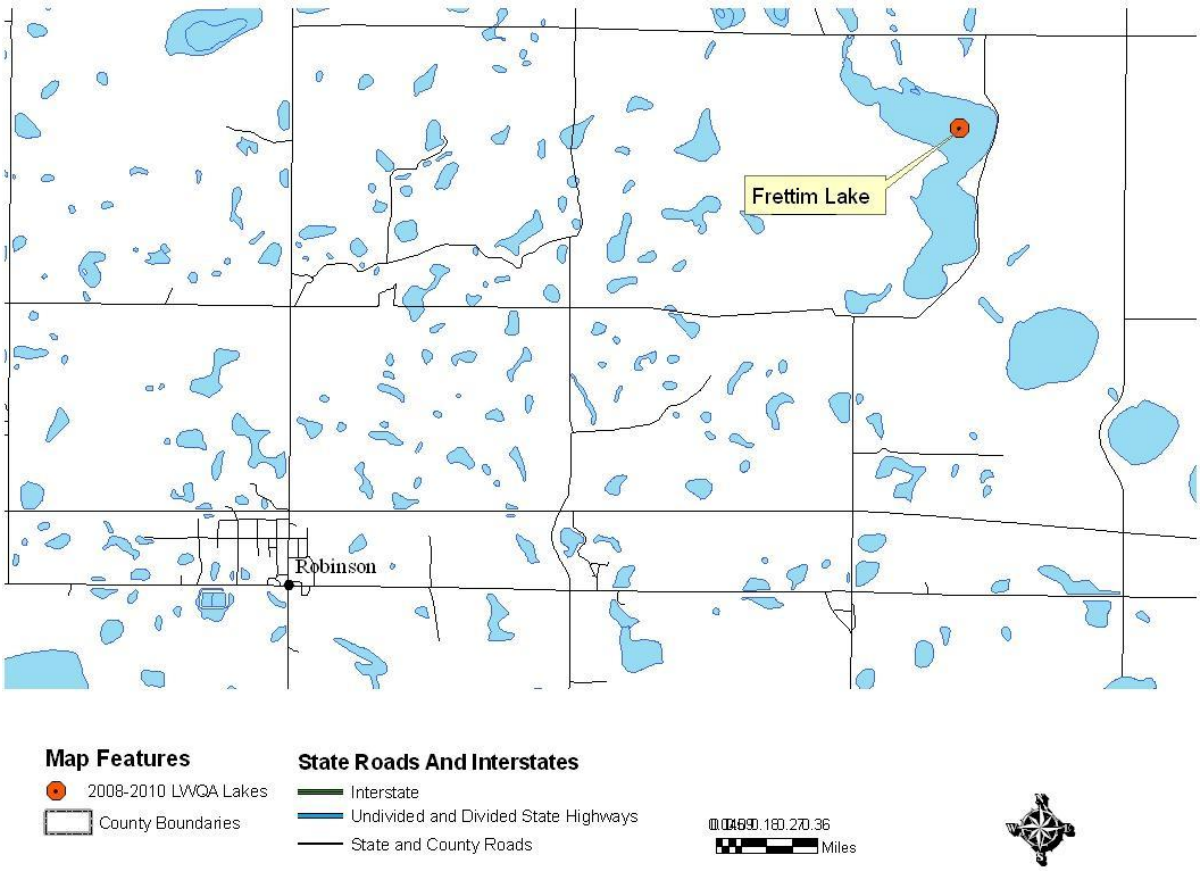

Figure 1. Location of Frettim Lake

Physiographic/Ecological Setting: Frettim Lake has a surface area of 105.6 acres, a maximum depth of 29.2 ft and an average depth 8.2 (Figure 2). The lake is located within the Northwestern Glaciated Plains Level III Ecoregion, which is part of the broader Rangeland Plains region (Figures 3 and 4).

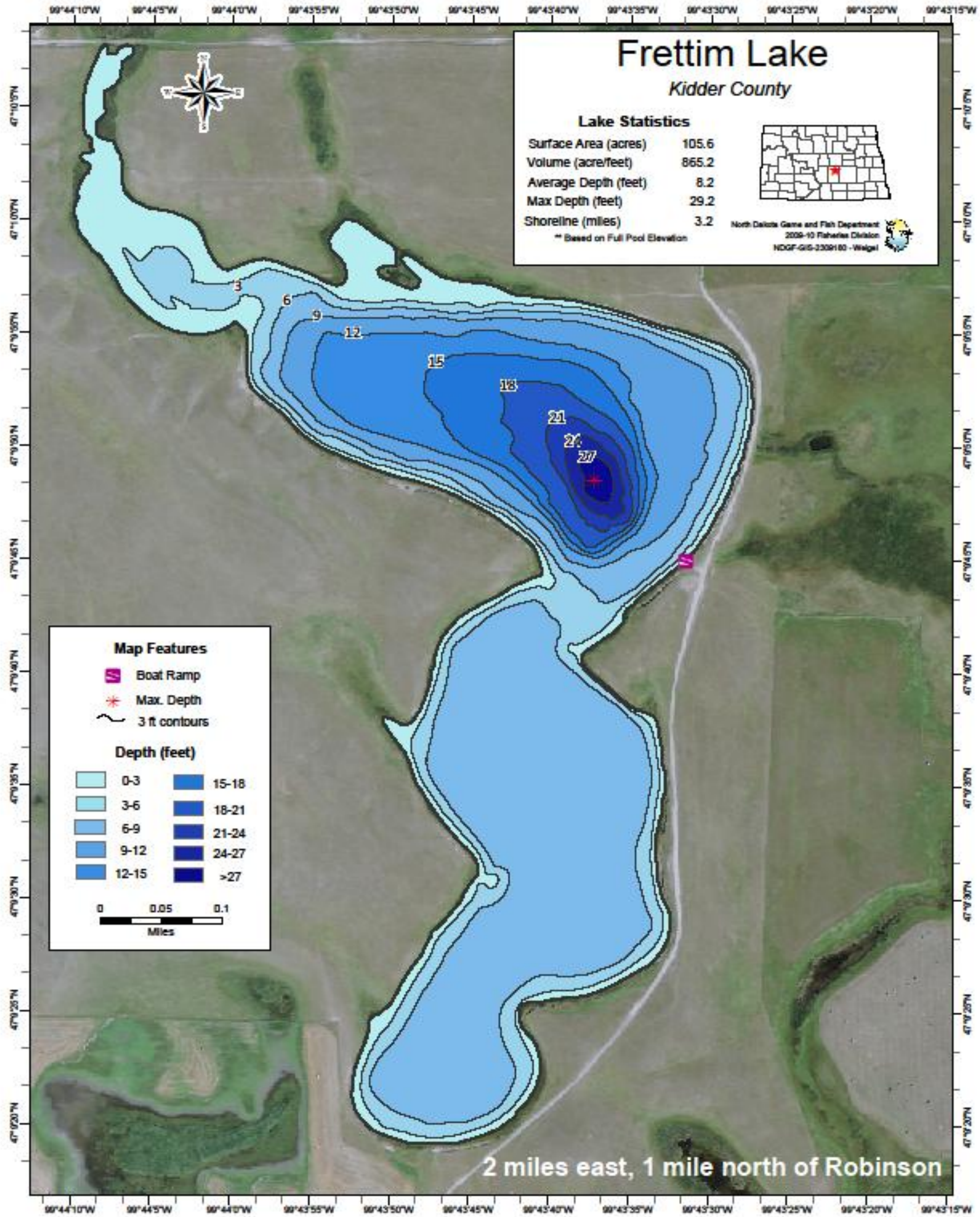

Figure 2. Contour Map of Frettim Lake (Map Courtesy of North Dakota Game and Fish Department)

Recreational Facilities: Recreational facilities at Frettim Lake include a cement boat ramp and vehicle parking.

Water Quality Standards Classification: Frettim Lake is classified in the state "Standards of Quality for Waters of the State" (NDDoH, 2011) as a class 2 lake. Class 2 lakes or reservoirs are defined as a "cool water fishery" or "waters capable of supporting natural reproduction and growth of cool water fishes (e.g., northern pike and walleye) and associated aquatic biota. These waters are also capable of supporting the growth and marginal survival of cold water species and associated biota.

Historical Water Quality Sampling: No historical water quality data.

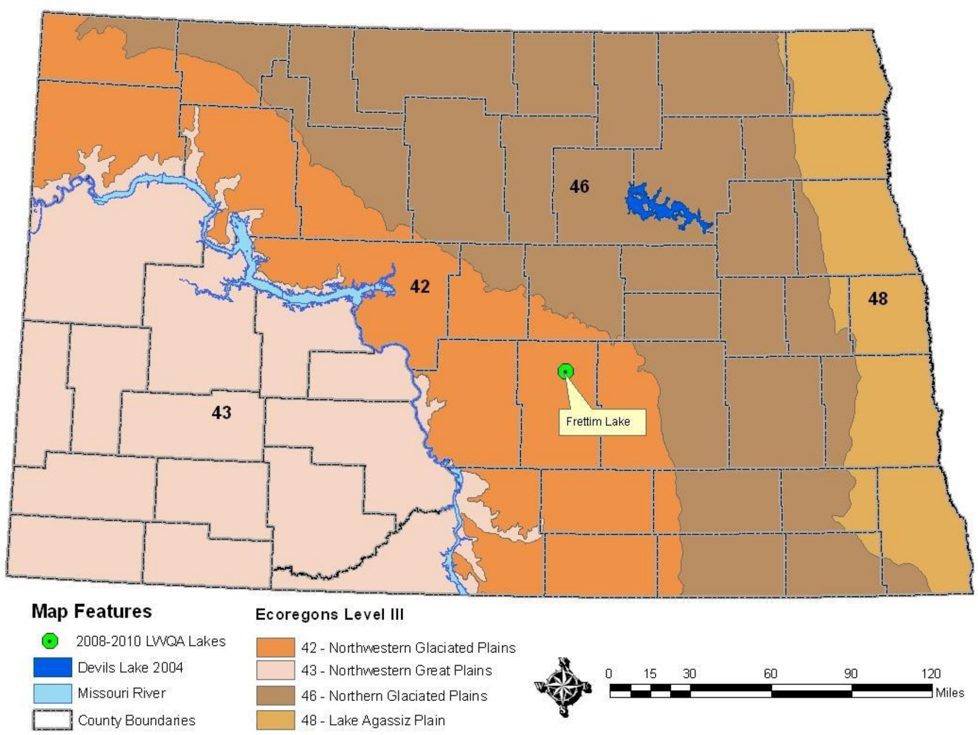

Figure 3. Frettim Lake's Location and the Level III Ecoregions

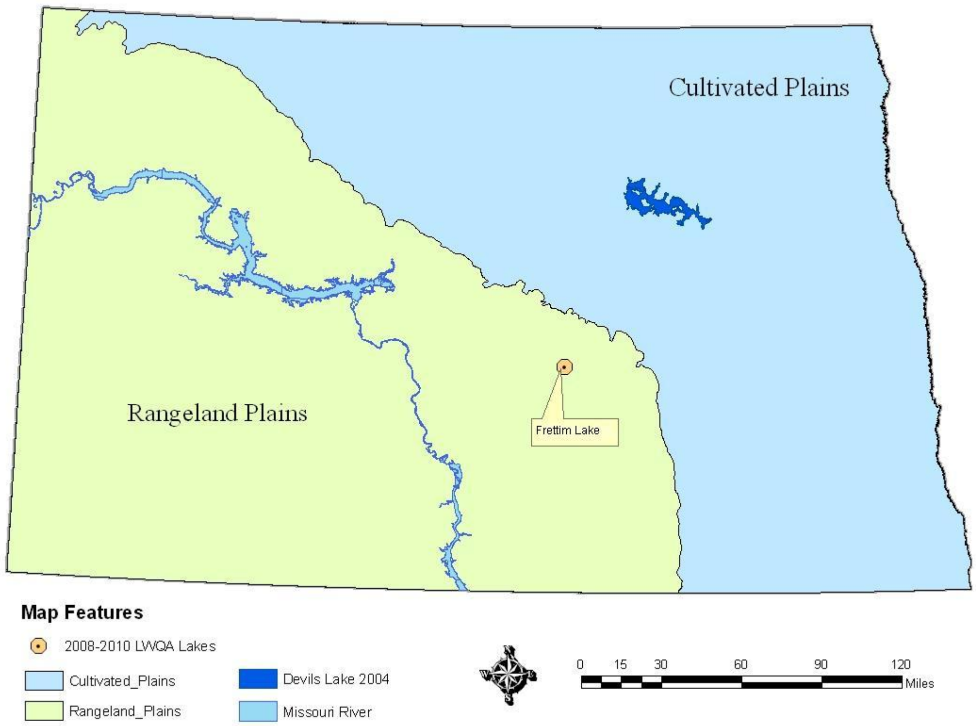

Figure 4. Frettim Lake Location and the Cultivated and Rangeland Plans Regions

WATER QUALITY MONITORING RESULTS

The water quality assessment for Frettim Lake is presented in four general categories: 1) temperature and dissolved oxygen profile results; 2) general water quality characterization; 3) nutrient limitation; and 4) trophic status. Additionally, where appropriate, results have been compared to regional data.

Temperature and Dissolved Oxygen Profile Results: There are two temperature and dissolved oxygen profiles for Frettim Lake collected in 2008 (Figures 5 and 6). The profile data shows that Frettim Lake was not thermally stratified during the open water sampling periods. Additionally during the sampling period the lake remained well enough oxygenated to support aquatic life.

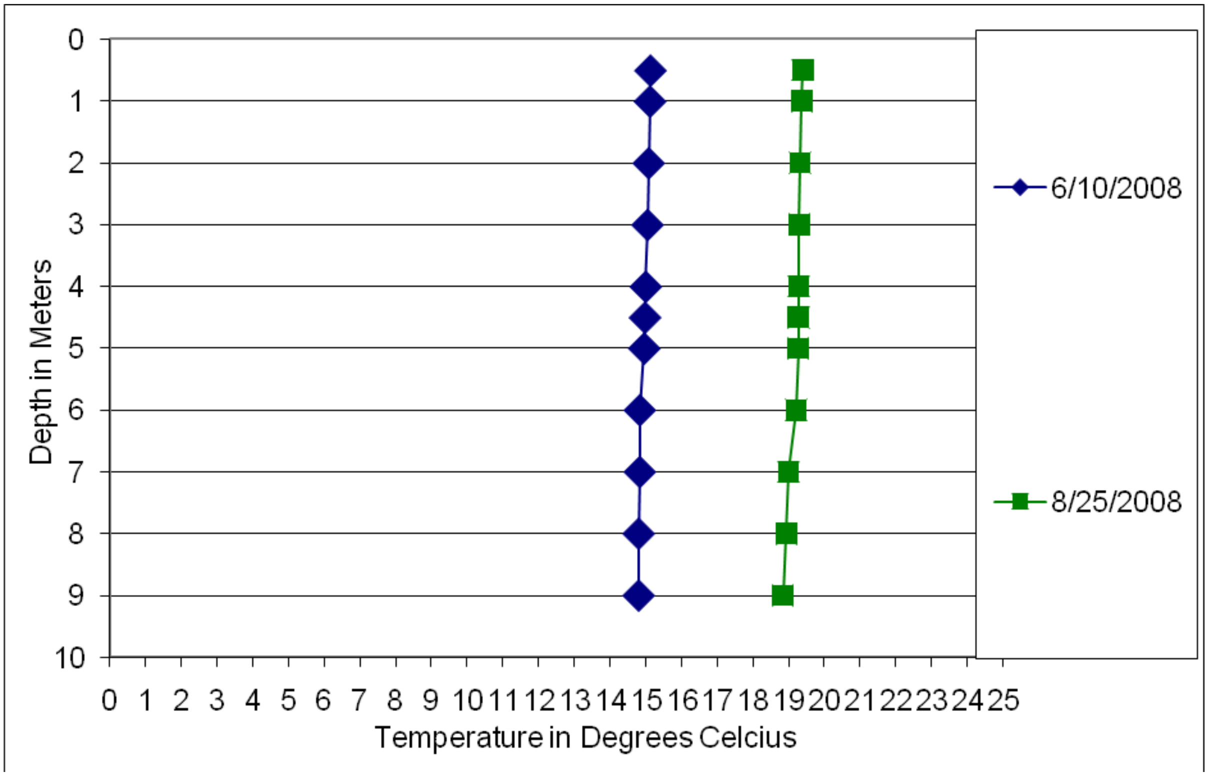

Figure 5. Temperature Profiles for Frettim Lake

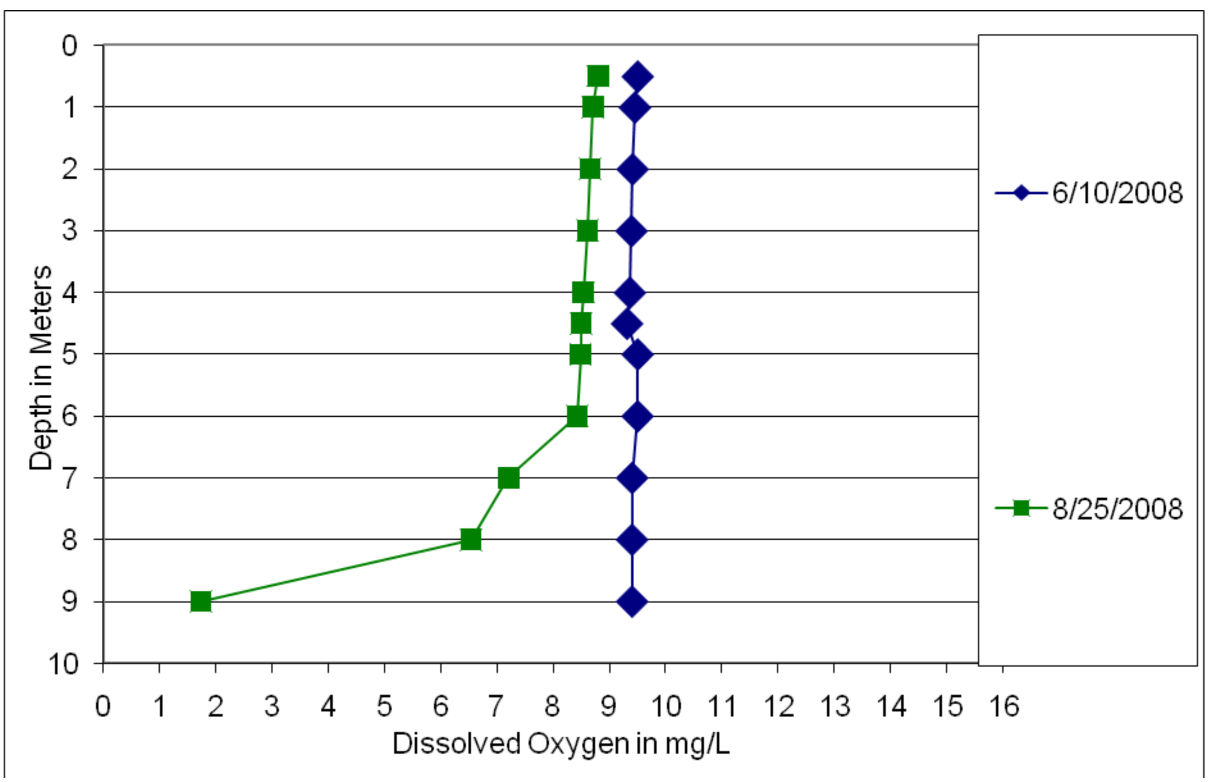

Figure 6. Dissolved Oxygen Profiles for Frettim Lake

General Water Quality: Data collected in 2008 indicate that Frettim Lake is well buffered with total alkalinity as $CaCO_3$ concentrations ranging from 445 to 451 mg/L (Table 1). The lake is sodium bicarbonate dominated with an average sodium concentration of 113.5 mg/L and an average bicarbonate concentration of 436 mg/L. The average total dissolved solids concentration and specific conductance measurement during the 2008 sampling period were 357 mg/L and 1080 µmhos/cm respectively, and the average total nitrogen as N and total phosphorus as P concentrations were 1.425 mg/L and 0.023 mg/L respectively.

When compared to the regional average water quality for natural lakes in the Rangeland Plans Ecoregion, Frettim Lake is fresher and less eutrophic than most (Table 3). For example, the regional average TDS, total nitrogen and total phosphorus concentrations are 1466 mg/L, 1.794 mg/L, and 0.233 mg/L respectively, compared to Frettim Lake's average TDS, total nitrogen and total phosphorus concentrations of 647 mg/L, 1.425 mg/L and 0.023 mg/L respectively.

Table 1. Statistical Summary of Frettim Lake's 2008 Water Quality Data

Parameter	Units	N	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	2	448	445	451	4
Total Ammonia as N	mg/L	2	0.030[1]	0.030[1]	0.030[1]	0.000
Bicarbonate (HCO_3)	mg/L	2	436	398	473	53
Calcium (Ca)	mg/L	2	25.9	22.9	28.9	4.2
Carbonate (CO_3)	mg/L	2	55	38	71	23
Chloride (Cl)	mg/L	2	34	33	35	1
Chlorophyll-a	µg/L	2	3.4	3.0	3.7	0.5
Specific Conductance	µmhos	2	1080	1060	1100	28
Total Dissolved Solids	mg/L	2	647	641	652	8
Total Hardness as ($CaCO_3$)	mg/L	2	357	344	370	18
Hydroxide (OH)	mg/L	2	1.0[1]	1.0[1]	1.0[1]	0.0
Iron (Fe)	mg/L	2	0.055	0.050	0.059	0.006
Magnesium (Mg)	mg/L	2	71.0	66.1	75.9	6.9
Nitrate + Nitrite as N	mg/L	2	0.030[1]	0.030[1]	0.030[1]	0.000
Total Kjeldahl Nitrogen as N	mg/L	2	1.395	1.170	1.620	0.318
Total Nitrogen as N	mg/L	2	1.425	1.200	1.650	0.318
pH		2	8.85	8.67	9.03	0.25
Total Phosphorus as P	mg/L	2	0.023	0.015	0.031	0.011
Potassium (K)	mg/L	2	10.6	9.7	11.5	1.3
Sodium (Na)	mg/L	2	113.5	112.0	115.0	2.1
Sulfate (SO4)	mg/L	2	122	117	126	6

[1]Equal to the lower reporting limit

Table 2. Statistical Summary of Water Quality Data[2] Collected from Natural and Enhanced Lakes in the Rangeland Plains Ecological Region of North Dakota

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	383	513	111	4770	487
Total Ammonia as N	mg/L	494	0.105	0.001[1]	2.230	0.229
Bicarbonate (HCO_3)	mg/L	383	469	60	2990	320
Calcium (Ca)	mg/L	384	41.1	0.5	282.0	34.4
Carbonate (CO_3)	mg/L	377	79	1[1]	1420	148
Chloride (Cl)	mg/L	383	44	3[1]	1070	103
Chlorophyll-a	µg/L	346	22.5	1.5[1]	292.0	37.4
Specific Conductance	µmhos	383	2028	424	20100	1976
Total Dissolved Solids	mg/L	383	1466	227	18200	1717
Total Hardness as ($CaCO_3$)	mg/L	384	529	74	2370	295
Hydroxide (OH)	mg/L	322	1.0	0.0[1]	1.0	0.2
Iron (Fe)	mg/L	385	0.245	0.001[1]	7.070	0.543
Magnesium (Mg)	mg/L	384	103.6	8.5	567.0	70.9
Nitrate + Nitrite as N	mg/L	491	0.04046	0.001[1]	0.54	0.054
Total Kjeldahl Nitrogen as N	mg/L	463	1.876	0.080	8.500	1.073
Total Nitrogen as N	mg/L	401	1.794	0.240	5.520	0.897
pH		383	8.80	7.40	9.87	0.36
Total Phosphorus as P	mg/L	501	0.233	0.002[1]	1.940	0.336
Potassium (K)	mg/L	384	34.0	3.1	356.0	37.0
Sodium (Na)	mg/L	384	299.6	16.9	4680.0	514.5
Sulfate (SO4)	mg/L	383	625	34	10500	885

[1]Equal to the lower reporting limit
[2]Data collected from 64 natural and enhanced Lakes between 1991 and 2010

Limiting Nutrients: The two water quality sample results for Frettim Lake indicate that phosphorus is the limiting nutrient (Figure 7). The limiting nutrient assessment is based on the assumption that either nitrogen or phosphorus is limiting algal growth with the water body, and that the ratio of total nitrogen as N to total phosphorus as P (N:P), by weight in the average algae, is approximately 15 to 1. When the N:P ratio is less than 15:1, nitrogen is assumed to be the limiting nutrient and when it exceeds 15:1, the limiting nutrient is assumed to be phosphorus.

Trophic Status Assessment: Based on the chlorophyll-a, secchi disk transparency, and total phosphorus data collected in 2008, Frettim Lake's is mesotrophic. The trophic Status Index scores ranged from a low of 41 based on chlorophyll-a to a high of 57 based on secchi disk (Figure 8).

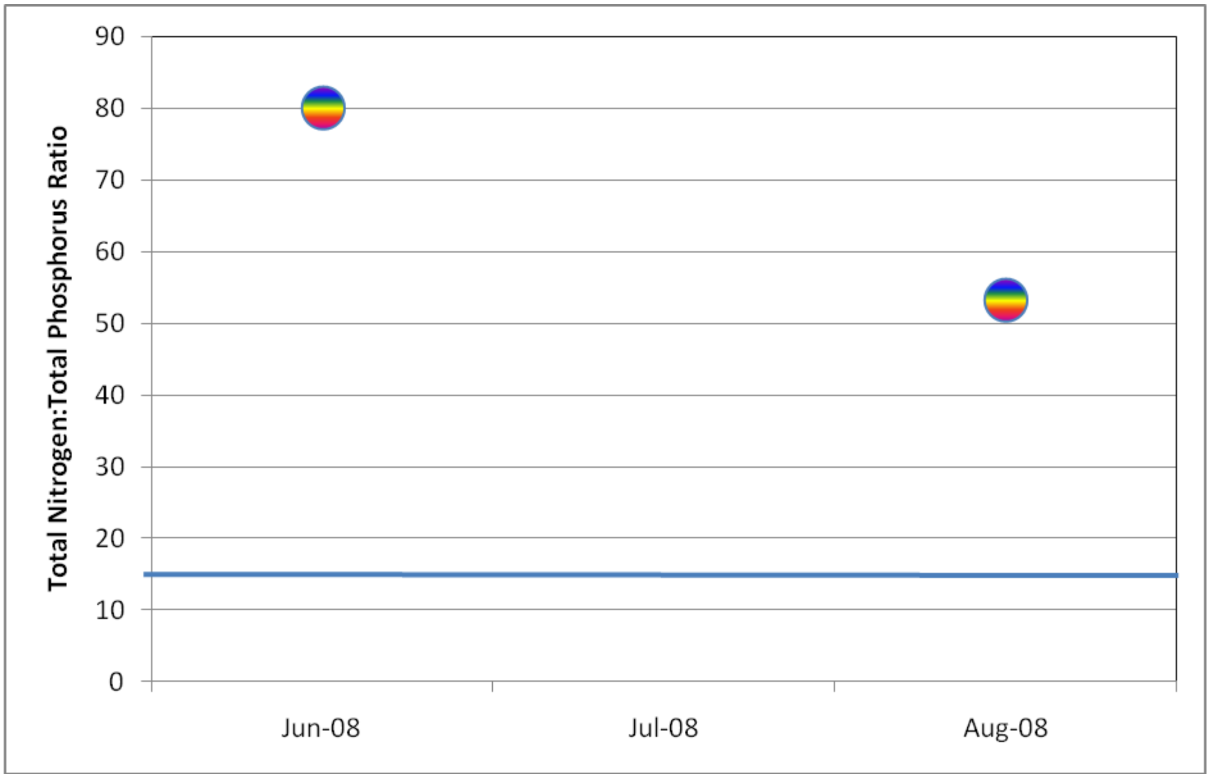

Figure 7. Frettim Lake's Total Nitrogen to Total Phosphorus Ratio

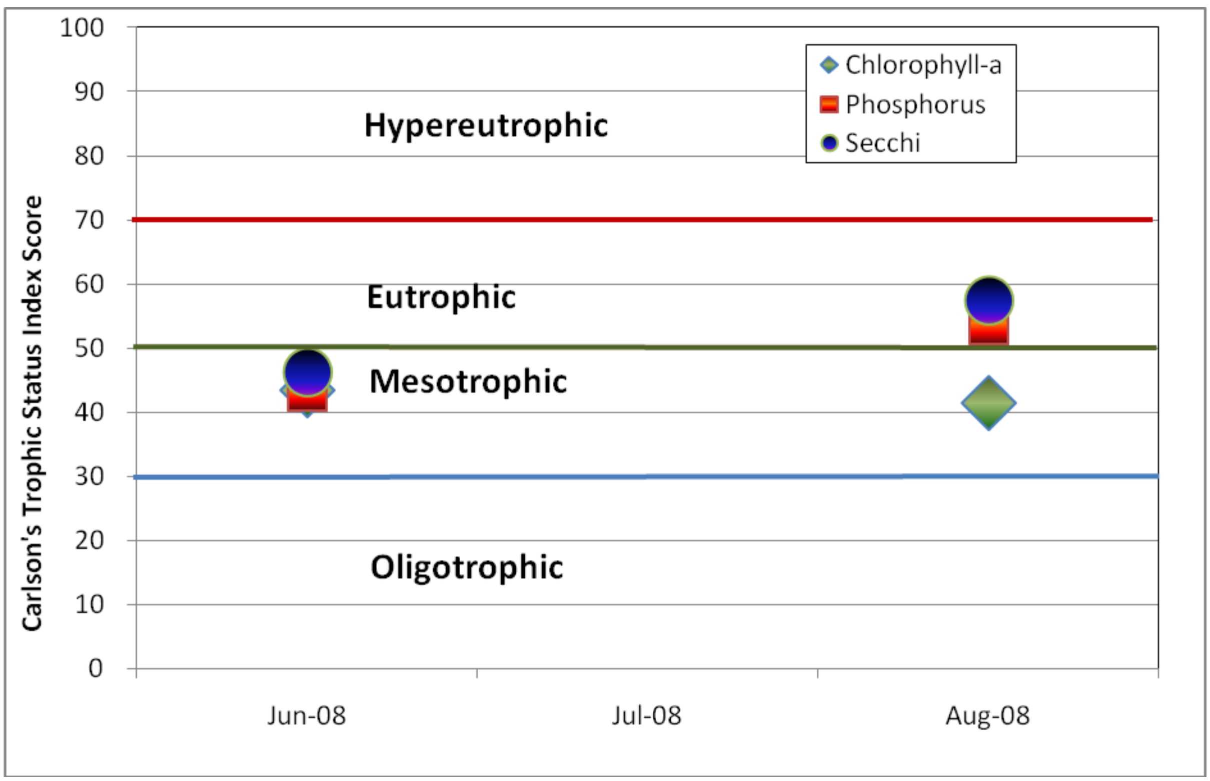

Figure 8. Frettim Lake's TSI Scores

Crystal Springs, Kidder and Stutsman County

BACKGROUND

Location: Crystal Springs is a shallow picturesque little lake wedged in between Interstate Highway 94 and County road 39. The natural lake has multiple small bays and two islands and is located a nine miles east of Tappen, North Dakota (Figure 1). The fishery is managed by the North Dakota Game and Fish. Fish species recently stocked are northern pike and walleye.

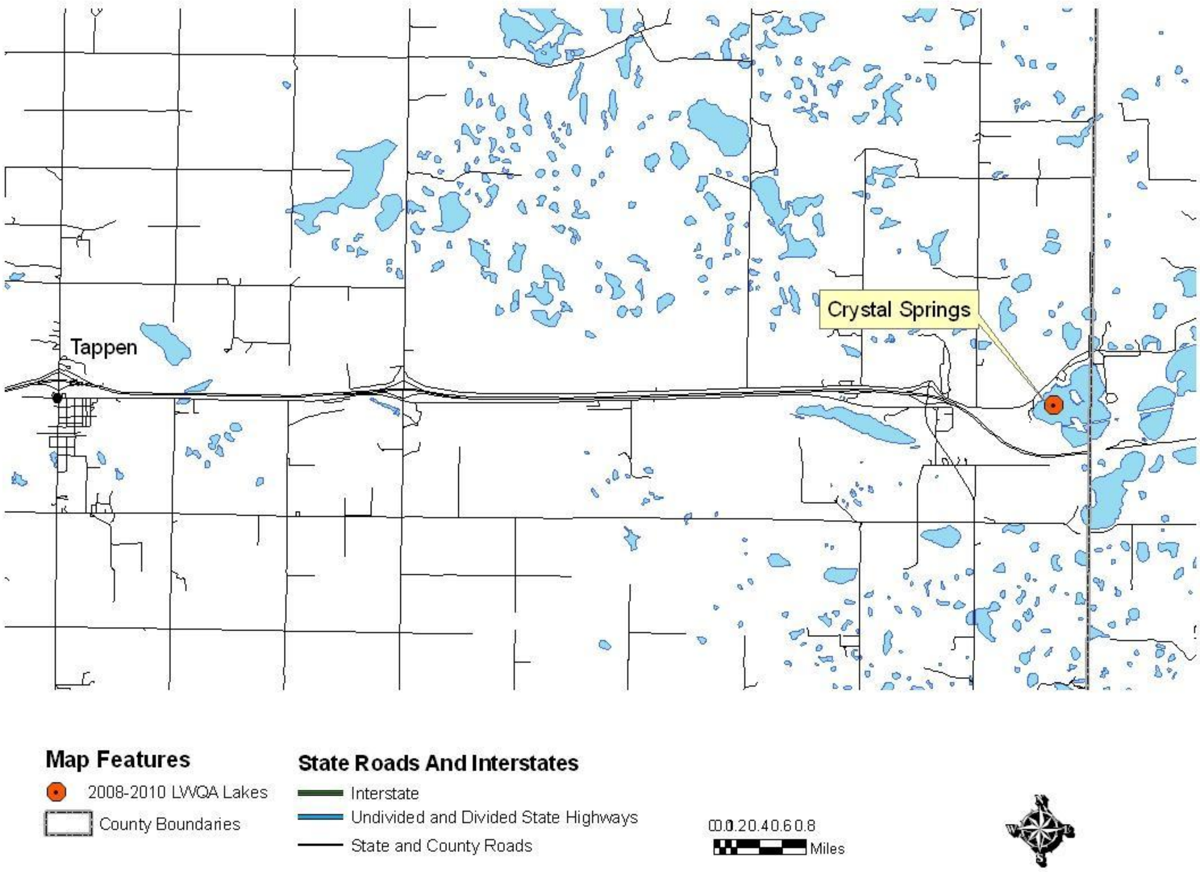

Figure 1. Location of Crystal Springs

Physiographic/Ecological Setting: Crystal Springs has a surface area of 136.6 acres, a maximum depth of only 8.3 ft and an average depth 5.4 ft. Crystal Springs has a limited amount of low density urban development on its north shore and a bible camp on its east shore (Figure 2). The lake is located within the Northwestern Glaciated Plains Level III Ecoregion, which is part of the broader Rangeland Plains region (Figures 3 and 4).

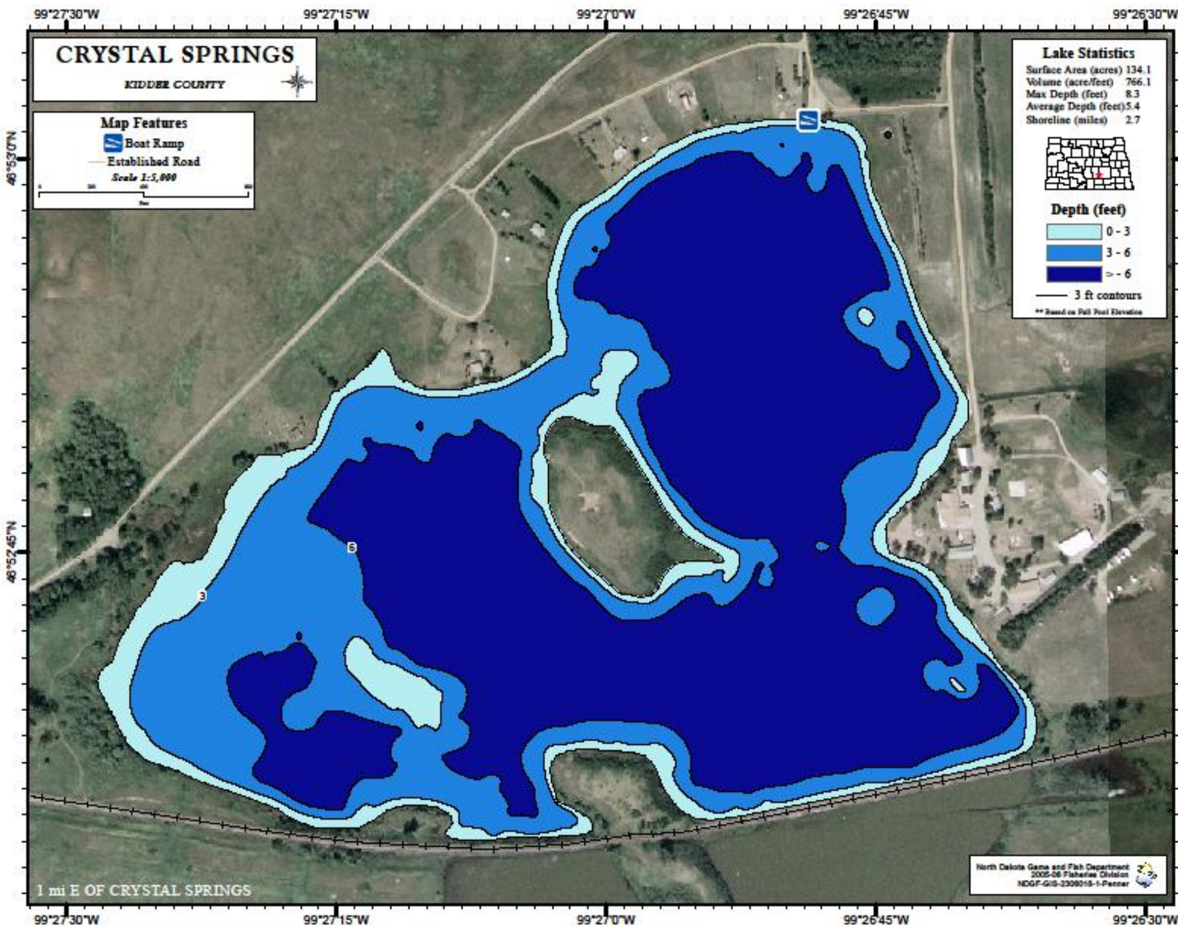

Figure 2. Contour Map of Crystal Springs (Map Courtesy of North Dakota Game and Fish Department)

Recreational Facilities: Recreational facilities at Crystal Springs include a cement boat ramp, courtesy dock and vehicle parking.

Water Quality Standards Classification: Crystal Springs is classified in the state "Standards of Quality for Waters of the State" (NDDoH, 2011) as a class 3 lake. Class 3 lakes or reservoirs are defined as a "warm water fishery" or "waters capable of supporting natural reproduction and growth of warm water fishes (e.g., Largemouth Bass and Bluegill) and associated aquatic biota. Some cool water species might also be present.

Historical Water Quality Sampling: No historical water quality data.

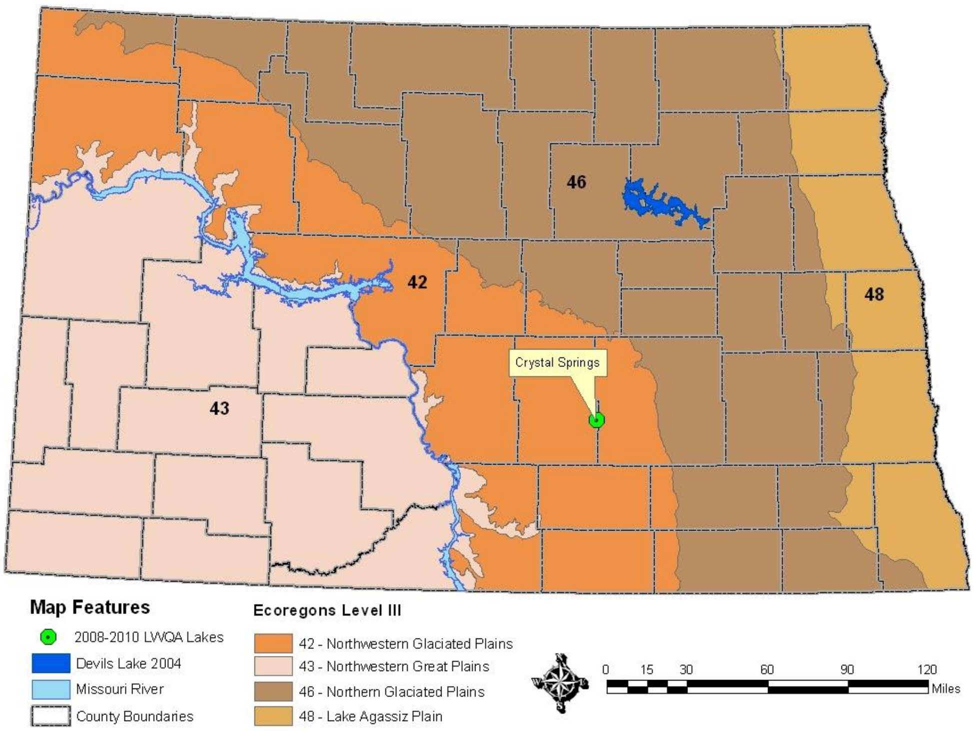

Figure 3. Crystal Spring's Location and the Level III Ecoregions

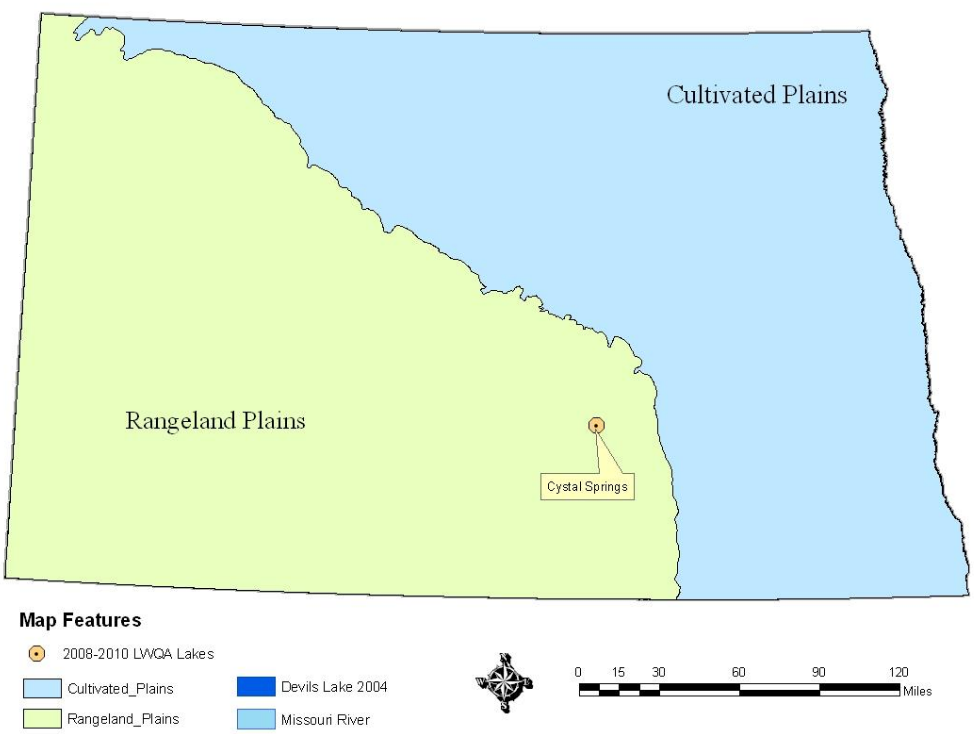

Figure 4. Crystal Spring's Location and the Cultivated and Rangeland Plans Regions

WATER QUALITY MONITORING RESULTS

The water quality assessment for Crystal Springs is presented in four general categories: 1) temperature and dissolved oxygen profile results; 2) general water quality characterization; 3) nutrient limitation; and 4) trophic status. Additionally, where appropriate, results have been compared to regional data.

Temperature and Dissolved Oxygen Profile Results: There are two temperature and dissolved oxygen profiles for Crystal Springs collected in 2008 (Figures 5 and 6). The profile data shows that the Lake was not thermally stratification during sampling in 2008. Additionally during the sampling period the lake remained well enough oxygenated to support aquatic life.

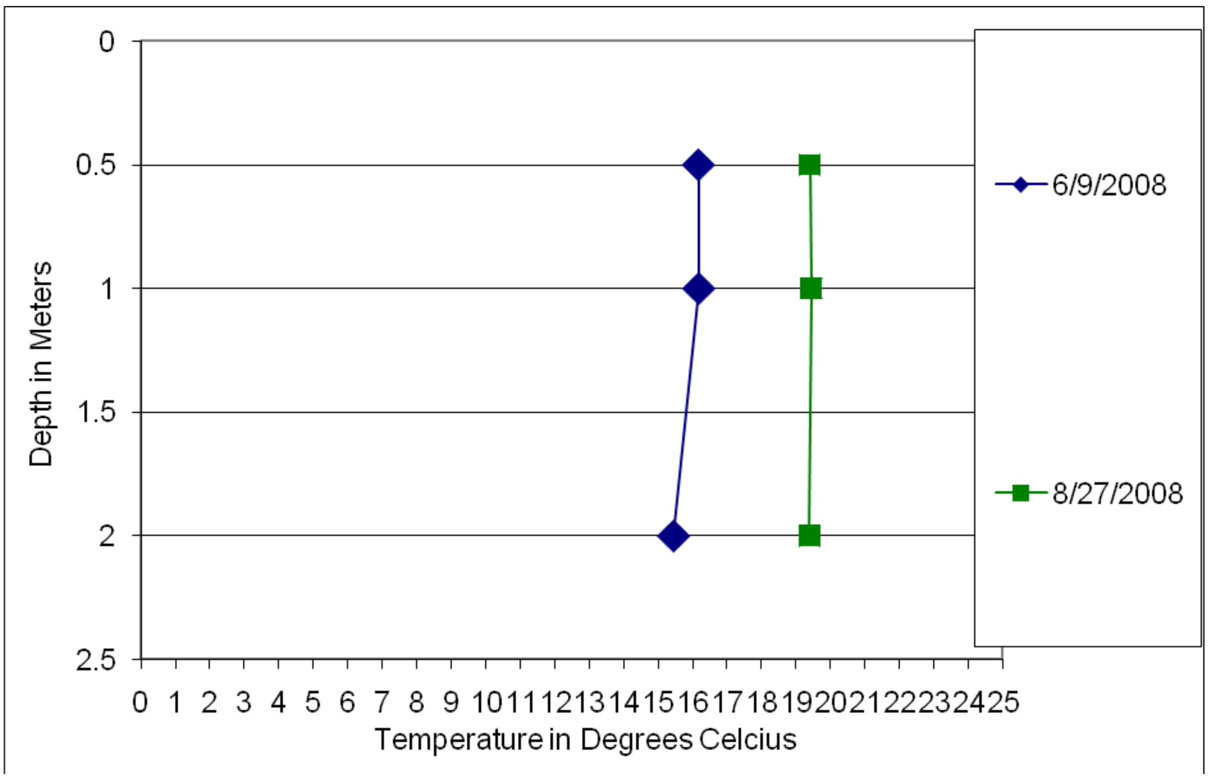

Figure 5. Temperature Profiles for Crystal Springs

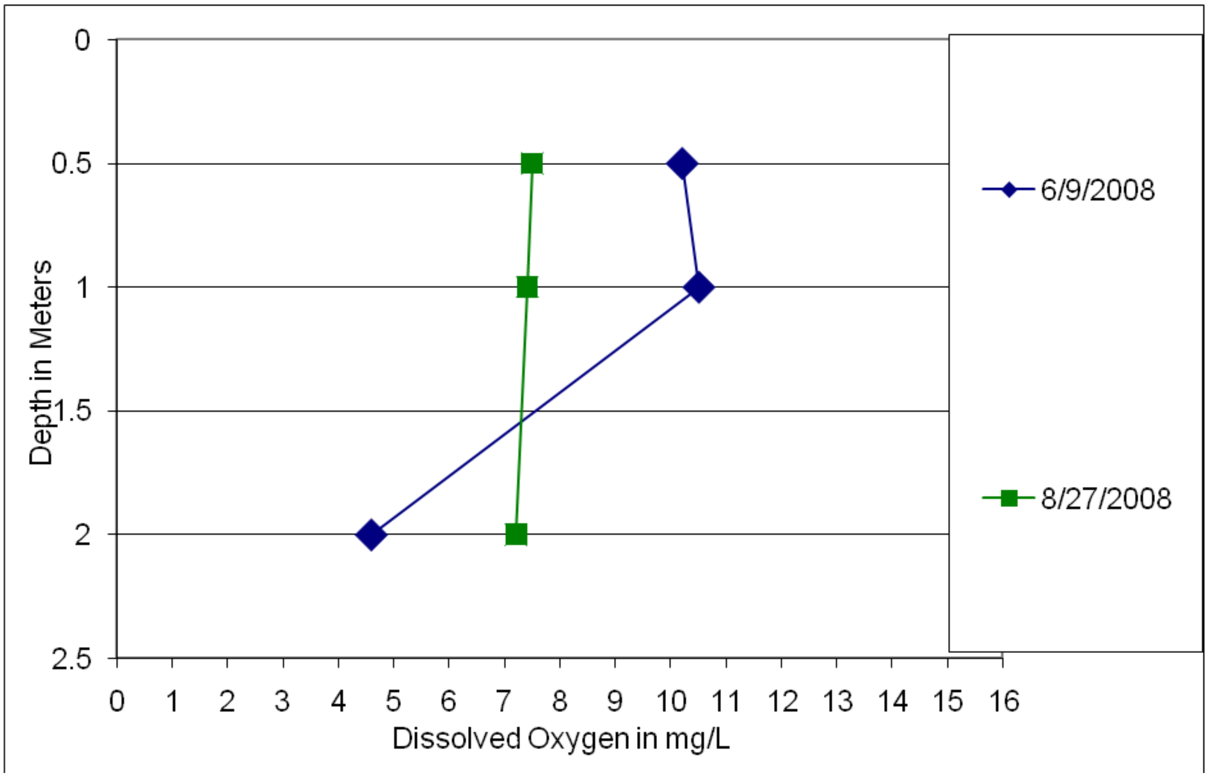

Figure 6. Dissolved Oxygen Profiles for Crystal Springs

General Water Quality: Data collected in 2008 indicate that Crystal Springs is moderately buffered with total alkalinity as $CaCO_3$ concentrations ranging from 190 to 207 mg/L (Table 1). The lake is sodium bicarbonate dominated with an average sodium concentration of 523 mg/L and an average bicarbonate concentration of 198 mg/L. The average total dissolved solids concentration and specific conductance measurement during the 2008 sampling period were 442 mg/L and 729 µmhos/cm respectively, and the average total nitrogen as N and total phosphorus as P concentrations were 0.884 mg/L and 0.031 mg/L respectively.

When compared to the regional water quality for natural lakes in the Rangeland Plans region, Crystal Springs has fewer dissolved solids and is less eutrophic than most (Table 3). For example, the regional average TDS, total nitrogen and total phosphorus concentrations are 1466 mg/L, 1.794 mg/L, and 0.233 mg/L respectively, compared to Frettim Lake's average TDS, total nitrogen and total phosphorus concentrations of 442 mg/L, 0.884 mg/L and 0.031 mg/L respectively.

Table 1. Statistical Summary of Crystal Spring's 2008 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	2	199	190	207	12
Total Ammonia as N	mg/L	2	0.030[1]	0.030[1]	0.030[1]	0.000
Bicarbonate (HCO_3)	mg/L	2	198	179	217	27
Calcium (Ca)	mg/L	2	23.4	22.3	24.5	1.6
Carbonate (CO_3)	mg/L	2	22	17	26	6
Chloride (Cl)	mg/L	2	15	14	16	1
Chlorophyll-a	µg/L	2	16.3	1.5[1]	31.0	20.9
Specific Conductance	µmhos	2	729	695	762	47
Total Dissolved Solids	mg/L	2	442	423	461	27
Total Hardness as ($CaCO_3$)	mg/L	2	268	243	293	35
Hydroxide (OH)	mg/L	2	1.0[1]	1.0[1]	1.0[1]	0.0
Iron (Fe)	mg/L	2	0.050	0.050	0.050	0.000
Magnesium (Mg)	mg/L	2	50.9	45.5	56.2	7.6
Nitrate + Nitrite as N	mg/L	2	0.030[1]	0.030[1]	0.030[1]	0.000
Total Kjeldahl Nitrogen as N	mg/L	2	0.854	0.588	1.120	0.376
Total Nitrogen as N	mg/L	2	0.884	0.618	1.150	0.376
pH		2	8.75	8.66	8.84	0.13
Total Phosphorus as P	mg/L	2	0.031	0.017	0.044	0.019
Potassium (K)	mg/L	2	10.0	8.3	11.6	2.3
Sodium (Na)	mg/L	2	52.3	51.4	53.2	1.3
Sulfate (SO4)	mg/L	2	170	164	176	8

[1]Equal to the lower reporting limit

Limiting Nutrients: Results of the two water quality samples for Crystal Springs identify the the limiting nutrient as phosphorus (Figure 7). The limiting nutrient assessment is based on the assumption that either nitrogen or phosphorus is limiting algal growth with the water body, and that the ratio of total nitrogen as N to total phosphorus as P (N:P), by weight in the average algae, is approximately 15 to 1. When the N:P ratio is less than 15:1, nitrogen is assumed to be the limiting nutrient and when it exceeds 15:1, the limiting nutrient is assumed to be phosphorus.

Trophic Status Assessment: Based on the chlorophyll-a, secchi disk transparency, and total phosphorus data collected in 2008, Crystal Springs is mesotrophic. The trophic Status Index scores ranged from a low of 35 to a high of 64 based on chlorophyll-a (Figure 8).

Table 2. Statistical Summary of Water Quality Data[2] Collected from Natural and Enhanced Lakes in the Rangeland Plains Ecological Region of North Dakota

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	383	513	111	4770	487
Total Ammonia as N	mg/L	494	0.105	0.001[1]	2.230	0.229
Bicarbonate (HCO_3)	mg/L	383	469	60	2990	320
Calcium (Ca)	mg/L	384	41.1	0.5	282.0	34.4
Carbonate (CO_3)	mg/L	377	79	1[1]	1420	148
Chloride (Cl)	mg/L	383	44	3[1]	1070	103
Chlorophyll-a	µg/L	346	22.5	1.5[1]	292.0	37.4
Specific Conductance	µmhos	383	2028	424	20100	1976
Total Dissolved Solids	mg/L	383	1466	227	18200	1717
Total Hardness as ($CaCO_3$)	mg/L	384	529	74	2370	295
Hydroxide (OH)	mg/L	322	1.0	0.0[1]	1.0	0.2
Iron (Fe)	mg/L	385	0.245	0.001[1]	7.070	0.543
Magnesium (Mg)	mg/L	384	103.6	8.5	567.0	70.9
Nitrate + Nitrite as N	mg/L	491	0.04046	0.001[1]	0.54	0.054
Total Kjeldahl Nitrogen as N	mg/L	463	1.876	0.080	8.500	1.073
Total Nitrogen as N	mg/L	401	1.794	0.240	5.520	0.897
pH		383	8.80	7.40	9.87	0.36
Total Phosphorus as P	mg/L	501	0.233	0.002[1]	1.940	0.336
Potassium (K)	mg/L	384	34.0	3.1	356.0	37.0
Sodium (Na)	mg/L	384	299.6	16.9	4680.0	514.5
Sulfate (SO4)	mg/L	383	625	34	10500	885

[1]Equal to the lower reporting limit
[2]Data collected from 64 natural and enhanced Lakes between 1991 and 2010

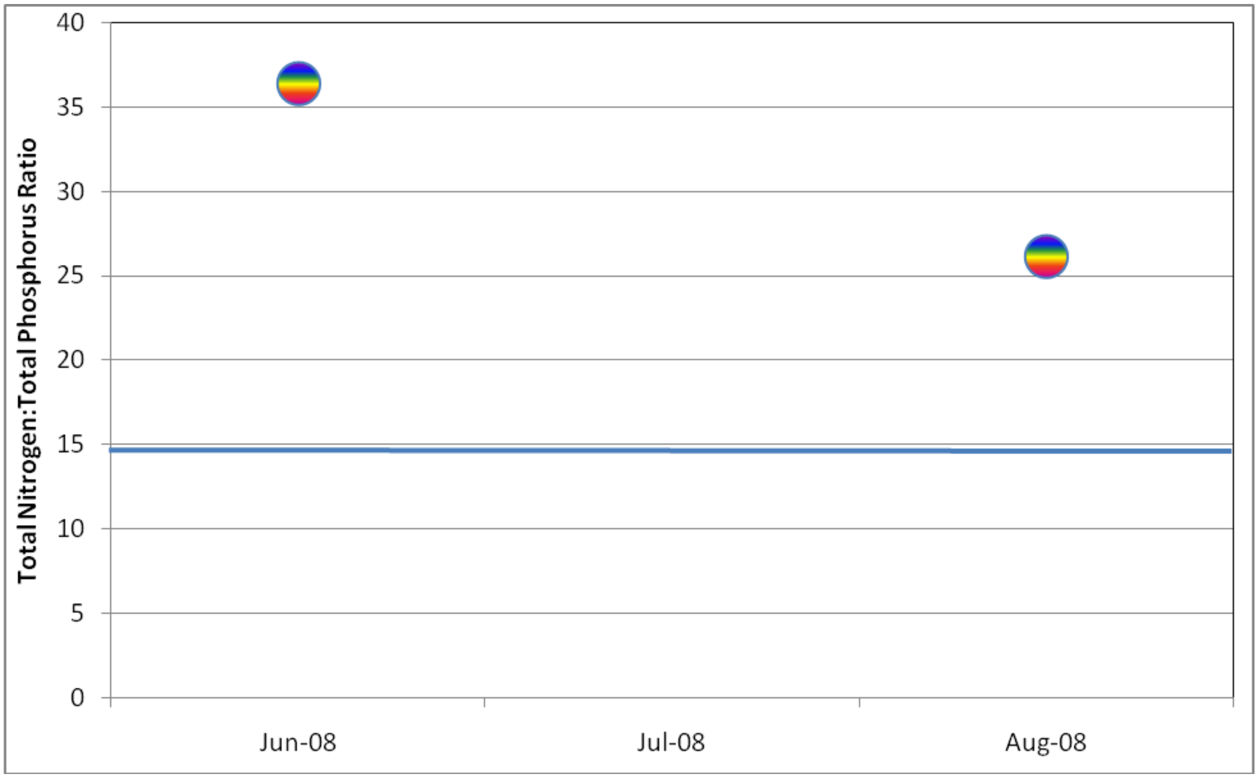

Figure 7. Crystal Springs's Total Nitrogen to Total Phosphorus Ratio

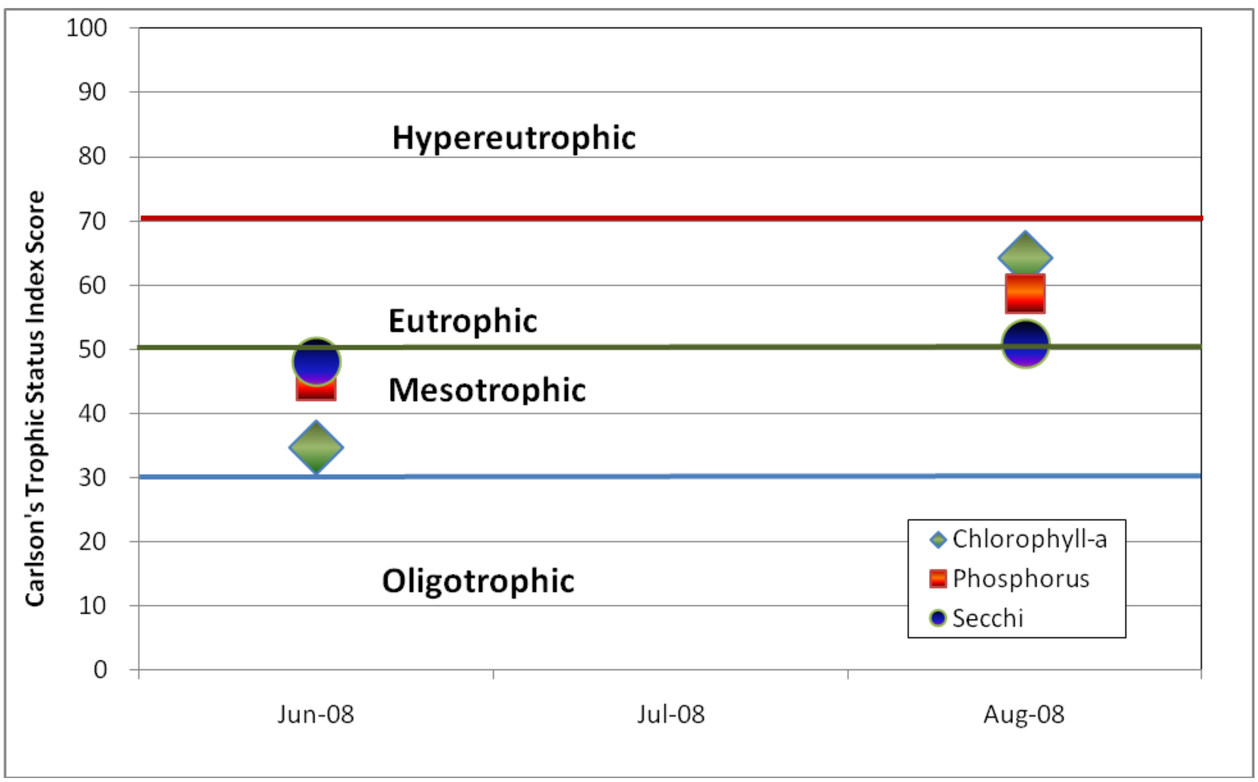

Figure 8. Crystal Spring's TSI Scores

Limesand-Seefedlt Dam, LaMoure County

BACKGROUND

Location: Limesand-Seefedlt Dam is a small impoundment on an un-named drainage of the James River approximately 6 miles southeast of the town of Dickey, North Dakota (Figure 1). The fishery is managed by the North Dakota Game and Fish Department (NDG&F). The fish species most recently stocked by the NDG&F is Largemouth Bass but previous stockings included northern pike and bluegill.

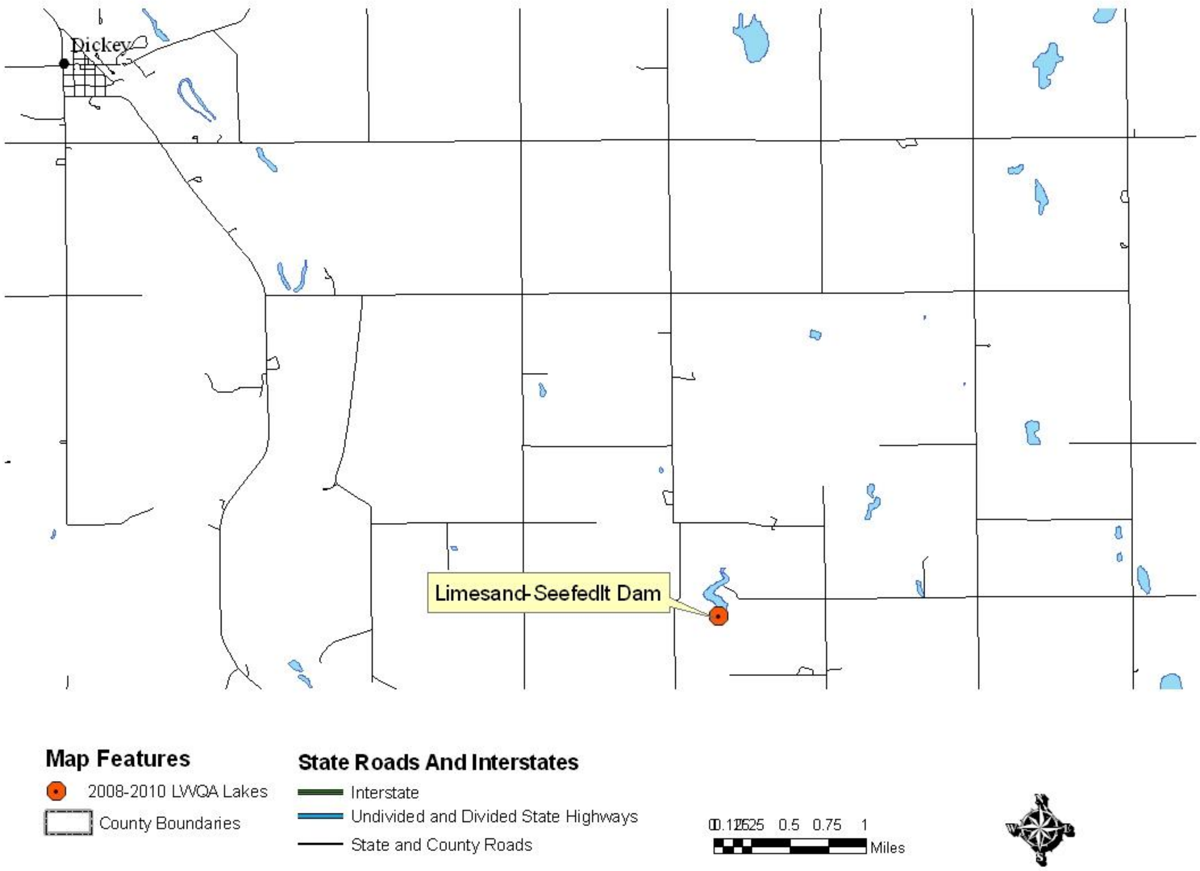

Figure 1. Location of Limesand-Seefedlt Dam

Physiographic/Ecological Setting: Limesand-Seefeldt Dam has a surface area of 12.5 acres, a maximum depth of 28 ft, and an average depth of 13.1 ft (Figure 2). The reservoir is located in the Northern Glaciated Plains Level III Ecoregion, which is part of the broader Cultivated Plains region (Figures 3 and 4).

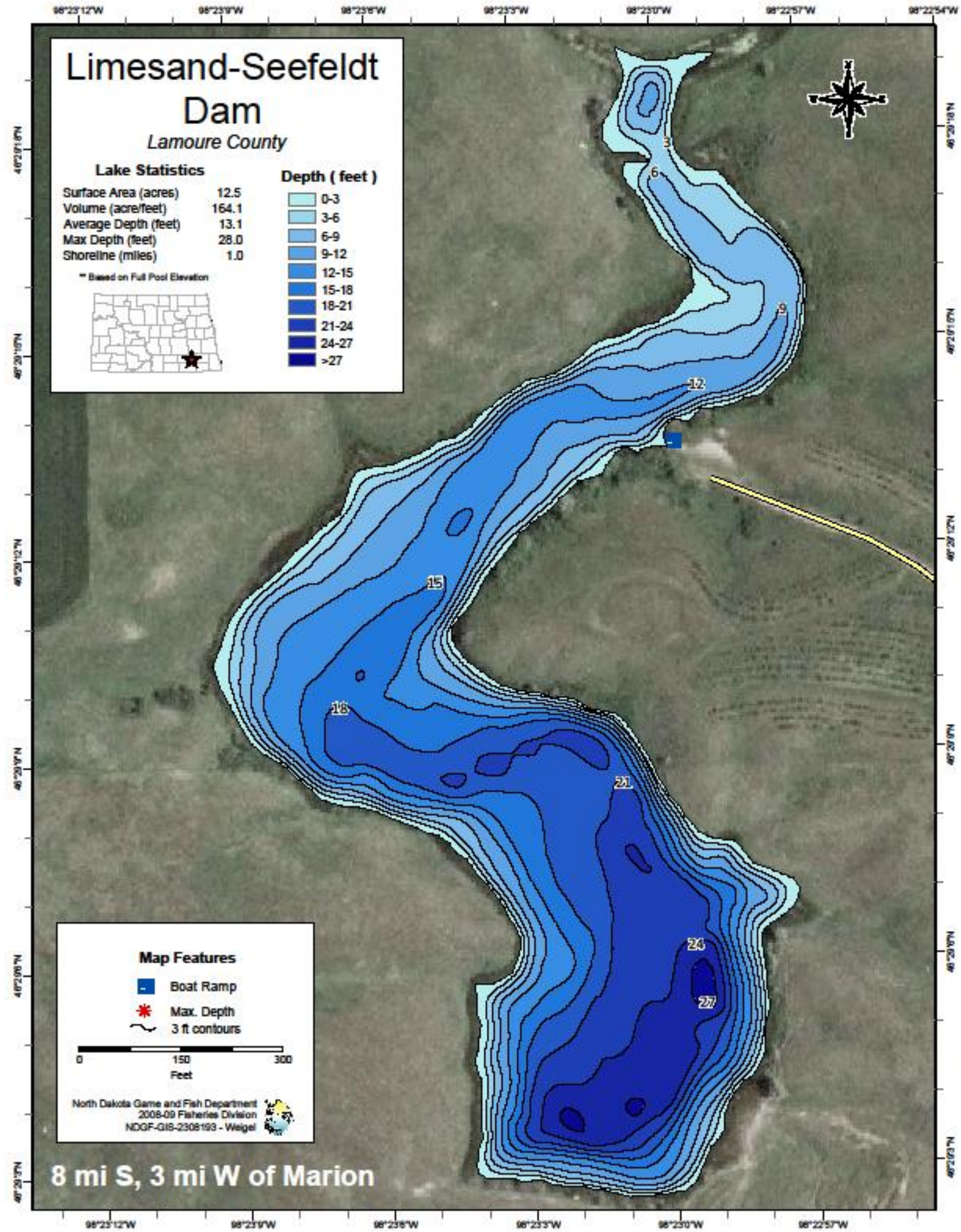

Figure 2. Contour Map of Casselton Reservoir (Map Courtesy of North Dakota Game and Fish Department)

Recreational Facilities: Recreational facilities at Limesand-Seefeldt Dam include a boat ramp and an interestingly steep access road.

Water Quality Standards Classification: Limesand-Seefedlt Dam is classified in the state "Standards of Quality for Waters of the State" (NDDoH, 2011) as a class 3 lake. Class 3 lakes or reservoirs are defined as a "warm water fishery" or "waters capable of supporting natural reproduction and growth of warm water fishes (e.g., largemouth bass and bluegill) and associated aquatic biota. Some cool water species may also be present."

Historical Water Quality Sampling: No historical water quality data.

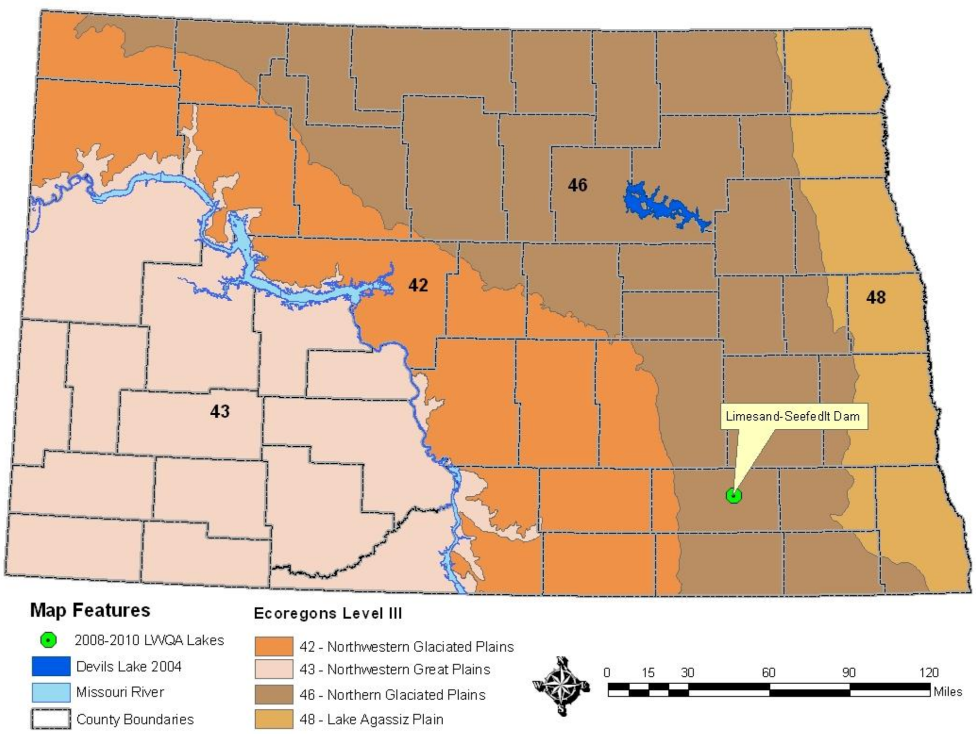

Figure 3. Limesand Seefeldt Dam's Location and the Level III Ecoregions

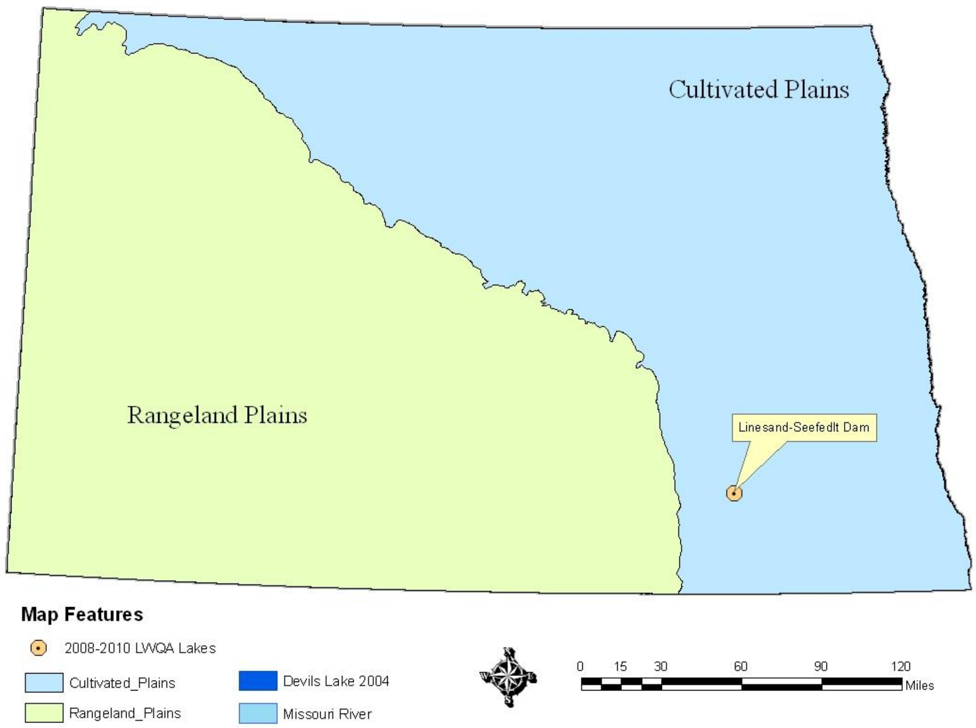

Figure 4. Limesand-Seefeldt Dam's Location and the Cultivated and Rangeland Plans Regions

WATER QUALITY MONITORING RESULTS

The water quality assessment for Limesand-Seefeldt Dam is presented in four general categories: 1) temperature and dissolved oxygen profile results; 2) general water quality characterization; 3) nutrient limitation; and 4) trophic status. Additionally, where appropriate, results have been compared to the regional data on reservoirs in the Cultivated Plains region.

Temperature and Dissolved Oxygen Profile Results: There are three temperature and dissolved oxygen profiles for Limesand-Seefeldt Dam collected in 2010. The profile data shows that the waterbody does periodically thermally stratify. During periods of thermal stratification the reservoir experiences rapid and nearly complete oxygen decay below the thermocline.

During periods of extended thermal stratification (7/22/2010) the oxygen concentrations become dangerously low at depths as shallow as 2.5 meters (7 ft). While dissolved oxygen below the thermal cline was below concentrations required to support some aquatic life, including many cool and cold water fish species, there was still a sufficient concentration of dissolved oxygen in the upper three meter of the water column (Figures 5 and 6).

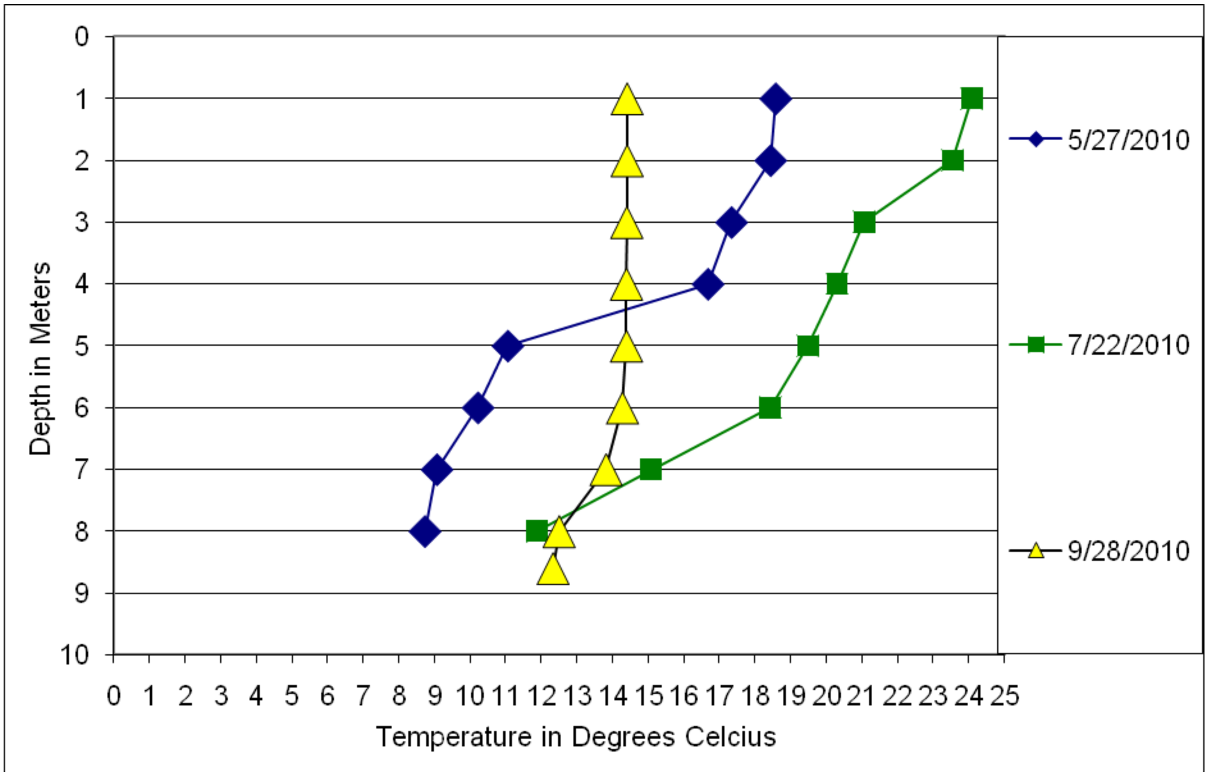

Figure 5. Temperature Profiles for Limesand-Seefeldt Dam

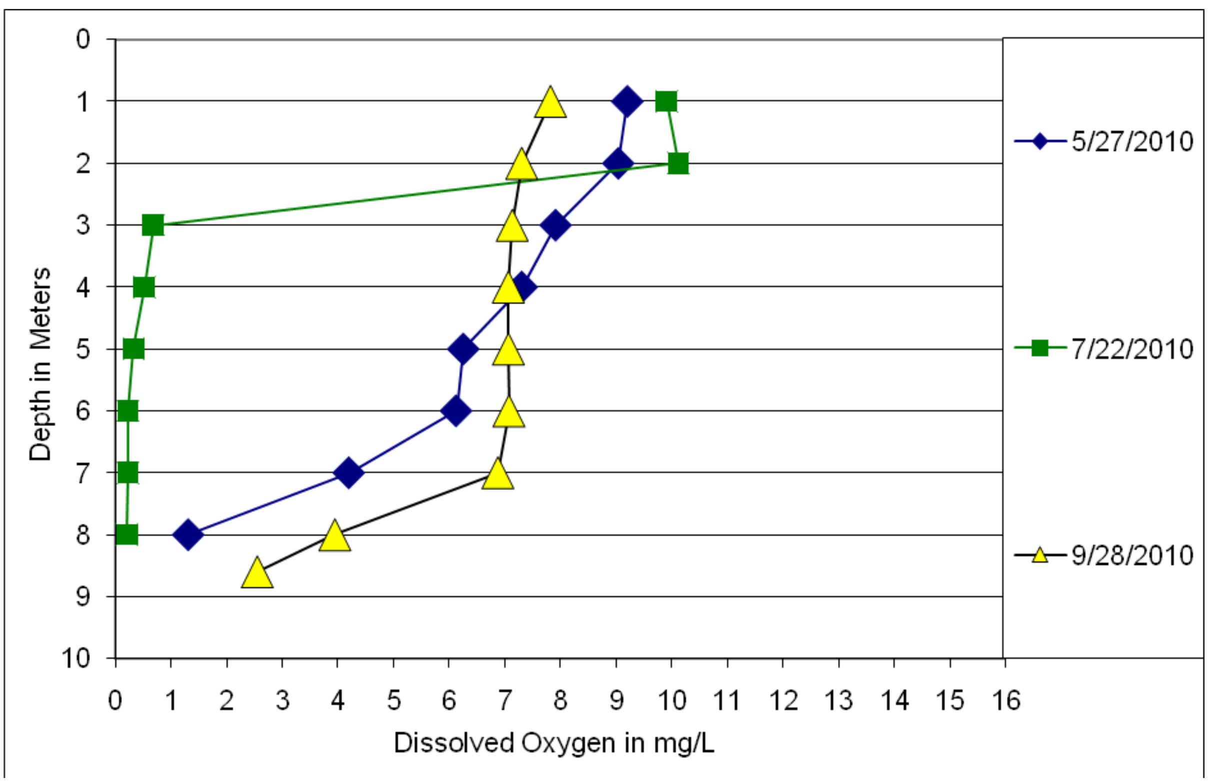

Figure 6. Dissolved Oxygen Profiles for Limesand-Seefedlt Dam

General Water Quality: Data collected in 2010 indicate that Limesand-Seefeldt Dam is well buffered with total alkalinity as $CaCO_3$ concentrations ranging from 257 to 293 mg/L (Table 1). The reservoir is sodium sulfate dominated with an average sodium concentration of 62.7 mg/L and an average sulfate concentration of 481 mg/L. The average total dissolved solids concentration and specific conductance measurements for the 2010 sampling period were 950 mg/L and 1333 µmhos/cm, respectively, and the average total nitrogen as N and total phosphorus as P concentrations were 2.337 mg/L and 0.605 mg/L respectively.

When compared to the regional average water quality for reservoirs in the Rangeland Plans region, Limesand-Seefedlt Dam has more dissolved solids and is more eutrophic than most (Table 3). For example, the regional average TDS, total nitrogen, and total phosphorus concentrations are 671 mg/L, 1.520 mg/L, and 0.327 mg/L respectively, compared to Limesand-Seefedlt's average TDS, total nitrogen, and total phosphorus concentrations of 950 mg/L, 2.337 mg/L and 0.605 mg/L respectively.

Table 1. Statistical Summary of Limesand-Seefedlt Dam's 2010 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	3	270	257	293	20
Total Ammonia as N	mg/L	3	0.383	0.084	0.873	0.428
Bicarbonate (HCO_3)	mg/L	3	308	250	358	54
Calcium (Ca)	mg/L	3	124.0	120.0	130.0	5.3
Carbonate (CO_3)	mg/L	3	11	1[1]	31	17
Chloride (Cl)	mg/L	3	18	17	20	2
Chlorophyll-a	µg/L	3	38.7	3.0	110.0	61.8
Specific Conductance	µmhos	3	1333	1290	1360	38
Total Dissolved Solids	mg/L	3	950	918	976	29
Total Hardness as ($CaCO_3$)	mg/L	3	657	637	686	26
Hydroxide (OH)	mg/L	3	1.0[1]	1.0[1]	1.0[1]	0.0
Iron (Fe)	mg/L	3	0.114	0.104	0.122	0.009
Magnesium (Mg)	mg/L	3	84.4	82.0	87.8	3.0
Nitrate + Nitrite as N	mg/L	3	0.420	0.240	0.680	0.231
Total Kjeldahl Nitrogen as N	mg/L	3	1.917	1.660	2.170	0.255
Total Nitrogen as N	mg/L	3	2.337	2.000	2.600	0.307
pH		3	8.34	8.04	8.74	0.36
Total Phosphorus as P	mg/L	3	0.605	0.550	0.670	0.061
Potassium (K)	mg/L	3	13.5	13.1	13.9	0.4
Sodium (Na)	mg/L	3	62.7	60.0	66.6	3.4
Sulfate (SO4)	mg/L	3	481	467	501	18

[1]Equal to the lower reporting limit

Table 2. Statistical Summary of Water Quality Data[2] Collected from Reservoirs and Impoundments in the Cultivated Plains Ecological Region of North Dakota.

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	400	261	88	891	99
Total Ammonia as N	mg/L	567	0.145	0.001[1]	2.070	0.208
Bicarbonate (HCO_3)	mg/L	400	294	91	951	110
Calcium (Ca)	mg/L	402	66.7	19.4	169.0	22.7
Carbonate (CO_3)	mg/L	382	13	1[1]	93	16
Chloride (Cl)	mg/L	400	21	3[1]	113	17
Chlorophyll-a	µg/L	445	19.9	1.5[1]	388.0	30.2
Specific Conductance	µmhos	400	1025	217	3140	501
Total Dissolved Solids	mg/L	392	671	127	2300	375
Total Hardness as ($CaCO_3$)	mg/L	402	341	95	1090	119
Hydroxide (OH)	mg/L	339	1.0	0.0[1]	1.0	0.2
Iron (Fe)	mg/L	400	0.143	0.007	3.190	0.220
Magnesium (Mg)	mg/L	402	42.3	11.2	161.0	19.6
Nitrate + Nitrite as N	mg/L	560	0.112	0.001[1]	2.060	0.213
Total Kjeldahl Nitrogen as N	mg/L	480	1.470	0.206	4.410	0.648
Total Nitrogen as N	mg/L	419	1.520	0.418	3.950	0.617
pH		401	8.34	1.76	9.40	0.54
Total Phosphorus as P	mg/L	569	0.327	0.002[1]	2.270	0.290
Potassium (K)	mg/L	402	11.6	2.7	34.5	5.4
Sodium (Na)	mg/L	402	96.8	2.2	582.0	102.9
Sulfate (SO4)	mg/L	400	272	1[1]	1350	210

[1]Equal to the lower reporting limit
[2]Data collected from 45 reservoirs between 1991 and 2010

Limiting Nutrients: The three water quality samples collected in 2010 indicate that Limesand-Seefedlt Dam is nitrogen limited (Figure 7). The limiting nutrient analysis is based on the assumption that either nitrogen or phosphorus is limiting algal growth and that the ratio of total nitrogen as N to total phosphorus as P (N:P), by weight in the average algae is approximately 15 to 1. When the N:P ratio is less than 15:1, nitrogen is assumed to be the limiting nutrient and when it exceeds 15:1, the limiting nutrient is assumed to be phosphorus.

Trophic Status Assessment: Based on the chlorophyll-a, secchi disk transparency, and total phosphorus data collected in 2010, Limsand-Seefeldt Dam's trophic status is estimated as eutrophic. The trophic status index (TSI) scores ranged from a low of 41 based on chlorophyll-a to a high of 98 based on total phosphorus (Figure 8).

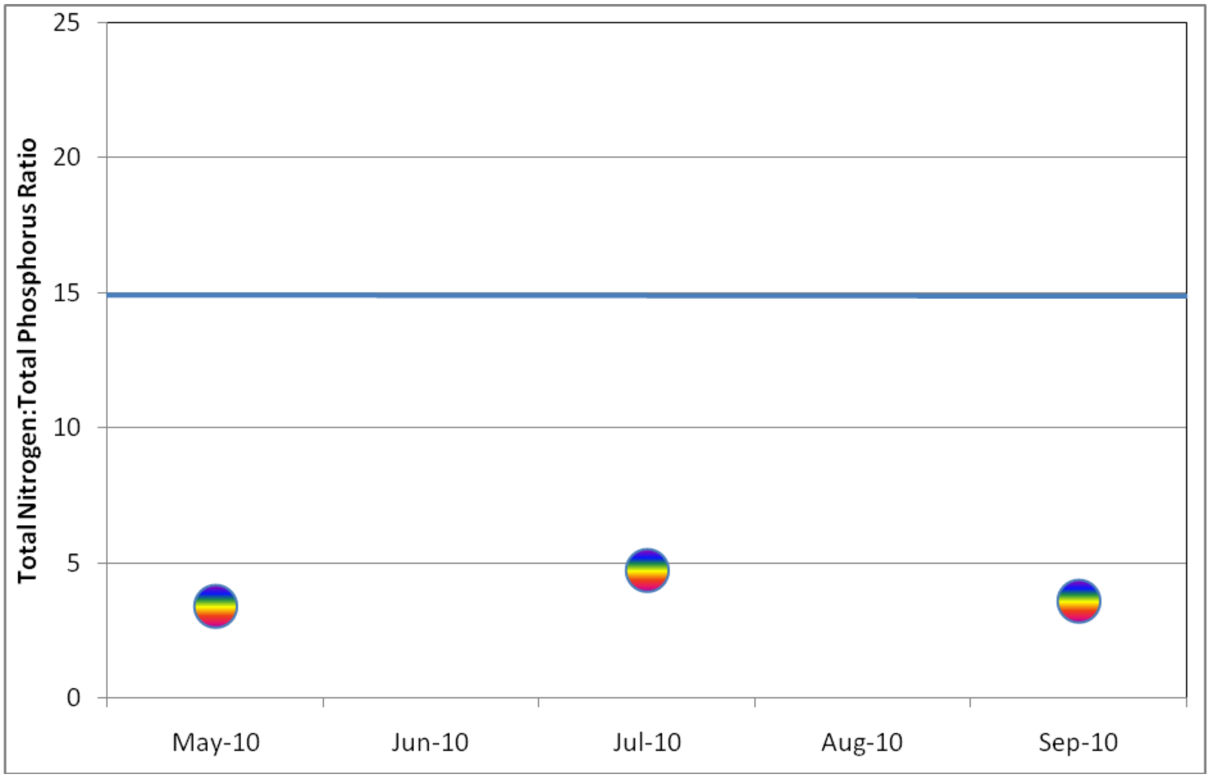

Figure 7. Limesand-Seefedlt Dam's Total Nitrogen to Total Phosphorus Ratio

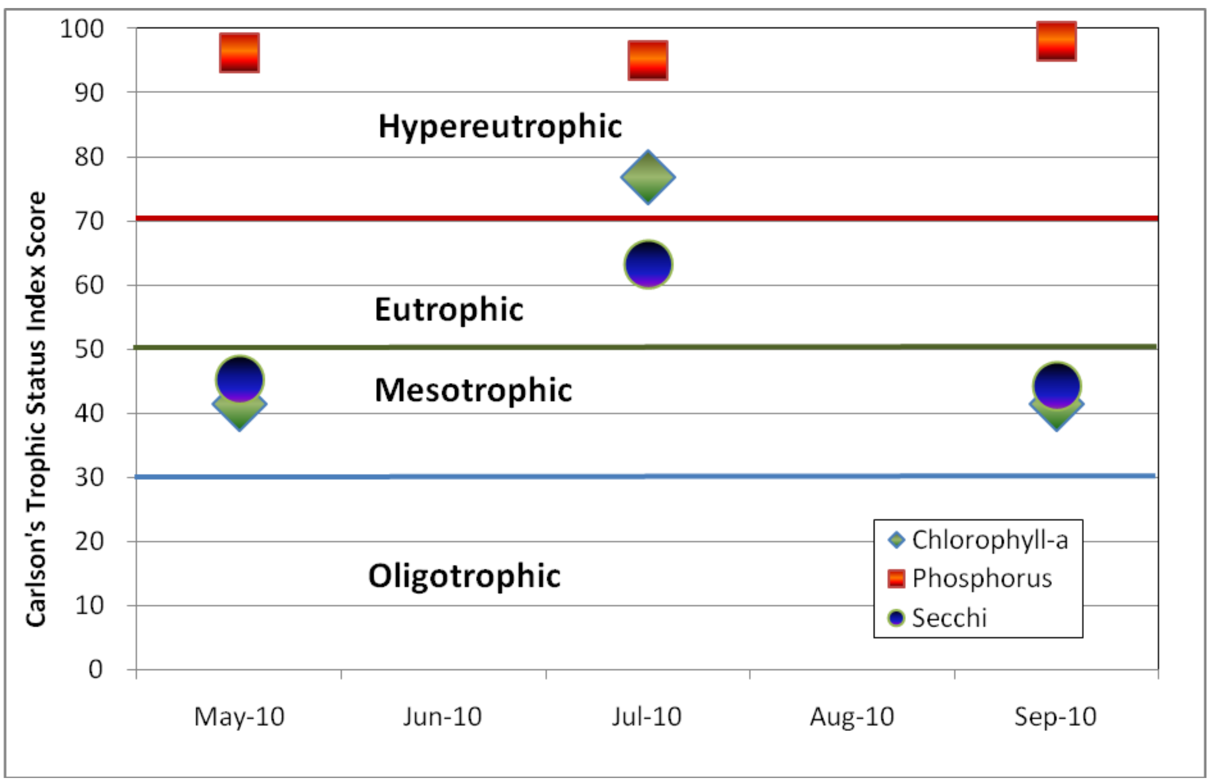

Figure 8. Limesand-Seefedlt Dam's TSI Scores

Mundt Lake, Logan County

BACKGROUND

Location: Mundt Lake is a natural glacial lake located 2.5 miles north and 4 miles east of Lehr, North Dakota (Figure 1). The fishery is managed by the North Dakota Game and Fish. Fish species managed for are northern pike, walleye and yellow perch.

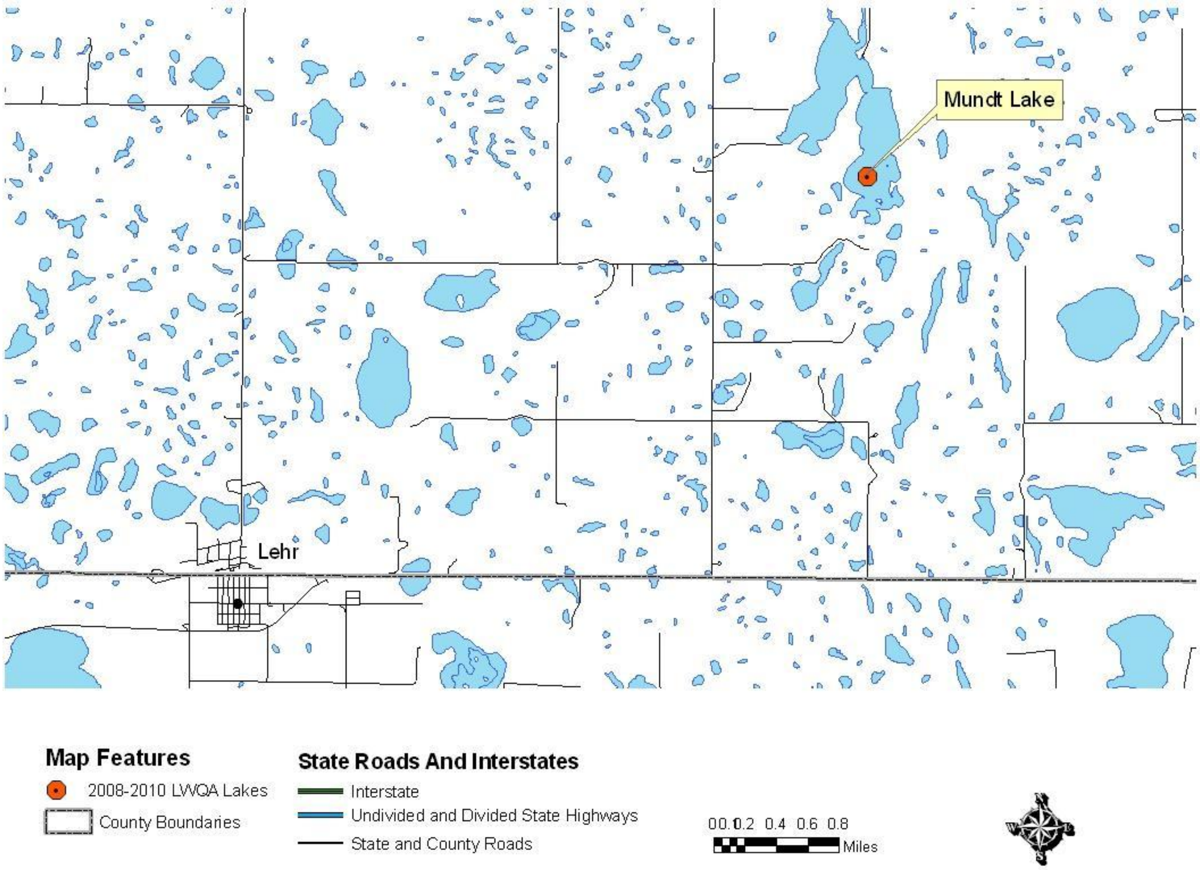

Figure 1. Location of Mundt Lake

Physiographic/Ecological Setting: Mundt Lake has a surface area of 270.2 acres, a maximum depth of 17.6 ft and an average depth 8.1 ft (Figure 2). The lake is located within the Northwestern Glaciated Plains Level III Ecoregion, which is part of the broader Rangeland Plains region (Figures 3 and 4).

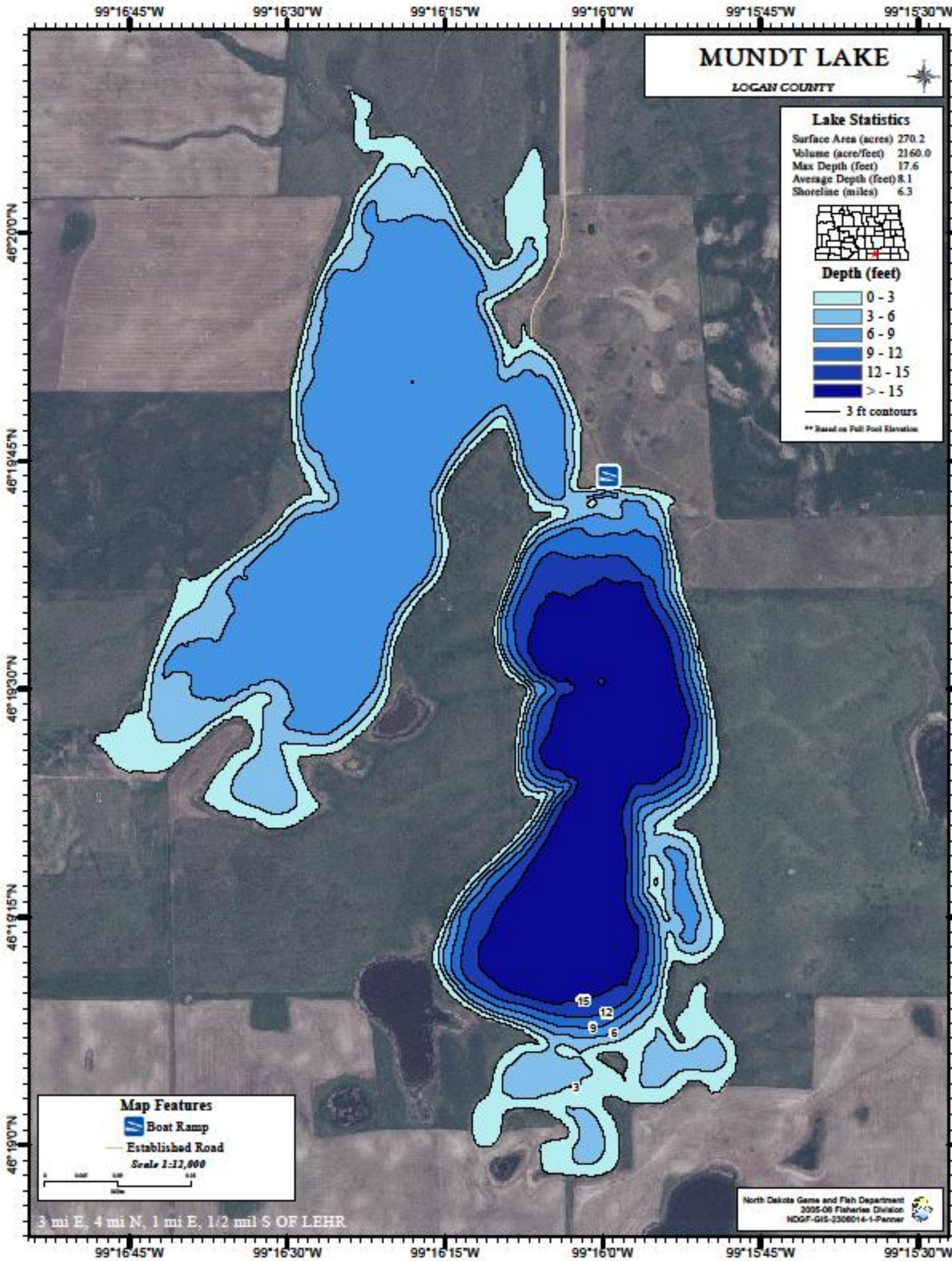

Figure 2. Contour Map of Mundt Lake (Map Courtesy of North Dakota Game and Fish Department)

Recreational Facilities: Recreational facilities at Mundt Lake include a cement boat ramp, courtesy dock, outdoor toilet and vehicle parking.

Water Quality Standards Classification: Mundt Lake is classified in the state "Standards of Quality for Waters of the State" (NDDoH, 2011) as a class 3 lake. Class 3 lakes or reservoirs are defined as a "warm water fishery" or "waters capable of supporting natural reproduction and growth of warm water fishes (e.g., largemouth bass and bluegill) and associated aquatic biota. Some cool water species may also be present."

Historical Water Quality Sampling: No historical water quality data.

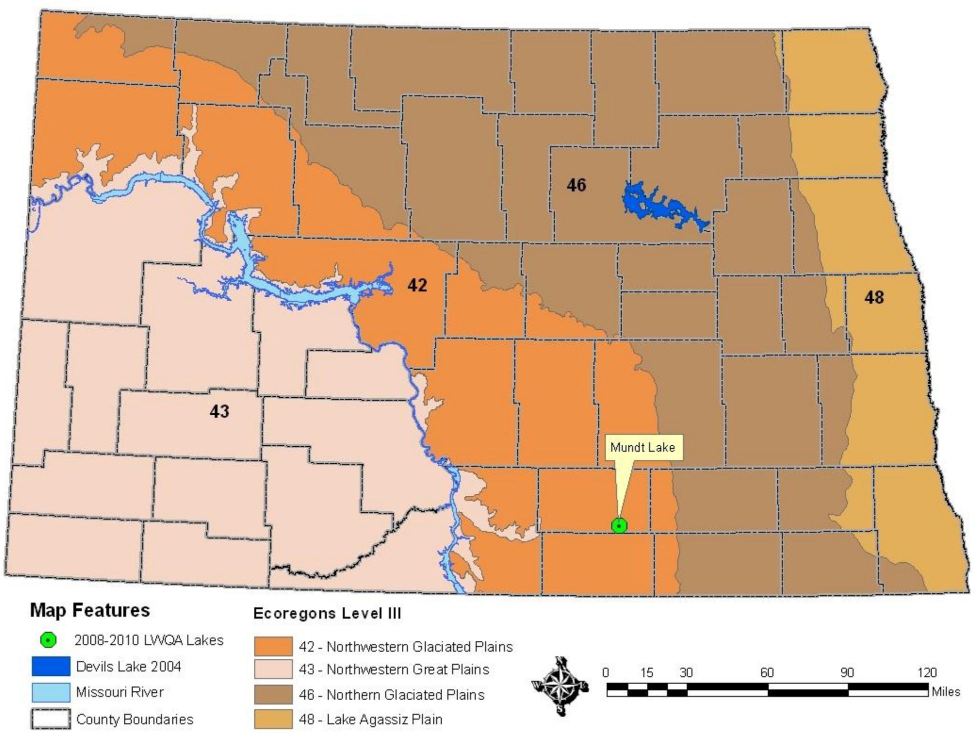

Figure 3. Mundt Lake's Location and the Level III Ecoregions

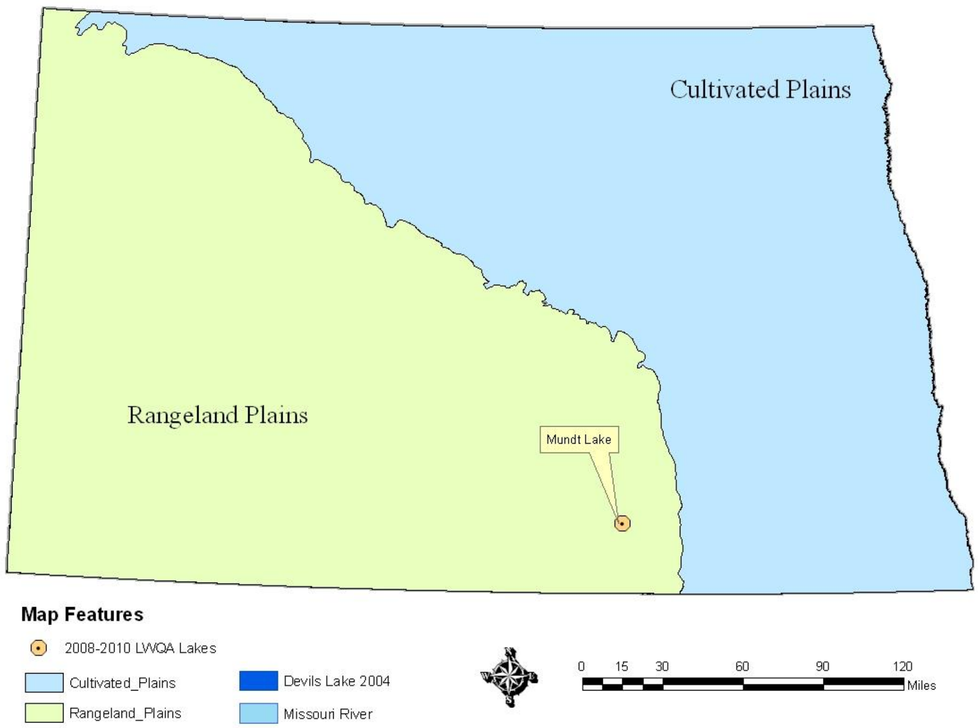

Figure 4. Mundt Lake Location and the Cultivated and Rangeland Plans Regions

WATER QUALITY MONITORING RESULTS

The water quality assessment for Mundt Lake is presented in four general categories: 1) temperature and dissolved oxygen profile results; 2) general water quality characterization; 3) nutrient limitation; and 4) trophic status. Additionally, where appropriate, results have been compared to regional data.

Temperature and Dissolved Oxygen Profile Results: There are three temperature and dissolved oxygen profiles for Mundt Lake collected in 2010 (Figures 5 and 6). The profile data shows that Mundt Lake was not thermally stratification during the open water period. Additionally during the open water period the lake remained well enough oxygenated to support aquatic Life.

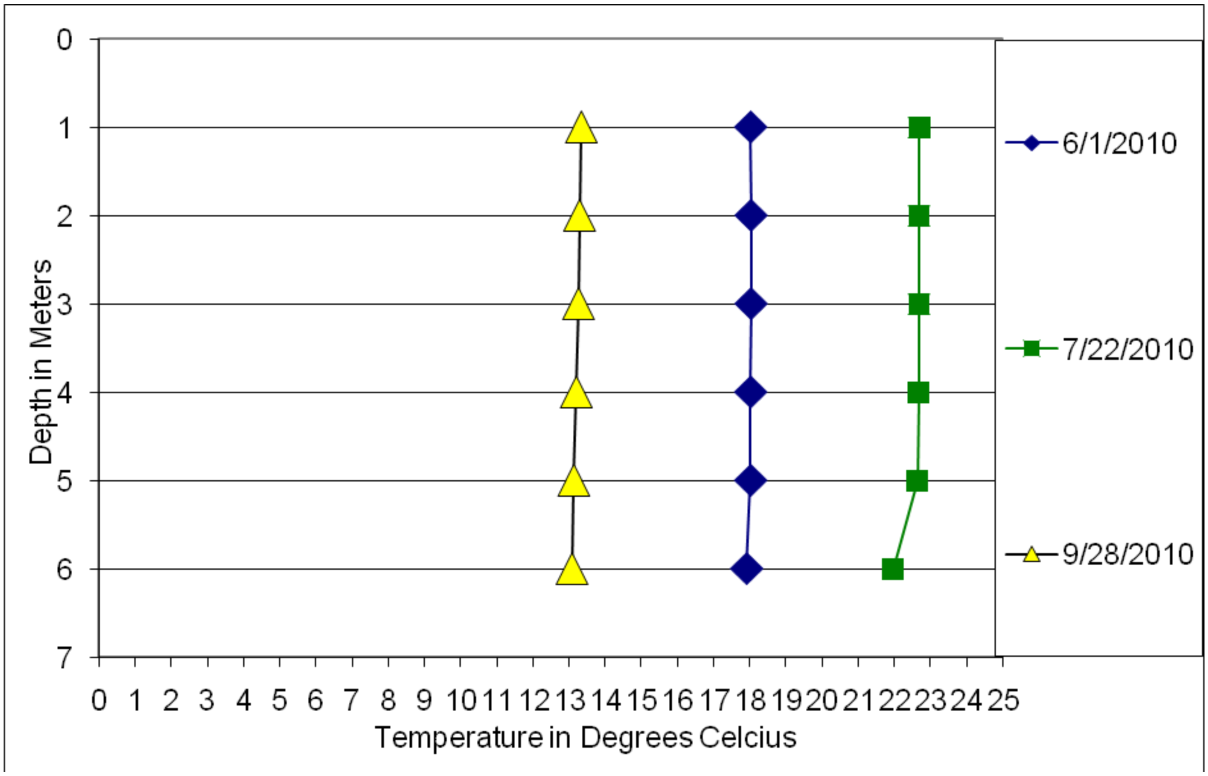

Figure 5. Temperature Profiles for Mundt Lake

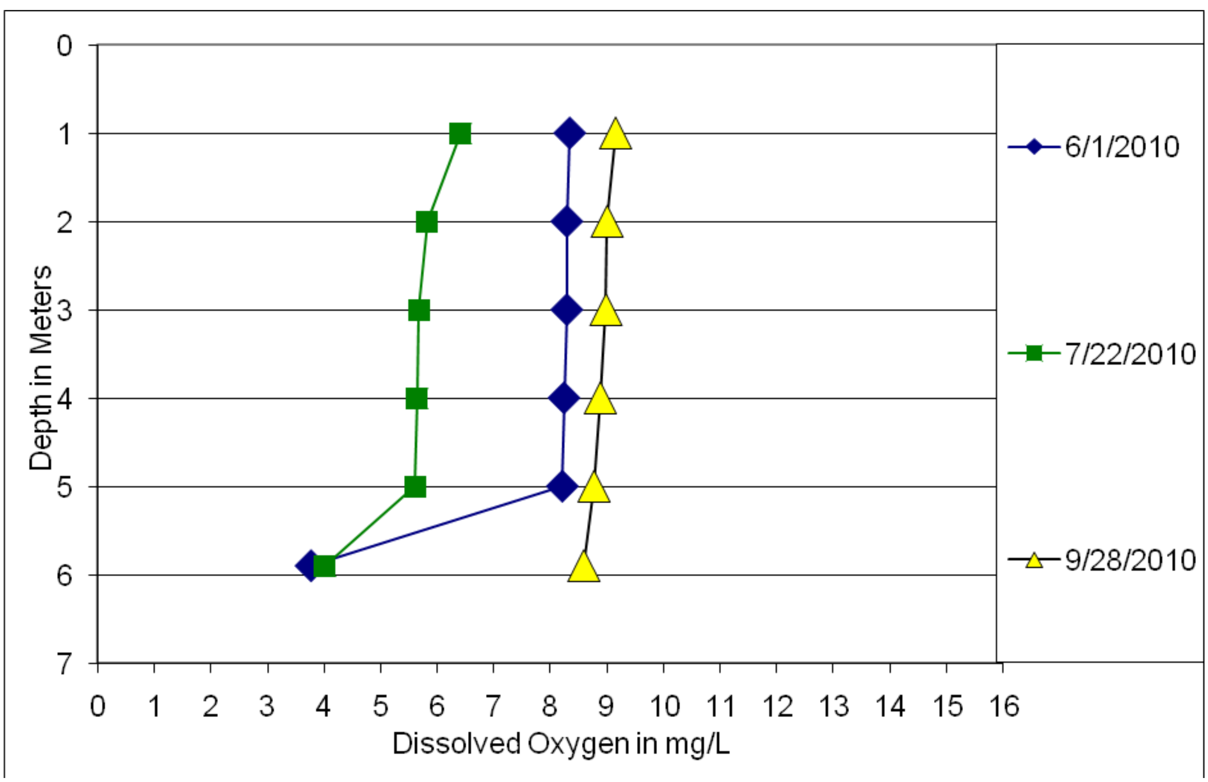

Figure 6. Dissolved Oxygen Profiles for Mundt Lake

General Water Quality: Data collected in 2010 indicate that Mundt Lake is well buffered with total alkalinity as $CaCO_3$ concentrations ranging from 440 to 458 mg/L (Table 1). The lake is sodium bicarbonate dominated with an average sodium concentration of 95.2 mg/L and an average bicarbonate concentration of 453 mg/L. The average total dissolved solids concentration and specific conductance measurement for 2010 sampling period were 929 mg/L and 1417 µmhos/cm respectively, and the average total nitrogen as N and total phosphorus as P concentrations were 2.68 mg/L and 0.178 mg/L respectively.

When compared to the regional average water quality for natural lakes in the Rangeland Plans Ecoregion, Mundt Lake is below average for dissolved minerals and total phosphorus but richer in total nitrogen then most (Table 3). For example, the regional average TDS, total nitrogen and total phosphorus concentrations are 1466 mg/L, 1.794 mg/L and 0.233 mg/L respectively, compared to Mundt Lake's average TDS, total nitrogen, and total phosphorus concentrations of 929 mg/L, 2.68 mg/L, and 0.178 mg/L, respectively.

Table 1. Statistical Summary of Mundt Lake's 2010 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	3	447	440	458	9
Total Ammonia as N	mg/L	3	0.123	0.030[1]	0.170	0.081
Bicarbonate (HCO_3)	mg/L	3	453	426	479	27
Calcium (Ca)	mg/L	3	41.8	37.7	45.3	3.8
Carbonate (CO_3)	mg/L	3	46	39	57	10
Chloride (Cl)	mg/L	3	50	48	53	2
Chlorophyll-a	µg/L	3	22.4	1.5[1]	39.0	19.1
Specific Conductance	µmhos	3	1417	1400	1450	29
Total Dissolved Solids	mg/L	3	929	912	958	25
Total Hardness as ($CaCO_3$)	mg/L	3	593	559	624	33
Hydroxide (OH)	mg/L	3	1.0[1]	1.0[1]	1.0[1]	0.0
Iron (Fe)	mg/L	3	0.080	0.050	0.119	0.036
Magnesium (Mg)	mg/L	3	118.7	113.0	124.0	5.5
Nitrate + Nitrite as N	mg/L	3	0.030[1]	0.030[1]	0.030[1]	0.000
Total Kjeldahl Nitrogen as N	mg/L	3	2.650	2.360	3.070	0.372
Total Nitrogen as N	mg/L	3	2.680	2.390	3.100	0.372
pH		3	8.66	8.56	8.75	0.10
Total Phosphorus as P	mg/L	3	0.178	0.158	0.190	0.017
Potassium (K)	mg/L	3	56.1	55.2	56.8	0.8
Sodium (Na)	mg/L	3	95.2	93.5	98.5	2.8
Sulfate (SO4)	mg/L	3	297	286	305	10

[1]Equal to the lower reporting limit

Table 2. Statistical Summary of Water Quality Data[2] Collected from Natural and Enhanced Lakes in the Rangeland Plains Ecological Region of North Dakota

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	383	513	111	4770	487
Total Ammonia as N	mg/L	494	0.105	0.001[1]	2.230	0.229
Bicarbonate (HCO_3)	mg/L	383	469	60	2990	320
Calcium (Ca)	mg/L	384	41.1	0.5	282.0	34.4
Carbonate (CO_3)	mg/L	377	79	1[1]	1420	148
Chloride (Cl)	mg/L	383	44	3[1]	1070	103
Chlorophyll-a	µg/L	346	22.5	1.5[1]	292.0	37.4
Specific Conductance	µmhos	383	2028	424	20100	1976
Total Dissolved Solids	mg/L	383	1466	227	18200	1717
Total Hardness as ($CaCO_3$)	mg/L	384	529	74	2370	295
Hydroxide (OH)	mg/L	322	1.0	0.0[1]	1.0	0.2
Iron (Fe)	mg/L	385	0.245	0.001[1]	7.070	0.543
Magnesium (Mg)	mg/L	384	103.6	8.5	567.0	70.9
Nitrate + Nitrite as N	mg/L	491	0.04046	0.001[1]	0.54	0.054
Total Kjeldahl Nitrogen as N	mg/L	463	1.876	0.080	8.500	1.073
Total Nitrogen as N	mg/L	401	1.794	0.240	5.520	0.897
pH		383	8.80	7.40	9.87	0.36
Total Phosphorus as P	mg/L	501	0.233	0.002[1]	1.940	0.336
Potassium (K)	mg/L	384	34.0	3.1	356.0	37.0
Sodium (Na)	mg/L	384	299.6	16.9	4680.0	514.5
Sulfate (SO4)	mg/L	383	625	34	10500	885

[1]Equal to the lower reporting limit
[2]Data collected from 64 natural and enhanced Lakes between 1991 and 2010

Limiting Nutrients: The water quality monitoring results for Mundt Lake are inconclusive at defining which nutrient (nitrogen or phosphorus) is limiting primary production. While inconclusive, the results do show that there is no shortage of either and most likely day light and temperature are the true factors limiting primary production (Figure 7).

The limiting nutrient assessment is based on the assumption that either nitrogen or phosphorus is limiting algal growth with the water body, and that the ratio of total nitrogen as N to total phosphorus as P (N:P), by weight in the average algae, is approximately 15 to 1. When the N:P ratio is less than 15:1, nitrogen is assumed to be the limiting nutrient and when it exceeds 15:1, the limiting nutrient is assumed to be phosphorus.

Trophic Status Assessment: Based on the chlorophyll-a, secchi disk transparency, and total phosphorus data collected in 2010, Mundt Lake's trophic condition is estimated as eutrophic. The trophic Status Index scores ranged from a low of 35 based on chlorophyll-a to a high of 80 based on total phosphorus (Figure 8).

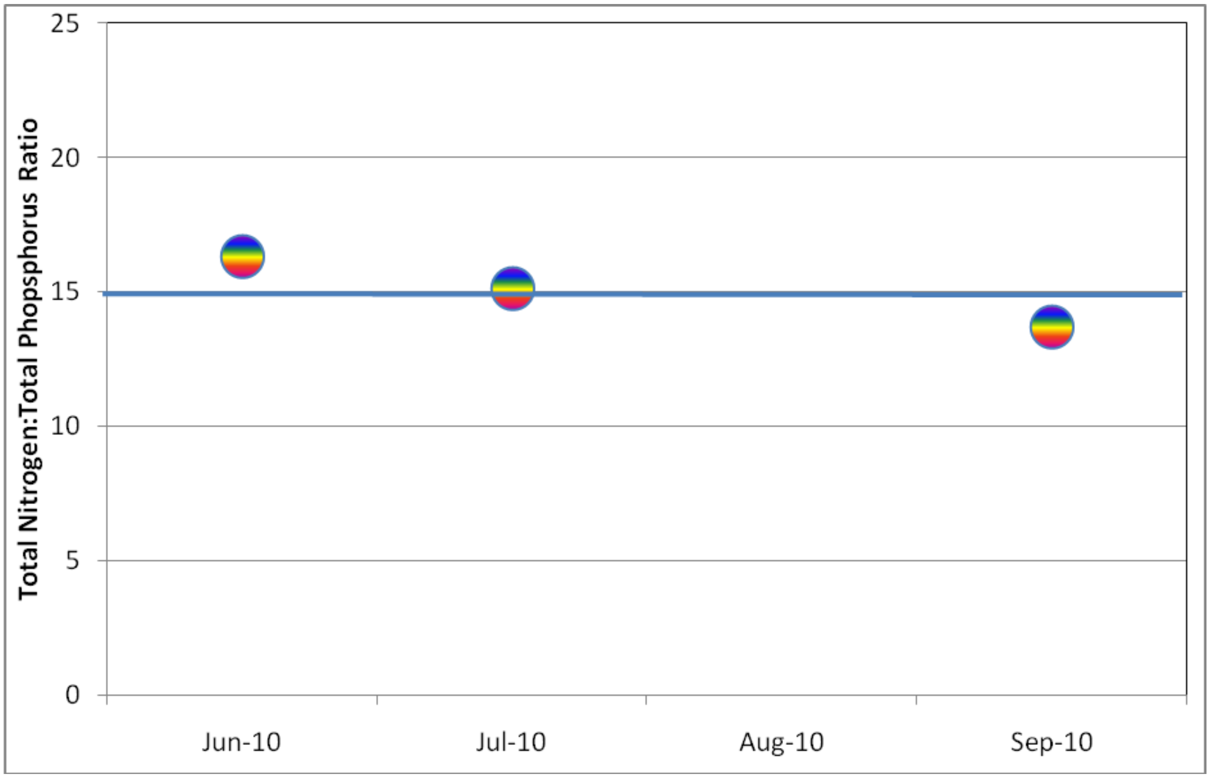

Figure 7. Mundt Lake's Total Nitrogen to Total Phosphorus Ratio

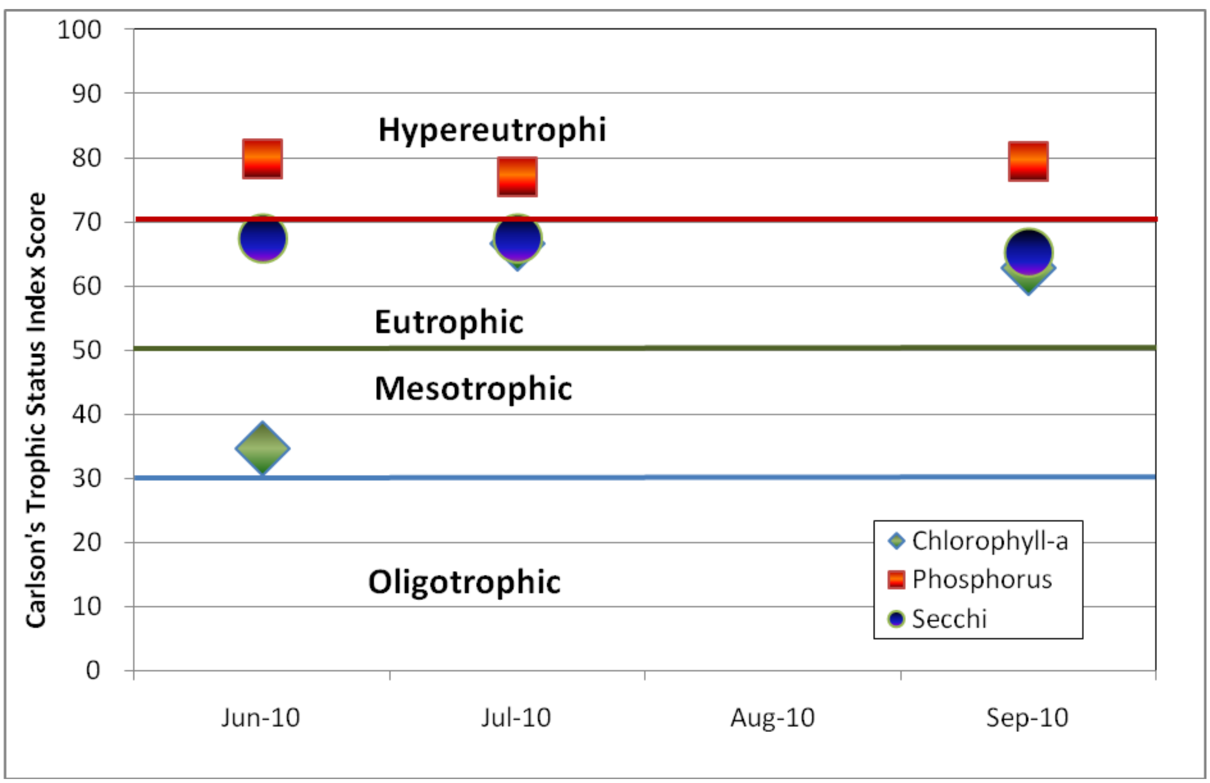

Figure 8. Mundt Lake's TSI Scores

Rudolph Lake, Logan County

BACKGROUND

Location: Rudolph Lake is a shallow natural glacial lake located 2.5 miles north and 4 miles east of Lehr, North Dakota (Figure 1). The fishery is managed by the North Dakota Game and Fish. Fish species managed for are northern pike, walleye and yellow perch.

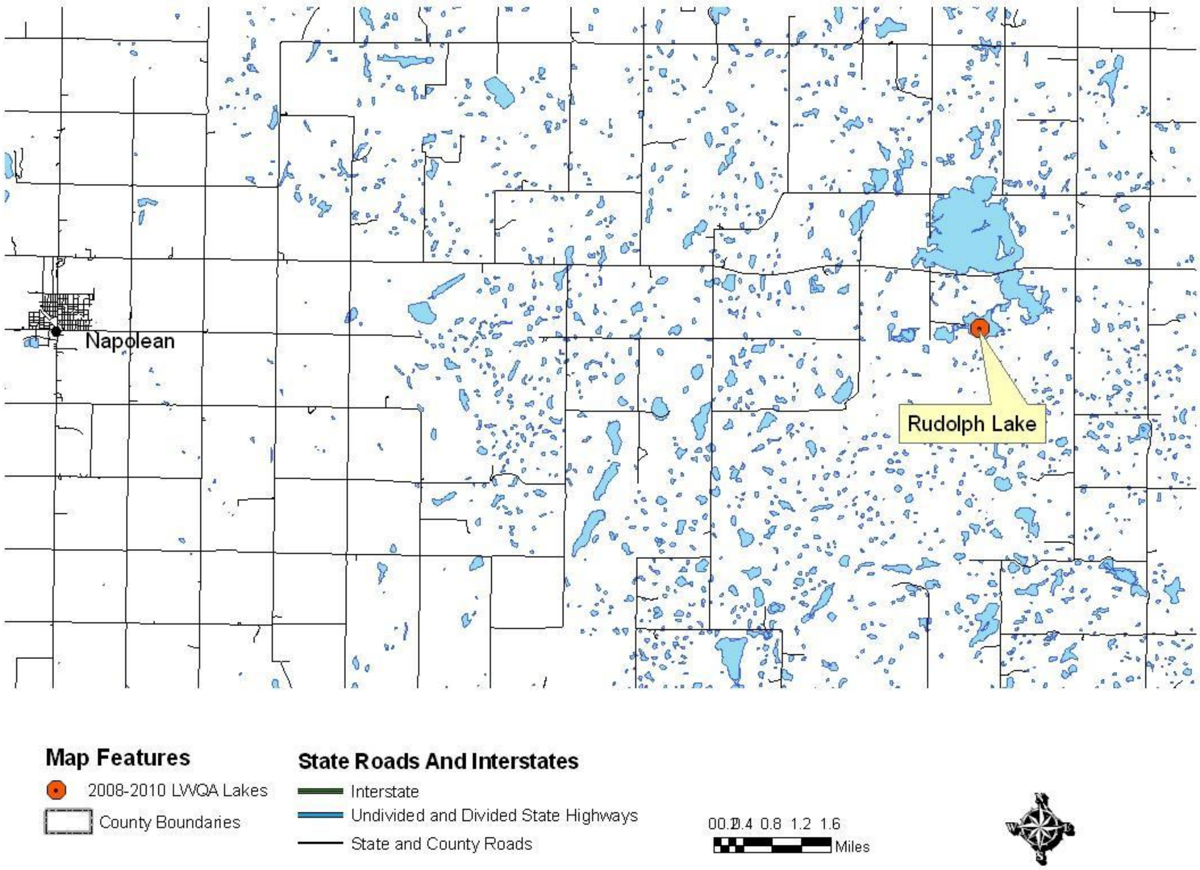

Figure 1. Location of Rudolph Lake

Physiographic/Ecological Setting: Rudolph Lake has a surface area of 82.3 acres, a maximum depth of 10.7 ft and an average depth 8.2 ft (Figure 2). The lake is located within the Northwestern Glaciated Plains Level III Ecoregion, which is part of the broader Rangeland Plains region (Figures 3 and 4).

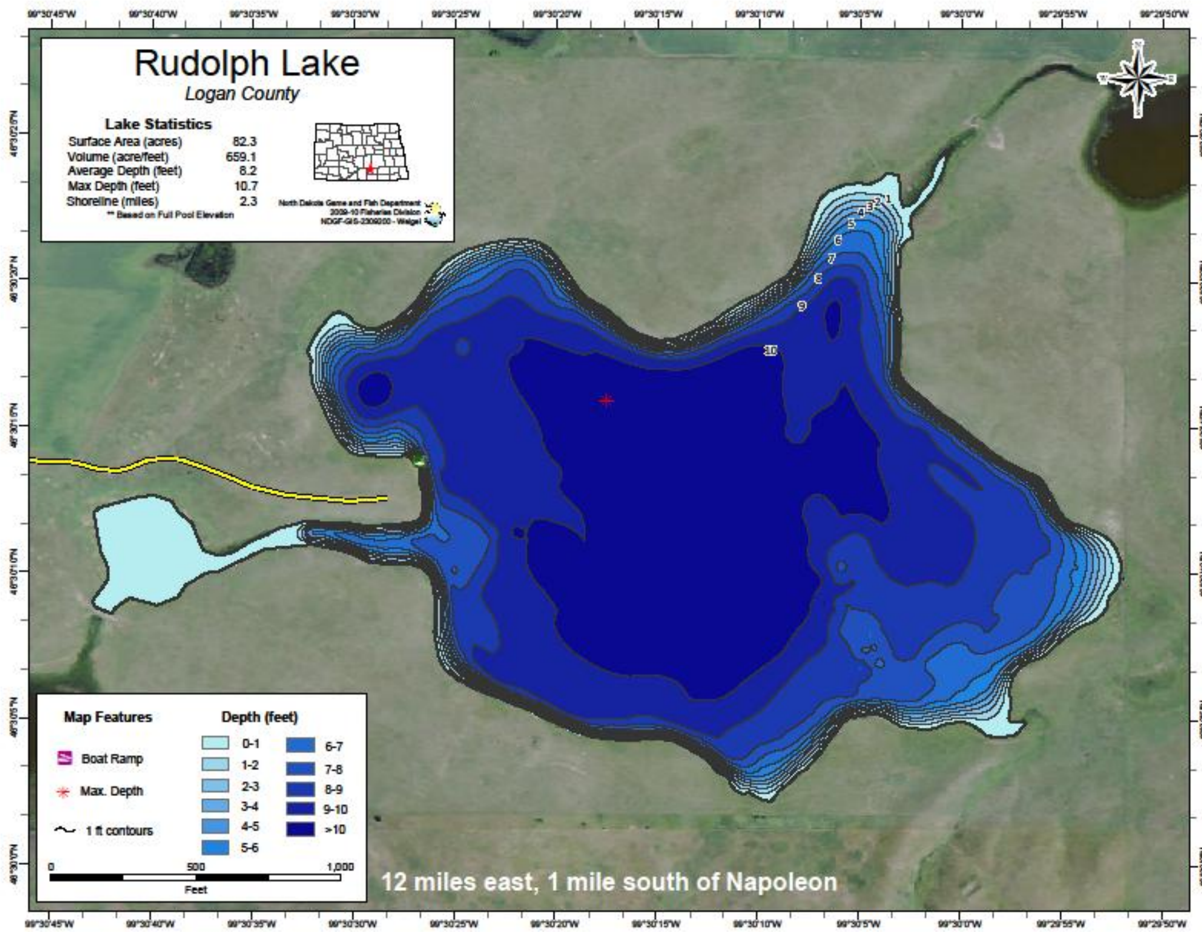

Figure 2. Contour Map of Rudolph Lake (Map Courtesy of North Dakota Game and Fish Department)

Recreational Facilities: There are no recreational facilities at Rudolph Lake. Access is by a rock and bolder infested two-track trail that wonders through a calving pasture.

Water Quality Standards Classification: Rudolph Lake is classified in the state "Standards of Quality for Waters of the State" (NDDoH, 2011) as a class 3 lake. Class 3 lakes or reservoirs are defined as a "warm water fishery" or "waters capable of supporting natural reproduction and growth of warm water fishes (e.g., largemouth bass and bluegill) and associated aquatic biota. Some cool water species may also be present."

Historical Water Quality Sampling: No historical water quality data.

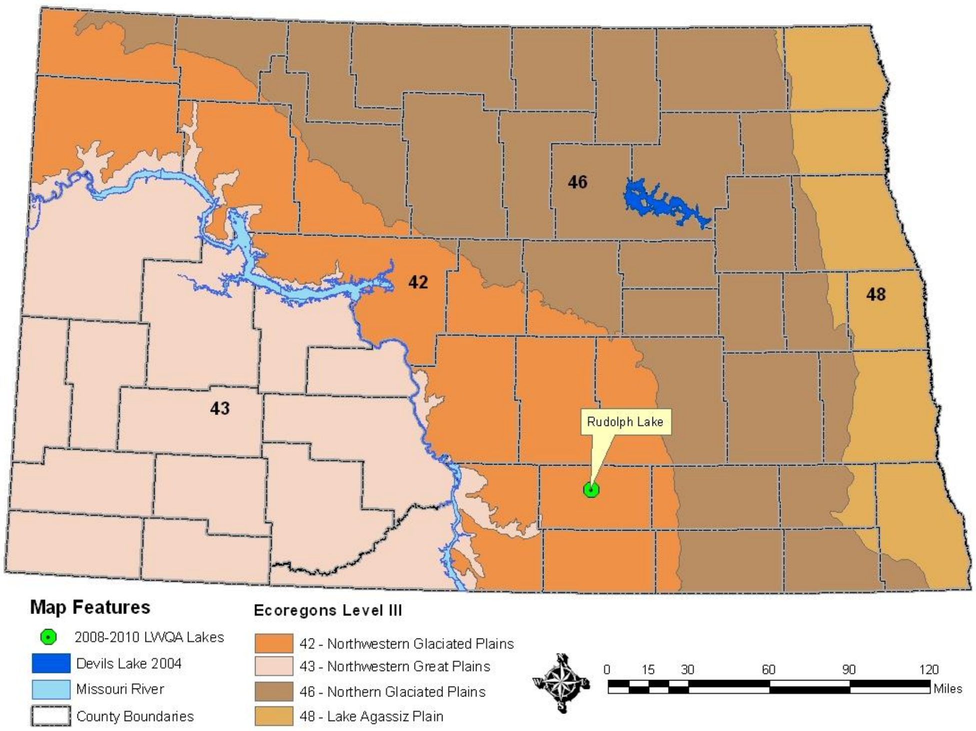

Figure 3. Rudolph Lake's Location and the Level III Ecoregions

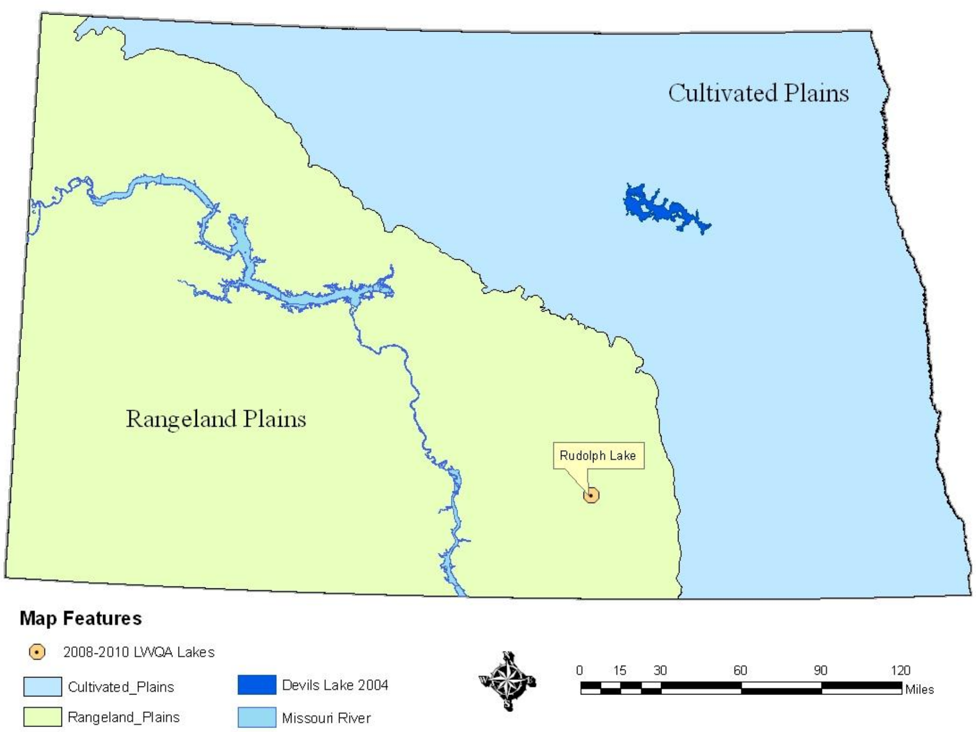

Figure 4. Rudolph Lake Location and the Cultivated and Rangeland Plans Regions

WATER QUALITY MONITORING RESULTS

The water quality assessment for Rudolph Lake is presented in four general categories: 1) temperature and dissolved oxygen profile results; 2) general water quality characterization; 3) nutrient limitation; and 4) trophic status. Additionally, where appropriate, results have been compared to regional data.

Temperature and Dissolved Oxygen Profile Results: There are three temperature and dissolved oxygen profiles for Rudolph Lake collected in 2010 (Figures 5 and 6). The profile data shows that Rudolph Lake was not thermally stratification during the open water monitoring period. Additionally during the open water period the lake remained well enough oxygenated to support aquatic Life.

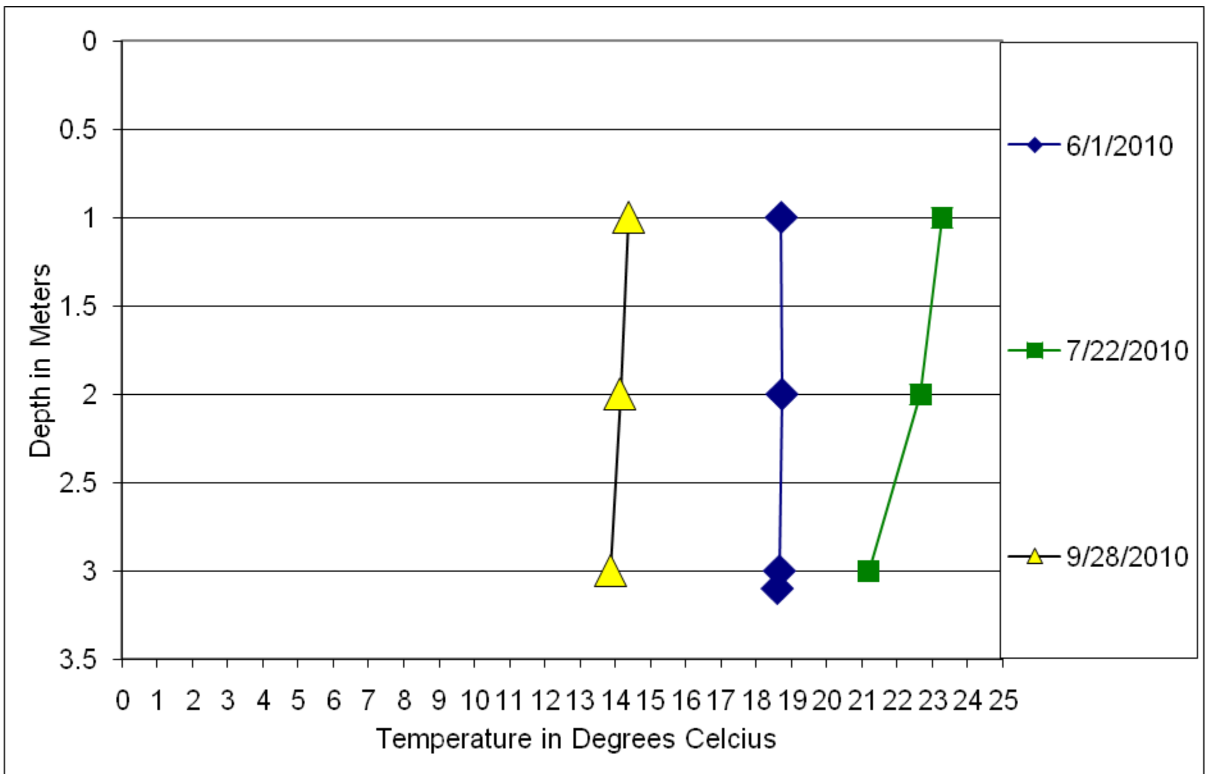

Figure 5. Temperature Profiles for Rudolph Lake

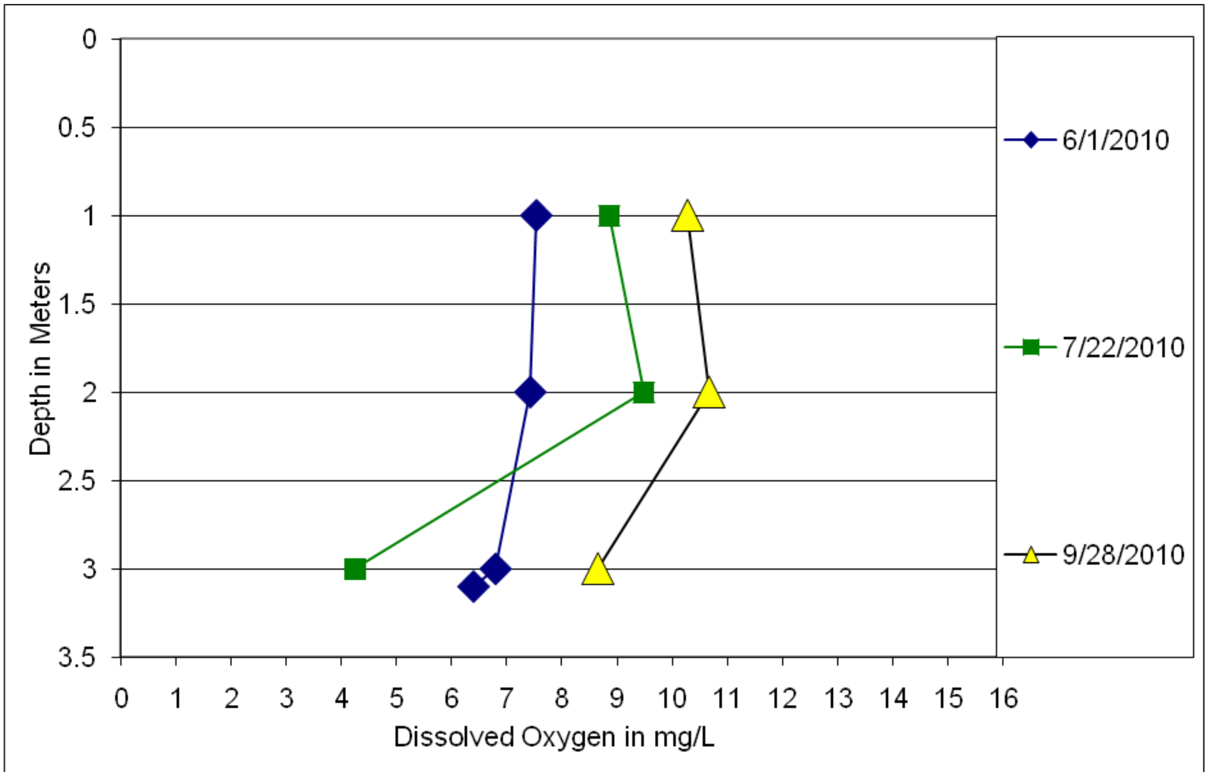

Figure 6. Dissolved Oxygen Profiles for Rudolph Lake

General Water Quality: Data collected in 2010 indicates that Rudolph Lake is well buffered with total alkalinity as $CaCO_3$ concentrations ranging from 270 to 300 mg/L (Table 1). The lake is sodium bicarbonate dominated with an average sodium concentration of 205 mg/L and an average bicarbonate concentration of 269 mg/L. The average total dissolved solids concentration and specific conductance measurement for 2010 sampling period were 1120 mg/L and 1597 µmhos/cm respectively, and the average total nitrogen as N and total phosphorus as P concentrations were 2.433 mg/L and 0.264 mg/L respectively.

When compared to the regional water quality for natural lakes in the Rangeland Plans region, Rudolph Lake is similar to but below average for dissolved minerals, but more nutrient rich then most (Table 3). For example, the regional average TDS, total nitrogen and total phosphorus concentrations are 1466 mg/L, 1.794 mg/L and 0.233 mg/L respectively, compared to Rudolph Lake's average TDS, total nitrogen, and total phosphorus concentrations of 1120 mg/L, 2.433 mg/L, and 0.264 mg/L, respectively.

Table 1. Statistical Summary of Rudolf Lake's 2010 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	3	288	270	300	16
Total Ammonia as N	mg/L	3	0.156	0.128	0.170	0.024
Bicarbonate (HCO_3)	mg/L	3	269	243	297	27
Calcium (Ca)	mg/L	3	51.0	46.8	53.5	3.7
Carbonate (CO_3)	mg/L	3	40	16	57	22
Chloride (Cl)	mg/L	3	22	20	24	2
Chlorophyll-a	µg/L	3	43.4	1.5[1]	82.2	40.4
Specific Conductance	µmhos	3	1597	1540	1670	67
Total Dissolved Solids	mg/L	3	1120	1070	1190	62
Total Hardness as ($CaCO_3$)	mg/L	3	456	415	494	40
Hydroxide (OH)	mg/L	3	1.0[1]	1.0[1]	1.0[1]	0.0
Iron (Fe)	mg/L	3	0.213	0.122	0.393	0.156
Magnesium (Mg)	mg/L	3	79.9	72.3	88.0	7.9
Nitrate + Nitrite as N	mg/L	3	0.043	0.030[1]	0.070	0.023
Total Kjeldahl Nitrogen as N	mg/L	3	2.390	1.830	2.990	0.581
Total Nitrogen as N	mg/L	3	2.433	1.860	3.060	0.602
pH		3	8.83	8.56	9.06	0.25
Total Phosphorus as P	mg/L	3	0.264	0.222	0.330	0.058
Potassium (K)	mg/L	3	31.3	30.1	33.4	1.9
Sodium (Na)	mg/L	3	205.0	191.0	226.0	18.5
Sulfate (SO4)	mg/L	3	557	543	580	20

[1]Equal to the lower reporting limit

Limiting Nutrients: The water quality monitoring results indicate that Rudolph Lake is nitrogen limited (Figure 7). The limiting nutrient assessment is based on the assumption that either nitrogen or phosphorus is limiting algal growth with the water body, and that the ratio of total nitrogen as N to total phosphorus as P (N:P), by weight in the average algae, is approximately 15 to 1. When the N:P ratio is less than 15:1, nitrogen is assumed to be the limiting nutrient and when it exceeds 15:1, the limiting nutrient is assumed to be phosphorus.

Trophic Status Assessment: Based on the chlorophyll-a, secchi disk transparency, and total phosphorus data collected in 2010, Rudolph Lake's trophic condition is hypereutrophic. The trophic Status Index scores ranged from a low of 35 based on chlorophyll-a to a high of 88 based on total phosphorus (Figure 8).

Table 2. Statistical Summary of Water Quality Data[2] Collected from Natural and Enhanced Lakes in the Rangeland Plains Ecological Region of North Dakota

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	383	513	111	4770	487
Total Ammonia as N	mg/L	494	0.105	0.001[1]	2.230	0.229
Bicarbonate (HCO_3)	mg/L	383	469	60	2990	320
Calcium (Ca)	mg/L	384	41.1	0.5	282.0	34.4
Carbonate (CO_3)	mg/L	377	79	1[1]	1420	148
Chloride (Cl)	mg/L	383	44	3[1]	1070	103
Chlorophyll-a	µg/L	346	22.5	1.5[1]	292.0	37.4
Specific Conductance	µmhos	383	2028	424	20100	1976
Total Dissolved Solids	mg/L	383	1466	227	18200	1717
Total Hardness as ($CaCO_3$)	mg/L	384	529	74	2370	295
Hydroxide (OH)	mg/L	322	1.0	0.0[1]	1.0	0.2
Iron (Fe)	mg/L	385	0.245	0.001[1]	7.070	0.543
Magnesium (Mg)	mg/L	384	103.6	8.5	567.0	70.9
Nitrate + Nitrite as N	mg/L	491	0.04046	0.001[1]	0.54	0.054
Total Kjeldahl Nitrogen as N	mg/L	463	1.876	0.080	8.500	1.073
Total Nitrogen as N	mg/L	401	1.794	0.240	5.520	0.897
pH		383	8.80	7.40	9.87	0.36
Total Phosphorus as P	mg/L	501	0.233	0.002[1]	1.940	0.336
Potassium (K)	mg/L	384	34.0	3.1	356.0	37.0
Sodium (Na)	mg/L	384	299.6	16.9	4680.0	514.5
Sulfate (SO4)	mg/L	383	625	34	10500	885

[1]Equal to the lower reporting limit
[2]Data collected from 64 natural and enhanced Lakes between 1991 and 2010

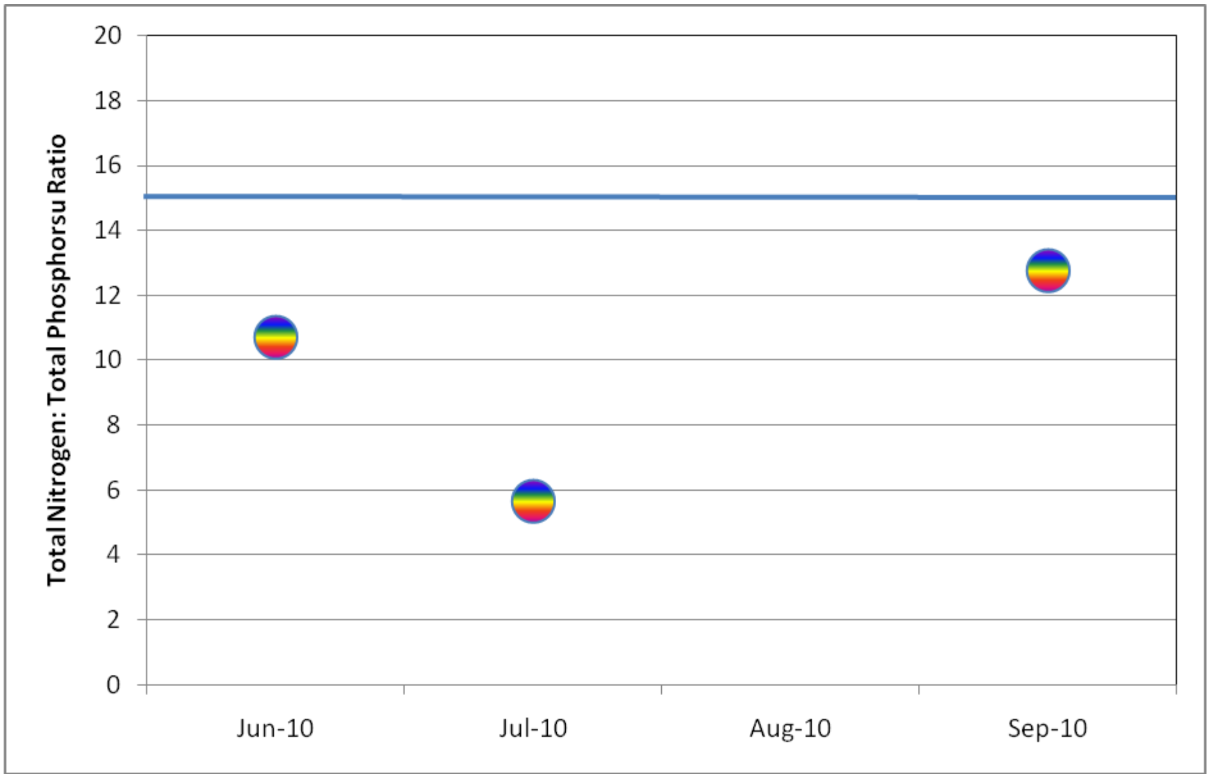

Figure 7. Rudolph Lake's Total Nitrogen to Total Phosphorus Ratio

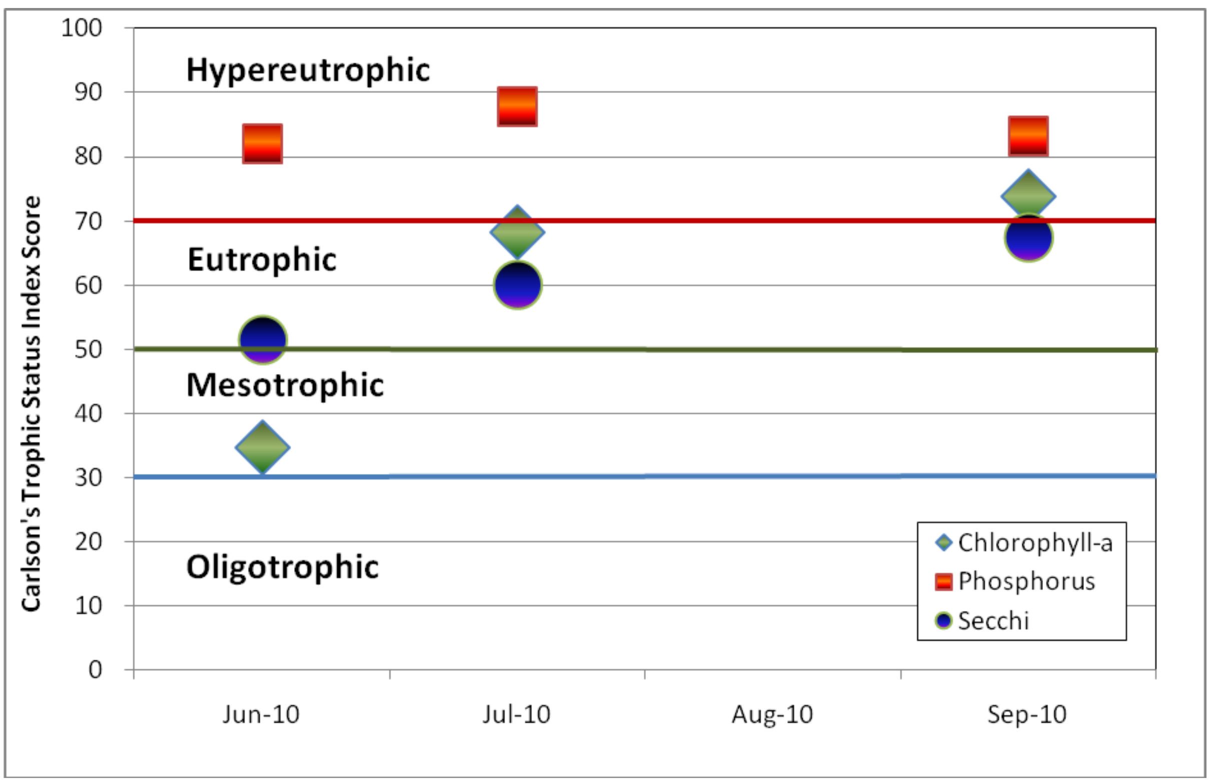

Figure 8. Rudolph Lake's TSI Scores

Round Lake, McHenry County

BACKGROUND

Location: Round Lake is a deep glacial lake. It is located on the southern edge the Glacial Lake Souris' outwash plain 4 miles east and 7 miles north of Drake, North Dakota (Figure 1). The fishery is managed by the North Dakota Game and Fish. Fish species managed for are walleye and yellow perch.

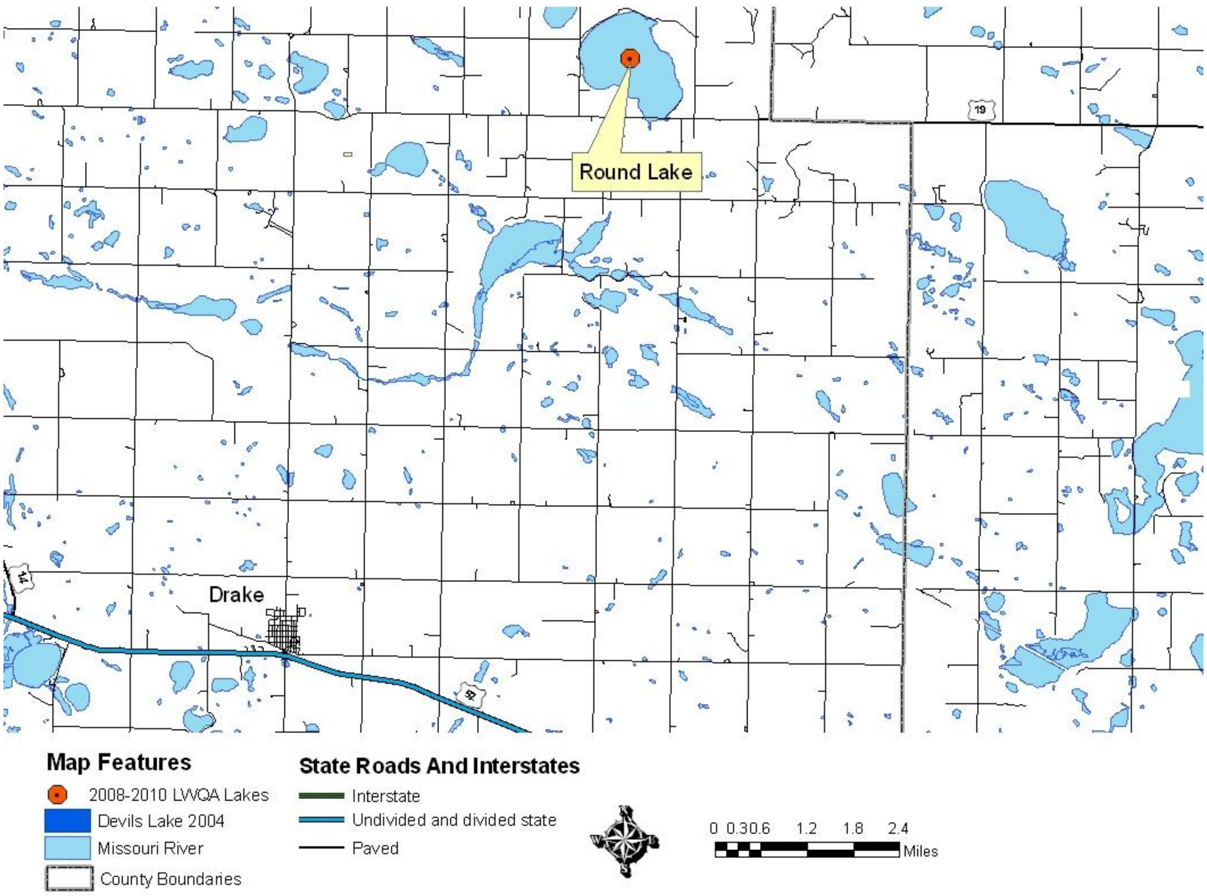

Figure 1. Location of Round Lake (McHenry County)

Physiographic/Ecological Setting: Round Lake has a surface area of approximately 730 acres and maximum depth of 50 ft (Figure 2). The lake is located within the Northwestern Great Plains Level III Ecoregion, which is part of the broader Cultivated Plains region (Figures 3 and 4).

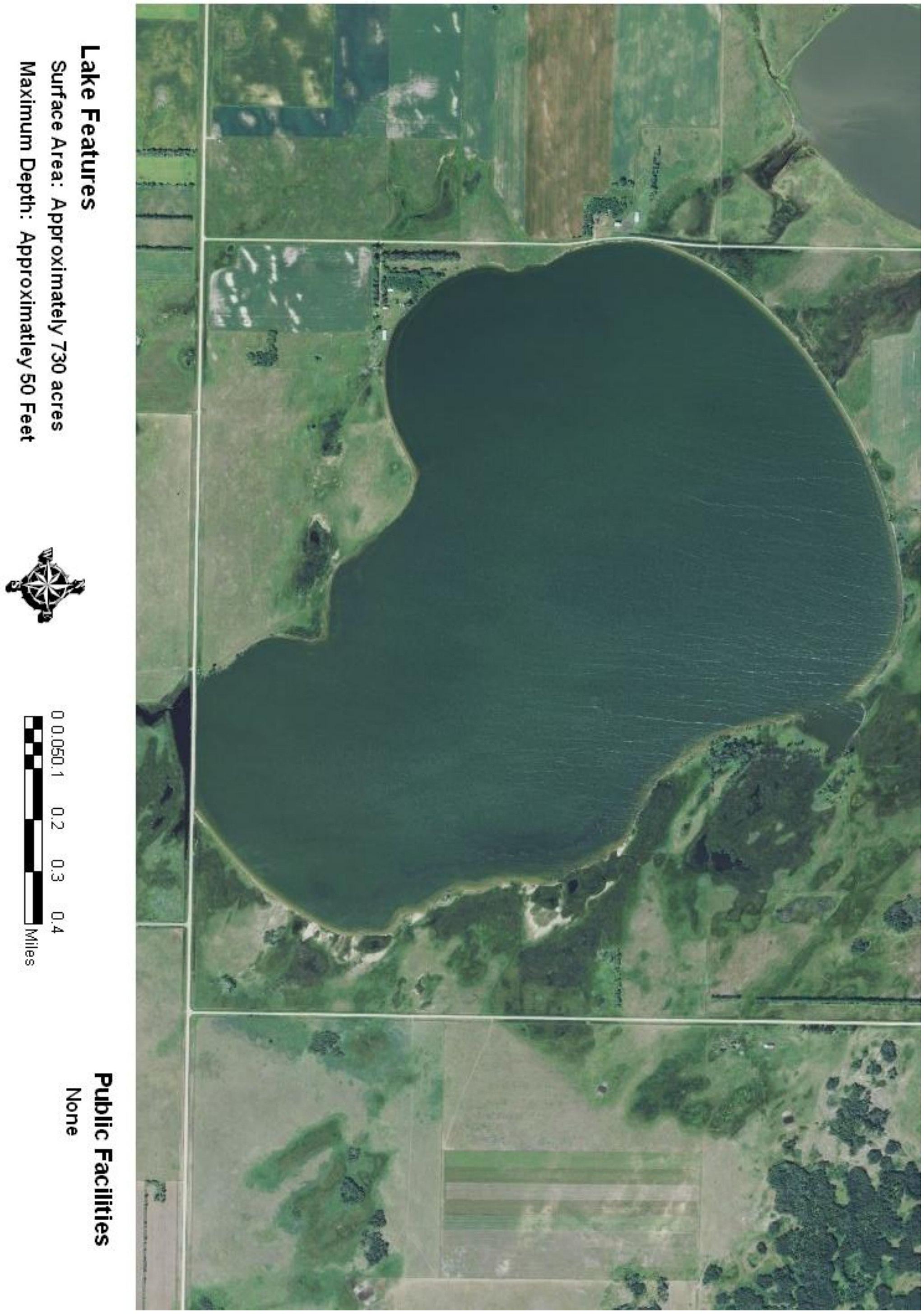

Figure 2. Aerial Map of Round Lake (McHenry County)

Recreational Facilities: There are no recreational facilities at Round Lake. Winter access is fair from either the south or west bordering roads. Summer access is for the experienced only from the west bordering road.

Water Quality Standards Classification: Round Lake is classified in the state "Standards of Quality for Waters of the State" (NDDoH, 2011) as a class 3 lake. Class 3 lakes or reservoirs are defined as a "warm water fishery" or "waters capable of supporting natural reproduction and growth of warm water fishes (e.g., largemouth bass and bluegill) and associated aquatic biota. Some cool water species may also be present."

Historical Water Quality Sampling: No historical water quality data.

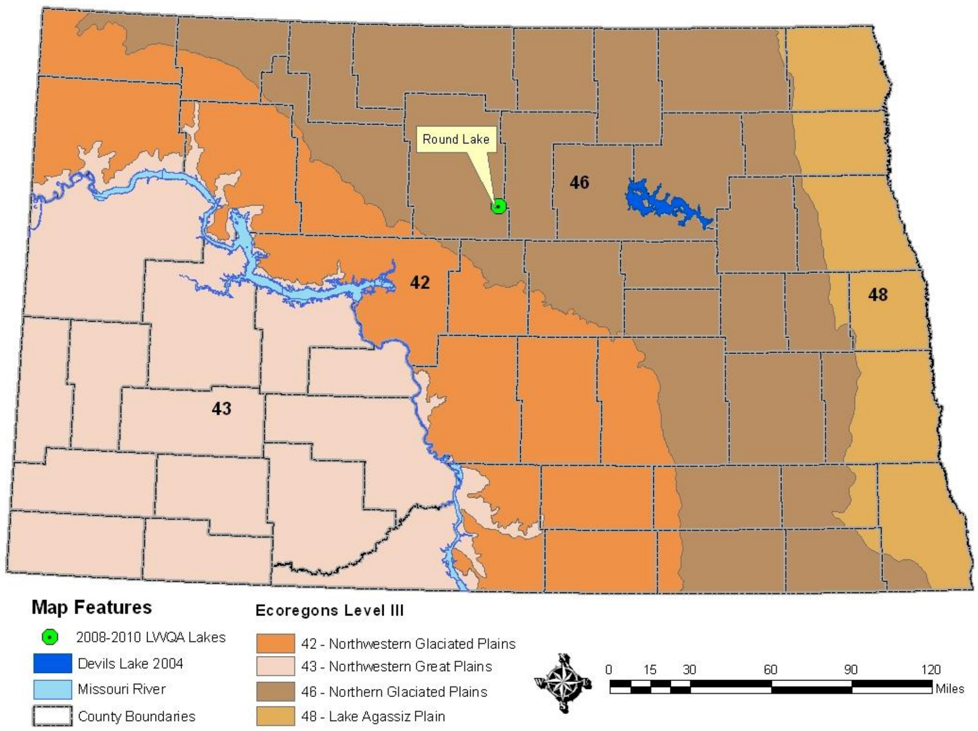

Figure 3. Round Lake's (McHenry County) Location and the Level III Ecoregions

WATER QUALITY MONITORING RESULTS

The water quality assessment for Round Lake is presented in four general categories: 1) temperature and dissolved oxygen profile results; 2) general water quality characterization; 3) nutrient limitation; and 4) trophic status. Additionally, where appropriate, results have been compared to regional data.

Temperature and Dissolved Oxygen Profile Results: There are three temperature and dissolved oxygen profiles for Round Lake collected in 2010 (Figures 5 and 6). The profile data indicates that Round Lake periodically weakly thermally stratifies. The dissolved oxygen profiles indicate that Round Lake, even below the thermocline, remains well enough oxygenated throughout the majority of the water column to support aquatic life.

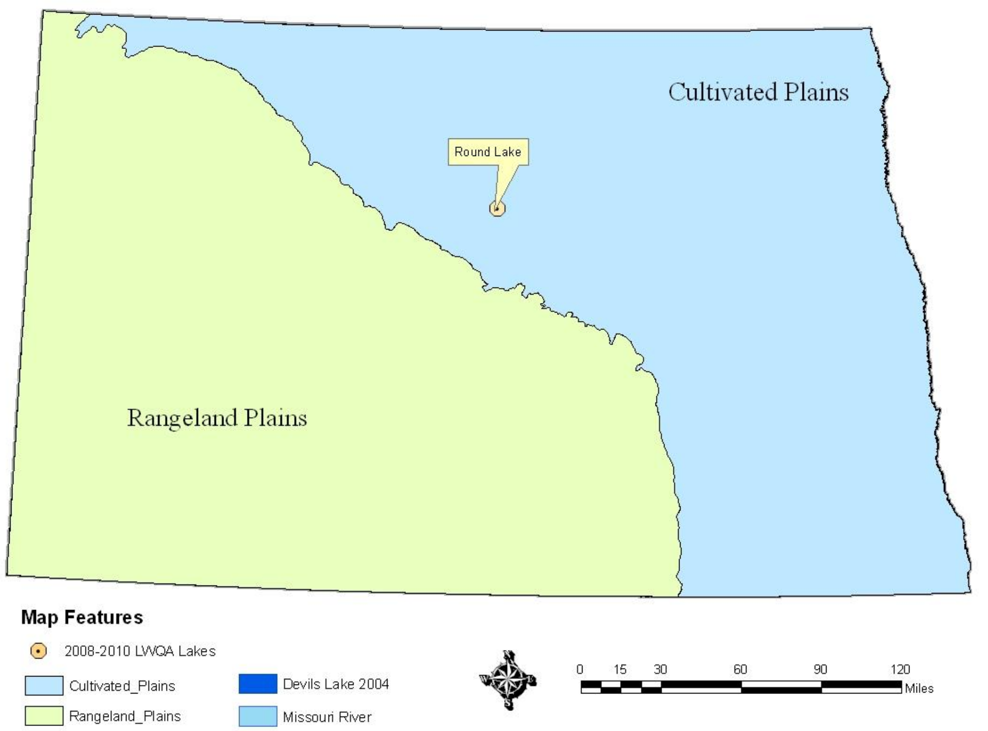

Figure 4. Round Lake's (McHenry County) Location and the Cultivated and Rangeland Plans Ecoregions

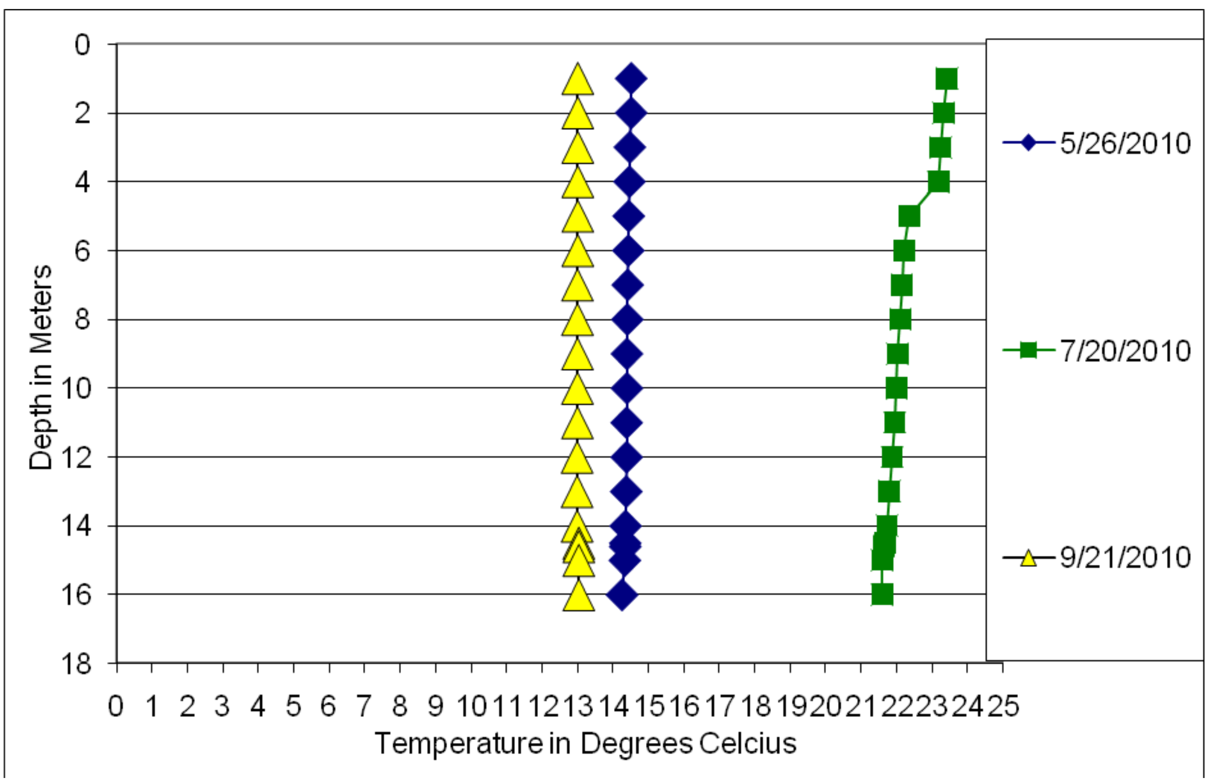

Figure 5. Temperature Profiles for Round Lake (McHenry County)

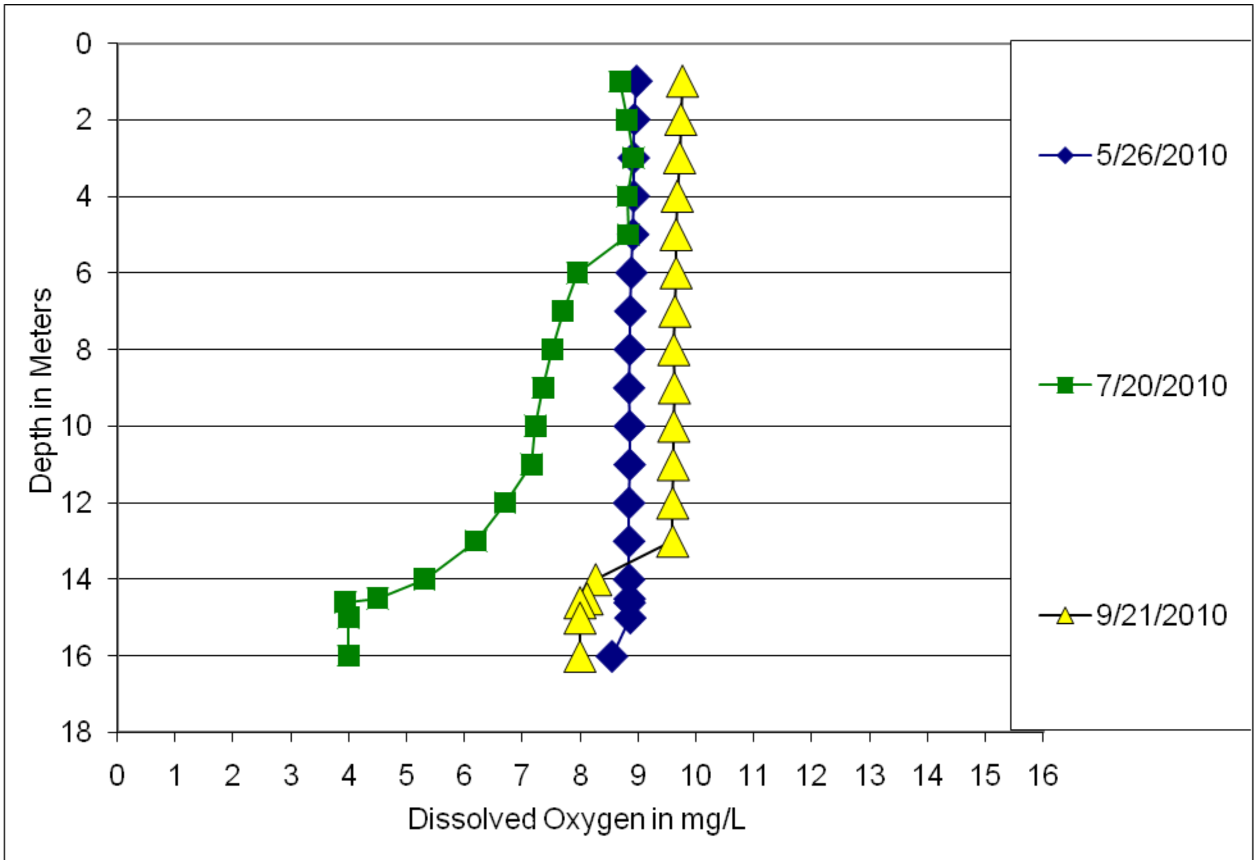

Figure 6. Dissolved Oxygen Profiles for Round Lake (McHenry County)

General Water Quality: Data collected in 2010 indicate that Round Lake is well buffered with total alkalinity as $CaCO_3$ concentrations ranging from 787 to 796 mg/L (Table 1). The lake is sodium bicarbonate dominated with an average sodium concentration of 320 mg/L and an average bicarbonate concentration of 726 mg/L. The average total dissolved solids concentration and specific conductance measurement for 2010 sampling period were 1163 mg/L and 1820 µmhos/cm respectively, and the average total nitrogen as N and total phosphorus as P concentrations were 1.817 mg/L and 0.029 mg/L respectively.

When compared to the regional water quality for natural lakes in the Cultivated Plans region, Round Lake is above average for dissolved minerals and total nitrogen but below average for total phosphorus (Table 3). For example, the regional average TDS, total nitrogen and total phosphorus concentrations are 507 mg/L, 1.486 mg/L and 0.090 mg/L respectively, compared to Round Lake's average TDS, total nitrogen, and total phosphorus concentrations of 1163 mg/L, 1.817 mg/L, and 0.029 mg/L, respectively.

Table 1. Statistical Summary of Round Lake's 2010 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	3	791	787	796	5
Total Ammonia as N	mg/L	3	0.123	0.030[1]	0.170	0.081
Bicarbonate (HCO_3)	mg/L	3	726	705	751	23
Calcium (Ca)	mg/L	3	13.6	12.6	14.9	1.2
Carbonate (CO_3)	mg/L	3	118	103	131	14
Chloride (Cl)	mg/L	3	32	31	33	1
Chlorophyll-a	µg/L	3	12.2	3.0	28.8	14.4
Specific Conductance	µmhos	3	1820	1810	1830	10
Total Dissolved Solids	mg/L	3	1163	1160	1170	6
Total Hardness as ($CaCO_3$)	mg/L	3	355	330	394	34
Hydroxide (OH)	mg/L	3	1.0[1]	1.0[1]	1.0[1]	0.0
Iron (Fe)	mg/L	3	0.173	0.143	0.232	0.051
Magnesium (Mg)	mg/L	3	78.1	72.5	86.7	7.6
Nitrate + Nitrite as N	mg/L	3	0.033	0.030[1]	0.040	0.006
Total Kjeldahl Nitrogen as N	mg/L	3	1.783	1.620	2.050	0.233
Total Nitrogen as N	mg/L	3	1.817	1.660	2.080	0.229
pH		3	9.00	8.91	9.06	0.08
Total Phosphorus as P	mg/L	3	0.029	0.016	0.040	0.012
Potassium (K)	mg/L	3	28.1	27.5	28.6	0.6
Sodium (Na)	mg/L	3	320.0	313.0	327.0	7.0
Sulfate (SO4)	mg/L	3	215	205	224	10

[1]Equal to the lower reporting limit

Limiting Nutrients: The water quality monitoring results indicate that Round Lake is phosphorus limited (Figure 7). The limiting nutrient assessment is based on the assumption that either nitrogen or phosphorus is limiting algal growth with the water body, and that the ratio of total nitrogen as N to total phosphorus as P (N:P), by weight, in the average algae is approximately 15 to 1. When the N:P ratio is less than 15:1, nitrogen is assumed to be the limiting nutrient and when it exceeds 15:1, the limiting nutrient is assumed to be phosphorus.

Trophic Status Assessment: Based on the chlorophyll-a, secchi disk transparency, and total phosphorus data collected in 2010, Round Lake's trophic condition is estimated as mesotrophic. The trophic Status Index scores ranged from a low of 41 and a high of 57 based on chlorophyll-a (Figure 8).

Table 2. Statistical Summary of Water Quality Data[2] Collected from Natural and Enhanced Natural Lakes in the Cultivated Plains Ecological Region of North Dakota

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	191	340	166	1120	181
Total Ammonia as N	mg/L	281	0.106	0.001	1.620	0.198
Bicarbonate (HCO_3)	mg/L	191	355	171	1040	154
Calcium (Ca)	mg/L	193	53.7	12.6	210.0	33.1
Carbonate (CO_3)	mg/L	188	30	1[1]	220	41
Chloride (Cl)	mg/L	191	90	3[1]	1260	206
Chlorophyll-a	µg/L	233	16.4	1.5[1]	908.0	61.8
Specific Conductance	µmhos	210	1742	361	11500	1879
Total Dissolved Solids	mg/L	192	1285	191	9880	1593
Total Hardness as ($CaCO_3$)	mg/L	193	507	173	1820	273
Hydroxide (OH)	mg/L	167	1.0	0.0[1]	1.0	0.2
Iron (Fe)	mg/L	189	0.162	0.007	1.620	0.226
Magnesium (Mg)	mg/L	193	90.6	28.4	413.0	63.1
Nitrate + Nitrite as N	mg/L	272	0.052	0.001[1]	0.680	0.086
Total Kjeldahl Nitrogen as N	mg/L	179	1.497	0.080	4.110	0.632
Total Nitrogen as N	mg/L	154	1.486	0.523	3.860	0.566
pH		193	8.48	1.78	9.56	0.76
Total Phosphorus as P	mg/L	283	0.090	0.002[1]	1.460	0.144
Potassium (K)	mg/L	193	27.7	2.2	179.0	35.6
Sodium (Na)	mg/L	193	227.8	4.5	2570.0	441.5
Sulfate (SO4)	mg/L	191	555	7	3880	728

[1]Equal to the lower reporting limit
[2]Data collected from 53 natural lakes between 1991 and 2010

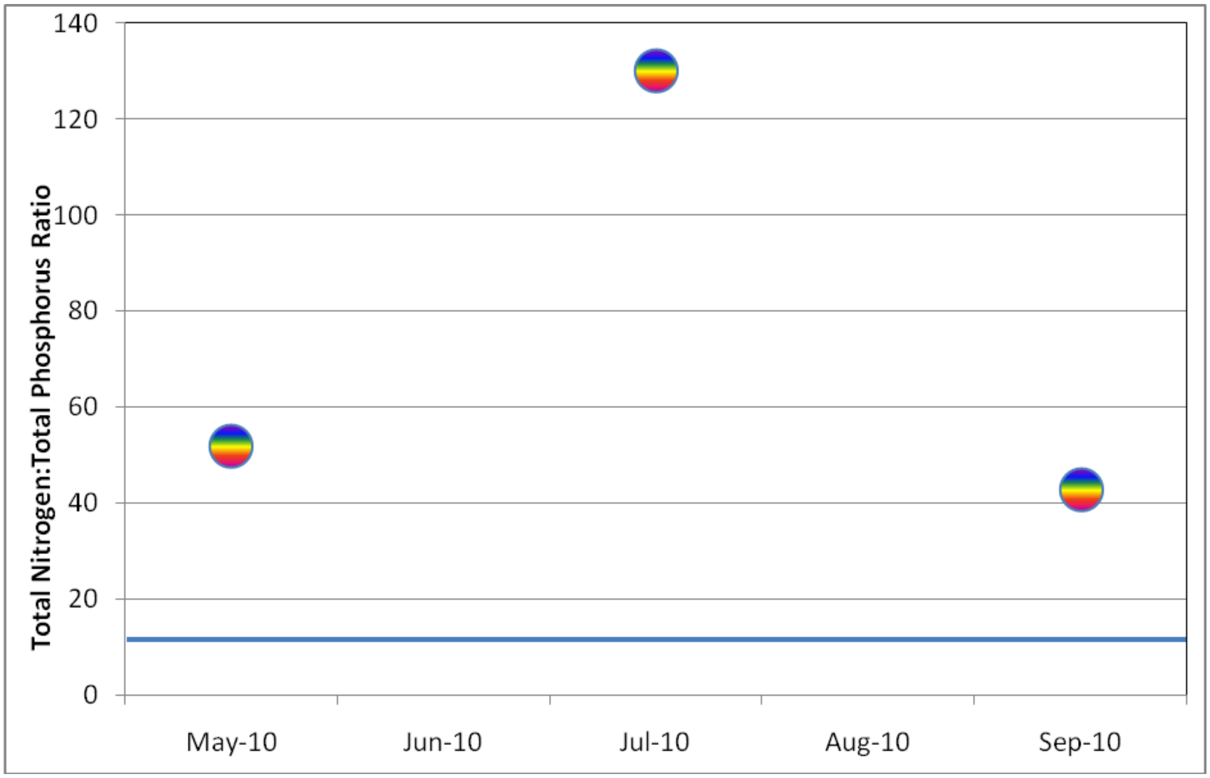

Figure 7. Round Lake's (McHenry County) Total Nitrogen to Total Phosphorus Ratio

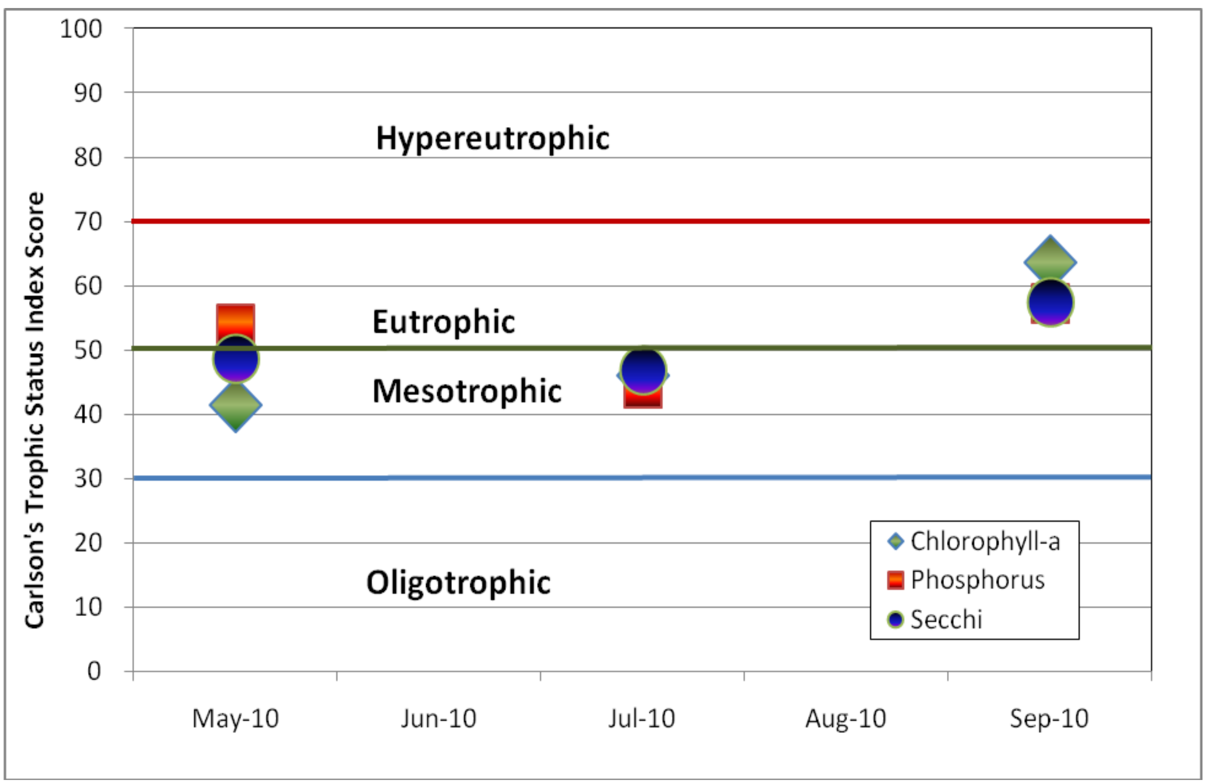

Figure 8. Round Lake's (McHenry County) TSI Scores

Clear Lake, McIntosh County

BACKGROUND

Location: Clear Lake is a shallow glacial lake located 5.5 miles east and 2 miles south of Wishek, North Dakota (Figure 1). The fishery is managed by the North Dakota Game and Fish. Fish species managed for are northern pike and yellow perch.

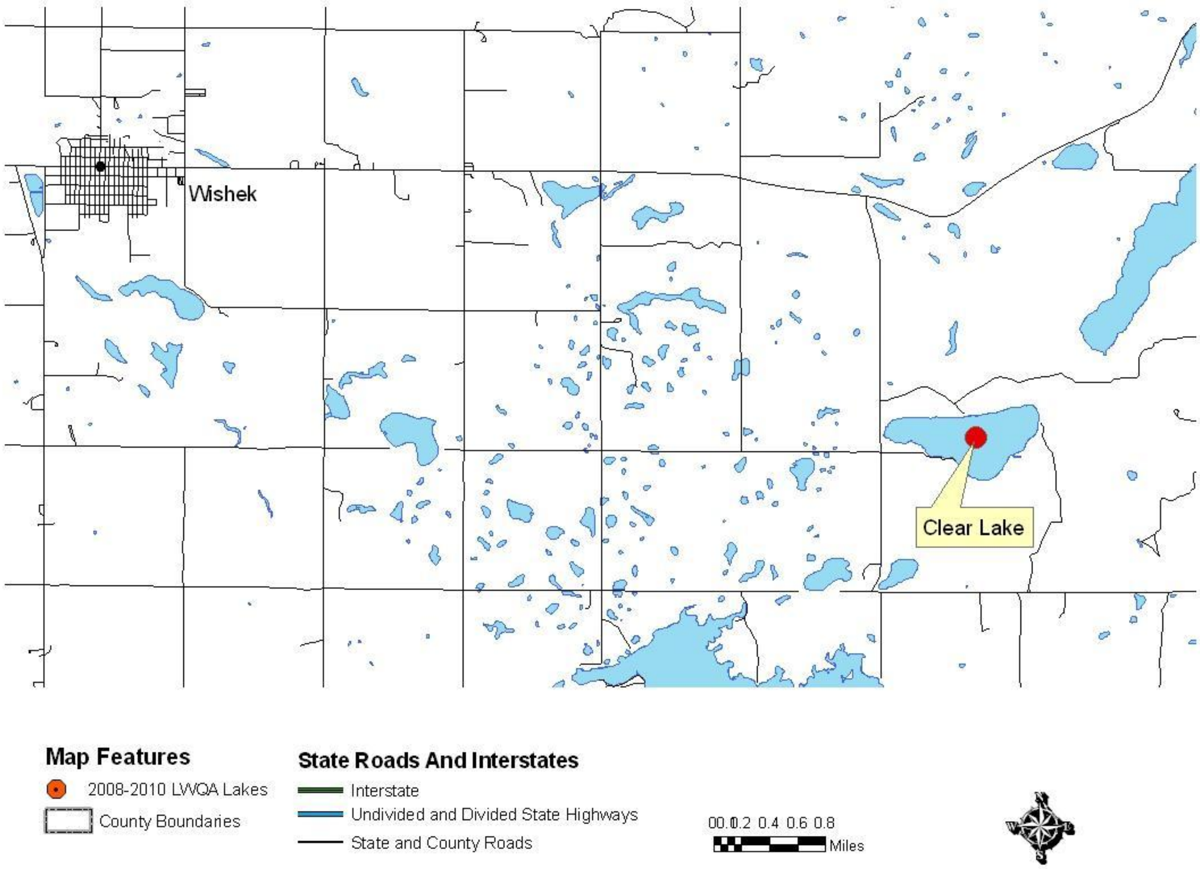

Figure 1. Location of Clear Lake

Physiographic/Ecological Setting: Clear Lake has a surface area of approximately 210 acres and a maximum depth of 14 ft (Figure 2). The lake is located within the Northwestern Glaciated Plains Level III Ecoregion, which is part of the broader Rangeland Plains region (Figures 3 and 4).

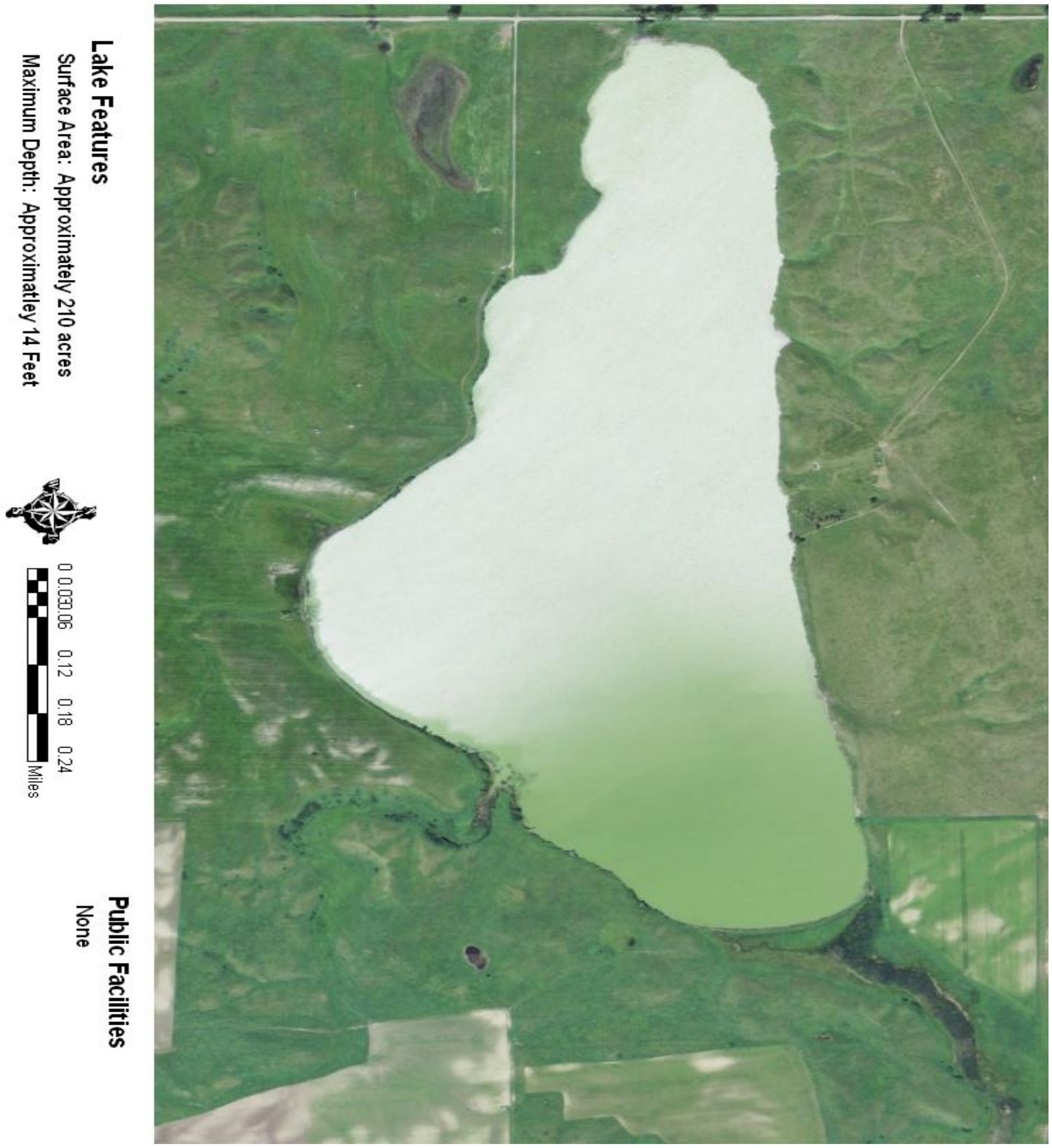

Figure 2. Aerial Map of Clear Lake

Recreational Facilities: There are no recreational facilities at Clear Lake. Access is by traveling a gated double fenced section-line road that ends at the lake. While there is not a boat ramp at Clear Lake an experienced boater can launch at this point being careful of boulders, metal posts, and barbwire.

Water Quality Standards Classification: Clear Lake is classified in the state "Standards of Quality for Waters of the State" (NDDoH, 2011) as a class 3 lake. Class 3 lakes or reservoirs are defined as a "warm water fishery" or "waters capable of supporting natural reproduction and growth of warm water fishes (e.g., largemouth bass and bluegill) and associated aquatic biota. Some cool water species may also be present."

Historical Water Quality Sampling: No historical water quality data.

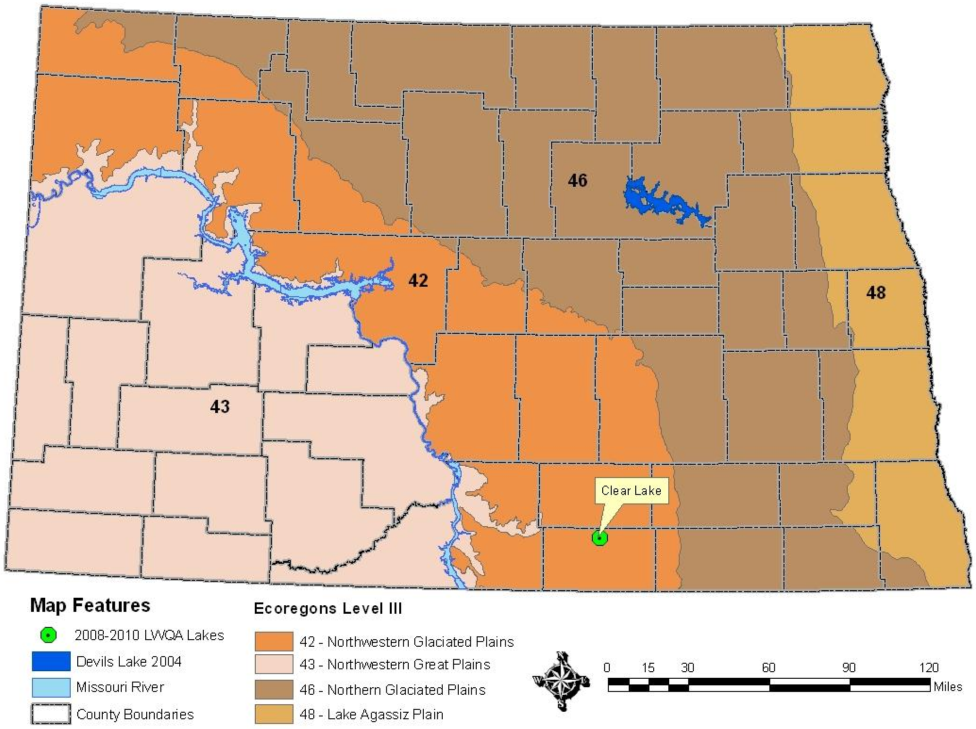

Figure 3. Clear Lake's Location and the Level III Ecoregions

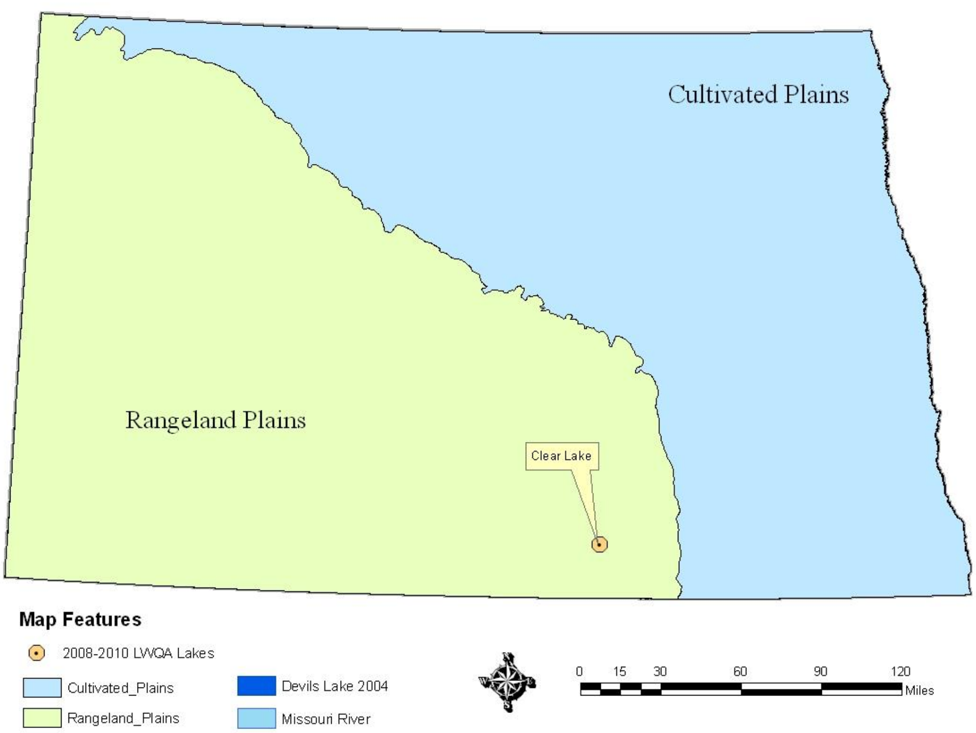

Figure 4. Clear Lake Location and the Cultivated and Rangeland Plans Regions

WATER QUALITY MONITORING RESULTS

The water quality assessment for Clear Lake is presented in four general categories: 1) temperature and dissolved oxygen profile results; 2) general water quality characterization; 3) nutrient limitation; and 4) trophic status. Additionally, where appropriate, results have been compared to regional data.

Temperature and Dissolved Oxygen Profile Results: There are three temperature and dissolved oxygen profiles for Clear Lake collected in 2010 (Figures 5 and 6). The profile data shows that Clear Lake was not thermally stratification during the open water monitoring water period. Additionally during the open water period the lake remained well enough oxygenated to support aquatic Life.

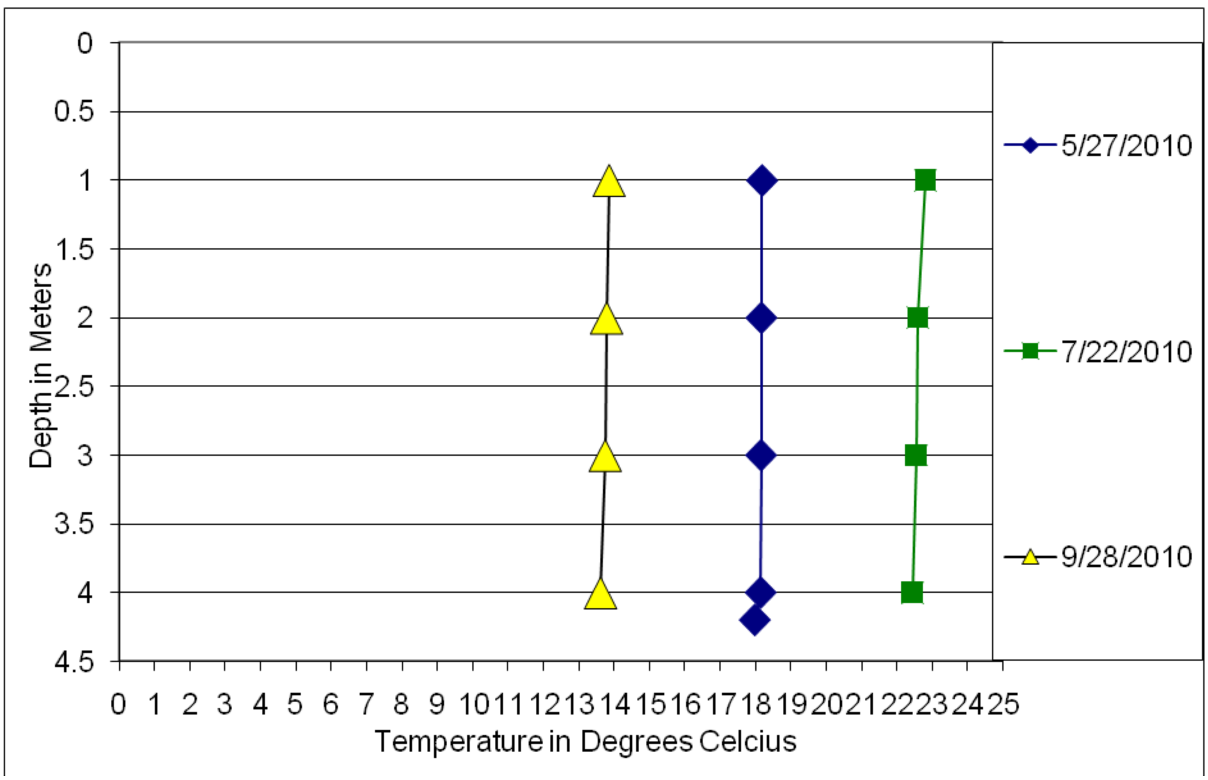

Figure 5. Temperature Profiles for Clear Lake

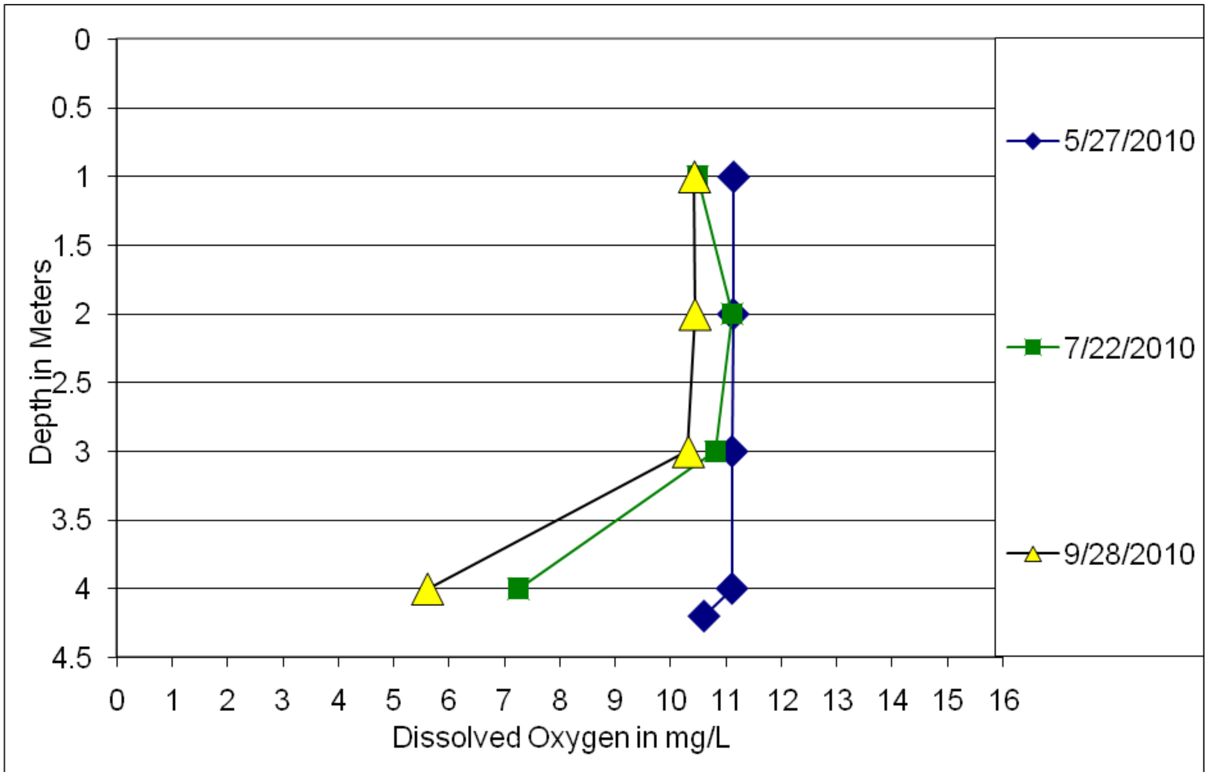

Figure 6. Dissolved Oxygen Profiles for Clear Lake

General Water Quality: Data collected in 2010 indicates that Clear Lake is well buffered with total alkalinity as $CaCO_3$ concentrations ranging from 531 to 541 mg/L (Table 1). The lake is sodium bicarbonate dominated with an average sodium concentration of 380.3 mg/L and an average bicarbonate concentration of 513 mg/L. The average total dissolved solids concentration and specific conductance measurement for 2010 sampling period were 1470 mg/L and 2143 µmhos/cm respectively, and the average total nitrogen as N and total phosphorus as P concentrations were 2.123 mg/L and 0.066 mg/L respectively.

When compared to water quality for natural lakes in the Rangeland Plans region, Clear Lake is about average for dissolved minerals and total nitrogen but below average for total phosphorus (Table 3). For example, the regional average TDS, total nitrogen and total phosphorus concentrations are 1466 mg/L, 1.794 mg/L and 0.233 mg/L respectively, compared to Mundt Lake's average TDS, total nitrogen, and total phosphorus concentrations of 1470 mg/L, 2.123 mg/L, and 0.066 mg/L, respectively.

Table 1. Statistical Summary of Clear Lake's 2010 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	3	537	531	541	6
Total Ammonia as N	mg/L	3	0.127	0.042	0.170	0.074
Bicarbonate (HCO_3)	mg/L	3	513	499	525	13
Calcium (Ca)	mg/L	3	17.9	13.7	24.6	5.9
Carbonate (CO_3)	mg/L	3	70	60	79	10
Chloride (Cl)	mg/L	3	26	24	29	2
Chlorophyll-a	µg/L	3	24.4	10.0	48.1	20.7
Specific Conductance	µmhos	3	2143	2110	2180	35
Total Dissolved Solids	mg/L	3	1470	1430	1510	40
Total Hardness as ($CaCO_3$)	mg/L	3	325	317	330	7
Hydroxide (OH)	mg/L	3	1.0[1]	1.0[1]	1.0[1]	0.0
Iron (Fe)	mg/L	3	0.123	0.086	0.164	0.039
Magnesium (Mg)	mg/L	3	68.2	64.8	71.9	3.6
Nitrate + Nitrite as N	mg/L	3	0.080	0.030[1]	0.180	0.087
Total Kjeldahl Nitrogen as N	mg/L	3	2.043	1.760	2.460	0.369
Total Nitrogen as N	mg/L	3	2.123	1.790	2.640	0.454
pH		3	8.86	8.77	8.91	0.08
Total Phosphorus as P	mg/L	3	0.066	0.042	0.084	0.022
Potassium (K)	mg/L	3	47.0	44.6	49.4	2.4
Sodium (Na)	mg/L	3	380.3	357.0	403.0	23.0
Sulfate (SO4)	mg/L	3	605	592	617	13

[1]Equal to the lower reporting limit

Limiting Nutrients: Water quality monitoring results for Clear Lake, indicate that total phosphorus is the limiting nutrient (Figure 7). The limiting nutrient assesment is based on the assumption that either nitrogen or phosphorus is limiting algal growth with the water body, and that the ratio of total nitrogen as N to total phosphorus as P (N:P), by weight in the average algae, is approximately 15 to 1. When the N:P ratio is less than 15:1, nitrogen is assumed to be the limiting nutrient and when it exceeds 15:1, the limiting nutrient is assumed to be phosphorus.

Trophic Status Assessment: Based on the chlorophyll-a, secchi disk transparency, and total phosphorus data collected in 2010, Clear Lake's trophic condition is estimated as eutrophic. The trophic Status Index scores ranged from a low of 53 based on chlorophyll-a to a high of 70 based on secchi disk (Figure 8).

Table 2. Statistical Summary of Water Quality Data[2] Collected from Natural and Enhanced Lakes in the Rangeland Plains Ecological Region of North Dakota

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	383	513	111	4770	487
Total Ammonia as N	mg/L	494	0.105	0.001[1]	2.230	0.229
Bicarbonate (HCO_3)	mg/L	383	469	60	2990	320
Calcium (Ca)	mg/L	384	41.1	0.5	282.0	34.4
Carbonate (CO_3)	mg/L	377	79	1[1]	1420	148
Chloride (Cl)	mg/L	383	44	3[1]	1070	103
Chlorophyll-a	µg/L	346	22.5	1.5[1]	292.0	37.4
Specific Conductance	µmhos	383	2028	424	20100	1976
Total Dissolved Solids	mg/L	383	1466	227	18200	1717
Total Hardness as ($CaCO_3$)	mg/L	384	529	74	2370	295
Hydroxide (OH)	mg/L	322	1.0	0.0[1]	1.0	0.2
Iron (Fe)	mg/L	385	0.245	0.001[1]	7.070	0.543
Magnesium (Mg)	mg/L	384	103.6	8.5	567.0	70.9
Nitrate + Nitrite as N	mg/L	491	0.04046	0.001[1]	0.54	0.054
Total Kjeldahl Nitrogen as N	mg/L	463	1.876	0.080	8.500	1.073
Total Nitrogen as N	mg/L	401	1.794	0.240	5.520	0.897
pH		383	8.80	7.40	9.87	0.36
Total Phosphorus as P	mg/L	501	0.233	0.002[1]	1.940	0.336
Potassium (K)	mg/L	384	34.0	3.1	356.0	37.0
Sodium (Na)	mg/L	384	299.6	16.9	4680.0	514.5
Sulfate (SO4)	mg/L	383	625	34	10500	885

[1]Equal to the lower reporting limit
[2]Data collected from 64 natural and enhanced Lakes between 1991 and 2010

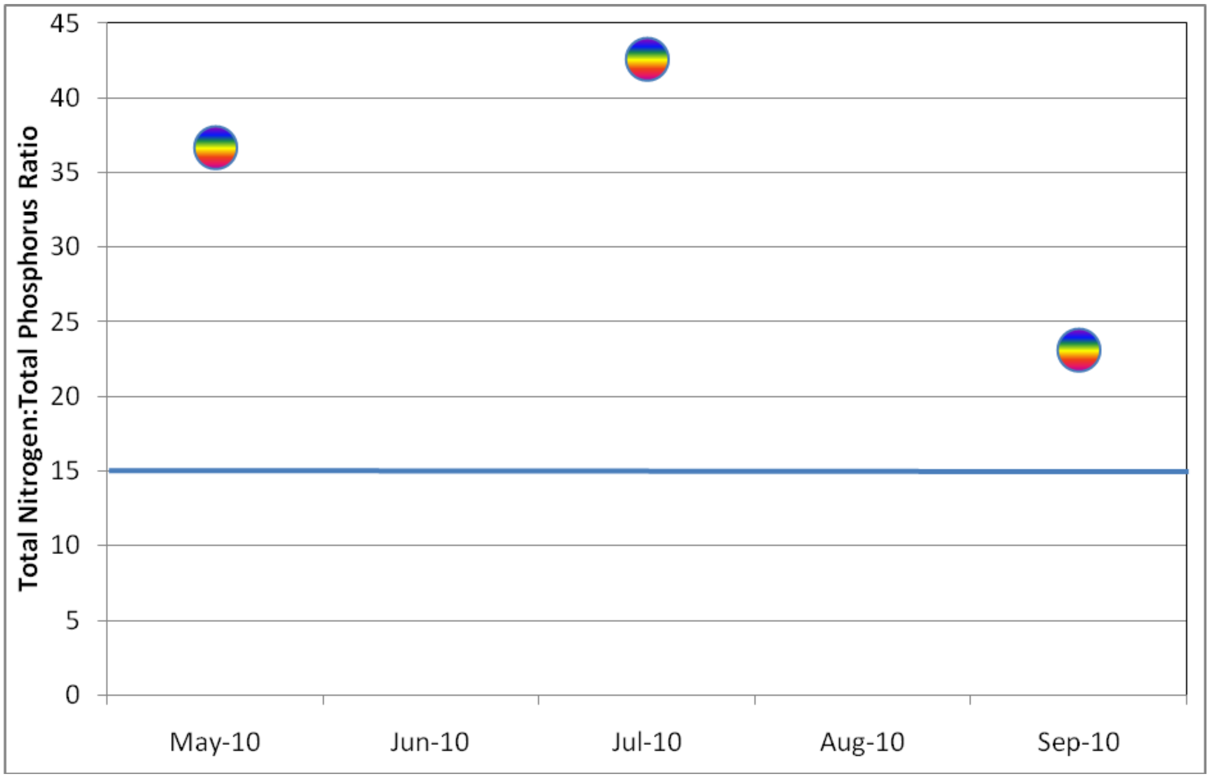

Figure 7. Clear Lake's Total Nitrogen to Total Phosphorus Ratio

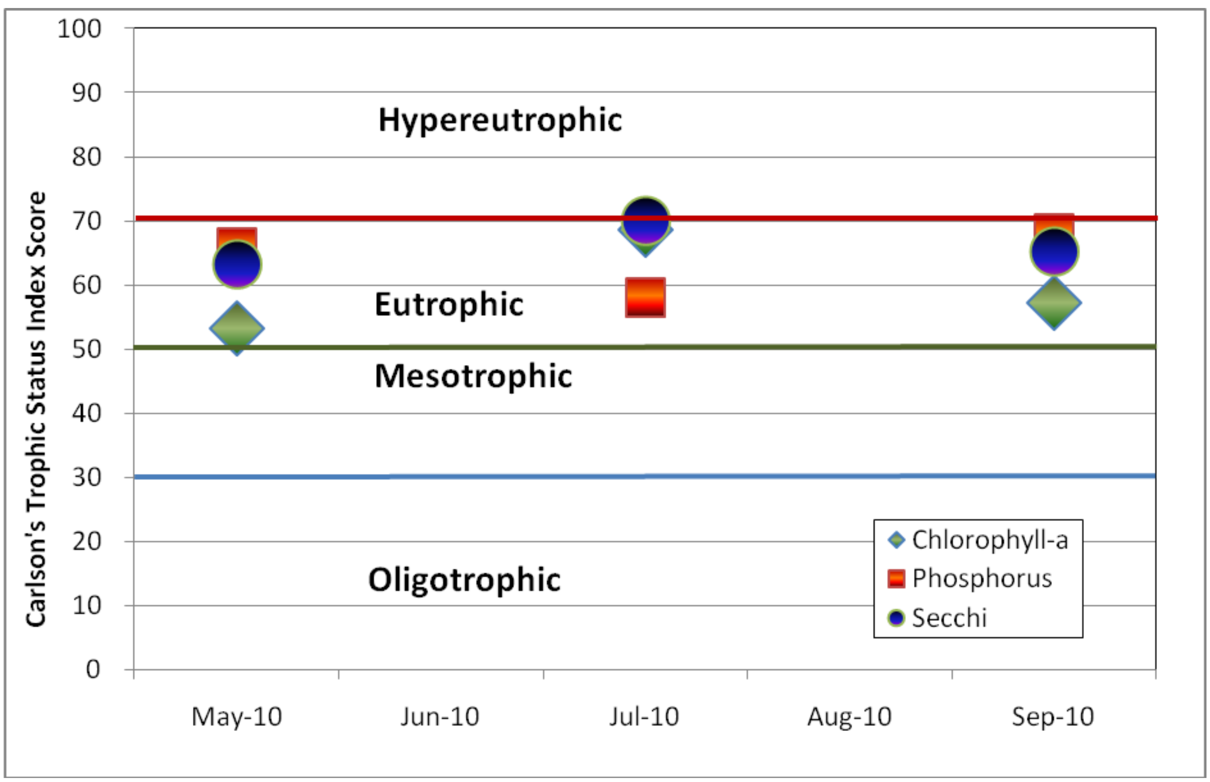

Figure 8. Clear Lake's TSI Scores

Arnegard Dam, McKenzie County

BACKGROUND

Location: Arnegard Dam is a narrow reservoir on Timber Creek just northwest of Arnegard, North Dakota (Figure 1). A small shallow cattail lined oasis of fresh water, Arnegard provides water based recreational to the small local population in this semi-arid region. The fishery is managed by the North Dakota Game and Fish Department. Fish species stocked in recent years are northern pike and yellow perch.

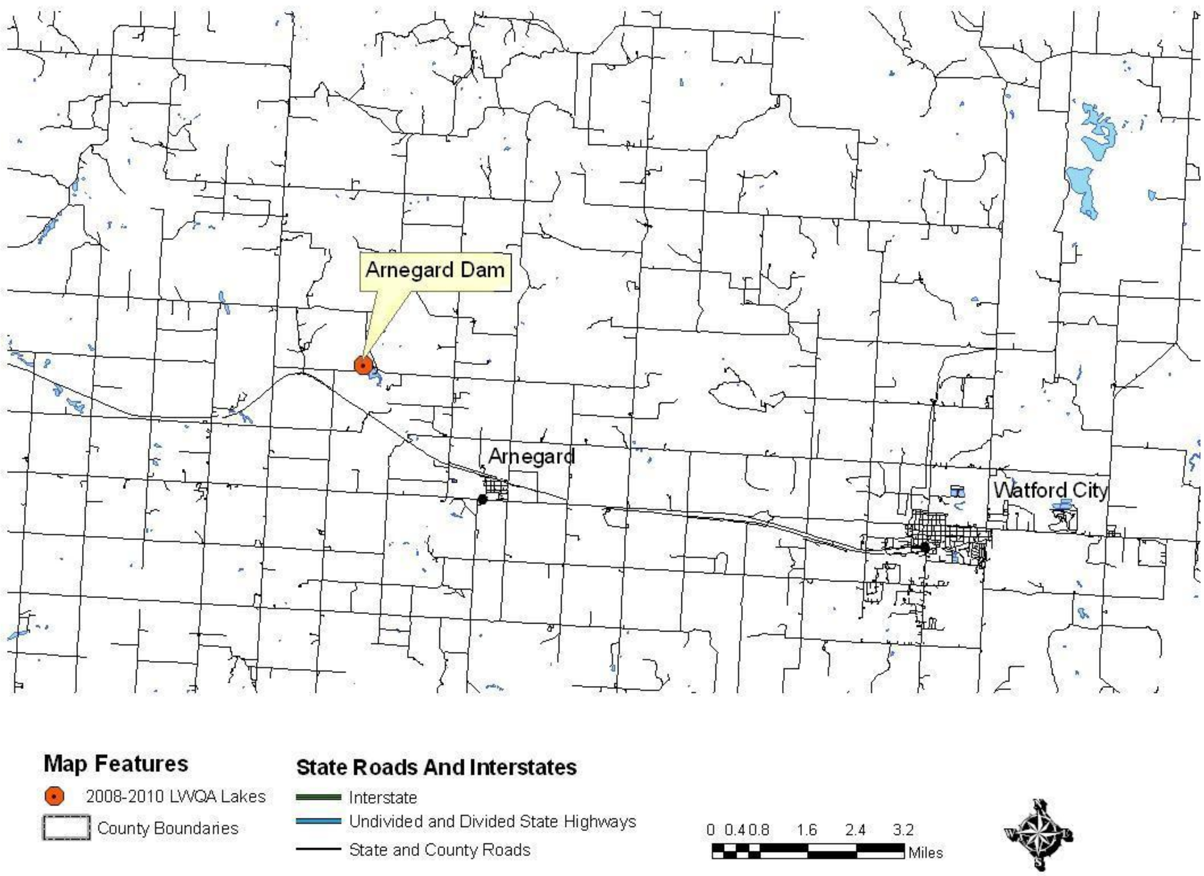

Figure 1. Location of Arnegard Dam

Physiographic/Ecological Setting: Arnegard Dam has a surface area of 24.3 acres, a maximum depth of 11ft, and an average depth of 5.5 ft. The reservoir is narrow and shallow but provides reasonable access to for shore fishing from select areas particularly on the west shore (Figure 2). The reservoir is located in the Northwestern Great Plains Level III Ecoregion, which is part of the broader Rangeland Plains Region (Figures 3 and 4).

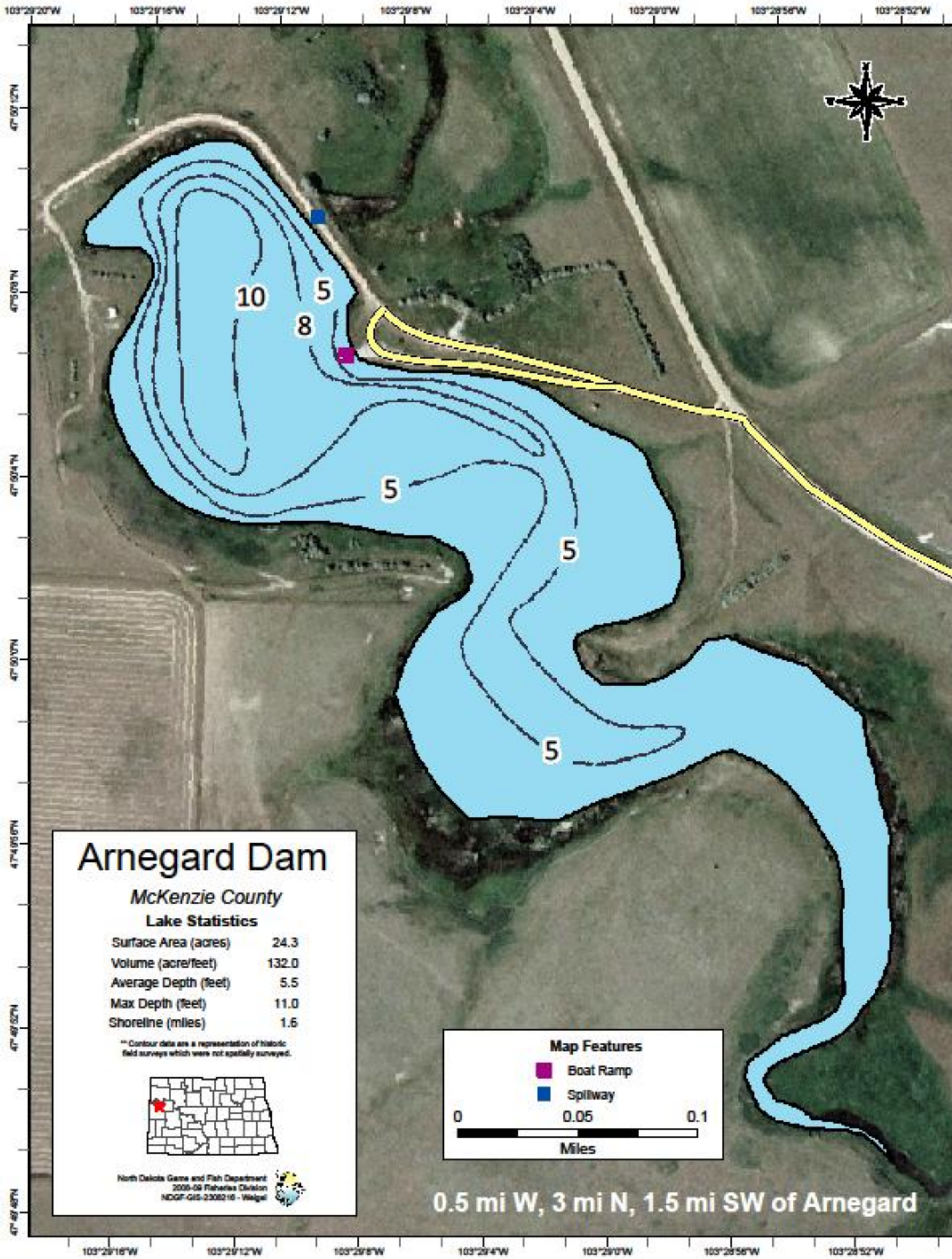

Figure 2. Contour Map of Arnegard Dam (Courtesy of the North Dakota Game and Fish Department)

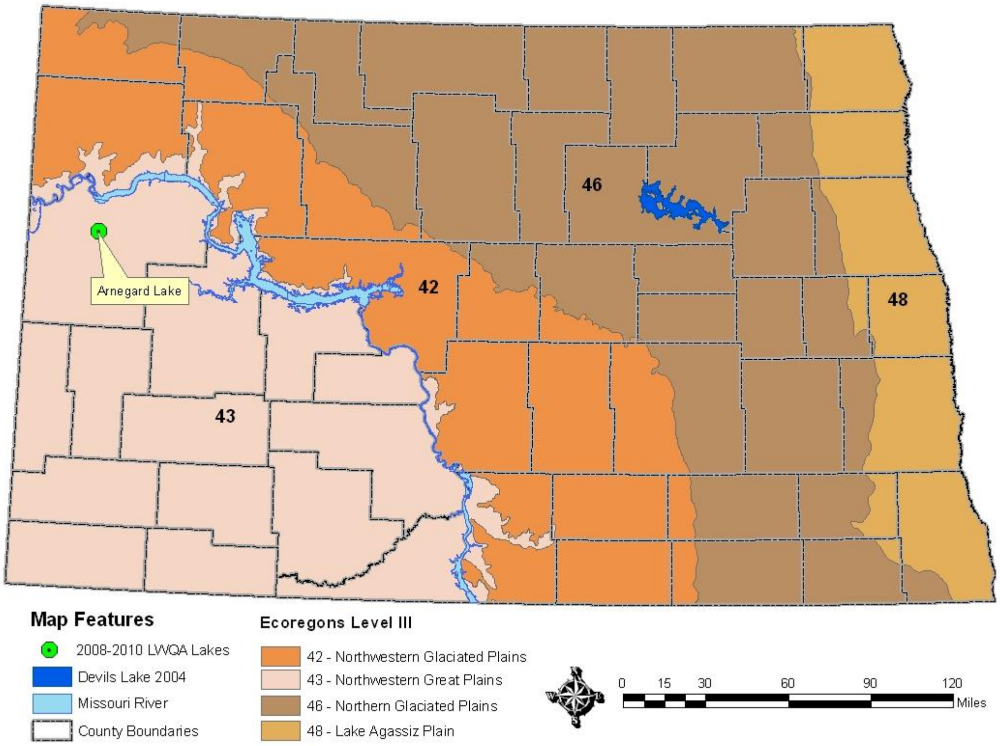

Figure 3. Arnegard Dam's Location and the Level III Ecoregions

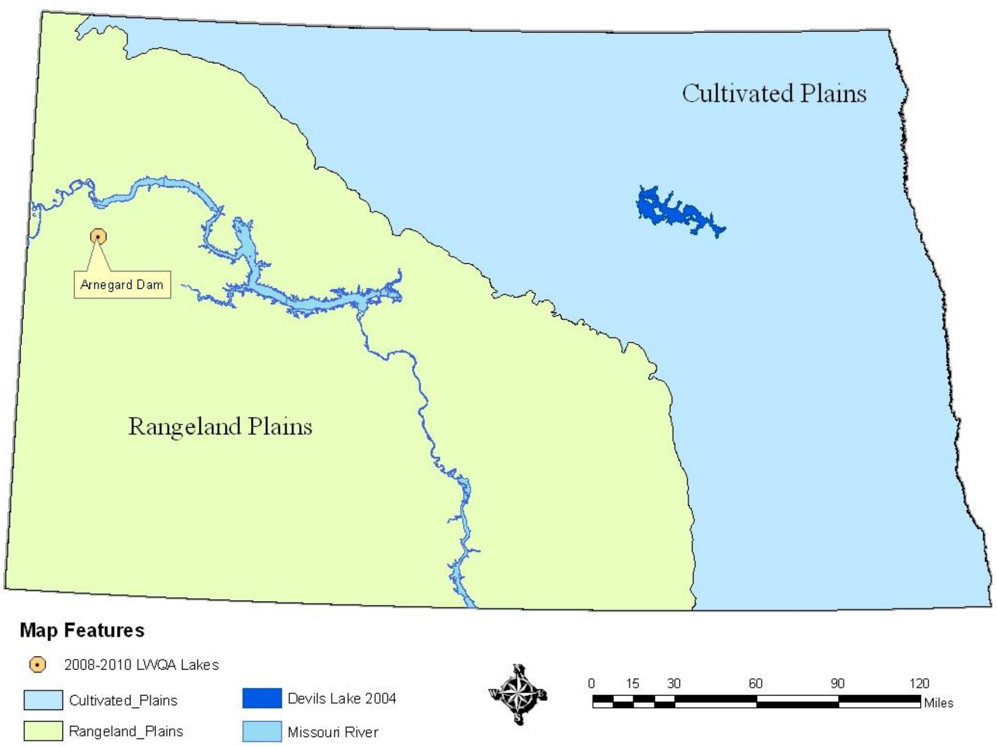

Figure 4. Arnegard Dams's Location and the Cultivated and Rangeland Plans Regions

Recreational Facilities: Recreational facilities at Arengard Dam are an access road, boat ramp, courtesy dock and outdoor toilet.

Water Quality Standards Classification: Arnegard Dam is classified in the state "Standards of Quality for Waters of the State" (NDDoH, 2011) as a class 4 reservoir. Class 4 lakes or reservoirs are defined as a "Marginal fisheries" or "waters capable of supporting a fishery on a short-term or seasonal basis (generally a "put and take" fishery).

Historical Water Quality Sampling: Historical water quality data include 3 samples collected in 1992-1993.

WATER QUALITY MONITORING RESULTS

The water quality assessment for Arnegard Dam is presented in four general categories: 1) temperature and dissolved oxygen profile results; 2) general water quality characterization; 3) nutrient limitation; and 4) trophic status. Where appropriate, results have been compared to the regional data for reservoirs in the Rangeland Plains region.

Temperature and Dissolved Oxygen Profile Results: There are 6 temperature and dissolved oxygen profiles for Arnegard Dam collected in 1992-93 and 2009 (Figures 5 and 6). The profile data shows that the water body does weakly thermally stratify and that in response to thermal stratification dissolved oxygen concentrations decline rapidly. Of note, the decline in dissolved oxygen appears to have been much more rapid and complete in 1992-1993 that in 2009 which could be pointing to an improvement in the overall condition of the reservoir (Figures 5 and 6). In 1992-1993 the reservoirs dissolved oxygen concentrations dropped below the state standard designed to protect aquatic life of 5.0 mg/L, but remained above it in 2009.

General Water Quality: Data collected in 2009 indicate that Arnegard Dam is well buffered with total alkalinity as $CaCO_3$ concentrations ranging from 214 to 320 mg/L (Table 1). The reservoir is sodium bicarbonate dominated closely followed by sodium sulfate with an average sodium, bicarbonate and sulfate concentration of 127 mg/L, 316 mg/L and 275 mg/L, respectively. The average total dissolved solids concentration and specific conductance measurements for the 2009 sampling period were 674 mg/L and 1032 µmhos/cm, respectively, and the average total nitrogen as N and total phosphorus as P concentrations were 0.743 mg/L and 0.051 mg/L respectively.

When compared to the average water quality for reservoirs in the Rangeland Plans Ecoregion, Arnegard Dam is fresher and less eutrophic than most (Table 3). For example, the average regional concentrations for TDS, total nitrogen, and total phosphorus concentrations are 1107 mg/L, 1.314 mg/L, and 0.128 mg/L respectively, compared to Arnegard Dam's average TDS, total nitrogen, and total phosphorus concentrations of 674 mg/L, 0.743 mg/L and 0.051 mg/L respectively.

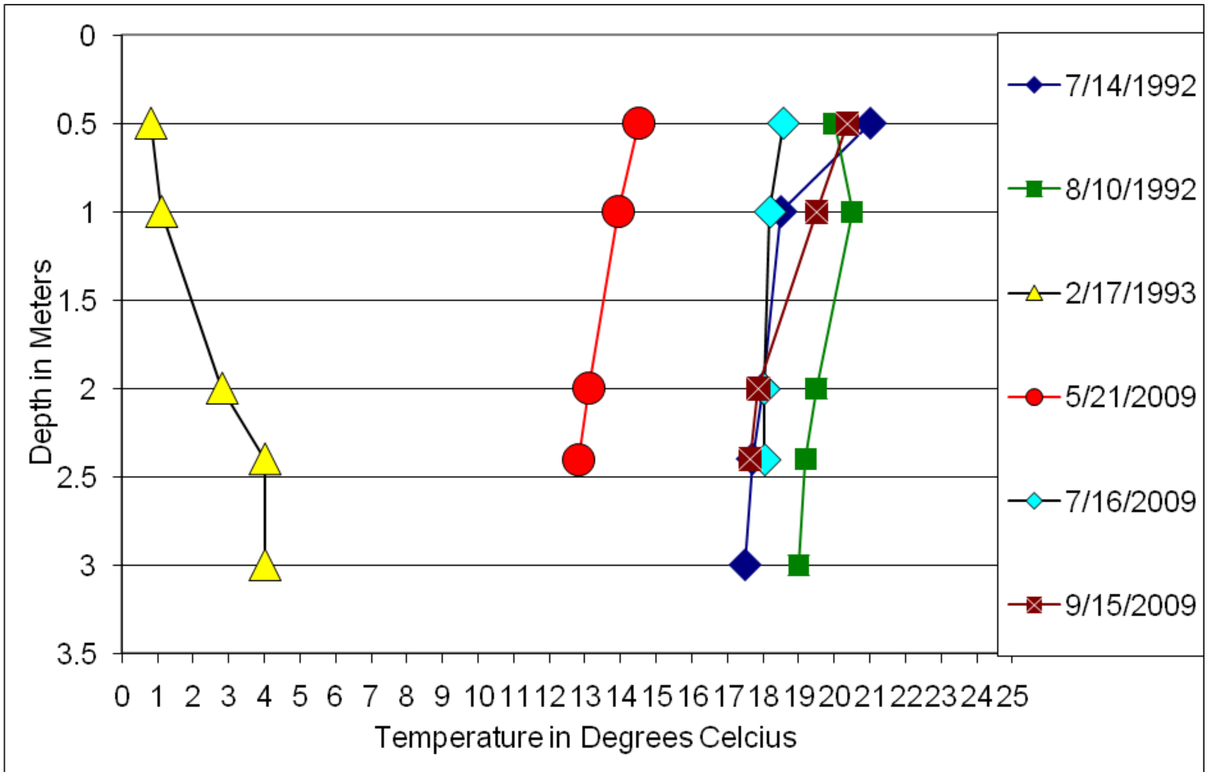

Figure 5. Temperature Profiles for Arnegard Dam

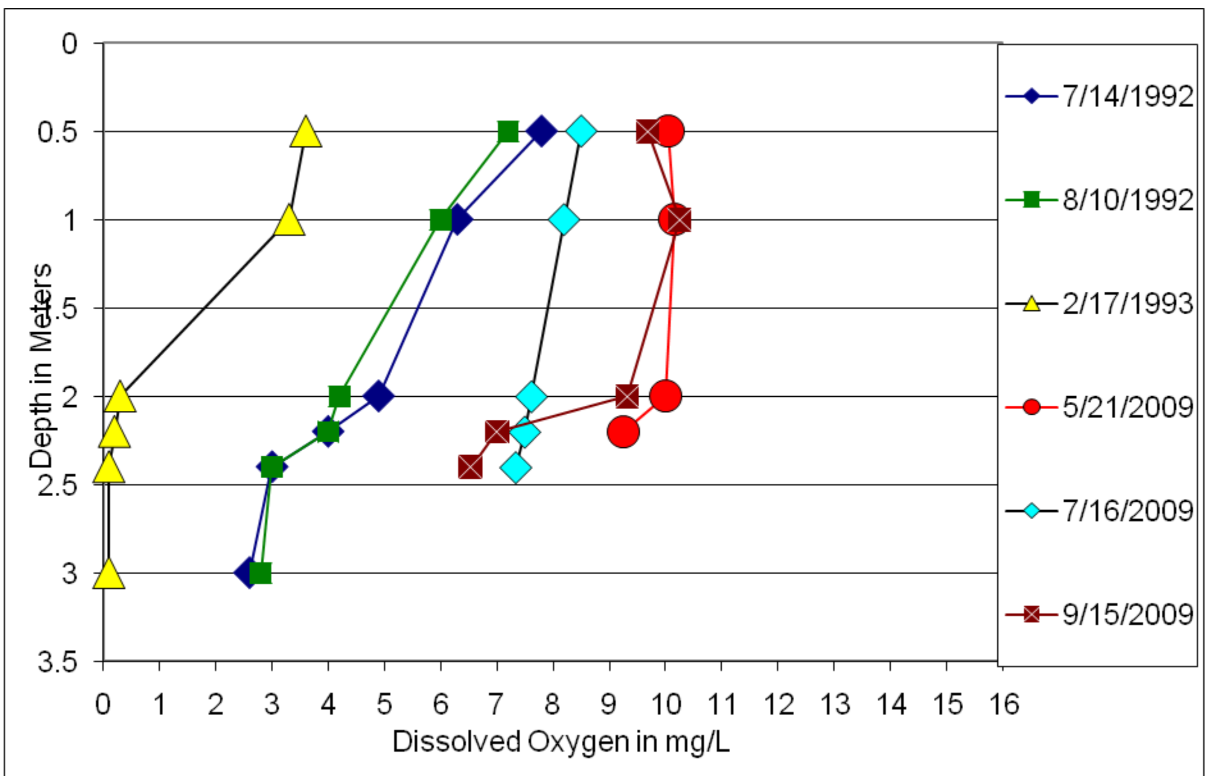

Figure 6. Dissolved Oxygen Profiles for Arnegard Dam

Table 1. Statistical Summary of Arnegard Dam's 2009 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	3	268	214	320	53
Total Ammonia as N	mg/L	3	0.030[1]	0.030[1]	0.030[1]	0.000
Bicarbonate (HCO_3)	mg/L	3	316	258	371	57
Calcium (Ca)	mg/L	3	55.7	48.1	61.5	6.9
Carbonate (CO_3)	mg/L	3	5	1[1]	10	5
Chloride (Cl)	mg/L	3	6	5	7	1
Chlorophyll-a	µg/L	2	20.6	16.6	24.6	5.7
Specific Conductance	µmhos	3	1032	966	1130	87
Total Dissolved Solids	mg/L	3	674	637	740	57
Total Hardness as ($CaCO_3$)	mg/L	3	300	263	336	37
Hydroxide (OH)	mg/L	3	1.0[1]	1.0[1]	1.0[1]	0.0
Iron (Fe)	mg/L	3	1.009	0.448	1.480	0.522
Magnesium (Mg)	mg/L	3	39.0	34.6	44.2	4.8
Nitrate + Nitrite as N	mg/L	3	0.030[1]	0.030[1]	0.030[1]	0.000
Total Kjeldahl Nitrogen as N	mg/L	3	0.713	0.454	0.859	0.225
Total Nitrogen as N	mg/L	3	0.743	0.484	0.889	0.225
pH		3	8.38	8.32	8.47	0.08
Total Phosphorus as P	mg/L	3	0.051	0.031	0.069	0.019
Potassium (K)	mg/L	3	8.4	7.6	8.9	0.7
Sodium (Na)	mg/L	3	127.3	120.0	138.0	9.5
Sulfate (SO4)	mg/L	3	275	251	288	21

[1]Equal to the lower reporting limit

When comparing historical water quality data (1992-1993) to the 2009 water quality data, with the exception of sulfates, it appears that water quality constituents have decreased. For example, the historical average bicarbonate, sulfate and sodium concentrations were 316 mg/L, 205 mg/L and 170.8 mg/L, respectively, compared to the 2009 averages of 674 mg/L, 275 mg/L and 127 mg/L (Tables 1 and 2). Like the dissolved solids, nutrient concentrations also appear to be trending downward with total nitrogen and total phosphorus concentrations decreasing from 1.115 mg/L and 0.157 mg/L, in 1992-93, to 0.743 mg/L and 0.051 mg/L in 2009.

Limiting Nutrients: The six water quality samples collected between 1992 and 2009 indicate that Arnegard Dam was nitrogen limited in the early 1990's but currently is trending toward equilibrium or even phosphorus limited (Figure 7). The limiting nutrient analysis is based on the assumption that either nitrogen or phosphorus is limiting algal growth and that the ratio of total nitrogen as N to total phosphorus as P (N:P), by weight in the average algae is approximately 15 to 1. When the N:P ratio is less than 15:1, nitrogen is assumed to be the limiting nutrient and when it exceeds 15:1, the limiting nutrient is assumed to be phosphorus.

Table 2. Statistical Summary of Arnegard Dam's 1992-1993 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	3	439	361	663	127
Total Ammonia as N	mg/L	3	0.093	0.013	0.250	0.136
Bicarbonate (HCO_3)	mg/L	3	491	371	810	183
Calcium (Ca)	mg/L	3	38.8	24.0	87.3	27.2
Carbonate (CO_3)	mg/L	3	22	1[1]	35	14
Chloride (Cl)	mg/L	3	7	5	11	2
Chlorophyll-a	µg/L	2	6.0	3.0	9.0	4.2
Specific Conductance	µmhos	3	1129	996	1560	242
Total Dissolved Solids	mg/L	3	744	618	1140	223
Total Hardness as ($CaCO_3$)	mg/L	3	311	240	536	126
Hydroxide (OH)	mg/L	1	1.0[1]	1.0[1]	1.0[1]	0.0
Iron (Fe)	mg/L	3	0.122	0.066	0.158	0.049
Magnesium (Mg)	mg/L	3	52.1	43.7	77.1	14.1
Nitrate + Nitrite as N	mg/L	3	0.010	0.001[1]	0.021	0.009
Total Kjeldahl Nitrogen as N	mg/L	3	1.105	0.670	1.470	0.392
Total Nitrogen as N	mg/L	3	1.115	0.670	1.491	0.401
pH		3	8.54	7.73	8.91	0.48
Total Phosphorus as P	mg/L	3	0.157	0.114	0.250	0.057
Potassium (K)	mg/L	3	7.0	5.7	9.1	1.3
Sodium (Na)	mg/L	3	170.8	141.0	239.0	39.3
Sulfate (SO4)	mg/L	3	205	171	322	66

[1]Equal to the lower reporting limit

Trophic Status Assessment: Based on the chlorophyll-a, secchi disk transparency, and total phosphorus data collected in 2009, Arnegard Dam's trophic status is eutrophic. The trophic status index (TSI) scores ranged from a low of 54 based on total phosphorus concentrations to a high of 77 based on secchi disk transparency (Figure 8).

Trends: A total of six total phosphorus samples, four chlorophyll-a samples and four Secchi disk transparency measurements collected during the sampling periods of 1992-93 and 2009 were available to evaluate trends in the trophic status of Arnegard Dam. While it would be difficult to make a conclusive assessment on water quality trends, the decreasing total phosphorus concentrations resulting in a shift towards phosphorus limitation are a strong indication that the reservoir is improving (Figures 7 and 8). This improvement is probably best physically expressed by the slower and less complete oxygen decay during periods of thermal stratification (Figures 5 and 6).

One concern is the increasing sulfate concentrations. However, identifying the cause of this increase is beyond the scope of this report. Additionally, the increase could simply be explained as a slightly lower elevation and resulting lake volume in 2009 than in 1992-1993.

Table 3. Statistical Summary of Water Quality Data[2] Collected from Reservoirs and Impoundments in the Rangeland Plains Ecological Region of North Dakota

Parameter	Units	N	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	522	283	54	982	131
Total Ammonia as N	mg/L	593	0.092	0.001[1]	2.440	0.183
Bicarbonate (HCO_3)	mg/L	522	295	14	1040	145
Calcium (Ca)	mg/L	522	52.3	4.7	163.0	27.3
Carbonate (CO_3)	mg/L	520	25	1[1]	197	29
Chloride (Cl)	mg/L	522	13	3[1]	75	9
Chlorophyll-a	µg/L	415	20.1	1.5[1]	218.0	27.0
Specific Conductance	µmhos	542	1621	173	5880	988
Total Dissolved Solids	mg/L	523	1107	100	5110	782
Total Hardness as ($CaCO_3$)	mg/L	522	396	45	2100	279
Hydroxide (OH)	mg/L	465	1.0	0.0[1]	1.0	0.2
Iron (Fe)	mg/L	523	0.193	0.007	4.110	0.349
Magnesium (Mg)	mg/L	522	64.5	5.6	412.0	54.0
Nitrate + Nitrite as N	mg/L	592	0.060	0.001[1]	0.790	0.102
Total Kjeldahl Nitrogen as N	mg/L	483	1.375	0.108	7.720	0.789
Total Nitrogen as N	mg/L	426	1.314	0.178	4.840	0.605
pH		542	8.55	6.73	9.87	0.55
Total Phosphorus as P	mg/L	599	0.128	0.004[1]	3.160	0.190
Potassium (K)	mg/L	522	13.8	2.6	39.2	6.5
Sodium (Na)	mg/L	522	217.2	3.0	932.0	171.6
Sulfate (SO4)	mg/L	520	573	1[1]	3210	519

[1]Equal to the lower reporting limit
[2]Data collected from 76 reservoirs between 1991 and 2010

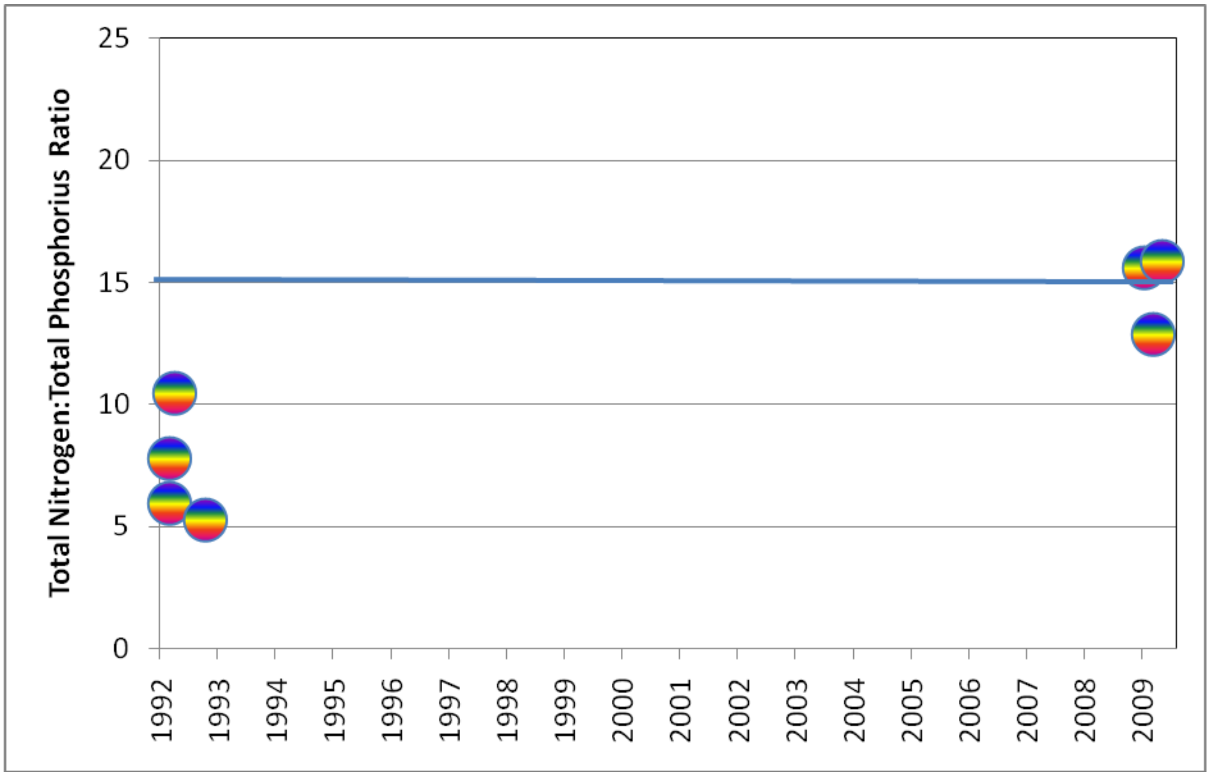

Figure 7. Arnegard Dam's Total Nitrogen to Total Phosphorus Ratio

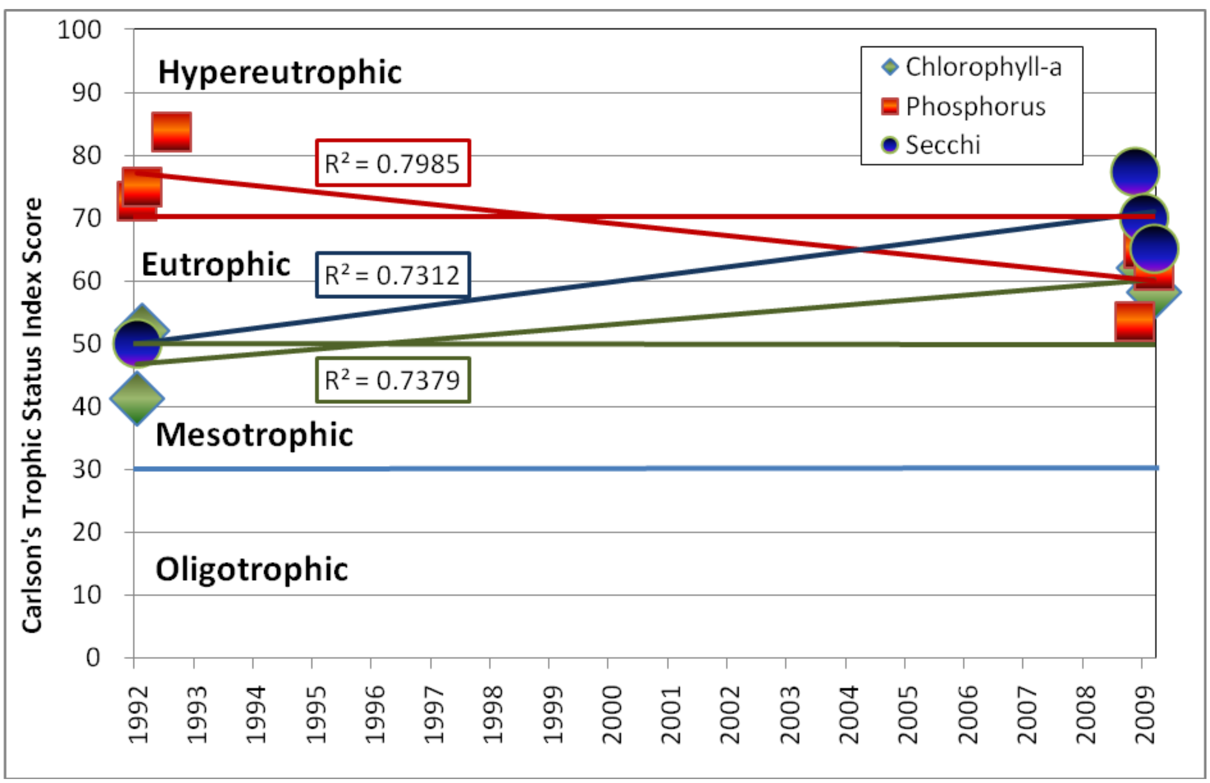

Figure 8. Arnegard Dam's TSI Scores

Custer Mine Pond, McLean County

BACKGROUND

Location: Custer Mine Pond is a small impoundment within the abandoned Custer coal mine 5 miles east and miles 2 south Garrison, North Dakota (Figure 1). It is at the end of a zero maintenance road in a very pleasant setting of tree covered abandoned mine spoils. The fishery is managed by the North Dakota Game and Fish Department (NDG&F). Fish species recently stocked by the NDG&F are rainbow trout, white and black crappie and bluegill.

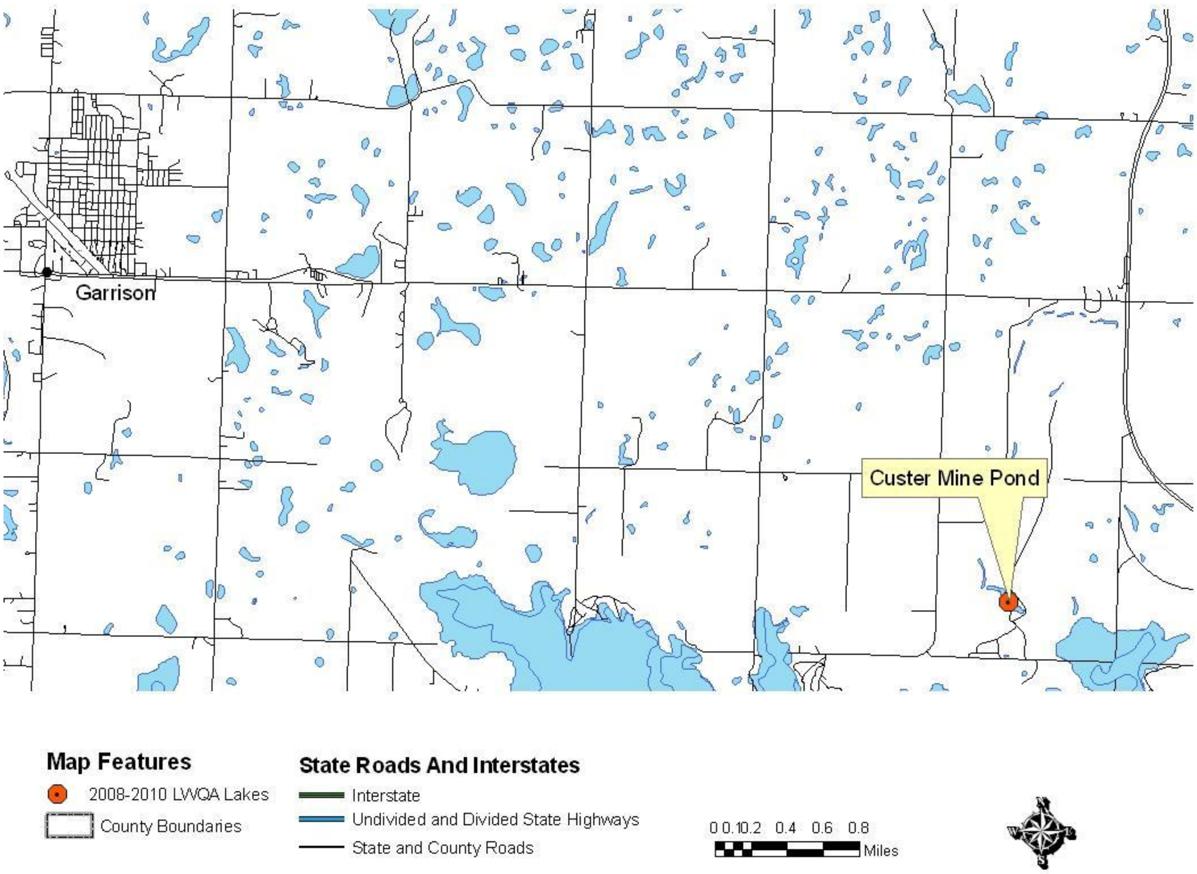

Figure 1. Location of Custer Mine Pond

Physiographic/Ecological Setting: Custer Mine Pond has a surface area of 4.1acres a maximum depth of 23.4 ft and an average depth of 10.4 ft (Figure 2). The reservoir is located in the Northwestern Glaciated Plains Level III Ecoregion, which is part of the broader Rangeland Plains Region (Figures 3 and 4).

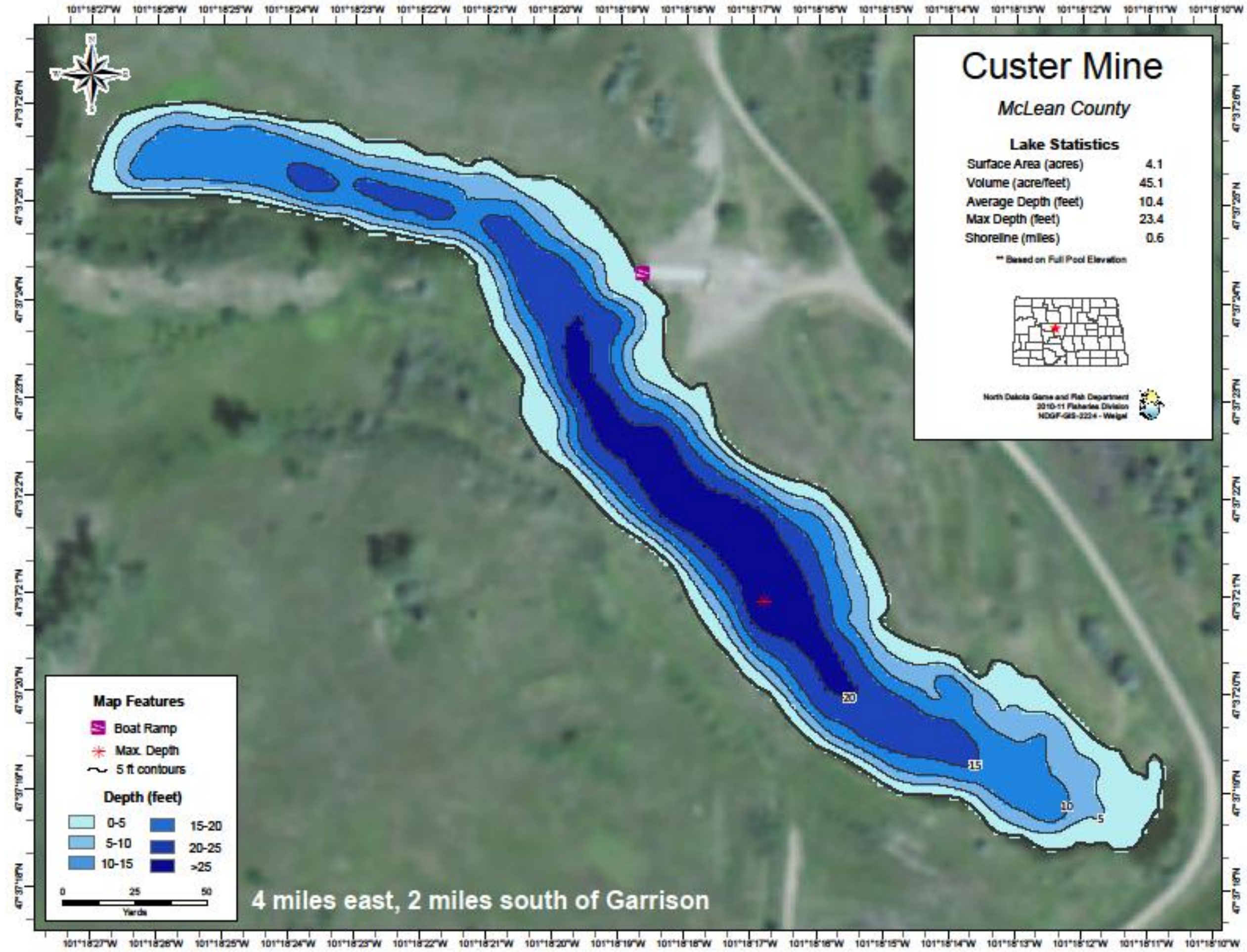

Figure 2. Aerial View of Custer Mine Pond (Map Courtesy of North Dakota Game and Fish Department)

Recreational Facilities: Recreational facilities at Custer Mine Pond include a minimum maintenance road, narrow and a tilted metal boat ramp. It should be noted that what this little pond lacks in facilities it makes up for in scenery and solitude.

Water Quality Standards Classification: Custer Mine Pond is classified in the state "Standards of Quality for Waters of the State" (NDDoH, 2011) as a class 2 lake. Class 2 lakes or impoundments are defined as a "cool water fishery" or "waters capable of supporting natural reproduction and growth of cool water fishes (e.g., northern pike and walleye) and associated aquatic biota. These waters are also capable of supporting the growth and marginal survival of cold water species and associated biota."

Historical Water Quality Sampling: No historical water quality data.

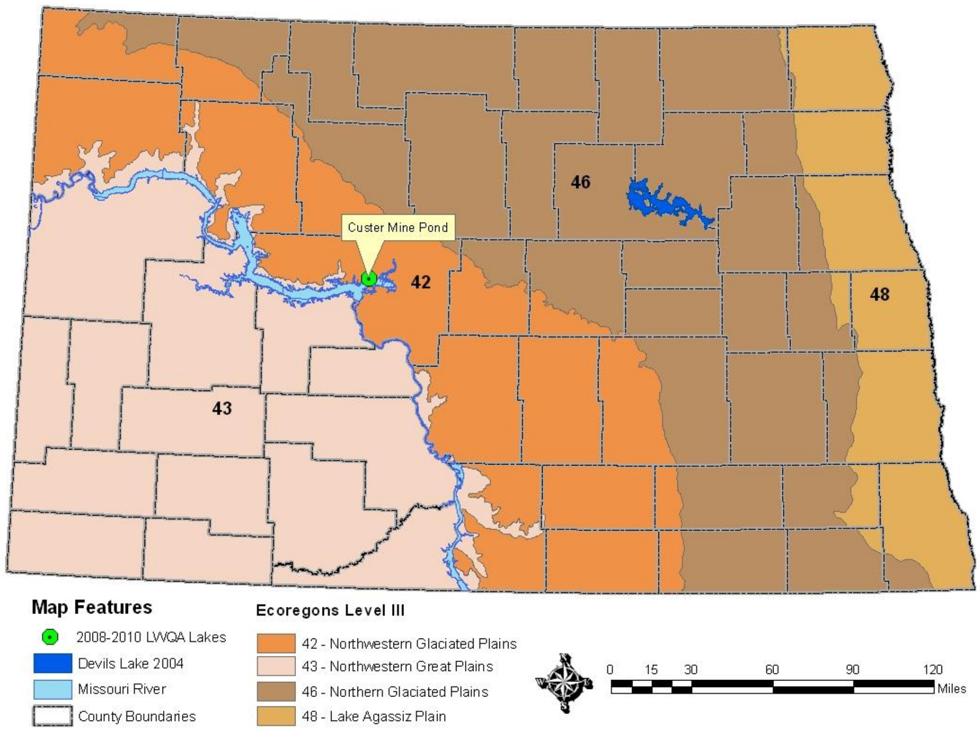

Figure 3. Custer Mine Pond's Location and the Level III Ecoregions

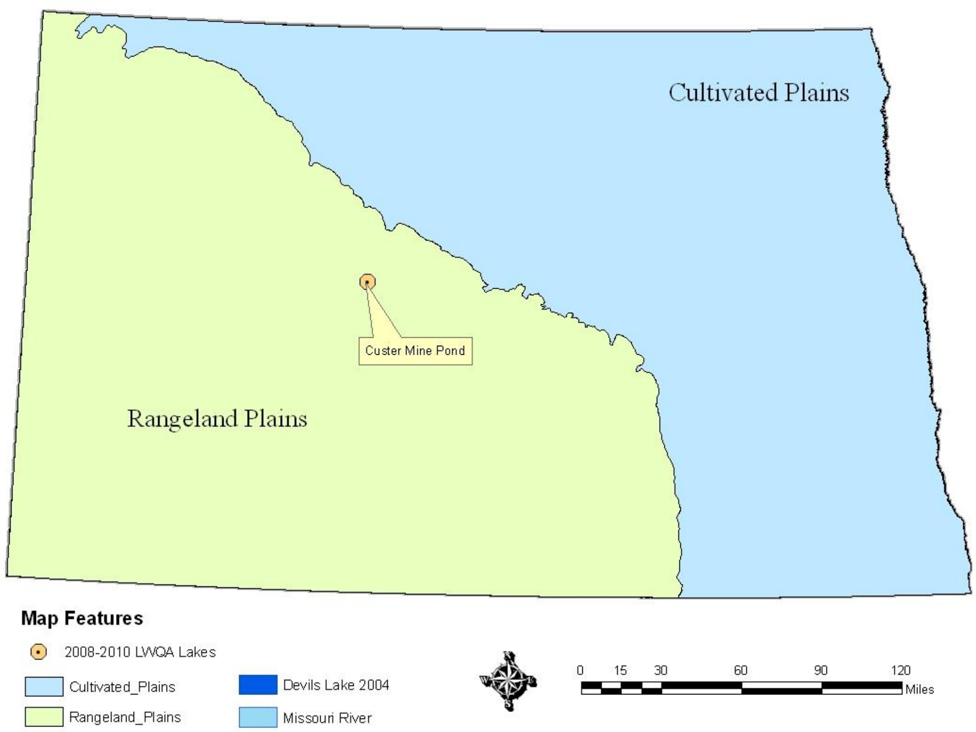

Figure 4. Custer Mine Pond's Location and the Cultivated and Rangeland Plans Regions

WATER QUALITY MONITORING RESULTS

The water quality assessment for Custer Mine Pond is presented in four general categories: 1) temperature and dissolved oxygen profile results; 2) general water quality characterization; 3) nutrient limitation; and 4) trophic status. Additionally, where appropriate, results have been compared to the regional data on reservoirs in the Cultivated Plains region.

Temperature and Dissolved Oxygen Profile Results: There are two temperature and dissolved oxygen profiles for Custer Mine Pond collected in 2008. The profile data shows that the water body does weakly thermally stratify. During periods of thermal stratification, the impoundment experienced oxygen decay below the thermocline. This decay, while rather rapid, was not complete and during both sampling visit there was sufficient oxygen to support cool water species throughout the majority if not the entire water column (Figures 5 and 6).

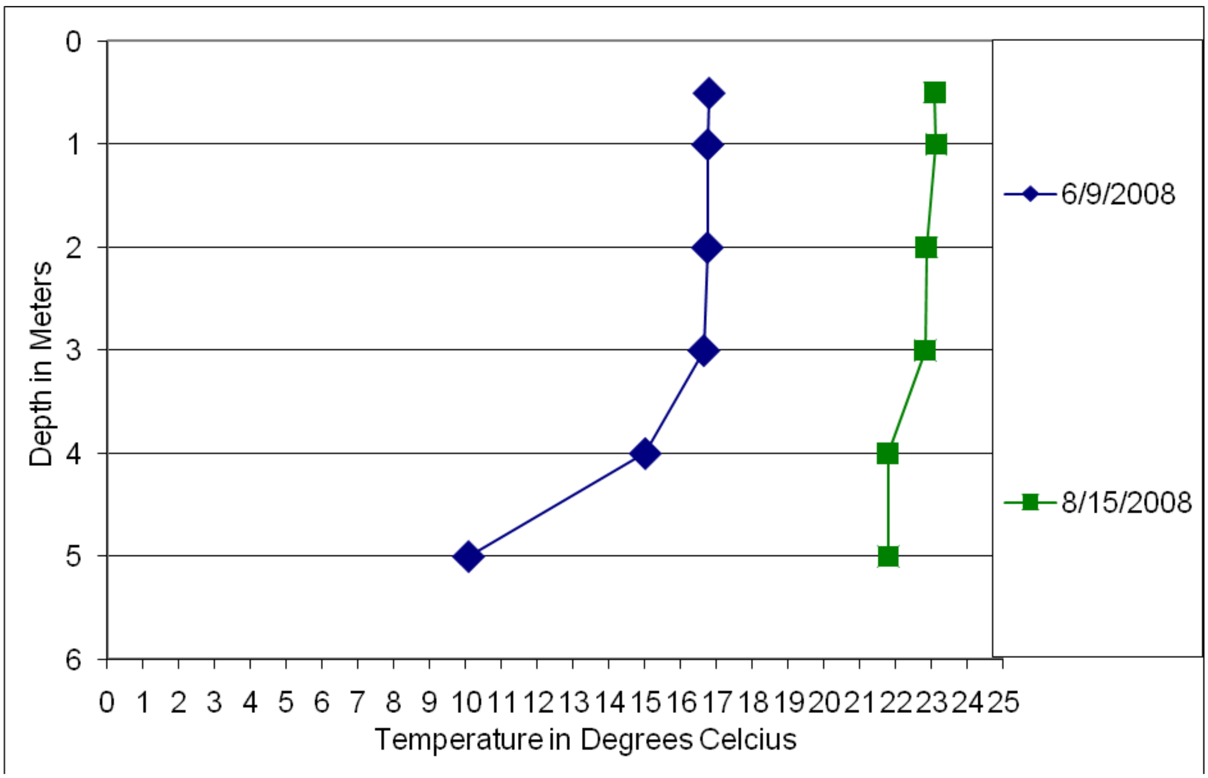

Figure 5. Temperature Profiles for Custer Mine Pond

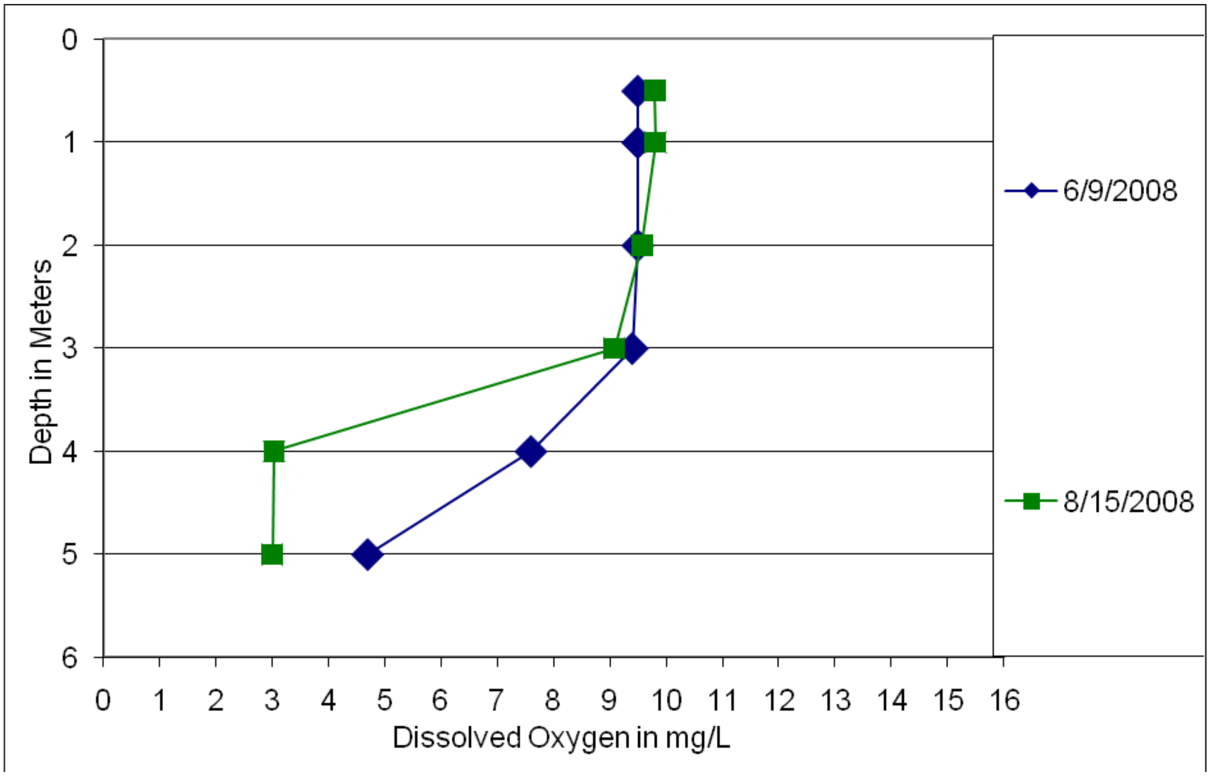

Figure 6. Dissolved Oxygen Profiles for Custer Mine Pond

General Water Quality: Data collected in 2008 indicate that Custer Mine Pond is well buffered with total alkalinity as $CaCO_3$ concentrations ranging from 486 to 496 mg/L (Table 1). The impoundment is sodium sulfate dominated with an average sodium concentration of 543 mg/L and an average sulfate concentration of 1505 mg/L. The average total dissolved solids concentration and specific conductance measurements for the 2008 sampling period were 2625 mg/L and 3435 µmhos/cm, respectively, and the average total nitrogen as N and total phosphorus as P concentrations were 1.046 mg/L and 0.011 mg/L respectively.

When compared to the regional average water quality for impoundments in the Rangeland Plans region, Custer Mine Pond is higher in dissolved solids but less eutrophic than most (Table 3). For example, the regional average TDS, total nitrogen, and total phosphorus concentrations are 1107 mg/L, 1.314 mg/L, and 0.128 mg/L respectively, compared to Custer Mine Pond's average TDS, total nitrogen, and total phosphorus concentrations of 2625 mg/L, 1.046 mg/L and 0.011 mg/L respectively.

Table 1. Statistical Summary of Custer Mine Pond's 2008 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	2	491	486	496	7
Total Ammonia as N	mg/L	2	0.046	0.030[1]	0.061	0.022
Bicarbonate (HCO_3)	mg/L	2	482	432	532	71
Calcium (Ca)	mg/L	2	35.1	28.7	41.4	9.0
Carbonate (CO_3)	mg/L	2	58	36	79	30
Chloride (Cl)	mg/L	2	27	26	27	1
Chlorophyll-a	µg/L	2	3.6	1.5[1]	5.7	3.0
Specific Conductance	µmhos	2	3435	3420	3450	21
Total Dissolved Solids	mg/L	2	2625	2610	2640	21
Total Hardness as ($CaCO_3$)	mg/L	2	905	869	940	50
Hydroxide (OH)	mg/L	2	1.0[1]	1.0[1]	1.0[1]	0.0
Iron (Fe)	mg/L	2	0.087	0.076	0.097	0.015
Magnesium (Mg)	mg/L	2	198.5	186.0	211.0	17.7
Nitrate + Nitrite as N	mg/L	2	0.030[1]	0.030[1]	0.030[1]	0.000
Total Kjeldahl Nitrogen as N	mg/L	2	1.016	0.951	1.080	0.091
Total Nitrogen as N	mg/L	2	1.046	0.981	1.110	0.091
pH		2	8.77	8.58	8.96	0.27
Total Phosphorus as P	mg/L	2	0.011	0.008	0.014	0.004
Potassium (K)	mg/L	2	18.3	16.7	19.8	2.2
Sodium (Na)	mg/L	2	543.0	528.0	558.0	21.2
Sulfate (SO4)	mg/L	2	1505	1480	1530	35

[1]Equal to the lower reporting limit

Limiting Nutrients: The two water quality samples collected in 2008 indicate that Custer Mine Pond is phosphorus limited (Figure 7). The limiting nutrient assessment is based on the assumption that either nitrogen or phosphorus is limiting algal growth and that the ratio of total nitrogen as N to total phosphorus as P (N:P), by weight in the average algae is approximately 15 to 1. When the N:P ratio is less than 15:1, nitrogen is assumed to be the limiting nutrient and when it exceeds 15:1, the limiting nutrient is assumed to be phosphorus.

Trophic Status Assessment: Based on the chlorophyll-a, secchi disk transparency, and total phosphorus data collected in 2008, Custer Mine Pond's trophic status is mesotrophic. The trophic status index (TSI) scores ranged from a low of 34 based on chlorophyll-a to a high of 52 based on secchi disk (Figure 8).

Table 2. Statistical Summary of Water Quality Data[2] Collected from Reservoirs and Impoundments in the Cultivated Plains Ecological Region of North Dakota

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	400	261	88	891	99
Total Ammonia as N	mg/L	567	0.145	0.001[1]	2.070	0.208
Bicarbonate (HCO_3)	mg/L	400	294	91	951	110
Calcium (Ca)	mg/L	402	66.7	19.4	169.0	22.7
Carbonate (CO_3)	mg/L	382	13	1[1]	93	16
Chloride (Cl)	mg/L	400	21	3[1]	113	17
Chlorophyll-a	µg/L	445	19.9	1.5[1]	388.0	30.2
Specific Conductance	µmhos	400	1025	217	3140	501
Total Dissolved Solids	mg/L	392	671	127	2300	375
Total Hardness as ($CaCO_3$)	mg/L	402	341	95	1090	119
Hydroxide (OH)	mg/L	339	1.0	0.0[1]	1.0	0.2
Iron (Fe)	mg/L	400	0.143	0.007	3.190	0.220
Magnesium (Mg)	mg/L	402	42.3	11.2	161.0	19.6
Nitrate + Nitrite as N	mg/L	560	0.112	0.001[1]	2.060	0.213
Total Kjeldahl Nitrogen as N	mg/L	480	1.470	0.206	4.410	0.648
Total Nitrogen as N	mg/L	419	1.520	0.418	3.950	0.617
pH		401	8.34	1.76	9.40	0.54
Total Phosphorus as P	mg/L	569	0.327	0.002[1]	2.270	0.290
Potassium (K)	mg/L	402	11.6	2.7	34.5	5.4
Sodium (Na)	mg/L	402	96.8	2.2	582.0	102.9
Sulfate (SO4)	mg/L	400	272	1[1]	1350	210

[1]Equal to the lower reporting limit
[2]Data collected from 45 reservoirs between 1991 and 2010

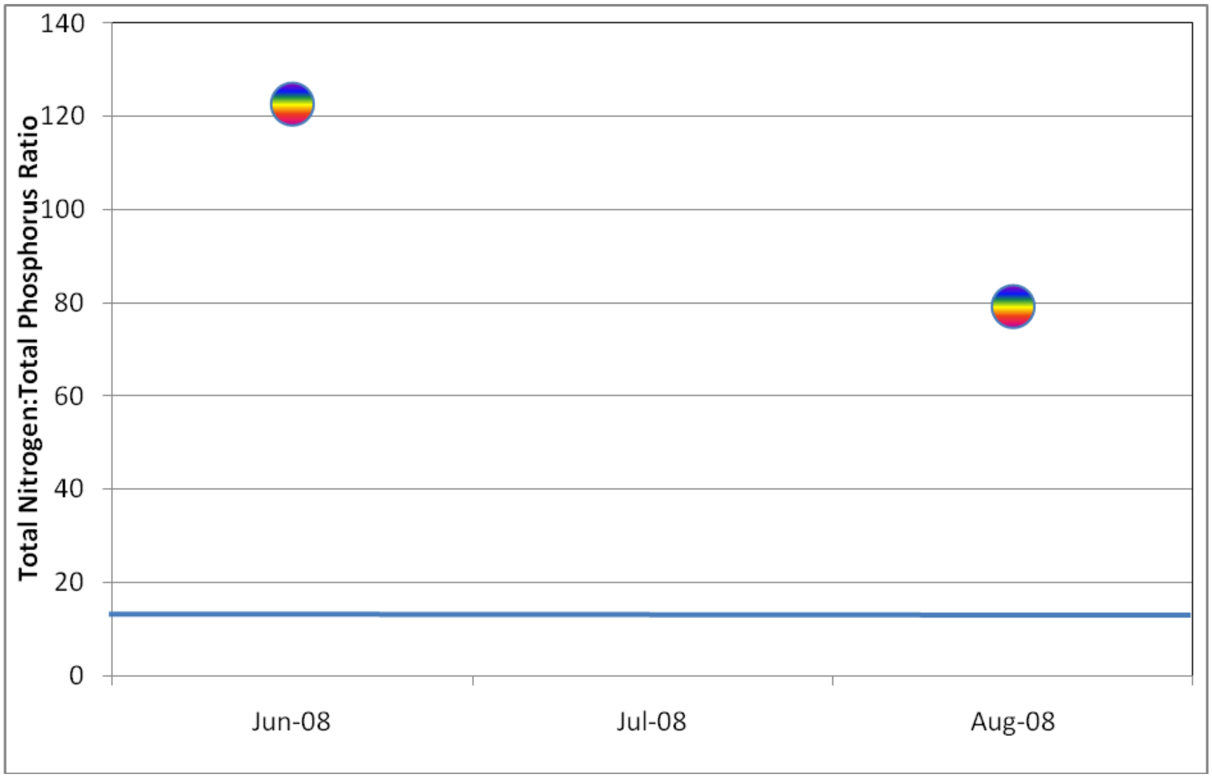

Figure 7. Custer Mine Pond's Total Nitrogen to Total Phosphorus Ratio

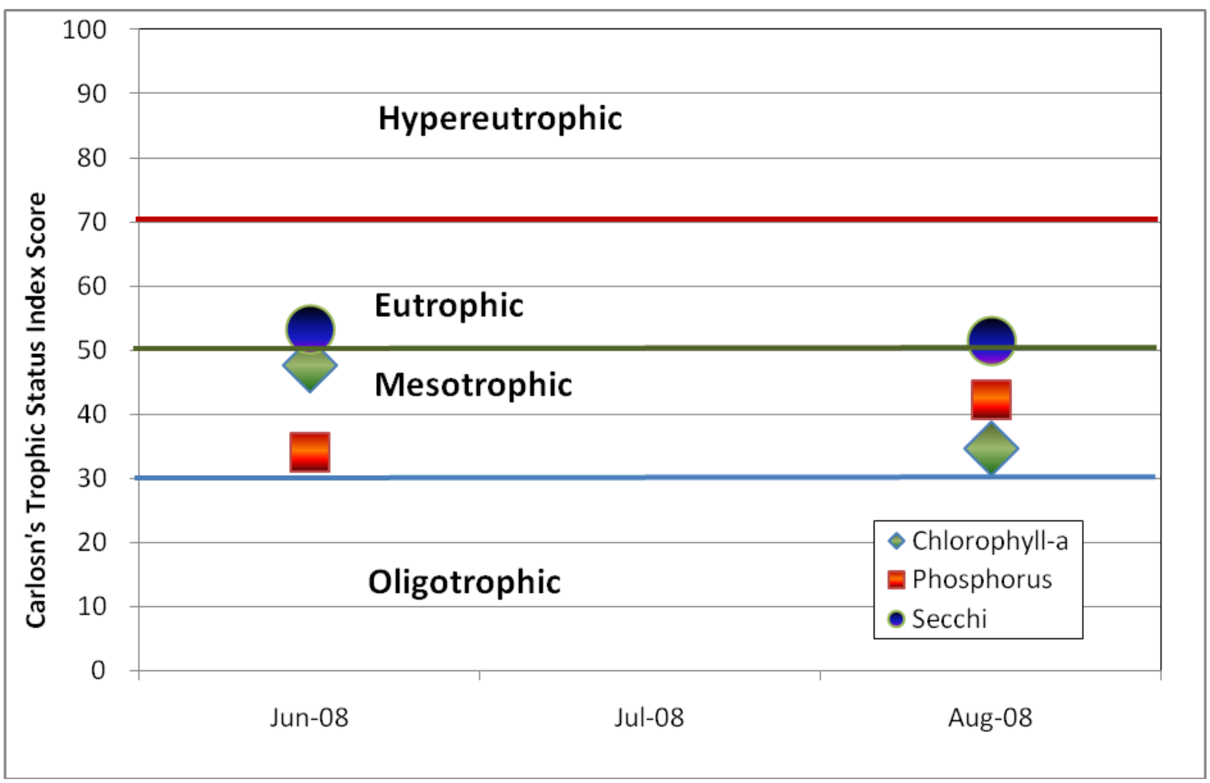

Figure 8. Custer Mine Pond's TSI Scores

Lightning Lake, McLean County

BACKGROUND

Location: Lightning Lake is a small enhanced lake along the McClusky Cannel in on the northeast edge of Turtle Lake, North Dakota (Figure 1). Lightning Lake is part of the Garrison Diversion irrigation project and the water elevation is maintained by the Bureau of Reclamation. The fishery is managed by the North Dakota Game and Fish Department (NDG&F). Fish species recently stocked by the NDG&F are cutthroat trout, rainbow trout, brown trout and bluegill.

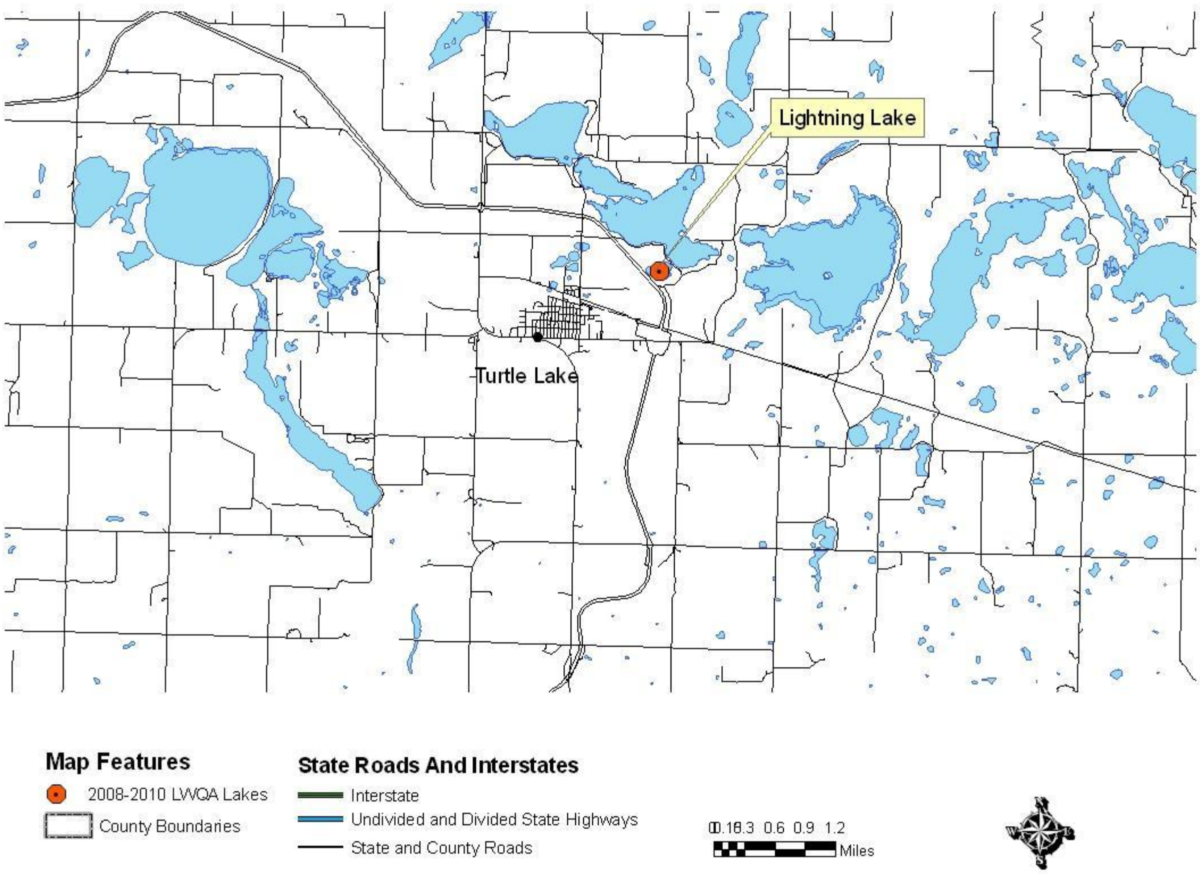

Figure 1. Location of Lightning Lake

Physiographic/Ecological Setting: Lightning Lake has a surface area of 18.5 acres a maximum depth of 23.9 ft and an average depth of 15.9 ft (Figure 2). The reservoir is located in the Northwestern Glaciated Plains Level III Ecoregion, which is part of the broader Rangeland Plains Region (Figures 3 and 4).

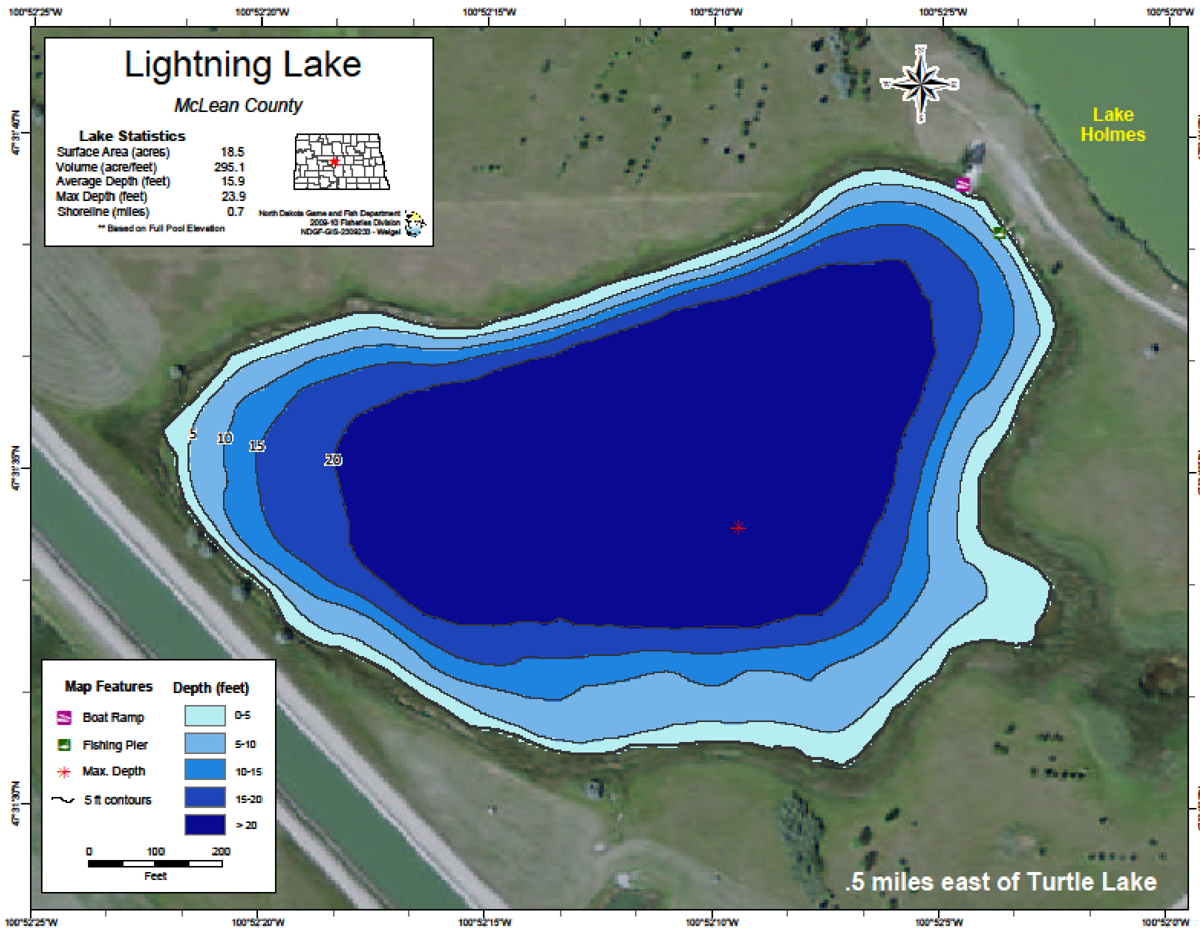

Figure 2. Contour Map of Lightning Lake (Map Courtesy of North Dakota Game and Fish Department)

Recreational Facilities: Recreational facilities at Lightning Lake include a well maintained access road, Boat ramp, courtesy dock, and fishing pier.

Water Quality Standards Classification: Lightning Lake is classified in the state “Standards of Quality for Waters of the State” (NDDoH, 2011) as a class 1 lake. Class 1 lakes or impoundments are defined as a “cold water fishery” or “waters capable of supporting growth of cold water fishes (e.g., salmonids) and associated aquatic biota.

Historical Water Quality Sampling: No historical water quality data.

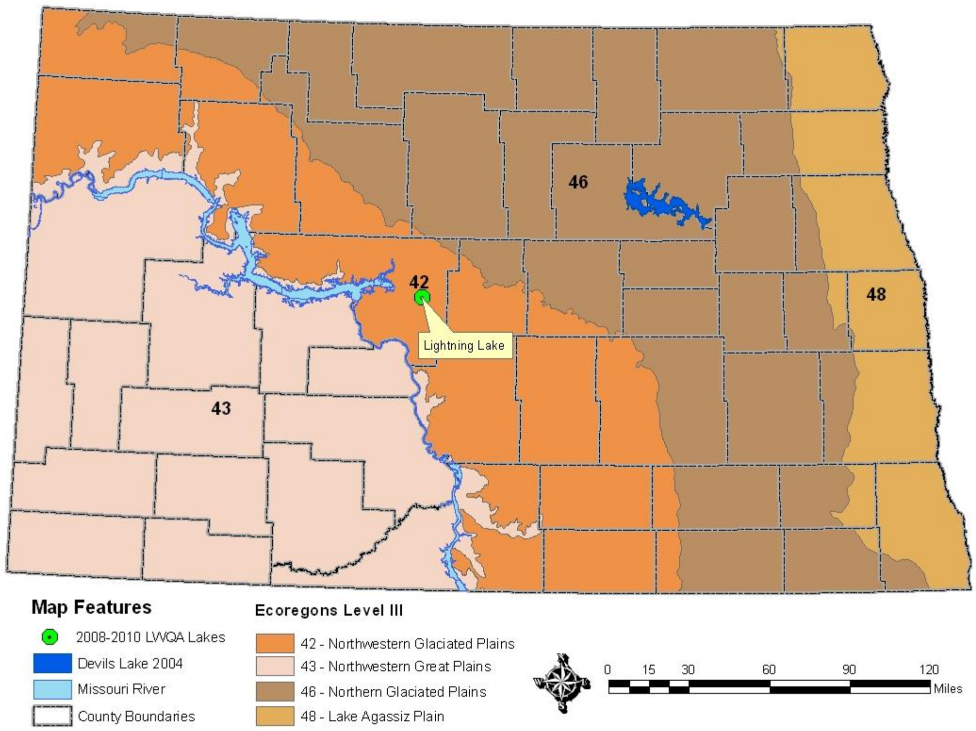

Figure 3. Lightning Lake's Location and the Level III Ecoregions

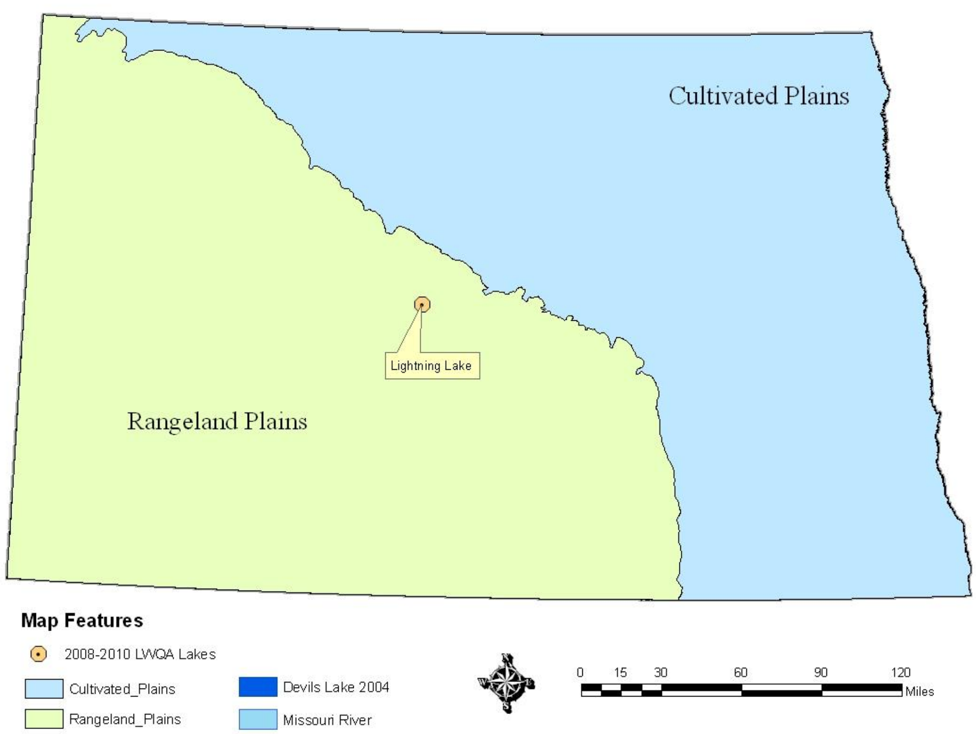

Figure 4. Lightning Lake's Location and the Cultivated and Rangeland Plans Regions

WATER QUALITY MONITORING RESULTS

The water quality assessment for Lightning Lake is presented in four general categories: 1) temperature and dissolved oxygen profile results; 2) general water quality characterization; 3) nutrient limitation; and 4) trophic status. Additionally, where appropriate, results have been compared to the regional data on reservoirs in the Cultivated Plains region.

Temperature and Dissolved Oxygen Profile Results: There are two temperature and dissolved oxygen profiles for Lightning Lake collected in 2008. The profile data shows that the water body does weakly thermally stratify. During periods of thermal stratification, the impoundment experienced rapid and nearly complete oxygen decay below the thermocline. Fortunately thermal stratification occurred between a depth of 3 to 4 meters leaving the majority of the water column well oxygenated (Figures 5 and 6).

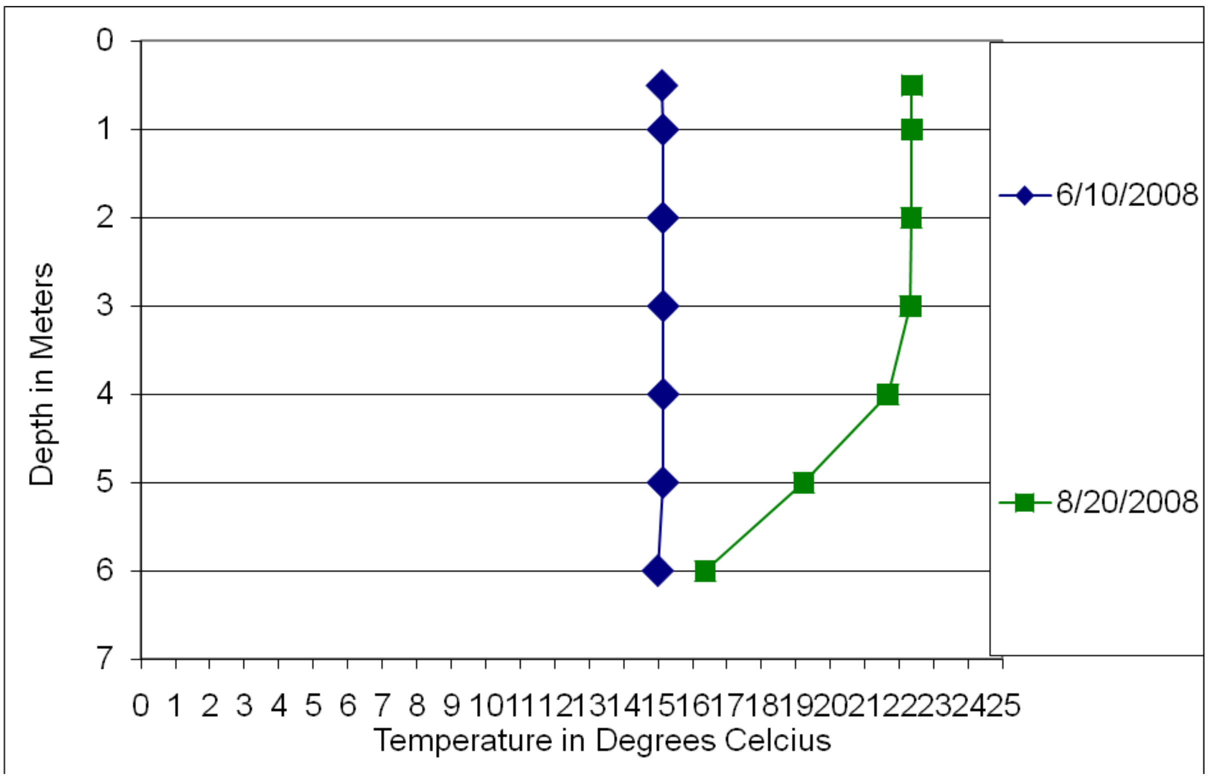

Figure 5. Temperature Profiles for Lightning Lake

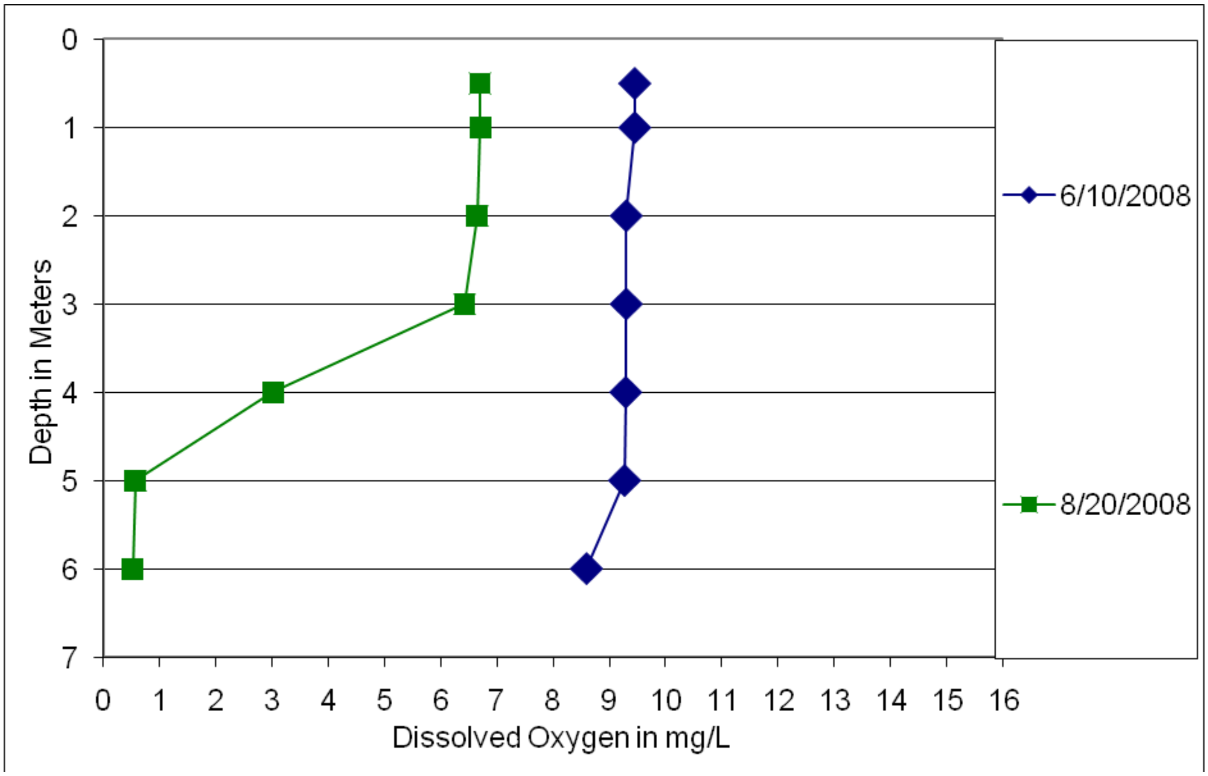

Figure 6. Dissolved Oxygen Profiles for Lightning Lake

General Water Quality: Data collected in 2008 indicate that Lightning Lake is well buffered with total alkalinity as $CaCO_3$ concentrations ranging from 229 to 253 mg/L (Table 1). The lake is sodium sulfate dominated with an average sodium concentration of 175 mg/L and an average sulfate concentration of 404 mg/L. The average total dissolved solids concentration and specific conductance measurements for the 2008 sampling period were 846 mg/L and 1280 µmhos/cm, respectively, and the average total nitrogen as N and total phosphorus as P concentrations were 1.040 mg/L and 0.019 mg/L respectively.

When compared to the regional average water quality for impoundments in the Rangeland Plans region, Lightning Lake is less alkaline and less eutrophic than most (Table 3). For example, the regional average TDS, total nitrogen, and total phosphorus concentrations are 1466 mg/L, 1.794 mg/L, and 0.233 mg/L respectively, compared to Lightning Lake's average TDS, total nitrogen, and total phosphorus concentrations of 846 mg/L, 1.040 mg/L and 0.019 mg/L respectively.

Limiting Nutrients: The two water quality samples collected in 2008 indicate that Lightning Lake is phosphorus limited (Figure 7). The limiting nutrient assessment is based on the assumption that either nitrogen or phosphorus is limiting algal growth and that the ratio of total nitrogen as N to total phosphorus as P (N:P), by weight in the average algae is approximately 15 to 1. When the N:P ratio is less than 15:1, nitrogen is assumed to be the limiting nutrient and when it exceeds 15:1, the limiting nutrient is assumed to be phosphorus.

Trophic Status Assessment: Based on the chlorophyll-a, secchi disk transparency, and total phosphorus data collected in 2008, Lightning Lake's trophic status is estimated to be mesotrophic. The trophic status index (TSI) scores ranged from a low of 43 based on chlorophyll-a to a high of 55 based on secchi disk (Figure 8).

Table 1. Statistical Summary of Lightning Lake's 2008 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	2	241	229	253	17
Total Ammonia as N	mg/L	2	0.033	0.030[1]	0.035	0.004
Bicarbonate (HCO_3)	mg/L	2	250	207	292	60
Calcium (Ca)	mg/L	2	32.7	29.0	36.4	5.2
Carbonate (CO_3)	mg/L	2	22	8	35	19
Chloride (Cl)	mg/L	2	22	21	22	0
Chlorophyll-a	µg/L	2	6.0	3.6	8.3	3.3
Specific Conductance	µmhos	2	1280	1270	1290	14
Total Dissolved Solids	mg/L	2	846	837	855	13
Total Hardness as ($CaCO_3$)	mg/L	2	322	311	332	15
Hydroxide (OH)	mg/L	2	1.0[1]	1.0[1]	1.0[1]	0.0
Iron (Fe)	mg/L	2	0.050	0.050	0.050	0.000
Magnesium (Mg)	mg/L	2	58.2	53.4	63.0	6.8
Nitrate + Nitrite as N	mg/L	2	0.030[1]	0.030[1]	0.030[1]	0.000
Total Kjeldahl Nitrogen as N	mg/L	2	1.010	0.810	1.210	0.283
Total Nitrogen as N	mg/L	2	1.040	0.840	1.240	0.283
pH		2	8.73	8.41	9.04	0.45
Total Phosphorus as P	mg/L	2	0.019	0.018	0.019	0.001
Potassium (K)	mg/L	2	8.7	7.8	9.6	1.3
Sodium (Na)	mg/L	2	175.0	171.0	179.0	5.7
Sulfate (SO4)	mg/L	2	404	394	414	14

[1]Equal to the lower reporting limit

Table 2. Statistical Summary of Water Quality Data[2] Collected from Natural and Enhanced Lakes in the Rangeland Plains Ecological Region of North Dakota

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	383	513	111	4770	487
Total Ammonia as N	mg/L	494	0.105	0.001[1]	2.230	0.229
Bicarbonate (HCO_3)	mg/L	383	469	60	2990	320
Calcium (Ca)	mg/L	384	41.1	0.5	282.0	34.4
Carbonate (CO_3)	mg/L	377	79	1[1]	1420	148
Chloride (Cl)	mg/L	383	44	3[1]	1070	103
Chlorophyll-a	µg/L	346	22.5	1.5[1]	292.0	37.4
Specific Conductance	µmhos	383	2028	424	20100	1976
Total Dissolved Solids	mg/L	383	1466	227	18200	1717
Total Hardness as ($CaCO_3$)	mg/L	384	529	74	2370	295
Hydroxide (OH)	mg/L	322	1.0	0.0[1]	1.0	0.2
Iron (Fe)	mg/L	385	0.245	0.001[1]	7.070	0.543
Magnesium (Mg)	mg/L	384	103.6	8.5	567.0	70.9
Nitrate + Nitrite as N	mg/L	491	0.04046	0.001[1]	0.54	0.054
Total Kjeldahl Nitrogen as N	mg/L	463	1.876	0.080	8.500	1.073
Total Nitrogen as N	mg/L	401	1.794	0.240	5.520	0.897
pH		383	8.80	7.40	9.87	0.36
Total Phosphorus as P	mg/L	501	0.233	0.002[1]	1.940	0.336
Potassium (K)	mg/L	384	34.0	3.1	356.0	37.0
Sodium (Na)	mg/L	384	299.6	16.9	4680.0	514.5
Sulfate (SO4)	mg/L	383	625	34	10500	885

[1]Equal to the lower reporting limit
[2]Data collected from 64 natural and enhanced Lakes between 1991 and 2010

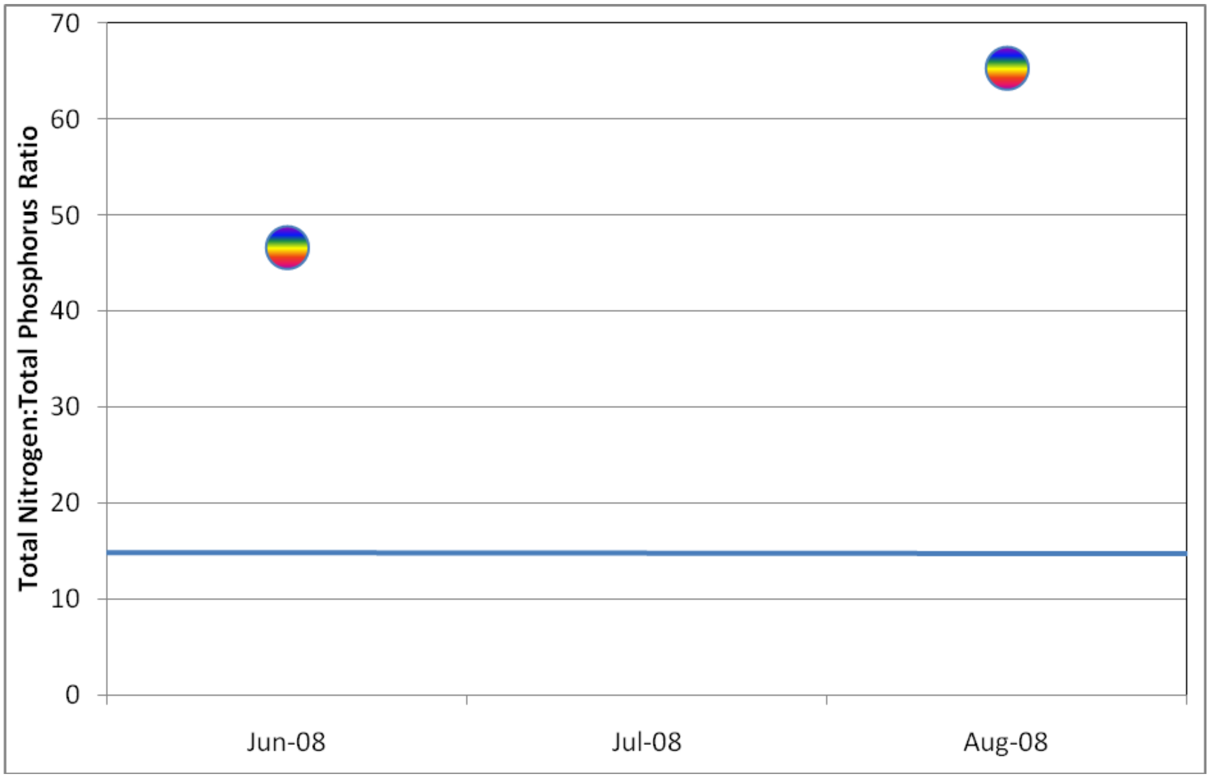

Figure 7. Lightning Lake's Total Nitrogen to Total Phosphorus Ratio

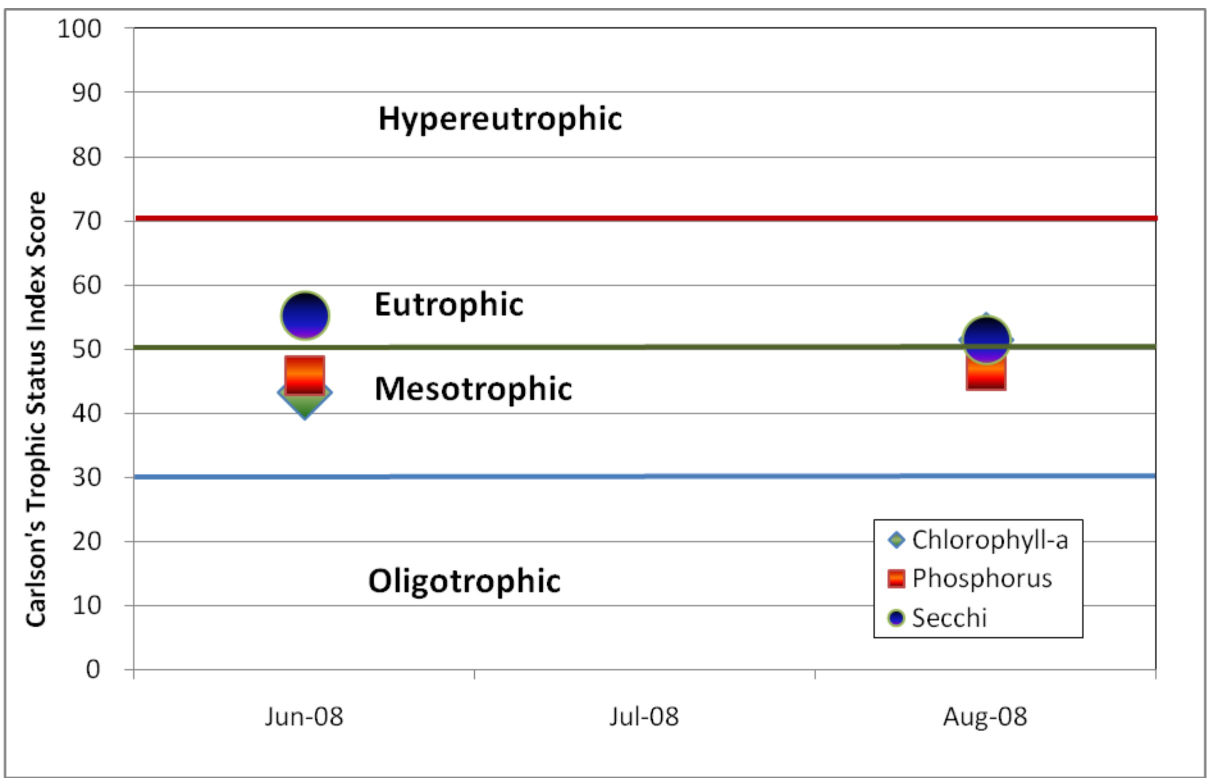

Figure 8. Lightning Lake's TSI Scores

Harmony Lake, Mercer County

BACKGROUND

Location: Harmony Lake is a small enhanced lake along the southern edge of a pre-reclamation coal mine approximately 6 miles north of Hazen, North Dakota (Figure 1). The lake and surface drainage feeding it are a relatively unique system developed by Coteau Properties to provide water based recreation to the local communities and state. The lake and immediate recreational area has been donated to the North Dakota game and Fish Department (NDG&F) for long term management. Fish species recently stocked by the NDG&F are white and black crappie, rainbow trout and bluegill. Initial stockings also included largemouth bass.

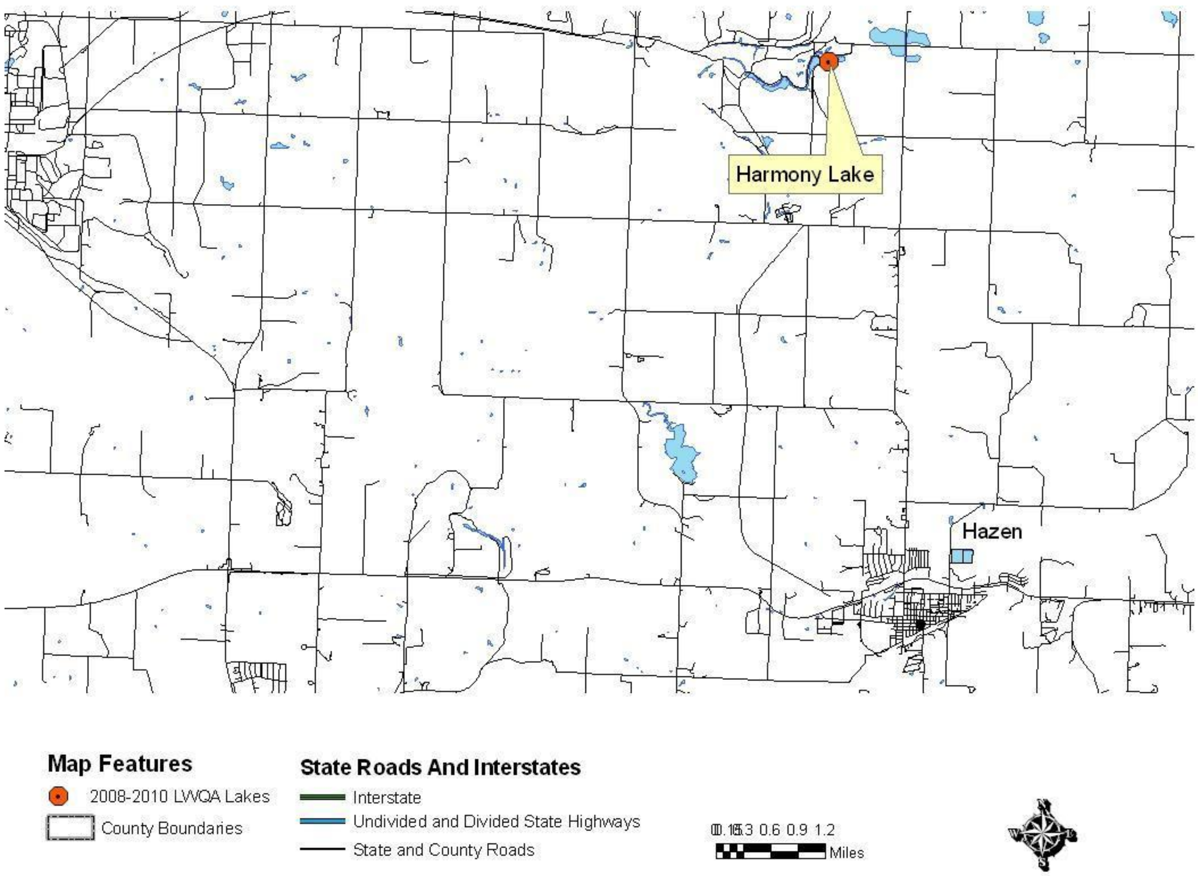

Figure 1. Location of Harmony Lake

Physiographic/Ecological Setting: Harmony Lake has a surface area of 37.7 acres a maximum depth of 21.2 ft and an average depth of 13.1 ft (Figure 2). The reservoir is located in the Northwestern Great Plains Level III Ecoregion, which is part of the broader Rangeland Plains Region (Figures 3 and 4).

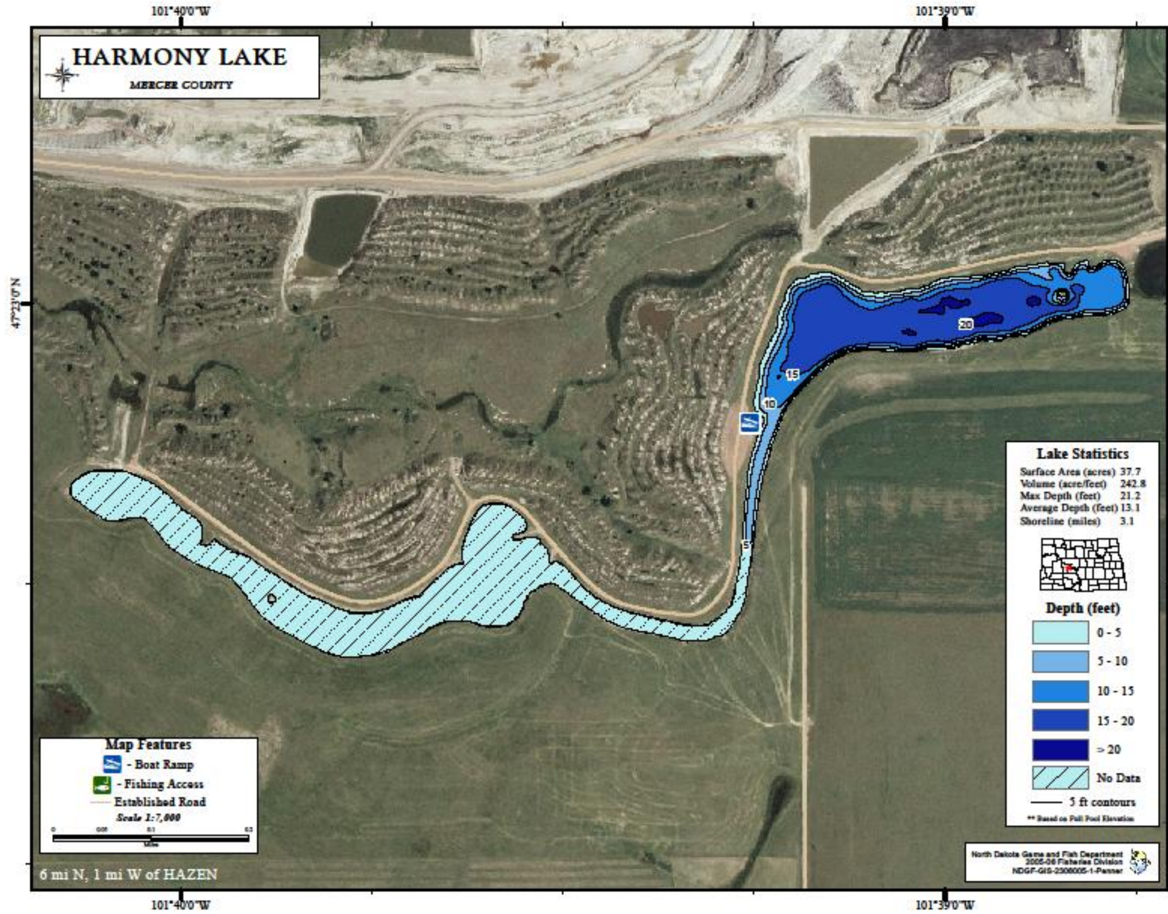

Figure 2. Contour Map of Harmony Lake (Map Courtesy of North Dakota Game and Fish Department)

Recreational Facilities: Recreational facilities at Harmony Lake include a boat ramp and courtesy dock. There are also a series of man-made rock points designed for shore fishing.

Water Quality Standards Classification: Harmony Lake is classified in the state "Standards of Quality for Waters of the State" (NDDoH, 2011) as a class 3 lake. Class 3 lakes or impoundments are defined as a "warm water fishery" or "waters capable of supporting natural reproduction and growth of warm water fishes (e.g., largemouth bass and bluegills).

Historical Water Quality Sampling: No historical water quality data.

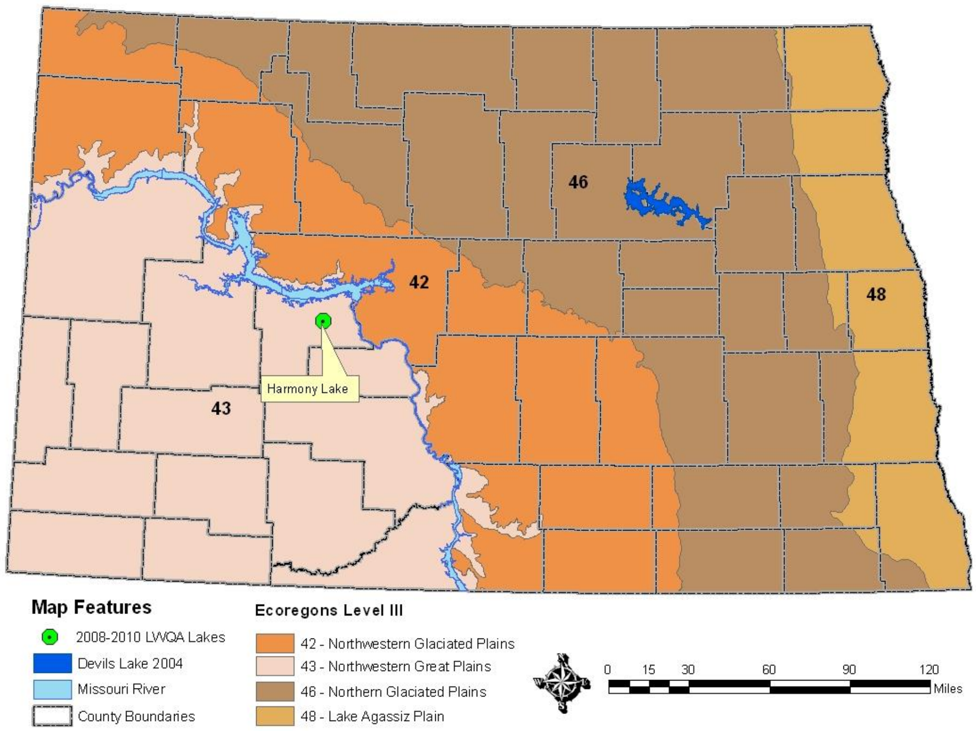

Figure 3. Harmony Lake's Location and the Level III Ecoregions

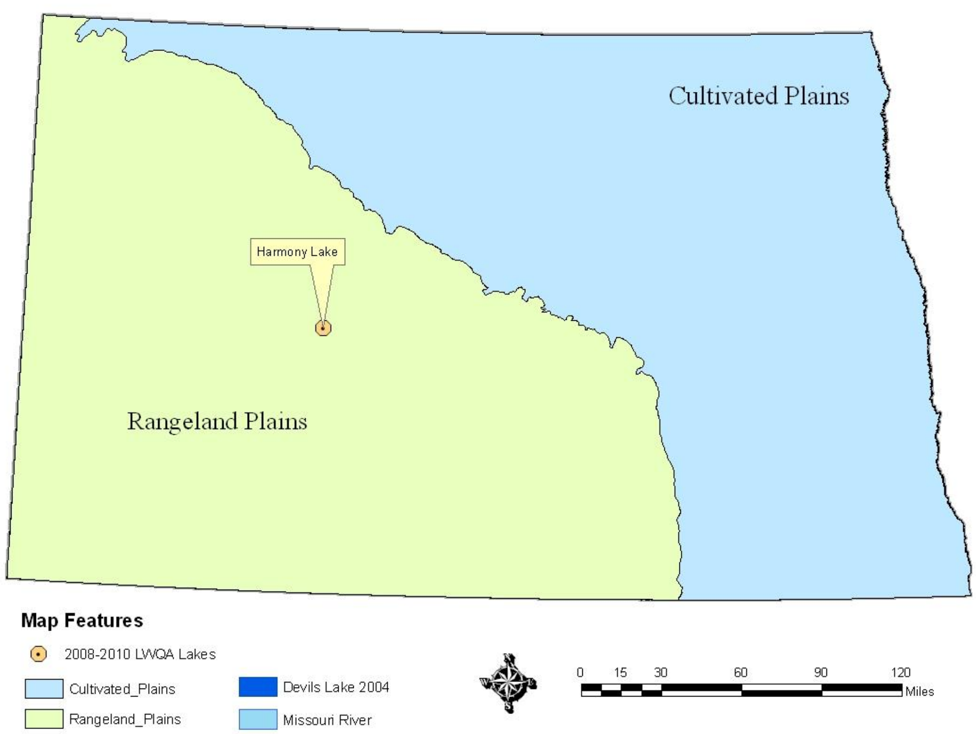

Figure 4. Harmony Lake's Location and the Cultivated and Rangeland Plans Regions

WATER QUALITY MONITORING RESULTS

The water quality assessment for Harmony Lake is presented in four general categories: 1) temperature and dissolved oxygen profile results; 2) general water quality characterization; 3) nutrient limitation; and 4) trophic status. Additionally, where appropriate, results have been compared to the regional data on reservoirs in the Cultivated Plains region.

Temperature and Dissolved Oxygen Profile Results: There are two temperature and dissolved oxygen profiles for Harmony Lake collected in 2008. The profile data shows that the water body was not thermally stratified on either date. Additionally, during both sampling visits the lake was well enough oxygenated to support a warm water fishery and associated biota (Figures 5 and 6).

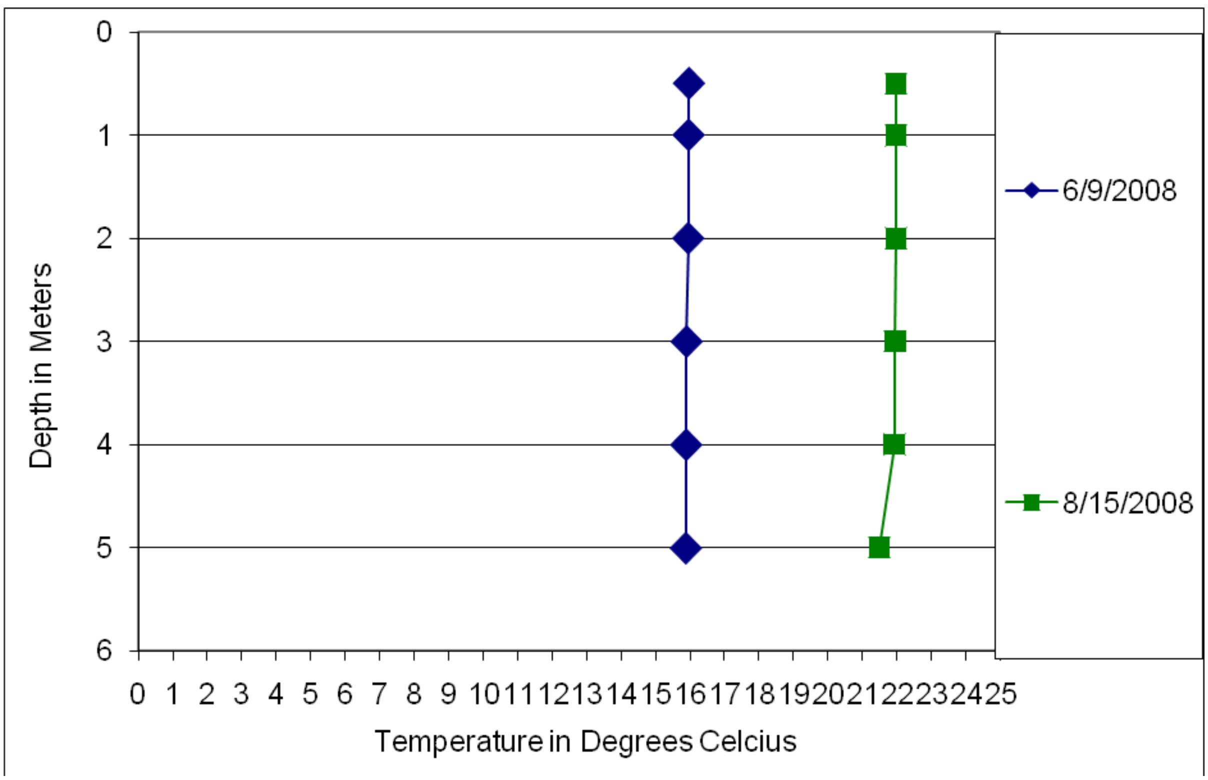

Figure 5. Temperature Profiles for Harmony Lake

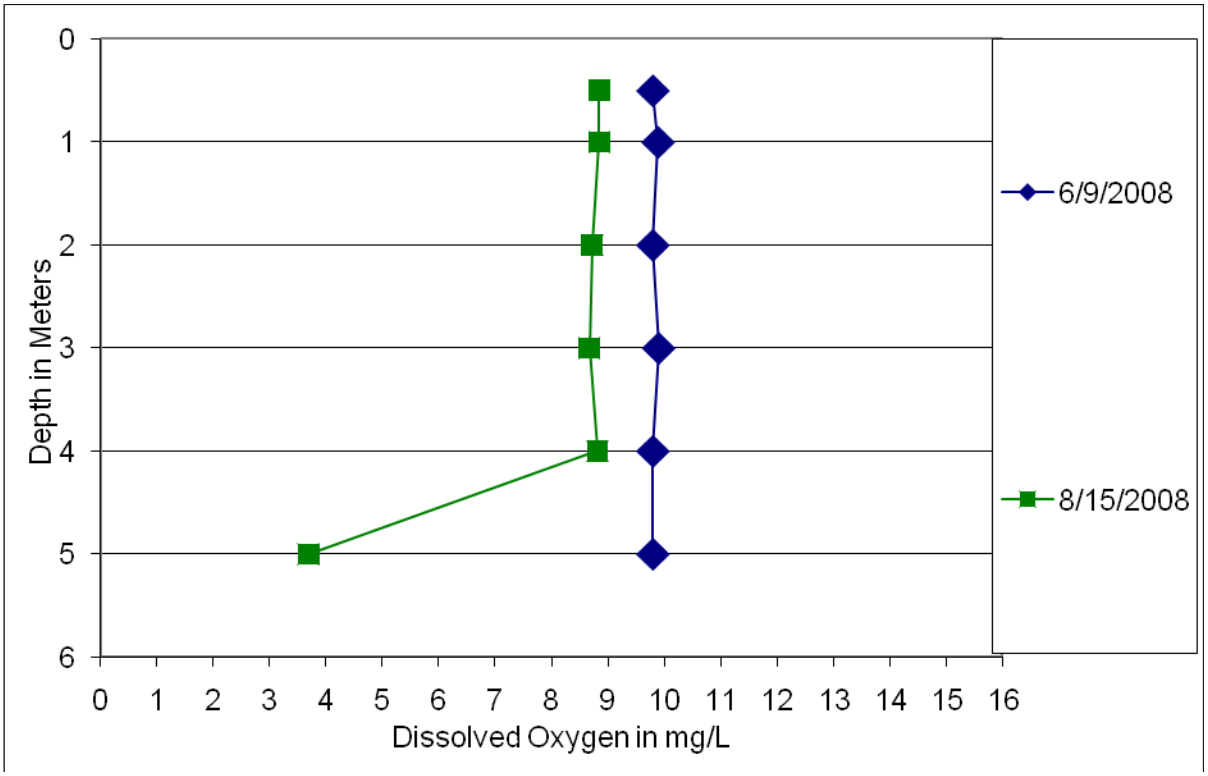

Figure 6. Dissolved Oxygen Profiles for Harmony Lake

General Water Quality: Data collected in 2008 indicate that Harmony Lake is well buffered with total alkalinity as $CaCO_3$ concentrations ranging from 222 to 243 mg/L (Table 1). The lake is sodium sulfate dominated with an average sodium concentration of 134 mg/L and an average sulfate concentration of 261 mg/L. The average total dissolved solids concentration and specific conductance measurements for the 2008 sampling period were 618 mg/L and 977 µmhos/cm, respectively, and the average total nitrogen as N and total phosphorus as P concentrations were 1.280 mg/L and 0.044 mg/L respectively.

When compared to the regional average water quality for lakes in the Rangeland Plans region, Harmony Lake is less alkaline and less eutrophic than most (Table 3). For example, the regional average TDS, total nitrogen, and total phosphorus concentrations are 1466 mg/L, 1.794 mg/L, and 0.233 mg/L respectively, compared to Harmony Lake's average TDS, total nitrogen, and total phosphorus concentrations of 618 mg/L, 1.280 mg/L and 0.044 mg/L respectively.

Table 1. Statistical Summary of Harmony Lake's 2008 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	2	233	222	243	15
Total Ammonia as N	mg/L	2	0.030[1]	0.030[1]	0.030[1]	0.000
Bicarbonate (HCO_3)	mg/L	2	235	189	281	65
Calcium (Ca)	mg/L	2	30.9	25.3	36.4	7.8
Carbonate (CO_3)	mg/L	2	24	7	40	23
Chloride (Cl)	mg/L	2	6	6	6	0
Chlorophyll-a	µg/L	2	25.4	5.3	45.4	28.4
Specific Conductance	µmhos	2	977	963	990	19
Total Dissolved Solids	mg/L	2	618	607	628	15
Total Hardness as ($CaCO_3$)	mg/L	2	205	196	214	13
Hydroxide (OH)	mg/L	2	1.0[1]	1.0[1]	1.0[1]	0.0
Iron (Fe)	mg/L	2	0.130	0.127	0.133	0.004
Magnesium (Mg)	mg/L	2	31.1	30.0	32.2	1.6
Nitrate + Nitrite as N	mg/L	2	0.185	0.030[1]	0.340	0.219
Total Kjeldahl Nitrogen as N	mg/L	2	1.095	0.690	1.500	0.573
Total Nitrogen as N	mg/L	2	1.280	1.030	1.530	0.354
pH		2	8.81	8.41	9.20	0.56
Total Phosphorus as P	mg/L	2	0.044	0.016	0.072	0.040
Potassium (K)	mg/L	2	13.9	13.1	14.7	1.1
Sodium (Na)	mg/L	2	134.0	131.0	137.0	4.2
Sulfate (SO4)	mg/L	2	261	258	264	4

[1]Equal to the lower reporting limit

Limiting Nutrients: The two water quality samples collected in 2008 indicate that Harmony Lake is phosphorus limited (Figure 7). The limiting nutrient assessment is based on the assumption that either nitrogen or phosphorus is limiting algal growth and that the ratio of total nitrogen as N to total phosphorus as P (N:P), by weight in the average algae is approximately 15 to 1. When the N:P ratio is less than 15:1, nitrogen is assumed to be the limiting nutrient and when it exceeds 15:1, the limiting nutrient is assumed to be phosphorus.

Trophic Status Assessment: Based on the chlorophyll-a, secchi disk transparency, and total phosphorus data collected in 2008, Harmony Lake's trophic status is eutrophic. The trophic status index (TSI) scores ranged from a low of 44 based on total phosphorus to a high of 68 based on chlorophyll-a (Figure 8).

Table 2. Statistical Summary of Water Quality Data[2] Collected from Natural and Enhanced Lakes in the Rangeland Plains Ecological Region of North Dakota

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	383	513	111	4770	487
Total Ammonia as N	mg/L	494	0.105	0.001[1]	2.230	0.229
Bicarbonate (HCO_3)	mg/L	383	469	60	2990	320
Calcium (Ca)	mg/L	384	41.1	0.5	282.0	34.4
Carbonate (CO_3)	mg/L	377	79	1[1]	1420	148
Chloride (Cl)	mg/L	383	44	3[1]	1070	103
Chlorophyll-a	µg/L	346	22.5	1.5[1]	292.0	37.4
Specific Conductance	µmhos	383	2028	424	20100	1976
Total Dissolved Solids	mg/L	383	1466	227	18200	1717
Total Hardness as ($CaCO_3$)	mg/L	384	529	74	2370	295
Hydroxide (OH)	mg/L	322	1.0	0.0[1]	1.0	0.2
Iron (Fe)	mg/L	385	0.245	0.001[1]	7.070	0.543
Magnesium (Mg)	mg/L	384	103.6	8.5	567.0	70.9
Nitrate + Nitrite as N	mg/L	491	0.04046	0.001[1]	0.54	0.054
Total Kjeldahl Nitrogen as N	mg/L	463	1.876	0.080	8.500	1.073
Total Nitrogen as N	mg/L	401	1.794	0.240	5.520	0.897
pH		383	8.80	7.40	9.87	0.36
Total Phosphorus as P	mg/L	501	0.233	0.002[1]	1.940	0.336
Potassium (K)	mg/L	384	34.0	3.1	356.0	37.0
Sodium (Na)	mg/L	384	299.6	16.9	4680.0	514.5
Sulfate (SO4)	mg/L	383	625	34	10500	885

[1]Equal to the lower reporting limit
[2]Data collected from 64 natural and enhanced Lakes between 1991 and 2010

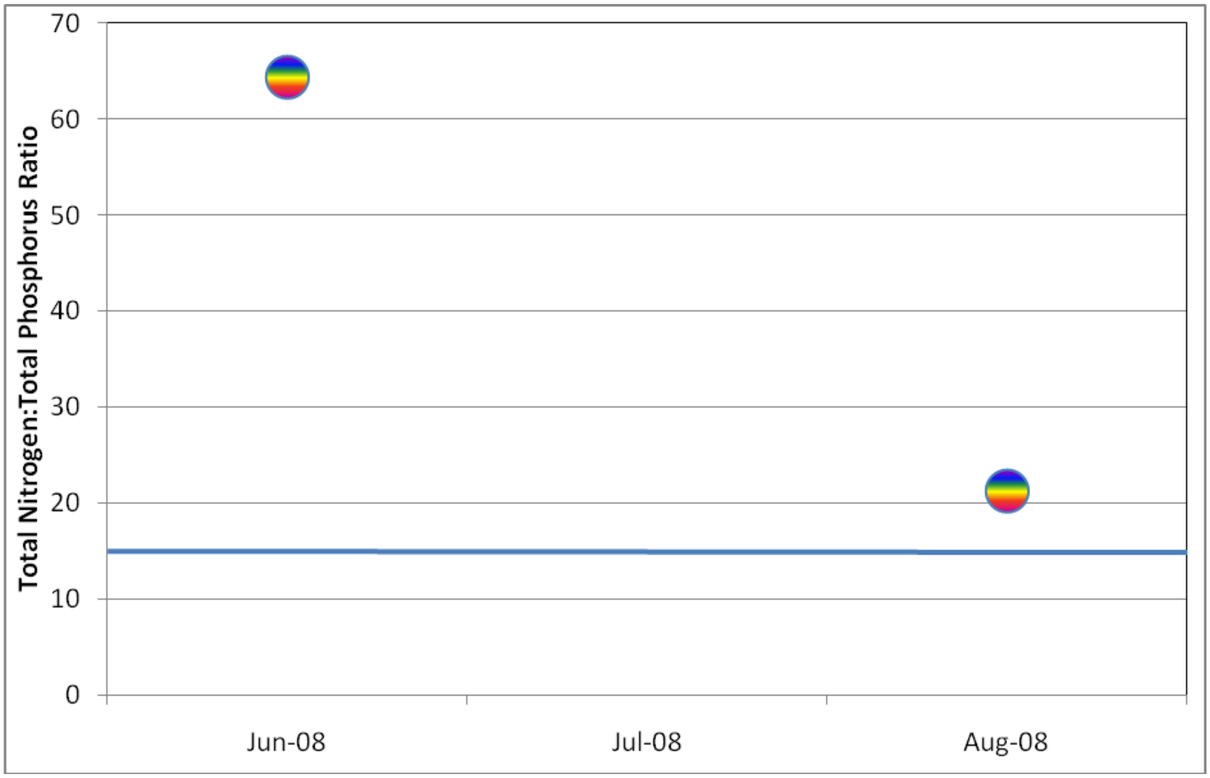

Figure 7. Harmony Lake's Total Nitrogen to Total Phosphorus Ratio

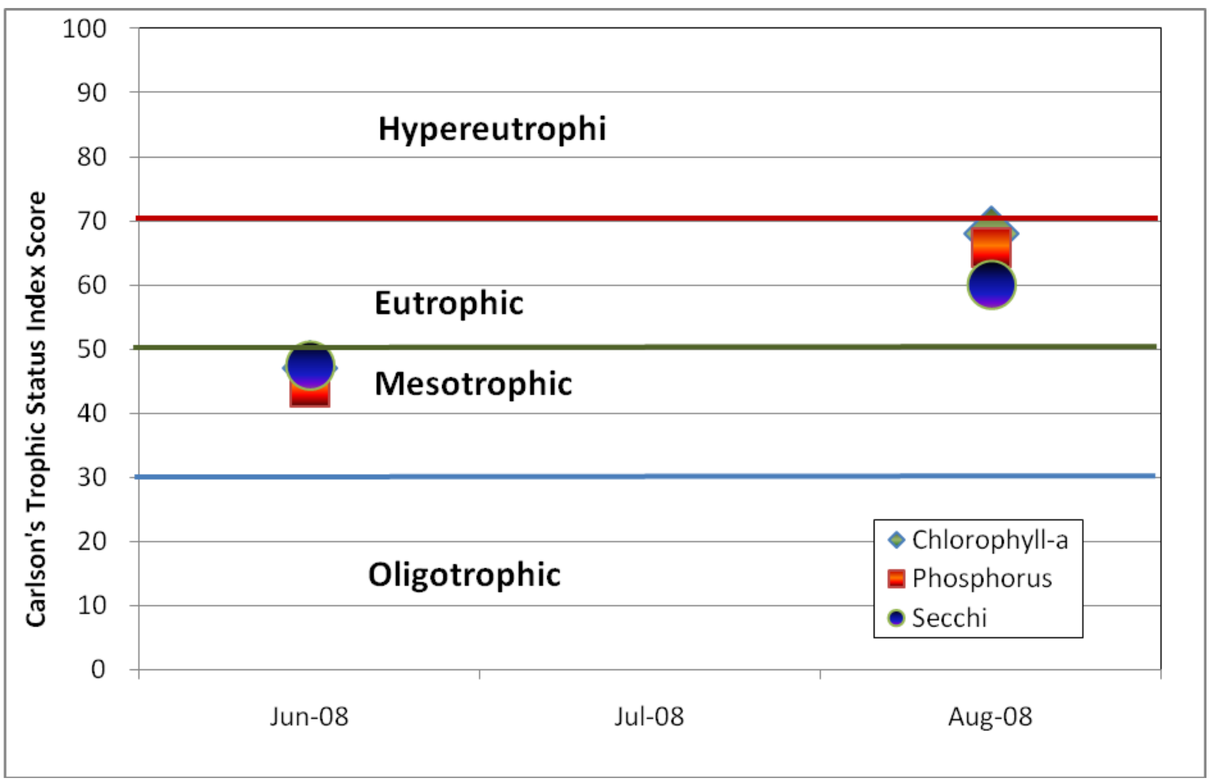

Figure 8. Harmony Lake's TSI Scores

Stanley City Pond, Mountrail County

BACKGROUND

Location: Stanley City Pond is a small impoundment on the northeast corner of Stanley, North Dakota (Figure 1). While small and somewhat hidden away the lake receives a fair amount of activity by the local town and surrounding community. The fishery is managed by the North Dakota game and Fish Department (NDG&F). Fish species recently stocked by the NDG&F are channel catfish, rainbow trout and largemouth bass.

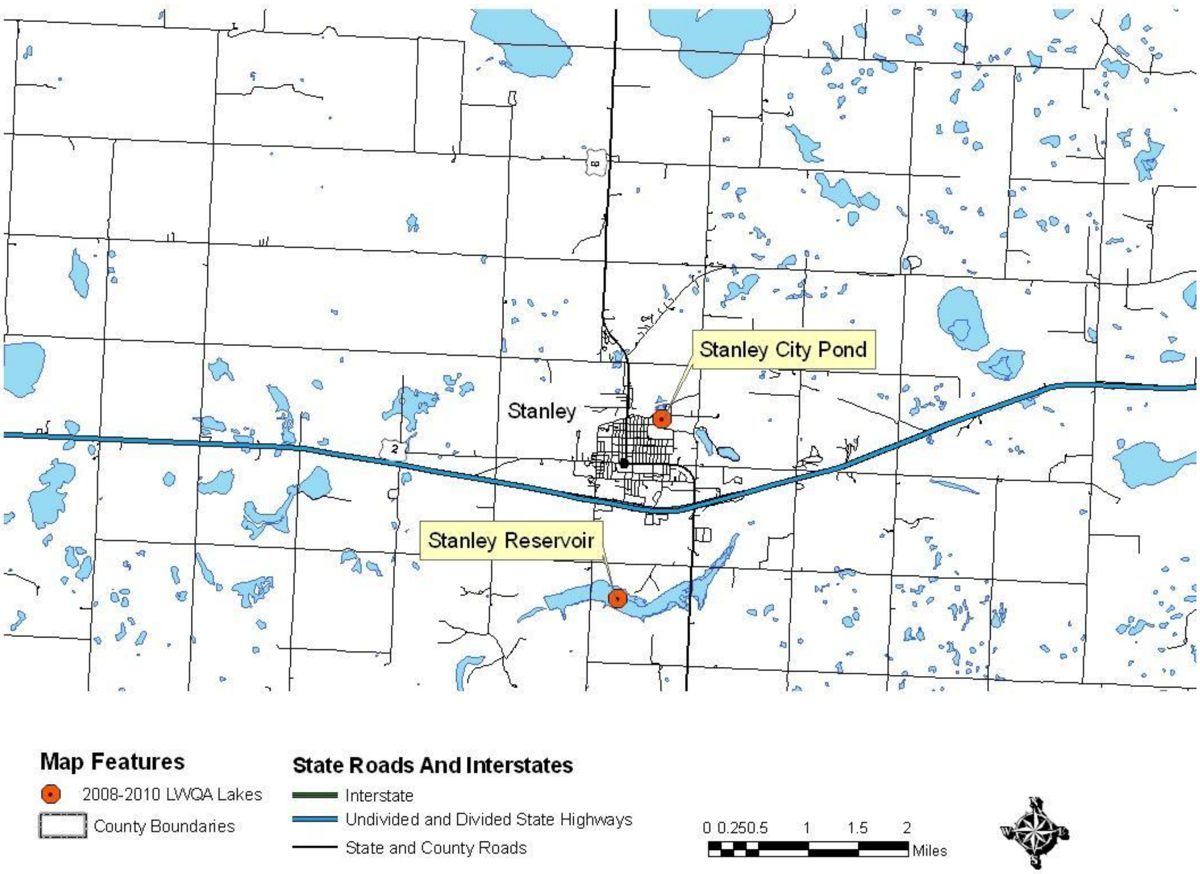

Figure 1. Location of Stanley City Pond

Physiographic/Ecological Setting: Stanley City Pond has a surface area of 8.1 acres a maximum depth of 22.4 ft and an average depth of 8.4 ft (Figure 2). The reservoir is located in the Northwestern Great Plains Level III Ecoregion, which is part of the broader Rangeland Plains Region (Figures 3 and 4).

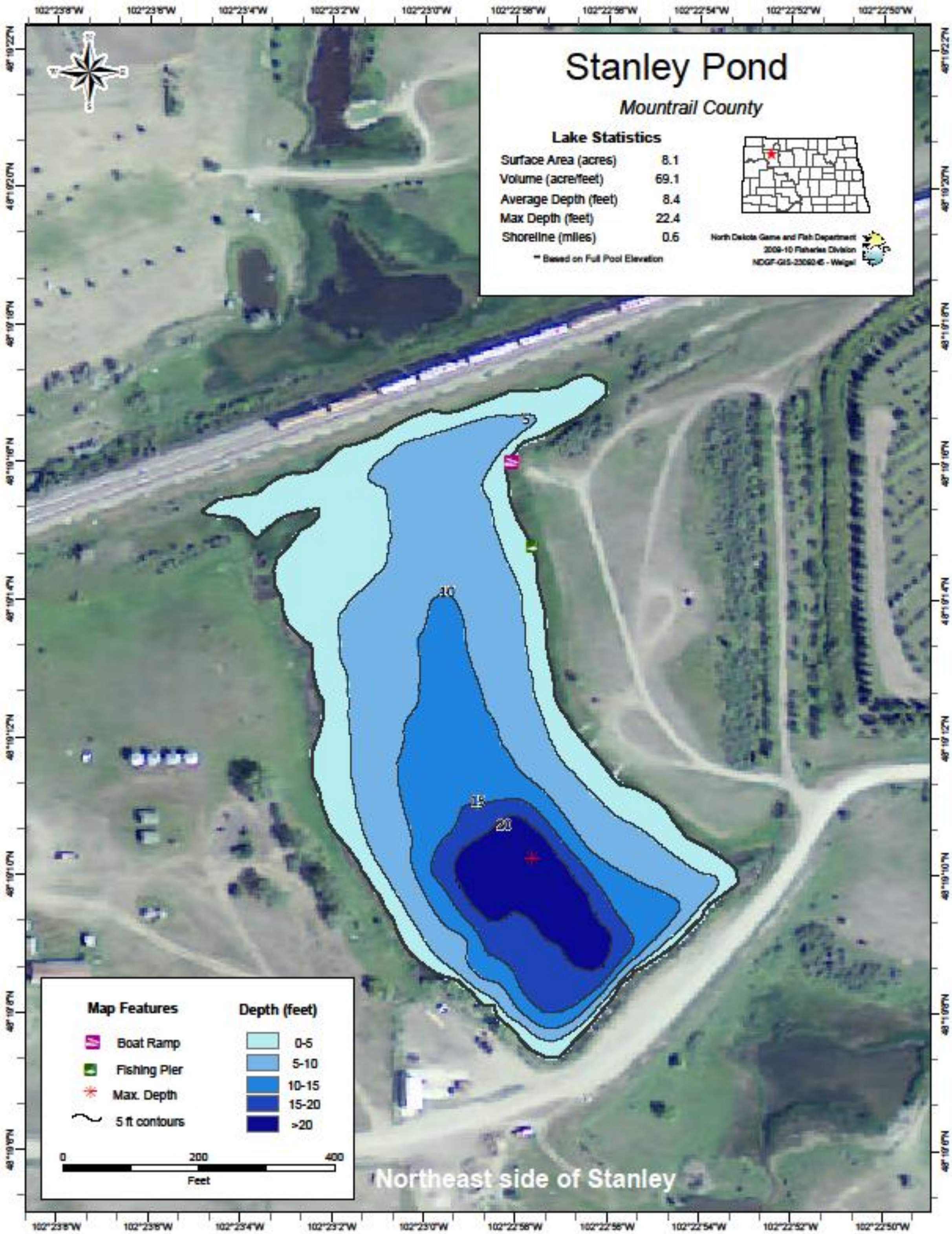

Figure 2. Contour Map of Stanley City Pond (Map Courtesy of North Dakota Game and Fish Department)

Recreational Facilities: Recreational facilities at Stanley City Pond include a boat ramp, picnic grounds and fishing pier. The boat ramp is primitive and lopsided but functional and the park and fishing pier are excellent and well maintained.

Water Quality Standards Classification: Stanley City Pond is classified in the state "Standards of Quality for Waters of the State" (NDDoH, 2011) as a class 3 lake. Class 3 lakes or impoundments are defined as a "warm water fishery" or "waters capable of supporting natural reproduction and growth of warm water fishes (e.g., largemouth bass and bluegills).

Historical Water Quality Sampling: No historical water quality data.

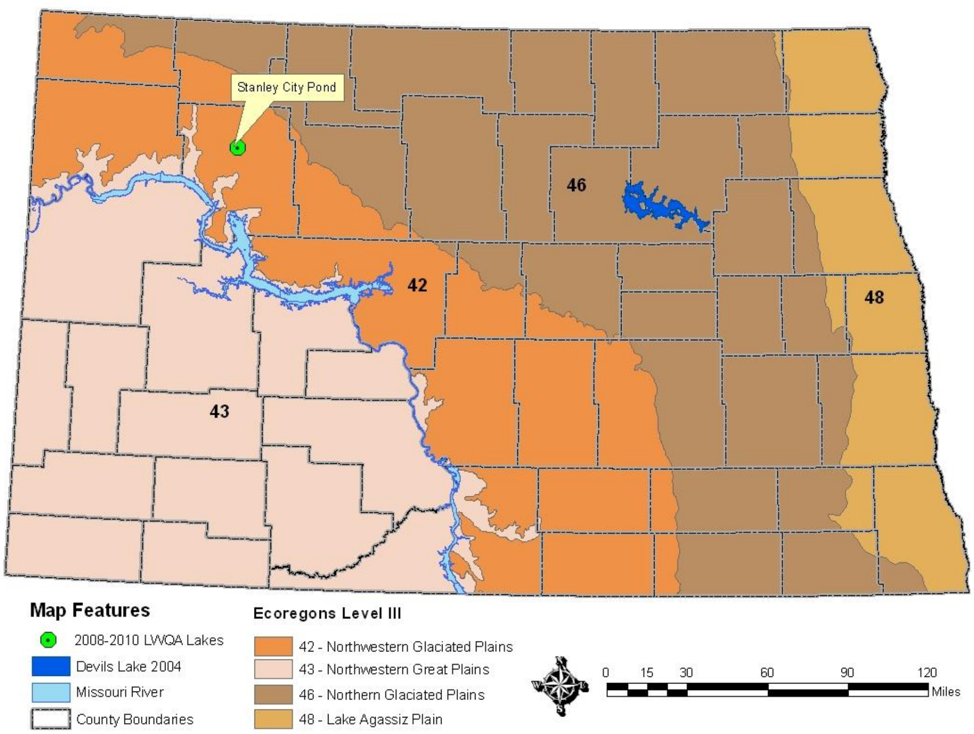

Figure 3. Stanley City Pond's Location and the Level III Ecoregions

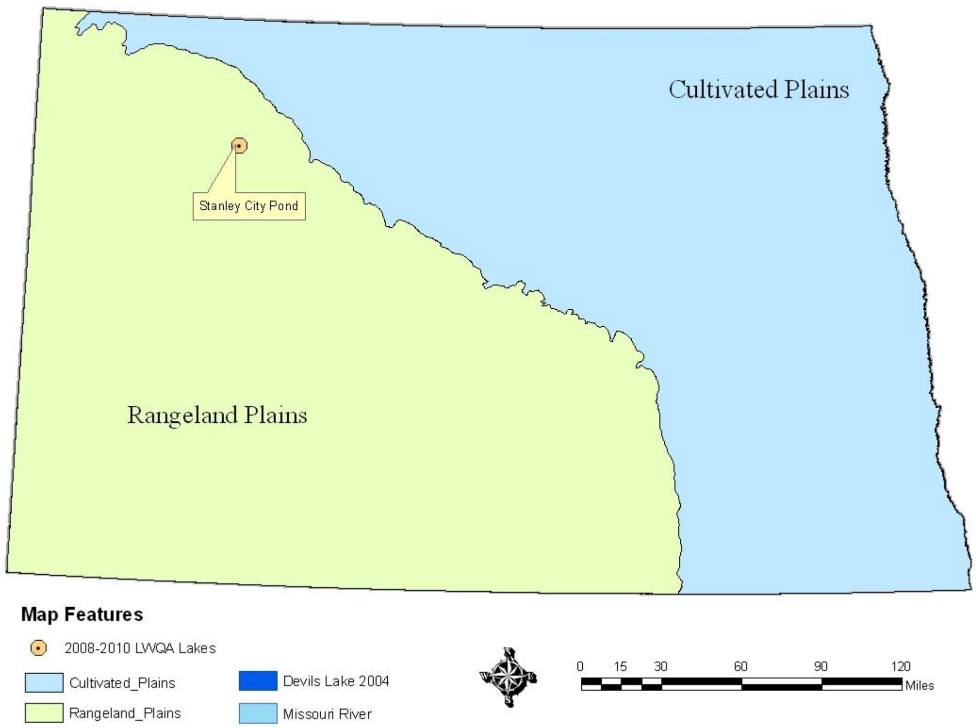

Figure 4. Stanley City Pond's Location and the Cultivated and Rangeland Plans Regions

WATER QUALITY MONITORING RESULTS

The water quality assessment for Stanley City Pond is presented in four general categories: 1) temperature and dissolved oxygen profile results; 2) general water quality characterization; 3) nutrient limitation; and 4) trophic status. Additionally, where appropriate, results have been compared to the regional data on reservoirs in the Cultivated Plains region.

Temperature and Dissolved Oxygen Profile Results: There are three temperature and dissolved oxygen profiles for Stanley City Pond collected in 2009. The profile data shows that the water body was weakly thermally stratified with 1.5 and 2.5 meters of the bottom on all three visits. While most of the water column remained very well oxygenated there is rapid and near complete oxygen decay below the thermally stratified layer (Figures 5 and 6).

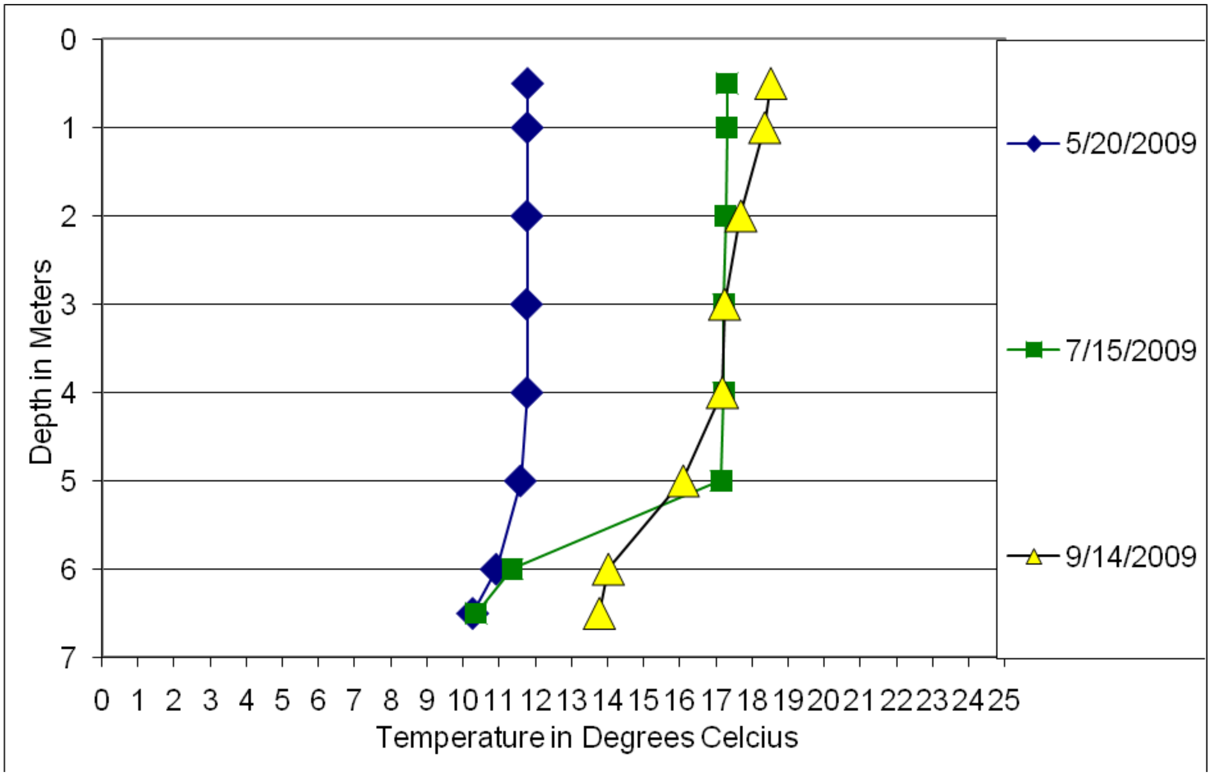

Figure 5. Temperature Profiles for Stanley City Pond

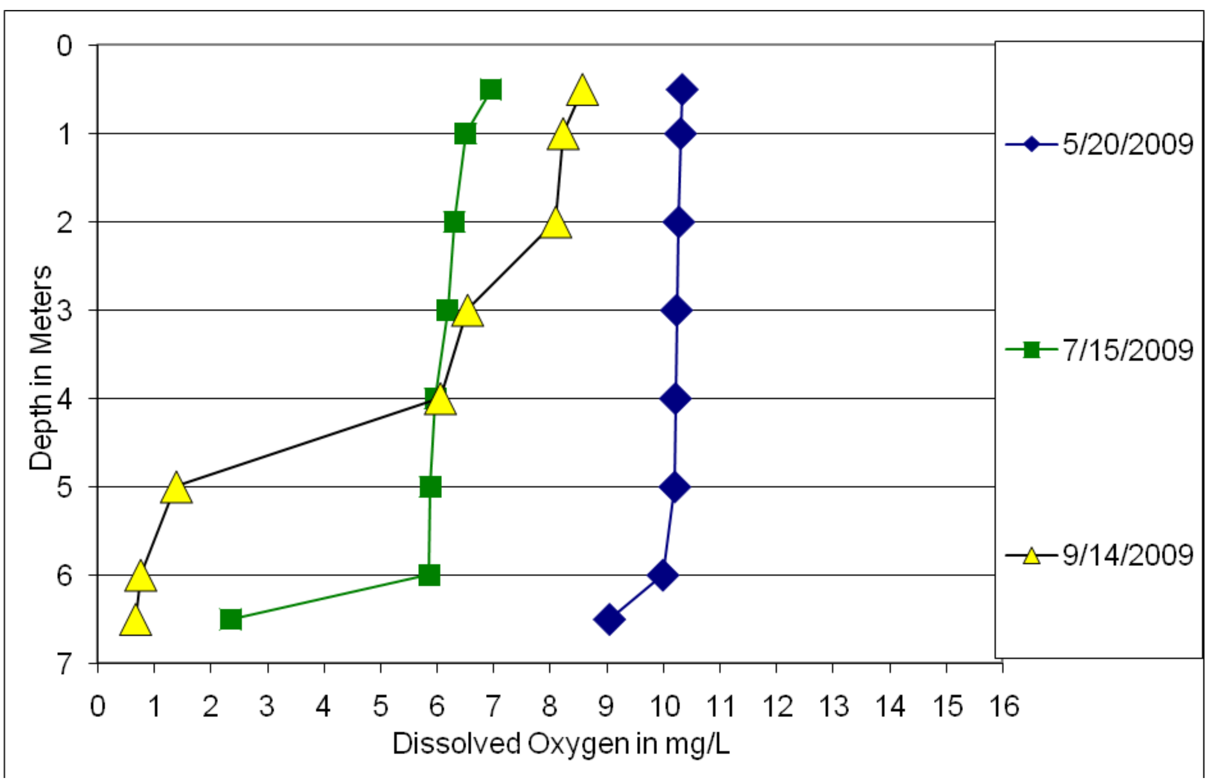

Figure 6. Dissolved Oxygen Profiles for Stanley City Pond

General Water Quality: Data collected in 2009 indicates that Stanley City Pond is well buffered with total alkalinity as $CaCO_3$ concentrations ranging from 186 to 211 mg/L (Table 1). The lake is sodium sulfate dominated with an average sodium concentration of 139.7 mg/L and an average sulfate concentration of 628 mg/L. The average total dissolved solids concentration and specific conductance measurements for the 2009 sampling period were 1163 mg/L and 1650 µmhos/cm, respectively, and the average total nitrogen as N and total phosphorus as P concentrations were 1.227 mg/L and 0.049 mg/L respectively.

When compared to the regional average water quality for impoundments in the Rangeland Plans region, Stanley City Pond is fairly average for dissolved solids and total nitrogen but measurably poorer for total phosphorus (Table 3). For example, the regional average TDS, total nitrogen, and total phosphorus concentrations are 1107 mg/L, 1.314 mg/L, and 0.128 mg/L respectively, compared to Stanley City Pond's average TDS, total nitrogen, and total phosphorus concentrations of 1163 mg/L, 1.227 mg/L and 0.049 mg/L respectively.

Table 1. Statistical Summary of Stanley City Pond's 2009 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	3	199	186	211	13
Total Ammonia as N	mg/L	3	0.084	0.030[1]	0.138	0.054
Bicarbonate (HCO_3)	mg/L	3	243	226	258	16
Calcium (Ca)	mg/L	3	96.2	94.7	98.3	1.9
Carbonate (CO_3)	mg/L	3	1[1]	1[1]	1[1]	0
Chloride (Cl)	mg/L	3	63	63	65	1
Chlorophyll-a	µg/L	2	33.0	24.8	41.1	11.5
Specific Conductance	µmhos	3	1650	1630	1680	26
Total Dissolved Solids	mg/L	3	1163	1140	1190	25
Total Hardness as ($CaCO_3$)	mg/L	3	662	655	674	11
Hydroxide (OH)	mg/L	3	1.0[1]	1.0[1]	1.0[1]	0.0
Iron (Fe)	mg/L	3	0.103	0.091	0.110	0.010
Magnesium (Mg)	mg/L	3	102.3	101.0	104.0	1.5
Nitrate + Nitrite as N	mg/L	3	0.030[1]	0.030[1]	0.030[1]	0.000
Total Kjeldahl Nitrogen as N	mg/L	3	1.197	0.911	1.350	0.248
Total Nitrogen as N	mg/L	3	1.227	0.941	1.380	0.248
pH		3	8.13	8.02	8.29	0.14
Total Phosphorus as P	mg/L	3	0.049	0.021	0.074	0.027
Potassium (K)	mg/L	3	10.1	9.9	10.4	0.3
Sodium (Na)	mg/L	3	139.7	127.0	151.0	12.1
Sulfate (SO4)	mg/L	3	628	610	650	20

[1]Equal to the lower reporting limit

Table 2. Statistical Summary of Water Quality Data[2] Collected from Reservoirs and Impoundments in the Rangeland Plains Ecological Region of North Dakota

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	522	283	54	982	131
Total Ammonia as N	mg/L	593	0.092	0.001[1]	2.440	0.183
Bicarbonate (HCO_3)	mg/L	522	295	14	1040	145
Calcium (Ca)	mg/L	522	52.3	4.7	163.0	27.3
Carbonate (CO_3)	mg/L	520	25	1[1]	197	29
Chloride (Cl)	mg/L	522	13	3[1]	75	9
Chlorophyll-a	µg/L	415	20.1	1.5[1]	218.0	27.0
Specific Conductance	µmhos	542	1621	173	5880	988
Total Dissolved Solids	mg/L	523	1107	100	5110	782
Total Hardness as ($CaCO_3$)	mg/L	522	396	45	2100	279
Hydroxide (OH)	mg/L	465	1.0	0.0[1]	1.0	0.2
Iron (Fe)	mg/L	523	0.193	0.007	4.110	0.349
Magnesium (Mg)	mg/L	522	64.5	5.6	412.0	54.0
Nitrate + Nitrite as N	mg/L	592	0.060	0.001[1]	0.790	0.102
Total Kjeldahl Nitrogen as N	mg/L	483	1.375	0.108	7.720	0.789
Total Nitrogen as N	mg/L	426	1.314	0.178	4.840	0.605
pH		542	8.55	6.73	9.87	0.55
Total Phosphorus as P	mg/L	599	0.128	0.004[1]	3.160	0.190
Potassium (K)	mg/L	522	13.8	2.6	39.2	6.5
Sodium (Na)	mg/L	522	217.2	3.0	932.0	171.6
Sulfate (SO4)	mg/L	520	573	1[1]	3210	519

[1]Equal to the lower reporting limit
[2]Data collected from 76 reservoirs between 1991 and 2010

Limiting Nutrients: The three water quality samples collected in 2009 indicate that Stanley City Pond is phosphorus limited (Figure 7). The limiting nutrient assessment is based on the assumption that either nitrogen or phosphorus is limiting algal growth and that the ratio of total nitrogen as N to total phosphorus as P (N:P), by weight in the average algae is approximately 15 to 1. When the N:P ratio is less than 15:1, nitrogen is assumed to be the limiting nutrient and when it exceeds 15:1, the limiting nutrient is assumed to be phosphorus.

Trophic Status Assessment: Based on the chlorophyll-a, secchi disk transparency, and total phosphorus data collected in 2009, Stanley City Pond's trophic status is estimated as eutrophic. The trophic status index (TSI) scores ranged from a low of 48 based on total phosphorus to a high of 67 based on chlorophyll-a (Figure 8).

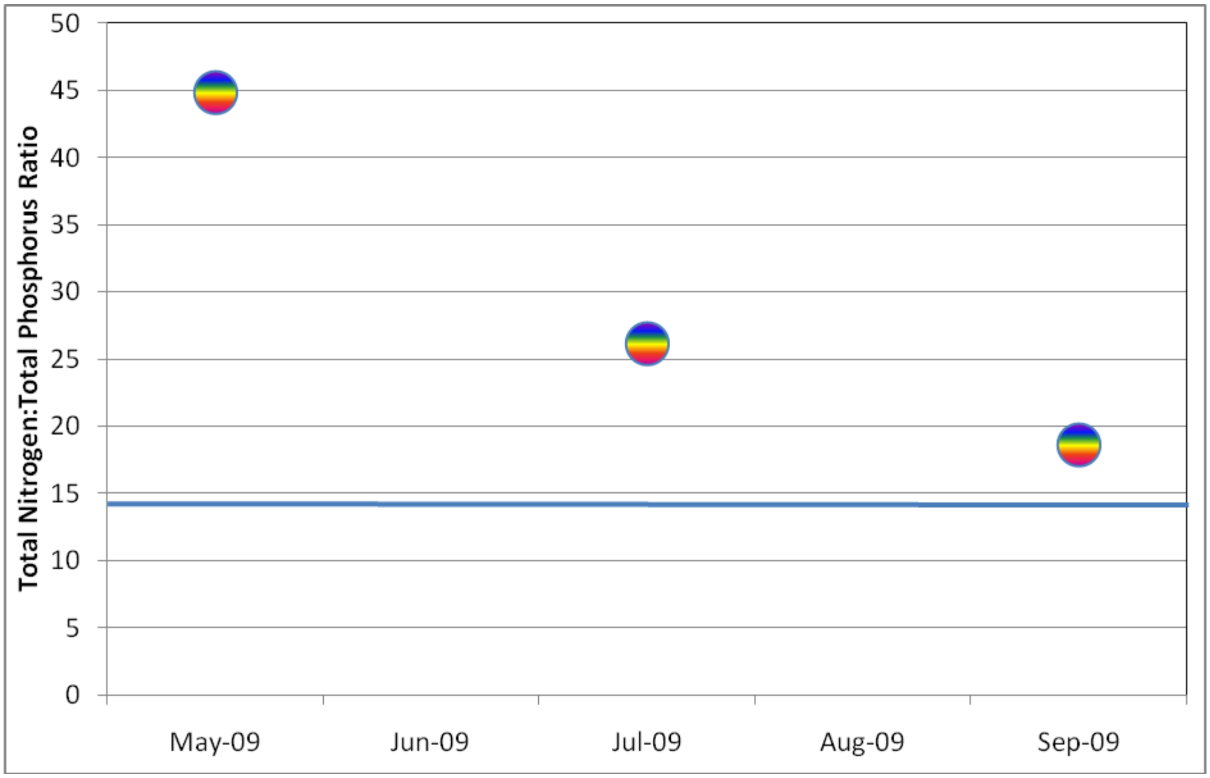

Figure 7. Stanley City Pond's Total Nitrogen to Total Phosphorus Ratio

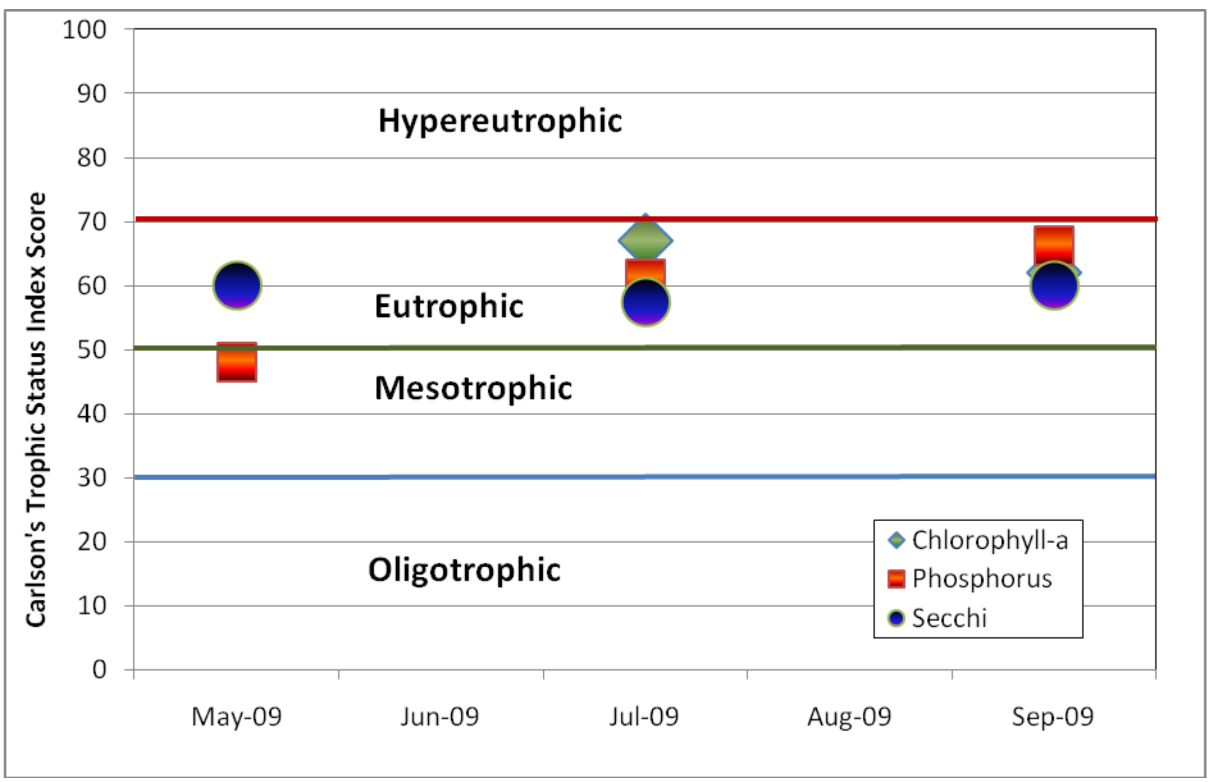

Figure 8. Stanley City Pond's TSI Scores

Stanley Reservoir, Mountrail County

BACKGROUND

Location: Stanley Reservoir is a shallow impoundment on the head waters of the Little Knife River just south of Stanley, North Dakota (Figure 1). The reservoir is relatively shallow but when given a year or two of cooperative weather it will provide some excellent northern pike and yellow perch fishing.

The fishery is managed by the North Dakota game and Fish Department (NDG&F). The most recent stocking to Stanley reservoir was in the summer of 2000, and the fish species were northern pike and yellow perch.

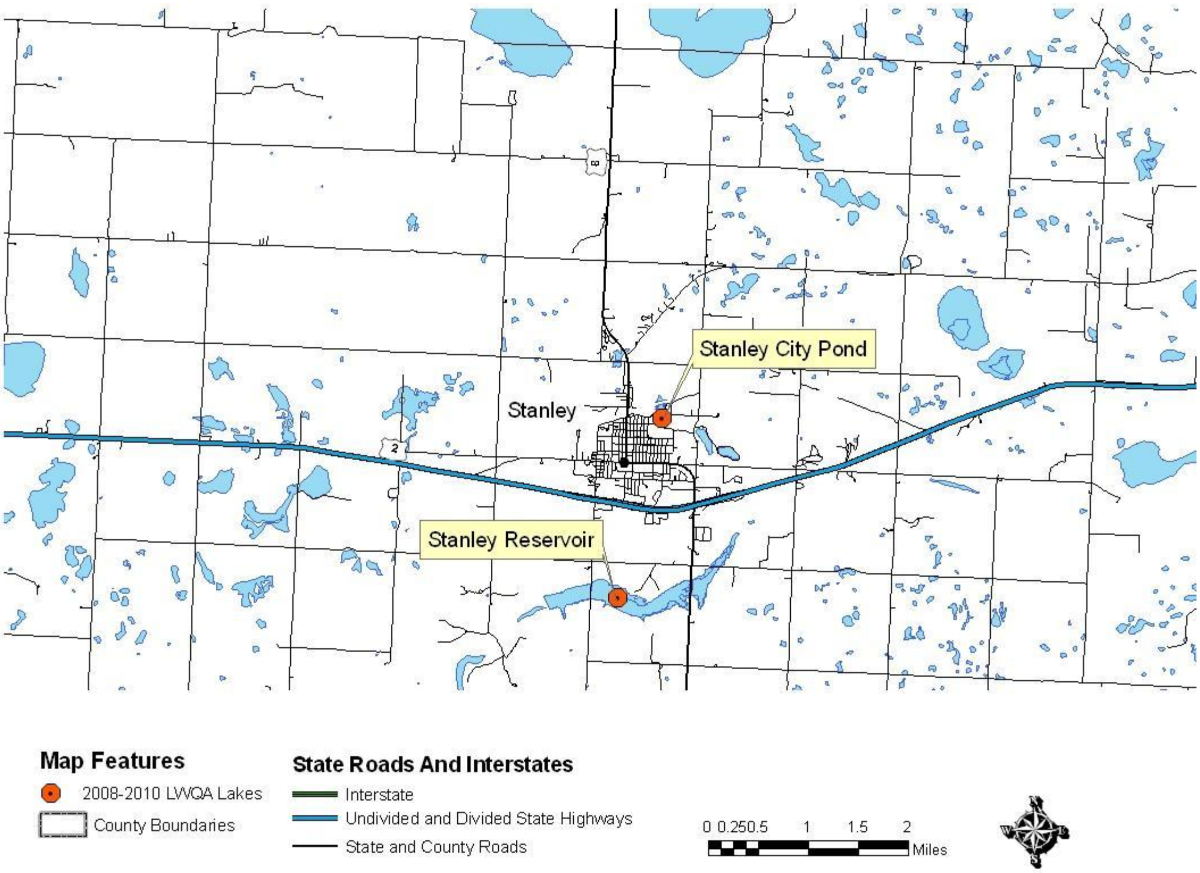

Figure 1. Location of Stanley Reservoir

Physiographic/Ecological Setting: Stanley Reservoir has a surface area of 177.2 acres a maximum depth of 11.1 ft and an average depth of 6.5 ft (Figure 2). The reservoir is located in the Northwestern Great Plains Level III Ecoregion, which is part of the broader Rangeland Plains Region (Figures 3 and 4).

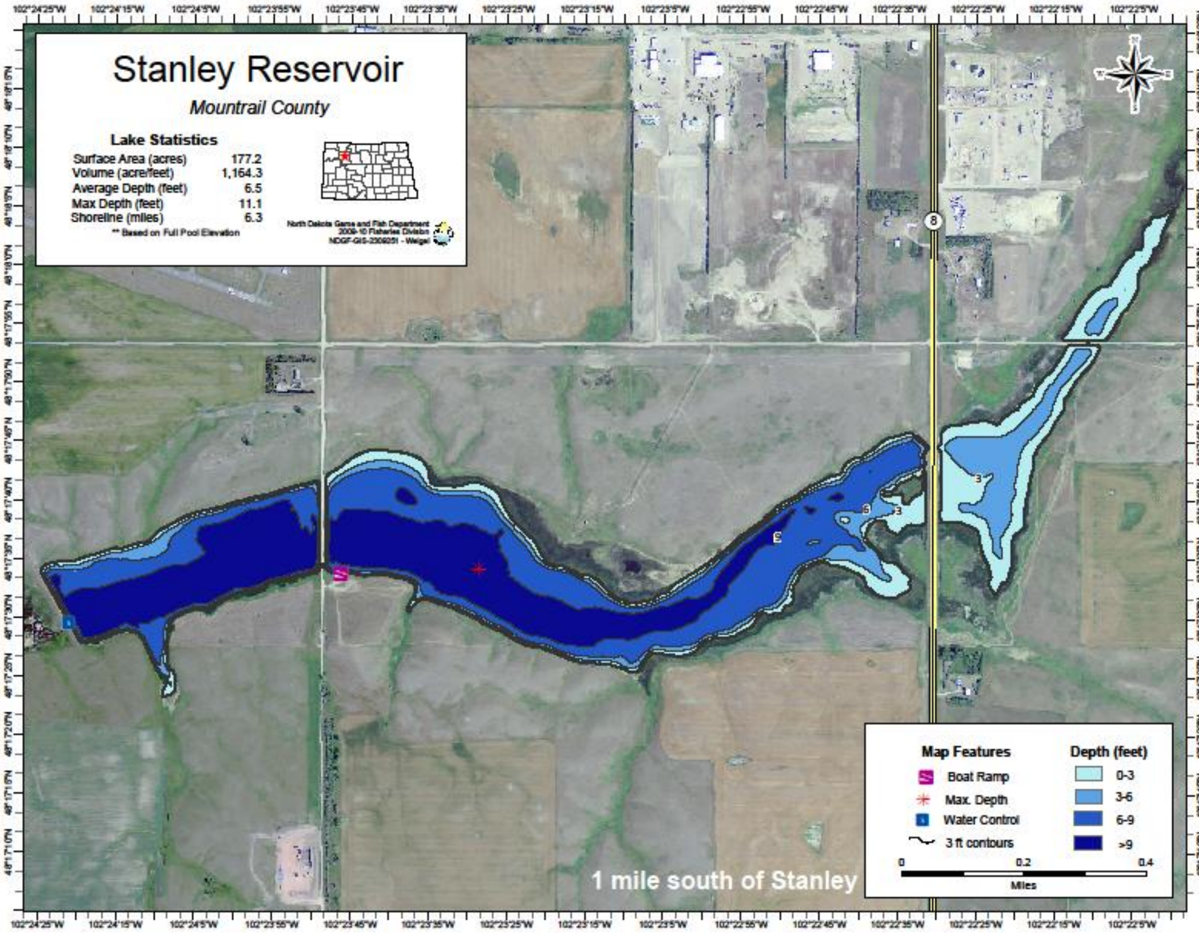

Figure 2. Contour Map of Stanley Reservoir (Map Courtesy of North Dakota Game and Fish Department)

Recreational Facilities: Recreational facilities at Stanley Reservoir include a metal boat ramp. The boat ramp is primitive, shallowly sloped and crowded by an oil field water pump, but still functional.

Water Quality Standards Classification: Stanley Reservoir is classified in the state “Standards of Quality for Waters of the State” (NDDoH, 2011) as a class 3 lake. Class 3 lakes or impoundments are defined as a “warm water fishery” or “waters capable of supporting natural reproduction and growth of warm water fishes (e.g., largemouth bass and bluegills).

Historical Water Quality Sampling: No historical water quality data.

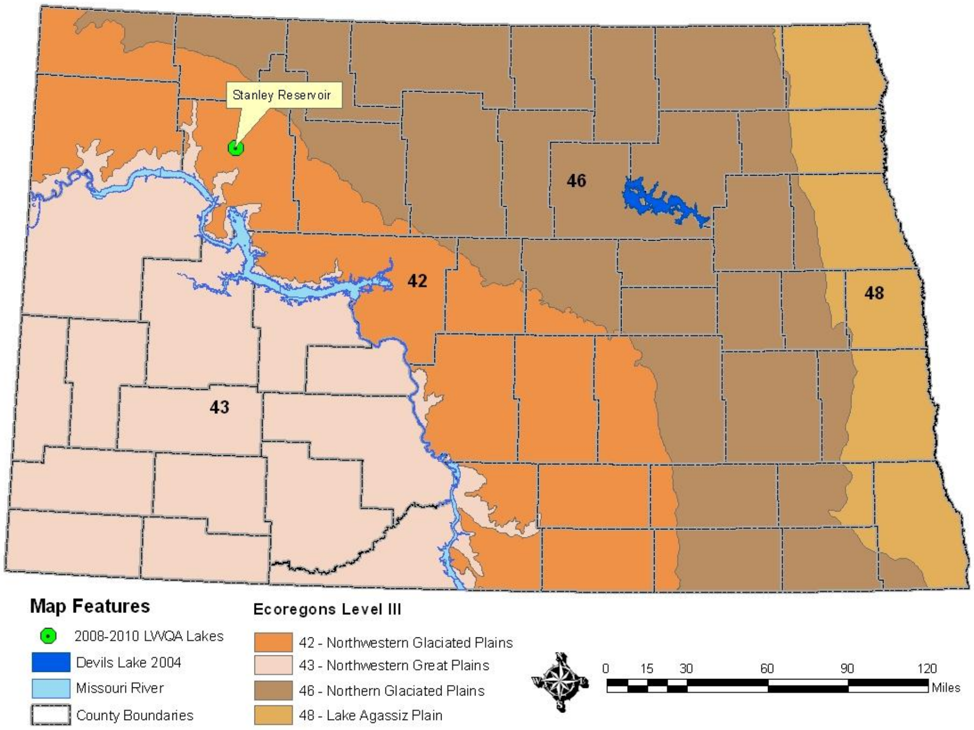

Figure 3. Stanley Reservoir's Location and the Level III Ecoregions

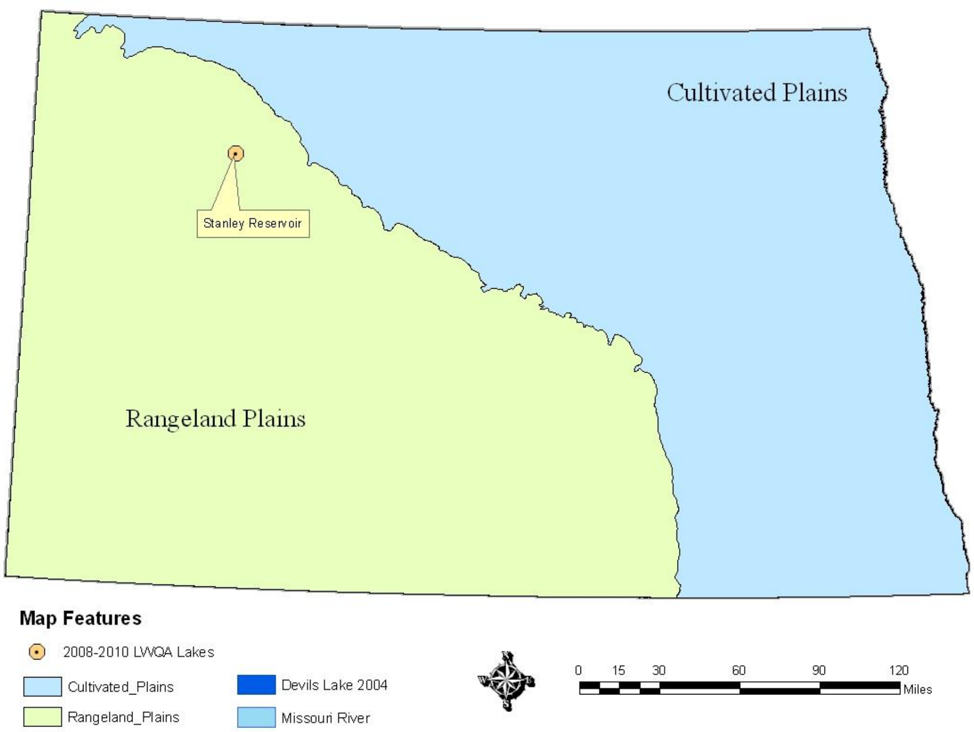

Figure 4. Stanley Reservoir's Location and the Cultivated and Rangeland Plans Regions

WATER QUALITY MONITORING RESULTS

The water quality assessment for Stanley Reservoir is presented in four general categories: 1) temperature and dissolved oxygen profile results; 2) general water quality characterization; 3) nutrient limitation; and 4) trophic status. Additionally, where appropriate, results have been compared to historical and regional water quality data.

Temperature and Dissolved Oxygen Profile Results: There are three temperature and dissolved oxygen profiles for Stanley Reservoir collected in 2009. The profile data shows that the water body lacked thermal stratified on all three visits. The lack of thermal stratification is normal on this type of shallow windswept reservoir. Additionally, the reservoirs dissolved oxygen concentrations behaved in a predictable manner remaining adequate to maintain fish and associated aquatic biota of a warm water fishery (Figures 5 and 6).

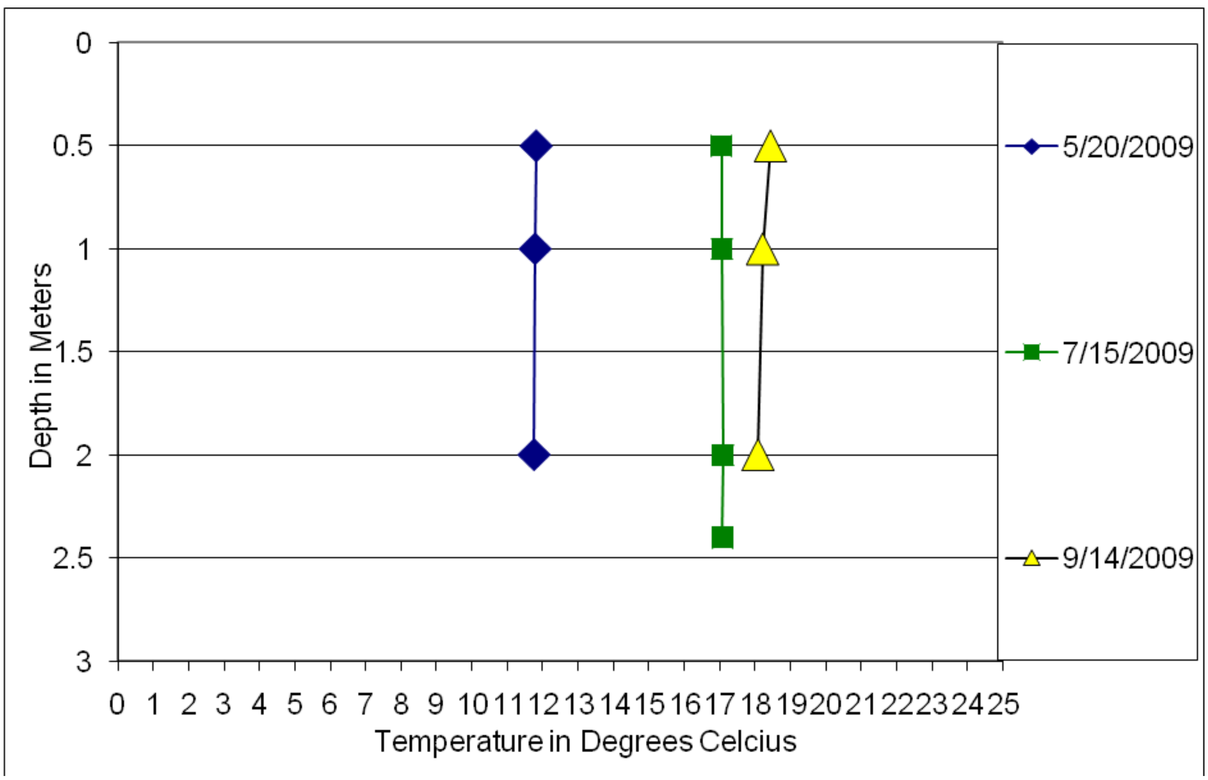

Figure 5. Temperature Profiles for Stanley Reservoir

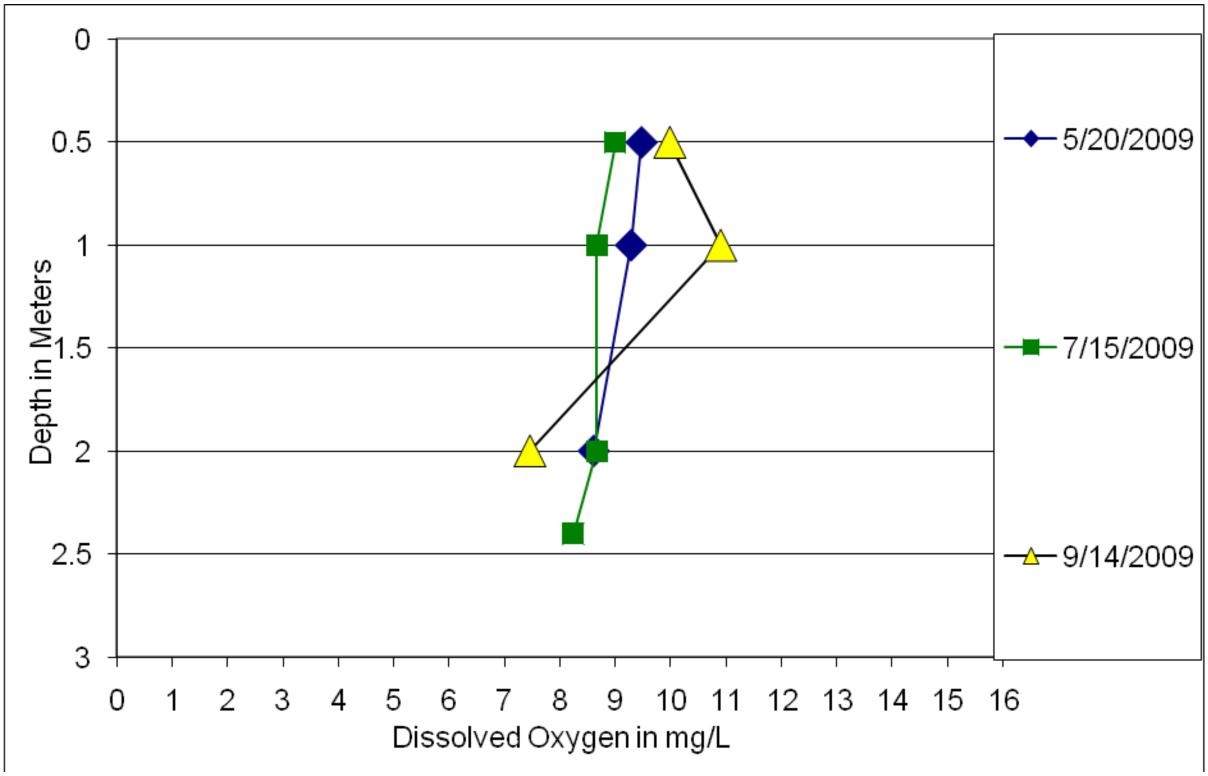

Figure 6. Dissolved Oxygen Profiles for Stanley Reservoir

General Water Quality: Data collected in 2009 indicates that Stanley Reservoir is well buffered with total alkalinity as $CaCO_3$ concentrations ranging from 574 to 708 mg/L (Table 1). The lake is sodium sulfate dominated with an average sodium concentration of 610.7 mg/L and an average sulfate concentration of 901 mg/L. The average total dissolved solids concentration and specific conductance measurements for the 2009 sampling period were 2377 mg/L and 3407 µmhos/cm, respectively, and the average total nitrogen as N and total phosphorus as P concentrations were 3.157 mg/L and 0.703 mg/L respectively.

When compared to the regional average water quality for impoundments in the Rangeland Plans region, Stanley Reservoir has higher concentrations of dissolved solids and nutrients (Table 3). For example, the regionsl average TDS, total nitrogen, and total phosphorus concentrations are 1107 mg/L, 1.314 mg/L, and 0.128 mg/L respectively, compared to Stanley Reservoir's average TDS, total nitrogen, and total phosphorus concentrations of 2377 mg/L, 3.157 mg/L and 0.703 mg/L respectively.

Table 1. Statistical Summary of Stanley Reservoir's 2009 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	3	650	574	708	69
Total Ammonia as N	mg/L	3	0.037	0.030[1]	0.041	0.006
Bicarbonate (HCO_3)	mg/L	3	602	578	627	25
Calcium (Ca)	mg/L	3	50.8	45.2	55.3	5.2
Carbonate (CO_3)	mg/L	3	94	60	130	35
Chloride (Cl)	mg/L	3	262	246	279	17
Chlorophyll-a	µg/L	2	72.6	39.2	106.0	47.2
Specific Conductance	µmhos	3	3407	3190	3660	237
Total Dissolved Solids	mg/L	3	2377	2190	2570	190
Total Hardness as ($CaCO_3$)	mg/L	3	672	623	727	52
Hydroxide (OH)	mg/L	3	1.0[1]	1.0[1]	1.0[1]	0.0
Iron (Fe)	mg/L	3	0.394	0.254	0.468	0.121
Magnesium (Mg)	mg/L	3	132.3	124.0	143.0	9.7
Nitrate + Nitrite as N	mg/L	3	0.030[1]	0.030[1]	0.030[1]	0.000
Total Kjeldahl Nitrogen as N	mg/L	3	3.127	2.740	3.330	0.335
Total Nitrogen as N	mg/L	3	3.157	2.770	3.360	0.335
pH		3	8.88	8.76	8.96	0.11
Total Phosphorus as P	mg/L	3	0.703	0.537	0.835	0.152
Potassium (K)	mg/L	3	29.9	26.5	33.7	3.6
Sodium (Na)	mg/L	3	610.7	571.0	636.0	34.8
Sulfate (SO4)	mg/L	3	901	832	1000	88

[1]Equal to the lower reporting limit

Limiting Nutrients: The three water quality samples collected in 2009 indicate that Stanley Reservoir is nitrogen limited (Figure 7). The limiting nutrient assessment is based on the assumption that either nitrogen or phosphorus is limiting algal growth and that the ratio of total nitrogen as N to total phosphorus as P (N:P), by weight in the average algae is approximately 15 to 1. When the N:P ratio is less than 15:1, nitrogen is assumed to be the limiting nutrient and when it exceeds 15:1, the limiting nutrient is assumed to be phosphorus.

Trophic Status Assessment: Based on the chlorophyll-a, secchi disk transparency, and total phosphorus data collected in 2009, Stanley Reservoir's trophic status is estimated as hypereutrophic. The trophic status index (TSI) scores ranged from a low of 59 based on secchi disk to a high of 101 based on total phosphorus (Figure 8).

Table 2. Statistical Summary of Water Quality Data[2] Collected from Reservoirs and Impoundments in the Rangeland Plains Ecological Region of North Dakota

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	522	283	54	982	131
Total Ammonia as N	mg/L	593	0.092	0.001[1]	2.440	0.183
Bicarbonate (HCO_3)	mg/L	522	295	14	1040	145
Calcium (Ca)	mg/L	522	52.3	4.7	163.0	27.3
Carbonate (CO_3)	mg/L	520	25	1[1]	197	29
Chloride (Cl)	mg/L	522	13	3[1]	75	9
Chlorophyll-a	µg/L	415	20.1	1.5[1]	218.0	27.0
Specific Conductance	µmhos	542	1621	173	5880	988
Total Dissolved Solids	mg/L	523	1107	100	5110	782
Total Hardness as ($CaCO_3$)	mg/L	522	396	45	2100	279
Hydroxide (OH)	mg/L	465	1.0	0.0[1]	1.0	0.2
Iron (Fe)	mg/L	523	0.193	0.007	4.110	0.349
Magnesium (Mg)	mg/L	522	64.5	5.6	412.0	54.0
Nitrate + Nitrite as N	mg/L	592	0.060	0.001[1]	0.790	0.102
Total Kjeldahl Nitrogen as N	mg/L	483	1.375	0.108	7.720	0.789
Total Nitrogen as N	mg/L	426	1.314	0.178	4.840	0.605
pH		542	8.55	6.73	9.87	0.55
Total Phosphorus as P	mg/L	599	0.128	0.004[1]	3.160	0.190
Potassium (K)	mg/L	522	13.8	2.6	39.2	6.5
Sodium (Na)	mg/L	522	217.2	3.0	932.0	171.6
Sulfate (SO4)	mg/L	520	573	1[1]	3210	519

[1]Equal to the lower reporting limit
[2]Data collected from 76 reservoirs between 1991 and 2010

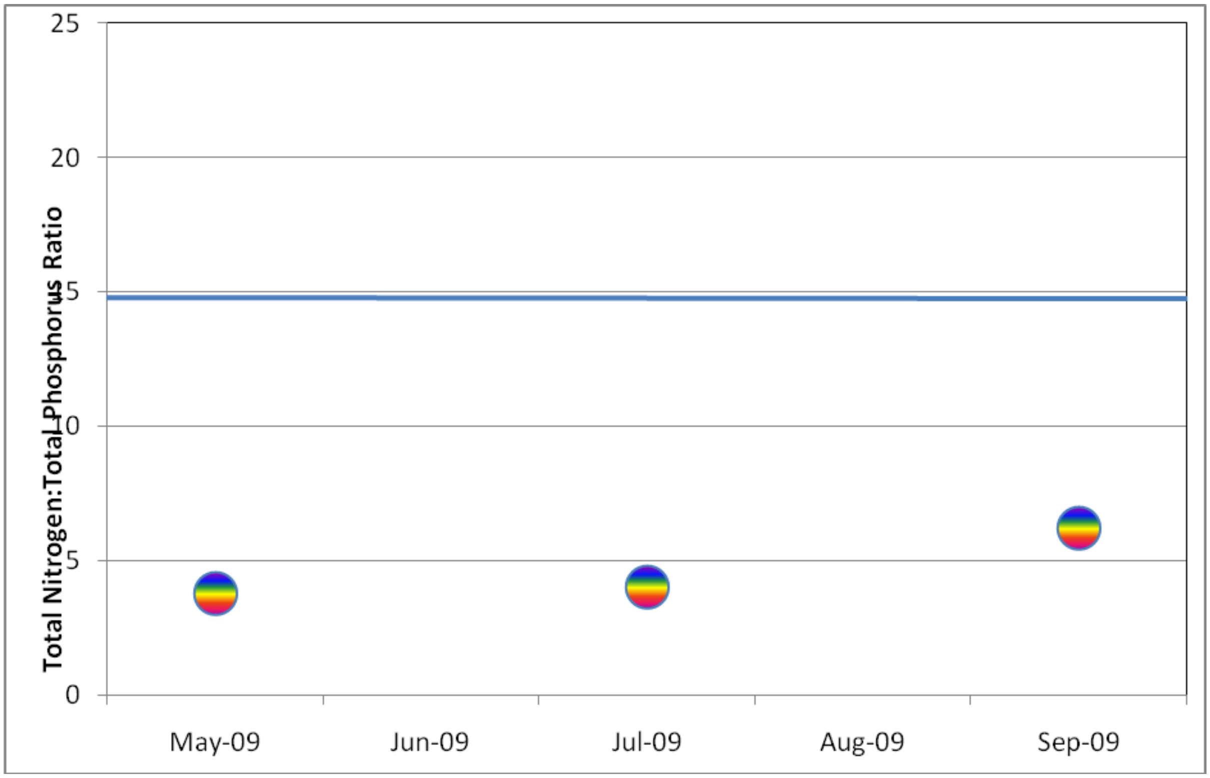

Figure 7. Stanley Reservoir's Total Nitrogen to Total Phosphorus Ratio

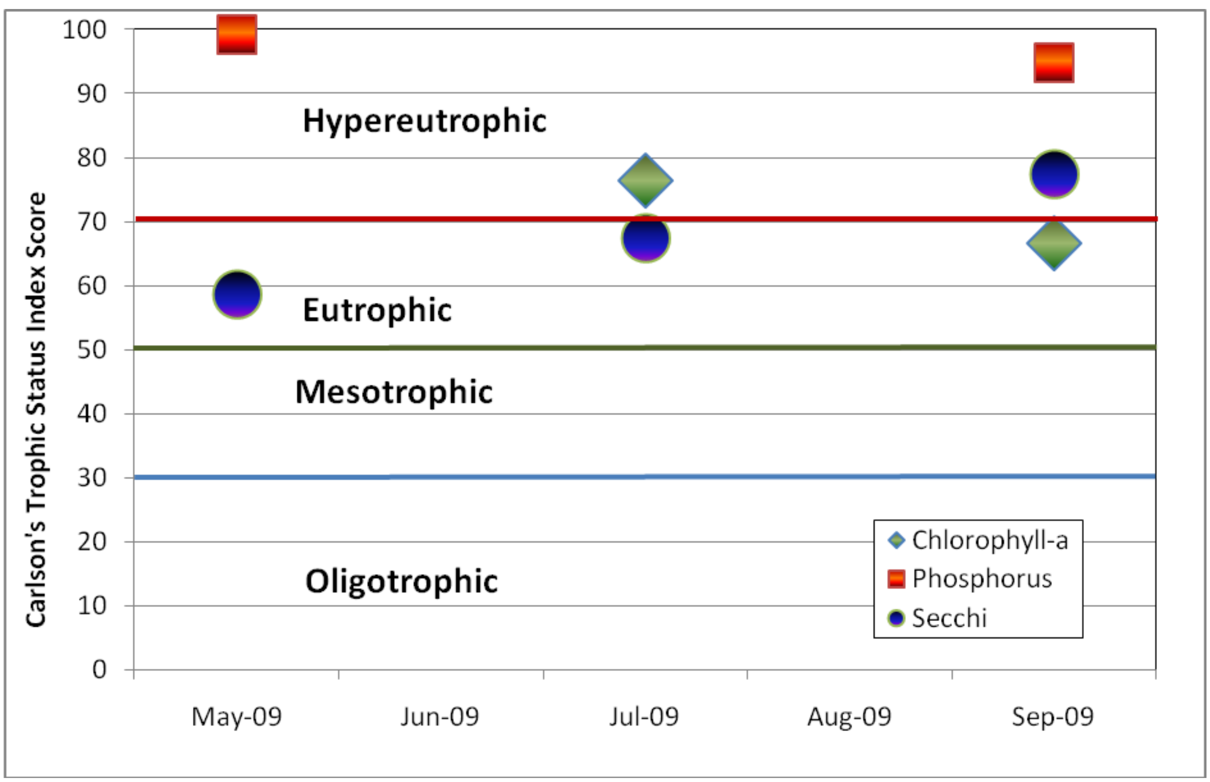

Figure 8. Stanley Reservoir's TSI Scores

Tolna Dam, Nelson County

BACKGROUND

Location: Tolna Dam is small reservoir on Tolna Coulee, a tributary of the Sheyenne River on the southeast edge of the town of Tolna, North Dakota (Figure 1). The Tolna Coulee is the natural outlet to the Devils Lake.

Tolna Dam's fishery is managed by the North Dakota game and Fish Department (NDG&F). The most recent stocking to Tolna Dam fish species stocked were walleye, northern pike and black crappie.

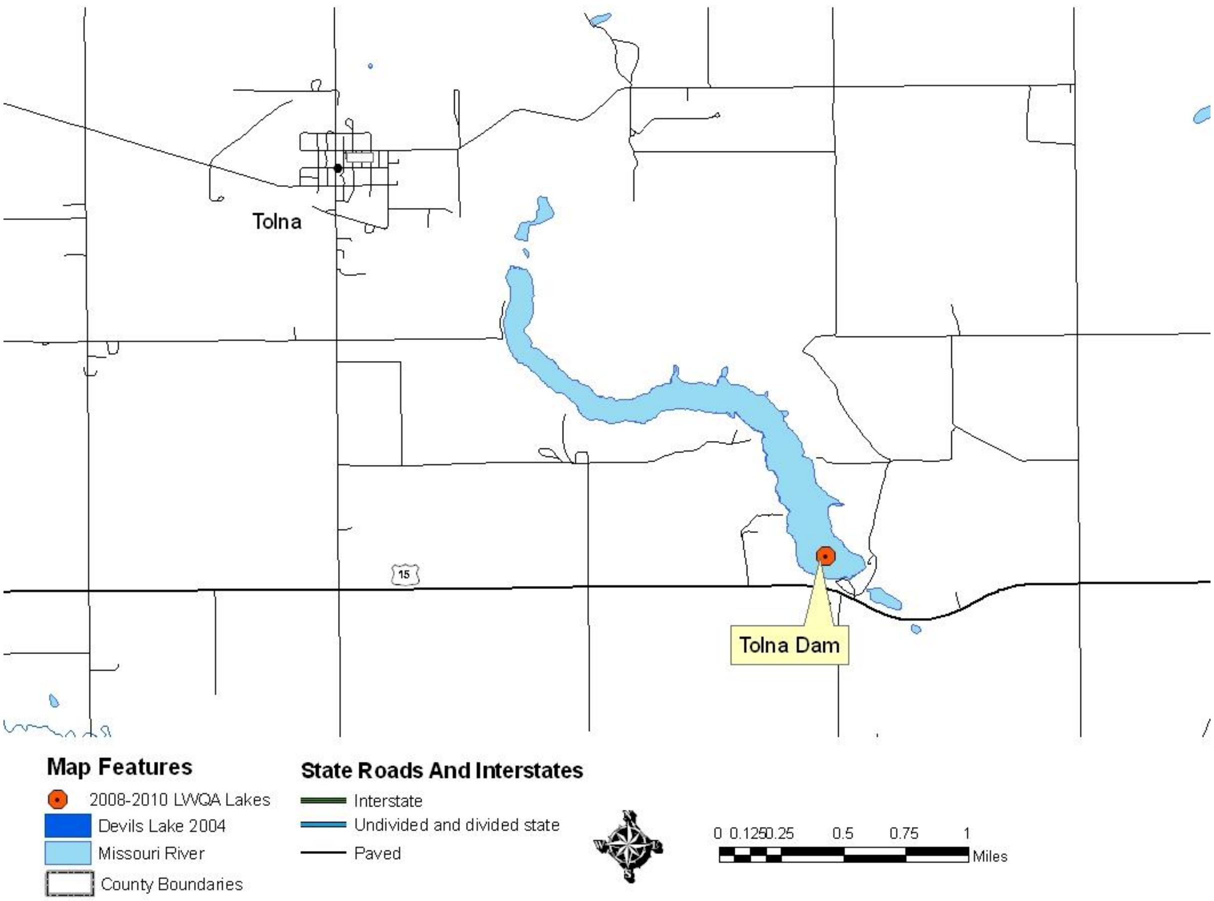

Figure 1. Location of Tolna Dam

Physiographic/Ecological Setting: Tolna Dam has a surface area of 164.6 acres a maximum depth of 22.8 ft and an average depth of 9.8 ft (Figure 2). The reservoir is located in the Northern Glaciated Plains Level III Ecoregion, which is part of the broader Cultivated Plains Region (Figures 3 and 4).

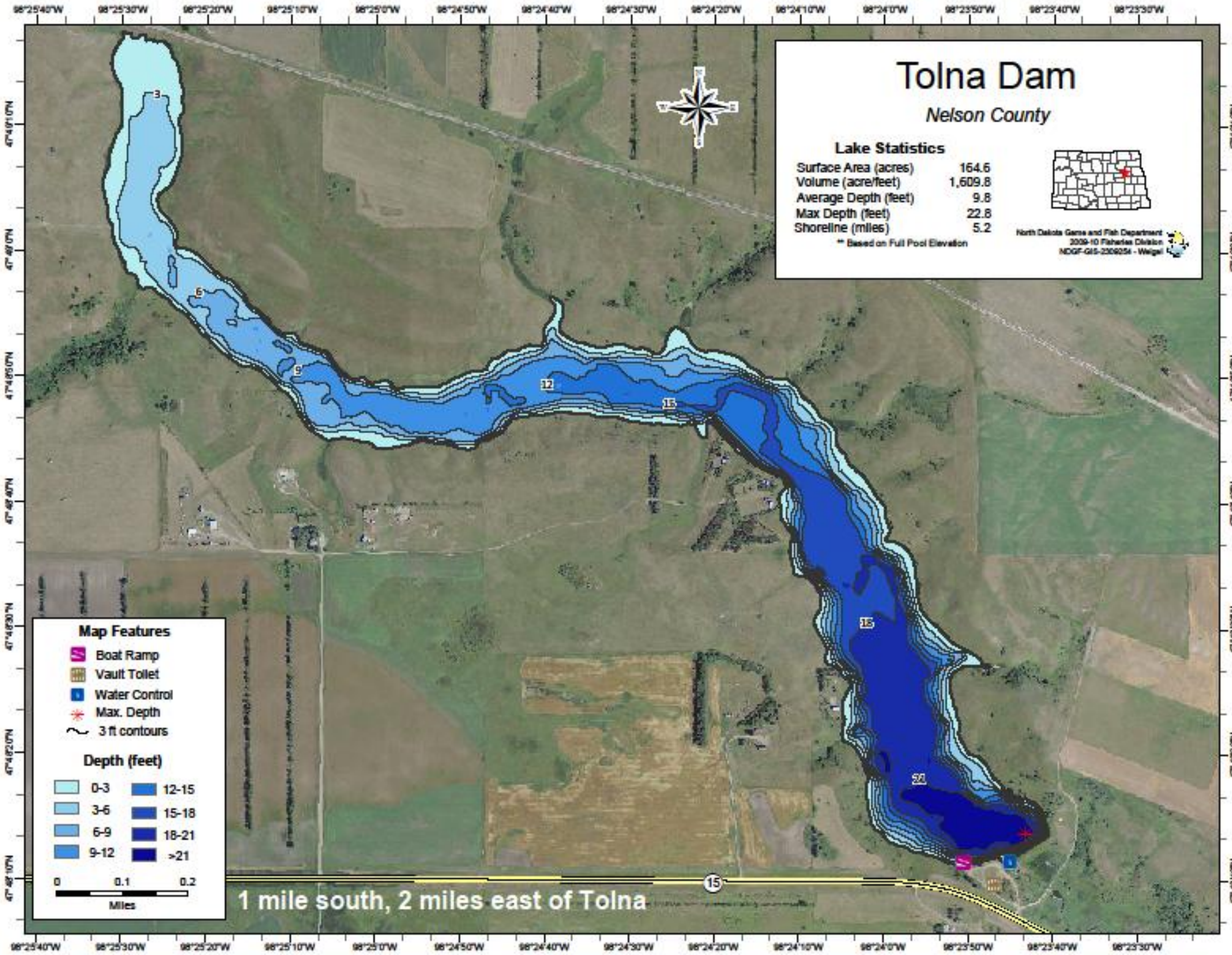

Figure 2. Contour Map of Tolna Dam (Map Courtesy of North Dakota Game and Fish Department)

Recreational Facilities: Recreational facilities at Tolna Dam include a cement boat ramp, courtesy dock, vault toilets and picnic area.

Water Quality Standards Classification: Tolna Dam is classified in the state "Standards of Quality for Waters of the State" (NDDoH, 2011) as a class 3 lake. Class 3 lakes or impoundments are defined as a "warm water fishery" or "waters capable of supporting natural reproduction and growth of warm water fishes (e.g., largemouth bass and bluegills).

Historical Water Quality Sampling: Historical data include three samples collected in 1992 and 1993.

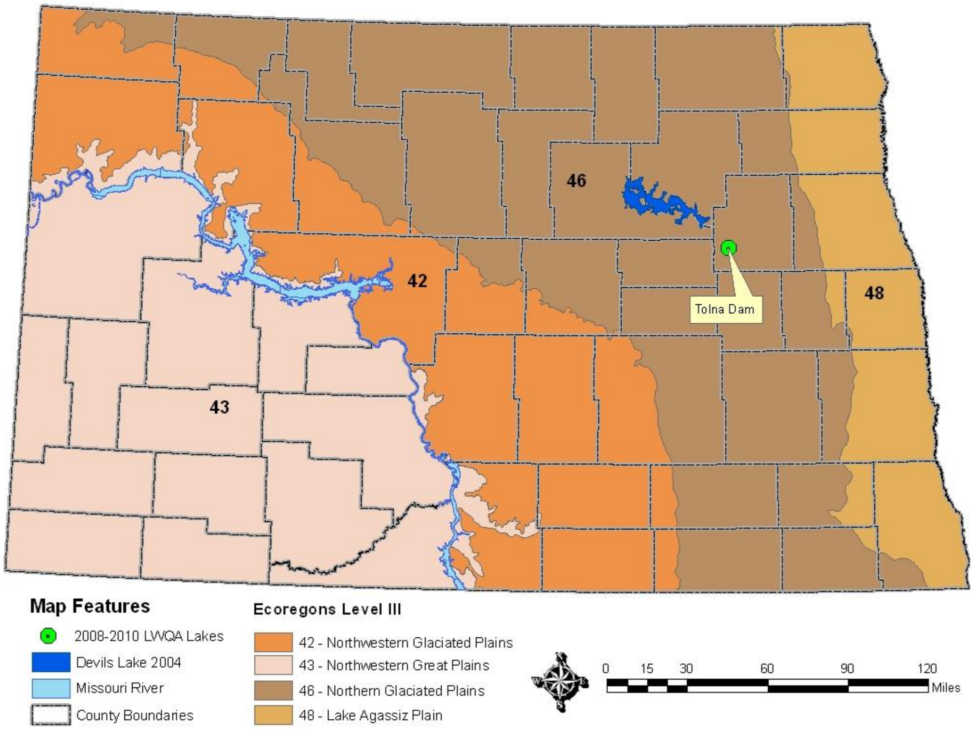

Figure 3. Tolna Dam's Location and the Level III Ecoregions

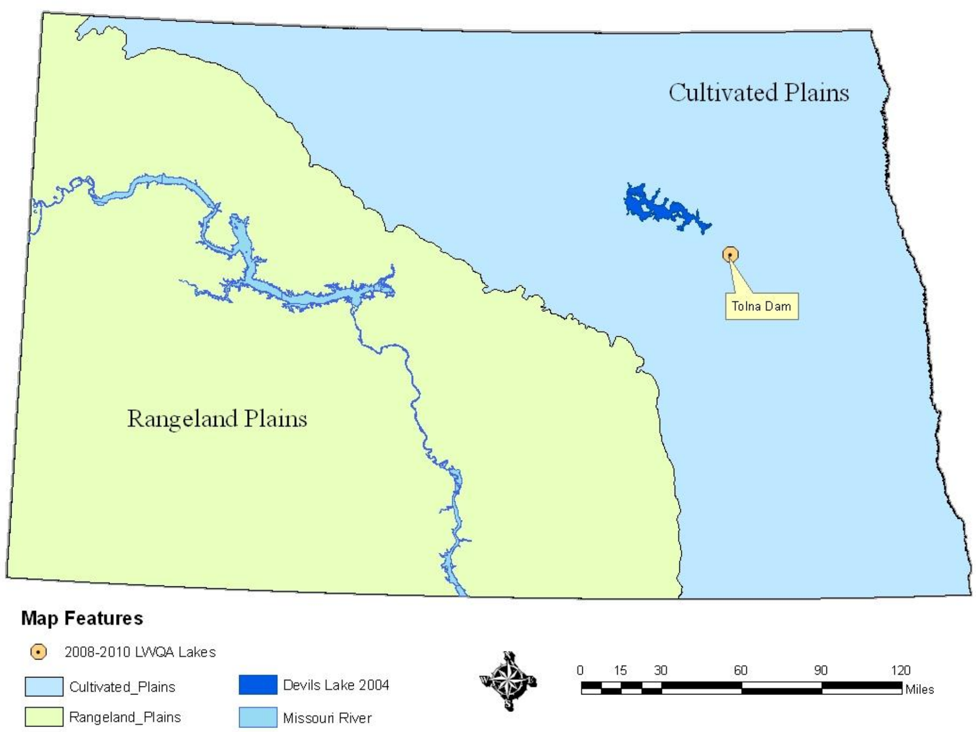

Figure 4. Tolna Dam's Location and the Cultivated and Rangeland Plans Regions

WATER QUALITY MONITORING RESULTS

The water quality assessment for Tolna Dam is presented in four general categories: 1) temperature and dissolved oxygen profile results; 2) general water quality characterization; 3) nutrient limitation; and 4) trophic status. Where appropriate, results have been compared to the regional and historical water quality data.

Temperature and Dissolved Oxygen Profile Results: There are six temperature and dissolved oxygen profiles for Tolna Dam collected in 1992-93 and 2010 (Figures 5 and 6). The temperature profile data shows that the water body does weakly thermally stratify.

During thermal stratification dissolved oxygen concentrations responded by increasing slightly at the metalimnion and then gradually decaying. Additionally the dissolved oxygen concentrations are noticeably lower under the ice and decayed much more rapidly and thoroughly during this period below the metalimnion.

Overall the dissolved oxygen concentrations were higher in 2010 than 1992-1993 and the response to thermal stratification less rapid (Figure 6). However, at no time during 1992-1993 or 2010 was there not adequate dissolved oxygen above the thermal cline to support a warm water fishery and associate aquatic biota.

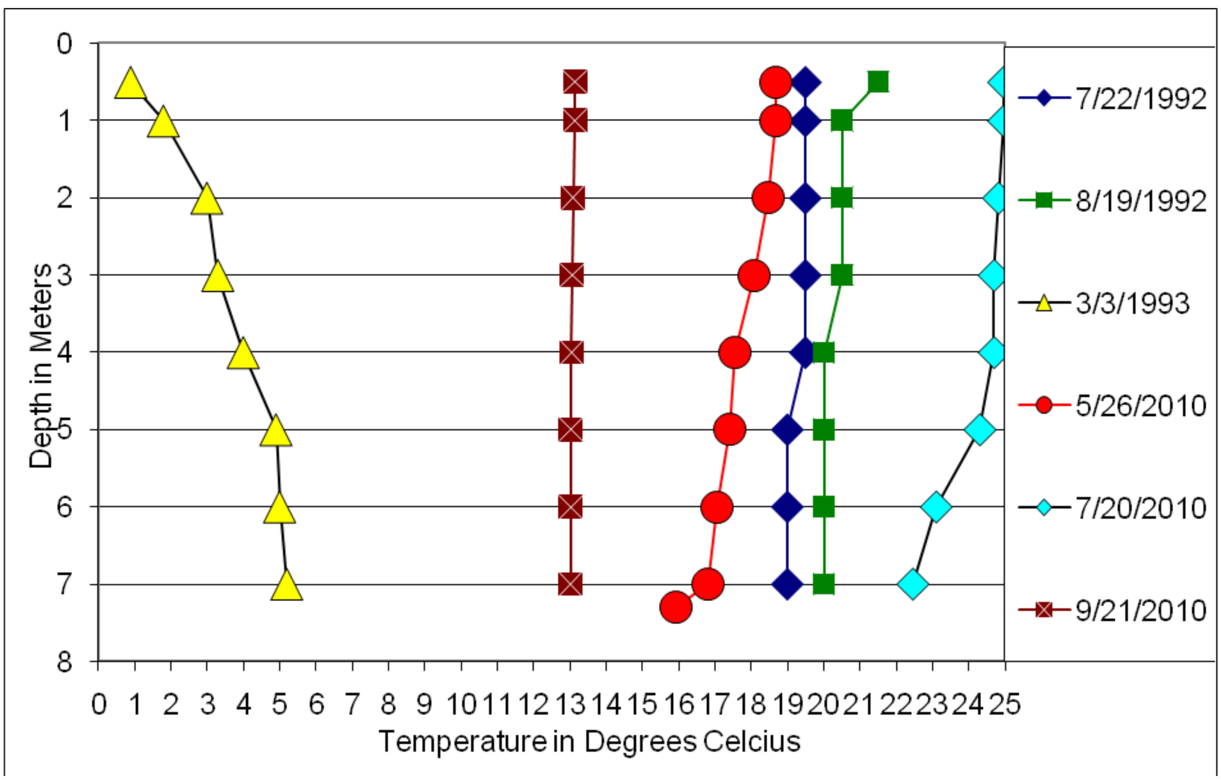

Figure 5. Temperature Profiles for Tolna Dam

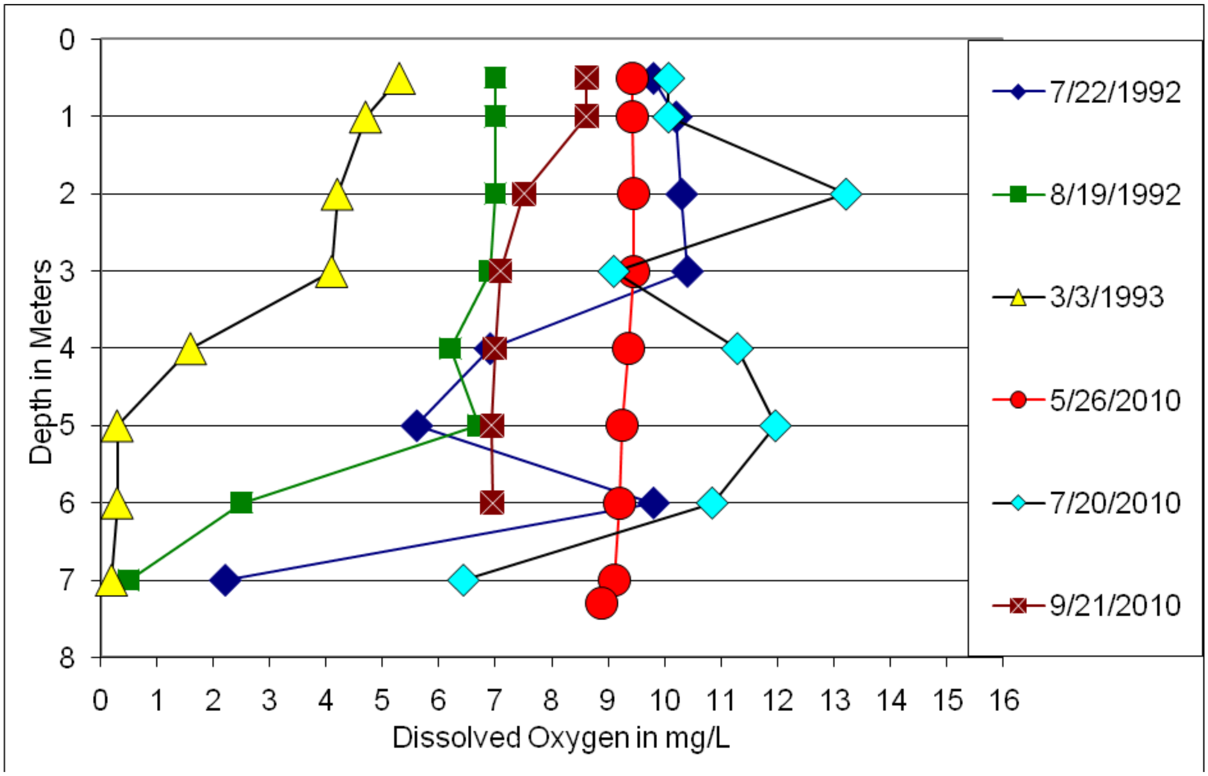

Figure 6. Dissolved Oxygen Profiles for Tolna Dam

General Water Quality: Data collected in 2010 indicate that Tolna Dam is well buffered with total alkalinity as $CaCO_3$ concentrations ranging from 299 to 304 mg/L (Table 1). The reservoir is sodium bicarbonate dominated with average sodium and sulfate concentrations of 28.8 mg/L, 280 mg/L, respectively. The average total dissolved solids concentration and specific conductance measurements for the 2010 sampling period were 391 mg/L, and 659 µmhos/cm, respectively, and the average total nitrogen as N and total phosphorus as P concentrations were 1.39 mg/L and 0.108 mg/L respectively.

When compared to the average water quality for reservoirs in the Cultivated Plans region, Tolna Dam is about on par for dissolved solids concentrations, but measureable less eutrophic than most (Table 3). For example, the average regional concentrations for TDS, total nitrogen, and total phosphorus concentrations are 671 mg/L, 1.52 mg/L, and 0.327 mg/L, respectively, compared to Tolna Dam's average TDS, total nitrogen, and total phosphorus concentrations of 659 mg/L, 1.39 mg/L and 0.108 mg/L respectively.

Table 1. Statistical Summary of Tolna Dam's 2010 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	2	302	299	304	4
Total Ammonia as N	mg/L	3	0.131	0.052	0.170	0.068
Bicarbonate (HCO_3)	mg/L	2	280	257	303	33
Calcium (Ca)	mg/L	3	54.5	51.8	56.5	2.4
Carbonate (CO_3)	mg/L	2	43	30	56	18
Chloride (Cl)	mg/L	2	4	3	4	0
Chlorophyll-a	µg/L	3	10.7	3.0	26.2	13.4
Specific Conductance	µmhos	2	659	649	668	13
Total Dissolved Solids	mg/L	2	391	382	399	12
Total Hardness as ($CaCO_3$)	mg/L	3	329	317	343	13
Hydroxide (OH)	mg/L	2	1.0[1]	1.0[1]	1.0[1]	0.0
Iron (Fe)	mg/L	3	0.230	0.069	0.500	0.235
Magnesium (Mg)	mg/L	3	46.9	42.7	49.7	3.7
Nitrate + Nitrite as N	mg/L	3	0.087	0.030[1]	0.120	0.049
Total Kjeldahl Nitrogen as N	mg/L	3	1.303	0.920	1.550	0.337
Total Nitrogen as N	mg/L	3	1.390	1.030	1.580	0.312
pH		3	6.46	1.76	8.98	4.07
Total Phosphorus as P	mg/L	3	0.108	0.066	0.146	0.040
Potassium (K)	mg/L	3	7.4	5.5	10.0	2.3
Sodium (Na)	mg/L	3	28.8	27.3	30.0	1.4
Sulfate (SO4)	mg/L	2	68	65	71	4

[1]Equal to the lower reporting limit

When comparing historical water quality data (1992-1993) to the 2010 water quality data it appears that the water quality has improved with reductions in dissolved solids and reductions in total phosphorus. For example the 1992-1993 averages for bicarbonate and sodium concentrations was 312 mg/L and 44.8 mg/L and in 2010 is 299 mg/L and 28.8 mg/L (Tables 1 and 2). Like dissolved solids, total phosphorus also appears to be trending downward from a 1992-19936 average of 0.187 mg/L and a 2010 average of 0.108 mg/L.

Limiting Nutrients: The six water quality samples collected between 1992 and 2010 indicate that Tolna Dam was nitrogen limited in the early 1990's but currently is trending toward equilibrium or even has become phosphorus limited (Figure 7). The limiting nutrient analysis is based on the assumption that either nitrogen or phosphorus is limiting algal growth and that the ratio of total nitrogen as N to total phosphorus as P (N:P), by weight in the average algae is approximately 15 to 1. When the N:P ratio is less than 15:1, nitrogen is assumed to be the limiting nutrient and when it exceeds 15:1, the limiting nutrient is assumed to be phosphorus.

Table 2. Statistical Summary of Tolna Dam's 1992-1993 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	3	295	265	334	35
Total Ammonia as N	mg/L	2	0.128	0.026	0.230	0.144
Bicarbonate (HCO_3)	mg/L	3	312	254	408	84
Calcium (Ca)	mg/L	3	48.7	40.6	54.7	7.3
Carbonate (CO_3)	mg/L	3	24	1[1]	37	21
Chloride (Cl)	mg/L	3	16	13	20	4
Chlorophyll-a	µg/L	2	8.0	6.0	10.0	2.8
Specific Conductance	µmhos	3	695	616	816	106
Total Dissolved Solids	mg/L	3	422	374	497	66
Total Hardness as ($CaCO_3$)	mg/L	3	296	258	344	44
Hydroxide (OH)	mg/L	1	1.0[1]	1.0[1]	1.0[1]	0.0
Iron (Fe)	mg/L	3	0.051	0.033	0.083	0.028
Magnesium (Mg)	mg/L	3	42.3	38.0	50.3	7.0
Nitrate + Nitrite as N	mg/L	3	0.110	0.009	0.300	0.165
Total Kjeldahl Nitrogen as N	mg/L	2	1.035	0.900	1.170	0.191
Total Nitrogen as N	mg/L	2	1.145	0.909	1.470	0.356
pH		3	8.65	7.99	9.04	0.57
Total Phosphorus as P	mg/L	3	0.187	0.097	0.248	0.080
Potassium (K)	mg/L	3	8.4	7.9	9.0	0.6
Sodium (Na)	mg/L	3	44.8	40.6	52.6	6.8
Sulfate (SO4)	mg/L	3	84	70	109	21

[1]Equal to the lower reporting limit

Trophic Status Assessment: Based on the chlorophyll-a, secchi disk transparency, and total phosphorus data collected in 2010, Tolna Dam's trophic status is estimated to be eutrophic. The trophic status index (TSI) scores ranged from a low of 41 based on chlorophyll-a concentrations to a high of 84 based on total phosphorus concentrations (Figure 8).

Trends: A total of six phosphorus samples, four chlorophyll-a samples, and four secchi disk transparency measurements collected during the sampling periods of 1992-93 and 2010 were available to evaluate trends in the trophic status of Tolna Dam. While it would be difficult to make a conclusive assessment on water quality trends, however the decreasing total phosphorus concentrations resulting in a shift towards phosphorus limitation are a strong indication that the reservoir is improving (Figures 7 and 8). This improvement is probably best expressed by the slower and less complete oxygen decay during periods of thermal stratification (Figures 5 and 6).

Table 3. Statistical Summary of Water Quality Data[2] Collected from Reservoirs and Impoundments in the Cultivated Plains Ecological Region of North Dakota

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	400	261	88	891	99
Total Ammonia as N	mg/L	567	0.145	0.001[1]	2.070	0.208
Bicarbonate (HCO_3)	mg/L	400	294	91	951	110
Calcium (Ca)	mg/L	402	66.7	19.4	169.0	22.7
Carbonate (CO_3)	mg/L	382	13	1[1]	93	16
Chloride (Cl)	mg/L	400	21	3[1]	113	17
Chlorophyll-a	µg/L	445	19.9	1.5[1]	388.0	30.2
Specific Conductance	µmhos	400	1025	217	3140	501
Total Dissolved Solids	mg/L	392	671	127	2300	375
Total Hardness as ($CaCO_3$)	mg/L	402	341	95	1090	119
Hydroxide (OH)	mg/L	339	1.0	0.0[1]	1.0	0.2
Iron (Fe)	mg/L	400	0.143	0.007	3.190	0.220
Magnesium (Mg)	mg/L	402	42.3	11.2	161.0	19.6
Nitrate + Nitrite as N	mg/L	560	0.112	0.001[1]	2.060	0.213
Total Kjeldahl Nitrogen as N	mg/L	480	1.470	0.206	4.410	0.648
Total Nitrogen as N	mg/L	419	1.520	0.418	3.950	0.617
pH		401	8.34	1.76	9.40	0.54
Total Phosphorus as P	mg/L	569	0.327	0.002[1]	2.270	0.290
Potassium (K)	mg/L	402	11.6	2.7	34.5	5.4
Sodium (Na)	mg/L	402	96.8	2.2	582.0	102.9
Sulfate (SO4)	mg/L	400	272	1[1]	1350	210

[1]Equal to the lower reporting limit
[2]Data collected from 45 reservoirs between 1991 and 2010

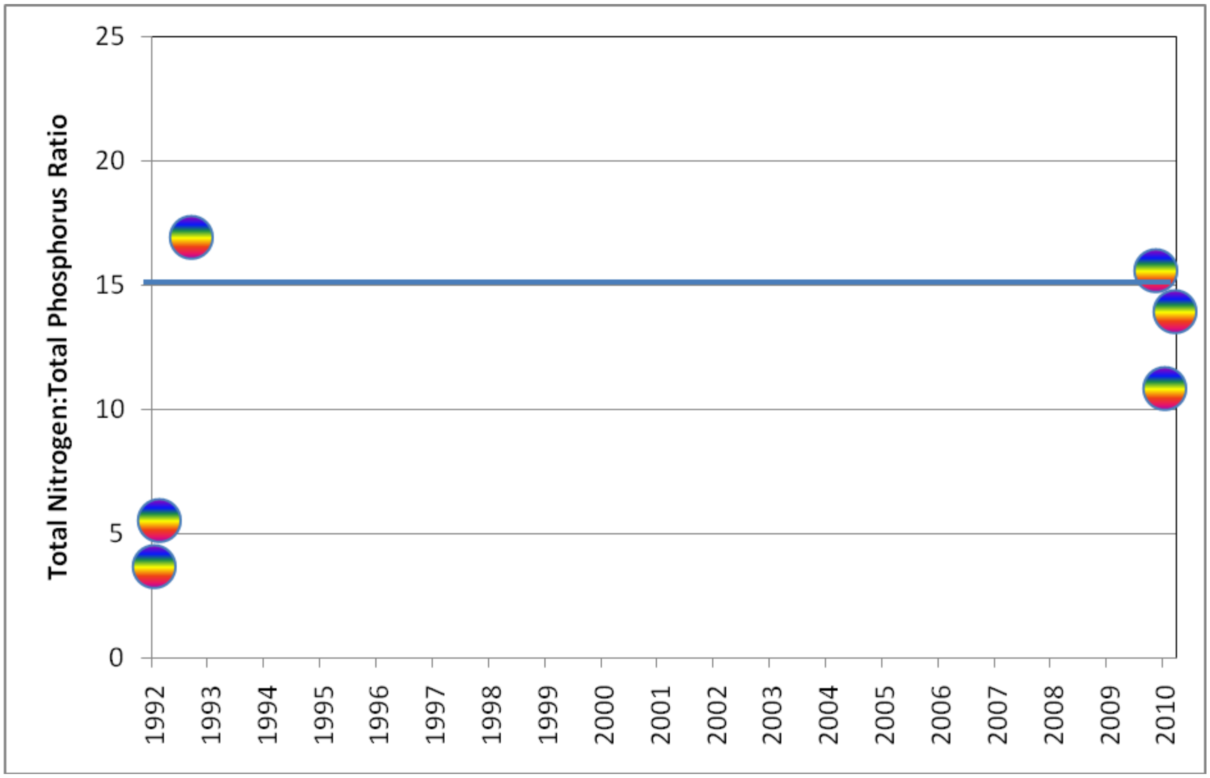

Figure 7. Tolna Dam's Total Nitrogen to Total Phosphorus Ratio

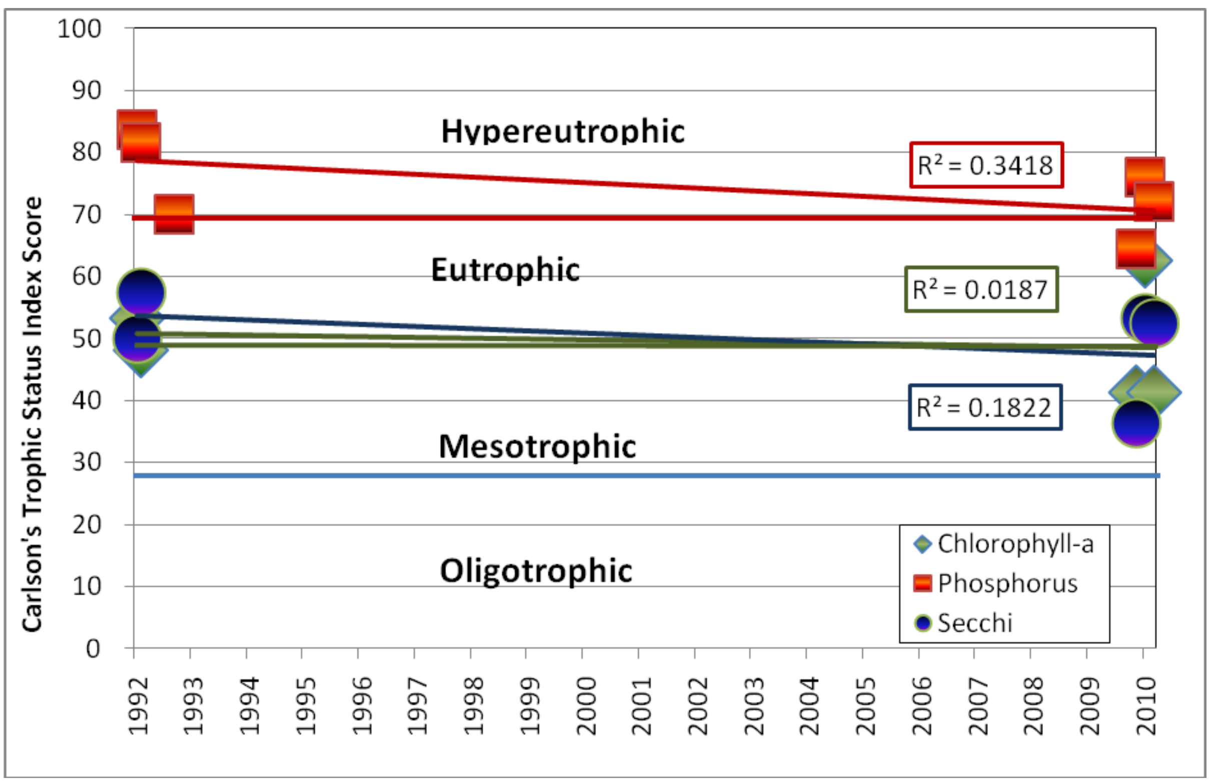

Figure 8. Tolna Dam's TSI Scores

Buffalo Lake, Pierce County

BACKGROUND

Location: Buffalo Lake is a shallow hypereutrophic reservoir on Buffalo Coulee, a tributary of the North Fork of the Sheyenne River, approximately 5 miles west of Esmond, North Dakota (Figure 1). The fishery is managed by the North Dakota Game and Fish. Fish species managed for are northern pike and yellow perch.

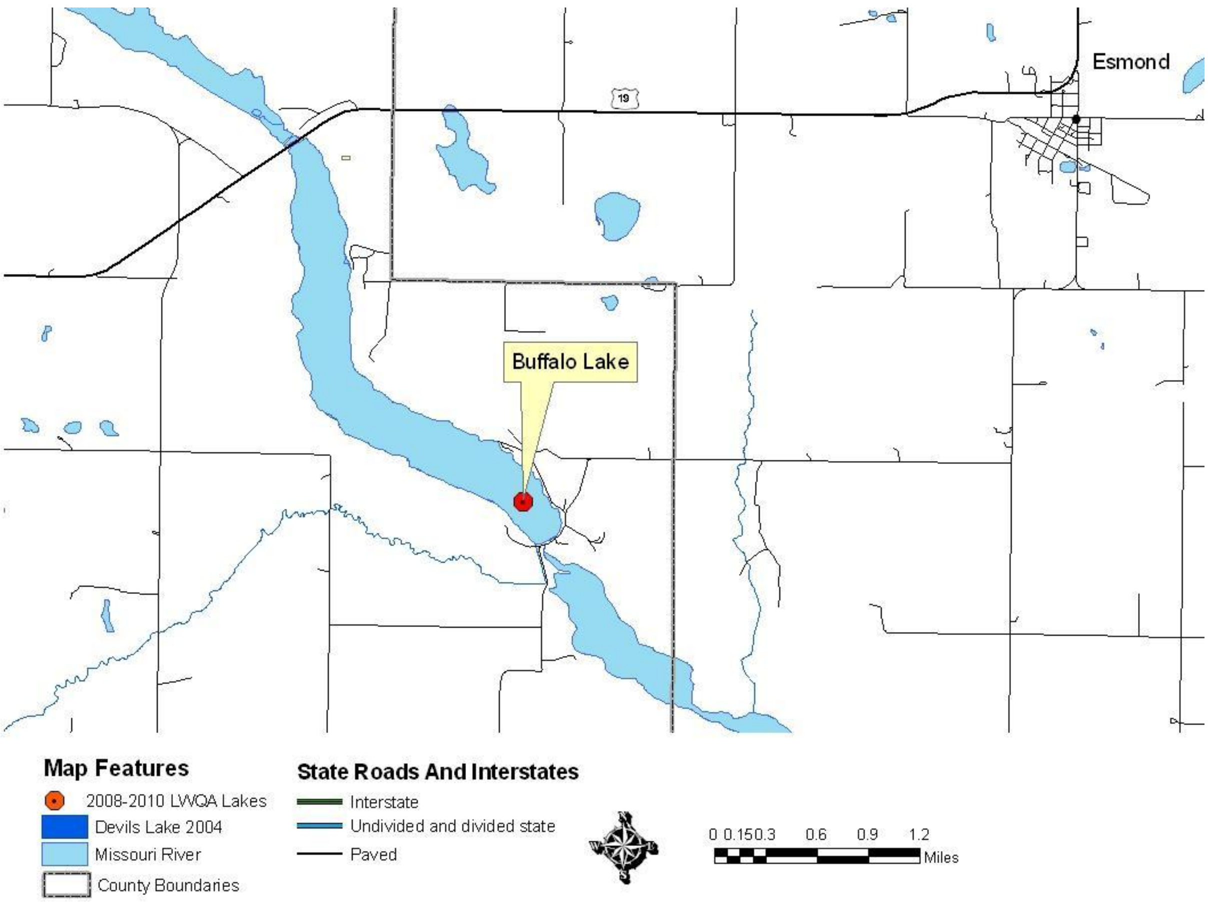

Figure 1. Location of Buffalo Lake

Physiographic/Ecological Setting: Buffalo Lake has an estimated surface area of 896 acres and a maximum depth of 7ft (Figure 2). The lake is located within the Northern Glaciated Plains Level III Ecoregion, which is part of the broader Cultivated Plains region (Figures 3 and 4).

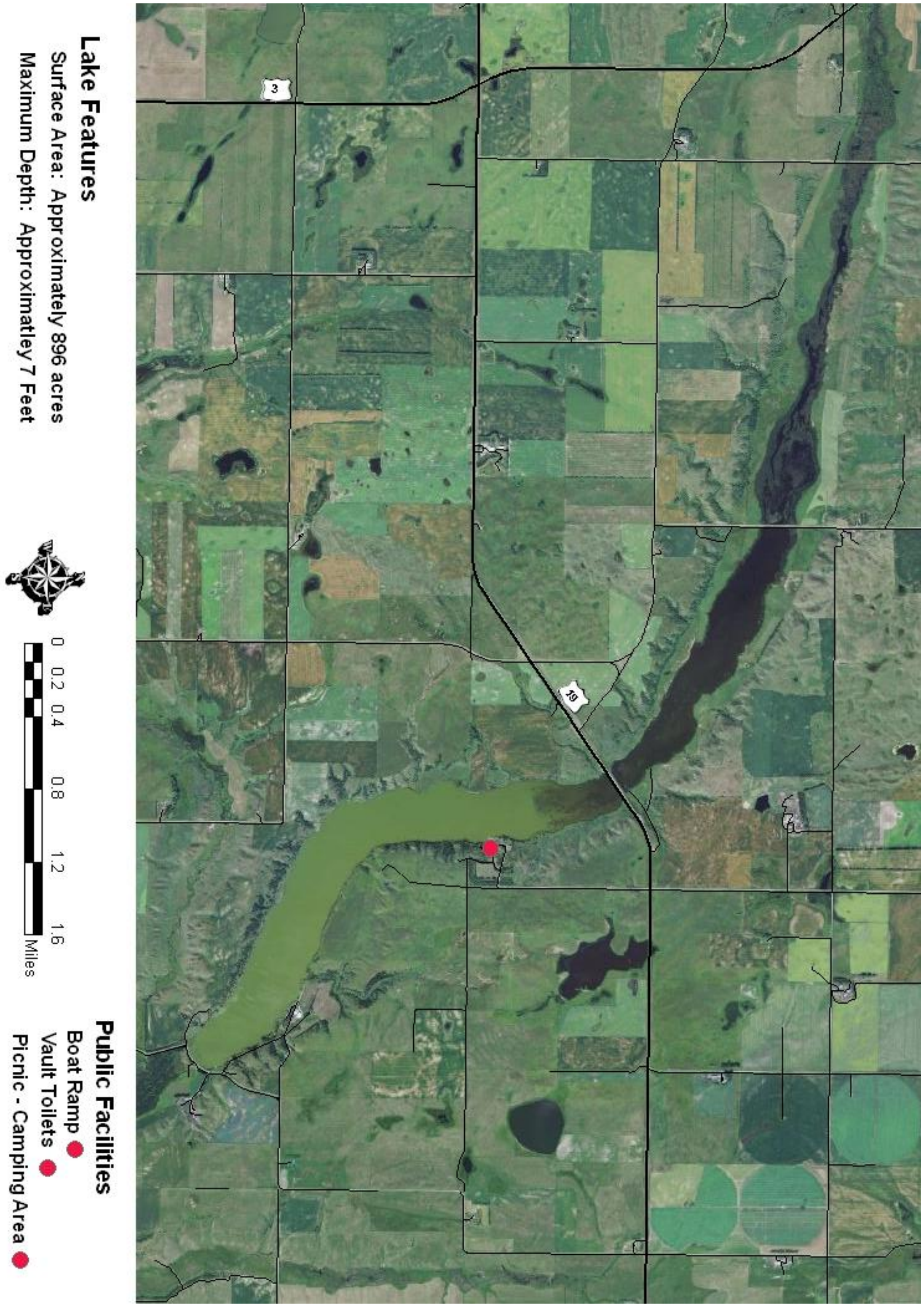

Figure 2. Map of Buffalo

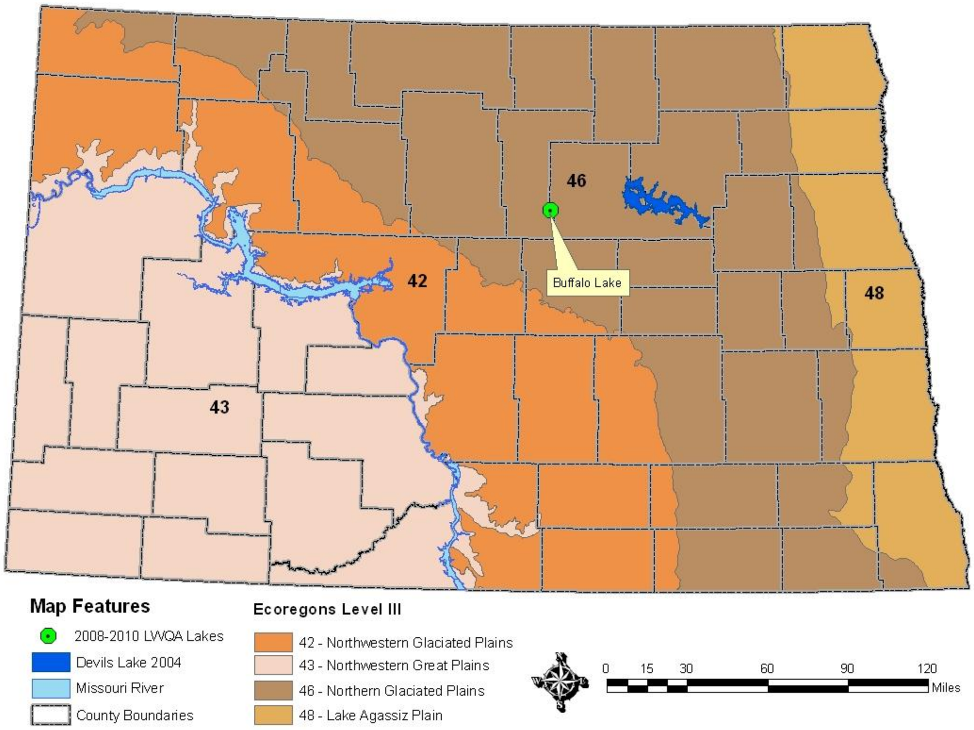

Figure 3. Buffalo Lake's Location and the Level III Ecoregions

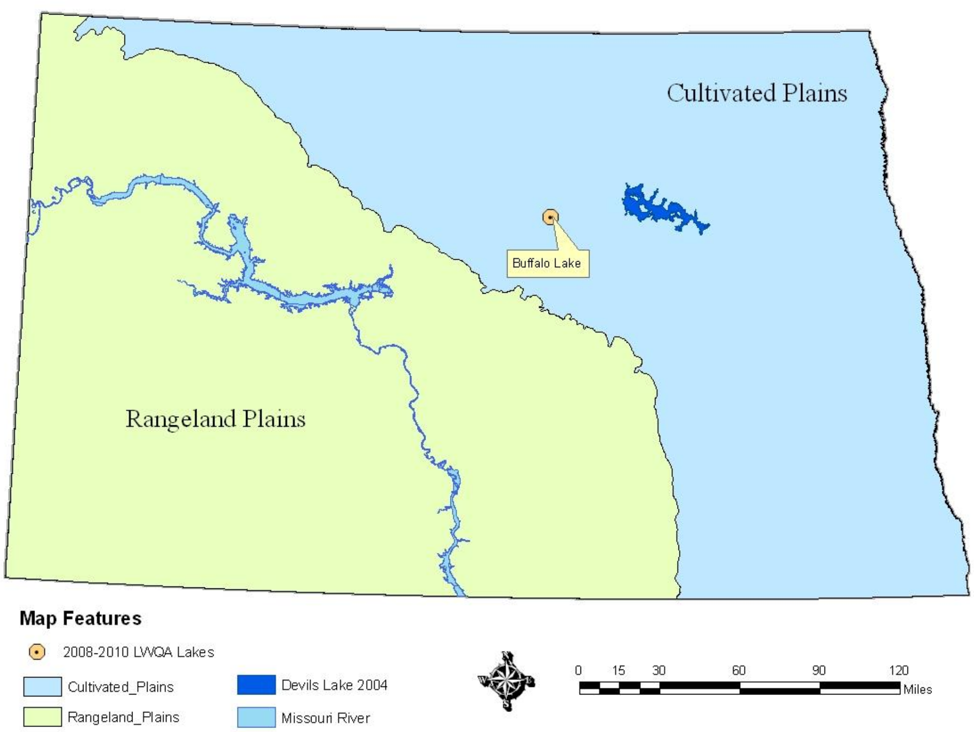

Figure 4. Buffalo Lake Location and the Cultivated and Rangeland Plans Regions

Recreational Facilities: Recreational facilities at Buffalo Lake are excellent and include a cement boat ramp, courtesy dock, outdoor toilet, water, campgrounds and picnic area.

Water Quality Standards Classification: Buffalo Lake is classified in the state "Standards of Quality for Waters of the State" (NDDoH, 2011) as a class 3 lake. Class 3 lakes or reservoirs are defined as a "warm water fishery" or "waters capable of supporting natural reproduction and growth of warm water fishes (e.g., largemouth bass and bluegill) and associated aquatic biota. Some cool water species may also be present."

Historical Water Quality Sampling: No historical water quality data.

WATER QUALITY MONITORING RESULTS

The water quality assessment for Buffalo Lake is presented in four general categories: 1) temperature and dissolved oxygen profile results; 2) general water quality characterization; 3) nutrient limitation; and 4) trophic status. Additionally, where appropriate, results have been compared to regional data.

Temperature and Dissolved Oxygen Profile Results: There are two temperature and dissolved oxygen profiles for Buffalo Lake collected in 2008 (Figures 5 and 6). The profile data shows that Buffalo Lake was not thermally stratification during the open water period. Additionally during the open water period the lake remained well enough oxygenated to support aquatic Life.

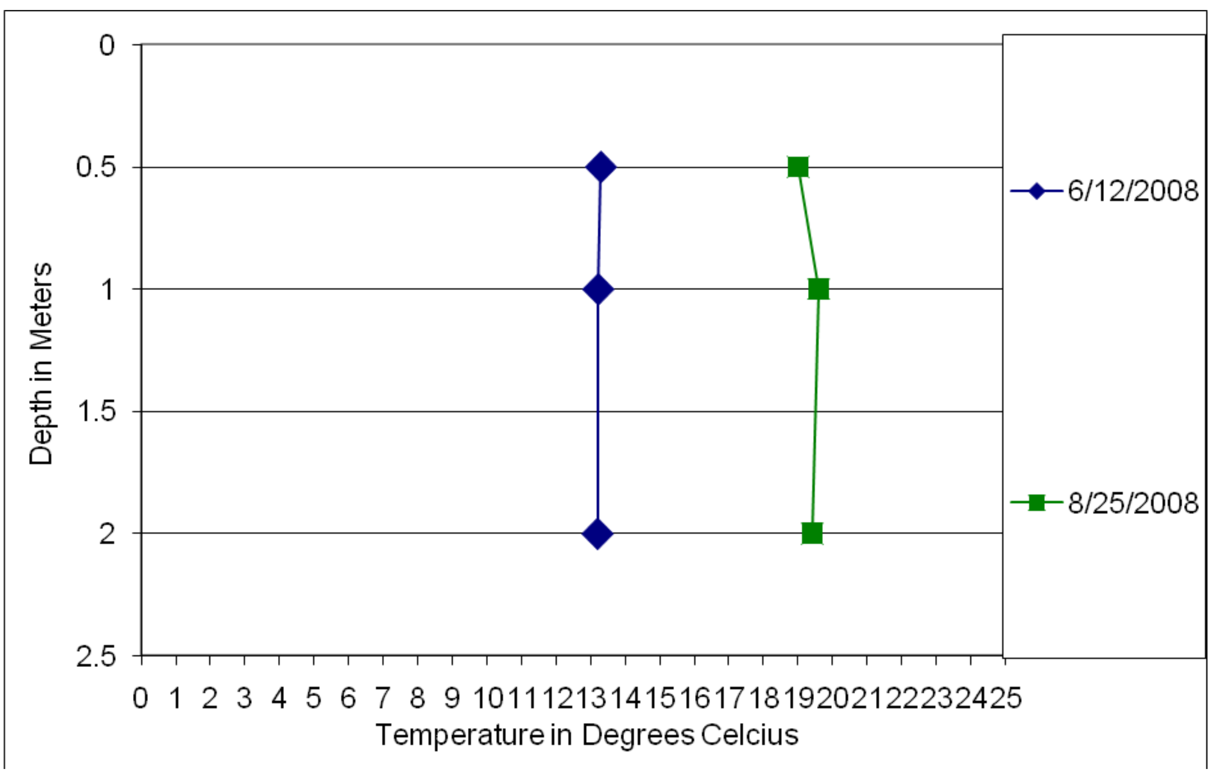

Figure 5. Temperature Profiles for Buffalo Lake

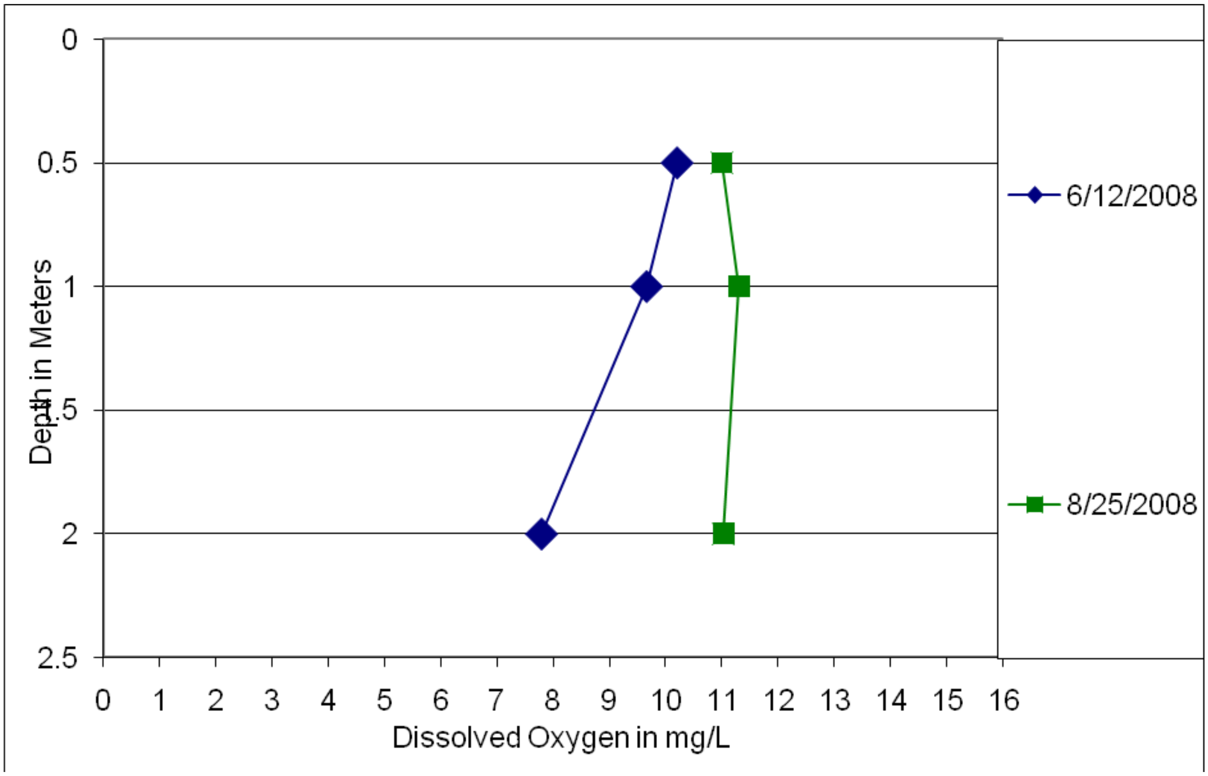

Figure 6. Dissolved Oxygen Profiles for Buffalo Lake

General Water Quality: Data collected in 2008 indicate that Buffalo Lake is well buffered with total alkalinity as $CaCO_3$ concentrations ranging from 753 to 824 mg/L (Table 1). The lake is sodium bicarbonate dominated with an average sodium concentration of 426 mg/L and an average bicarbonate concentration of 594 mg/L. The average total dissolved solids concentration and specific conductance measurement for 2008 sampling period were 1245 mg/L and 1945 µmhos/cm respectively, and the average total nitrogen as N and total phosphorus as P concentrations were 3.38 mg/L and 0.117 mg/L respectively.

When compared to the regional average water quality for natural lakes in the Cultivated Plans region, Buffalo Lake has more dissolved solids and is more nitrogen rich than most (Table 3). For example, the regional average TDS and total nitrogen concentrations are 671 mg/L and 1.520 mg/L, respectively, compared to Buffalo Lake's average TDS and total nitrogen concentrations of 1245 mg/L and 3.380 mg/L.

Table 1. Statistical Summary of Buffalo Lake's (Pierce County) 2008 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	2	789	753	824	50
Total Ammonia as N	mg/L	2	0.037	0.030[1]	0.043	0.009
Bicarbonate (HCO_3)	mg/L	2	595	558	632	52
Calcium (Ca)	mg/L	2	12.8	12.6	12.9	0.2
Carbonate (CO_3)	mg/L	2	181	141	220	56
Chloride (Cl)	mg/L	2	30	29	31	1
Chlorophyll-a	µg/L	2	463.6	19.2	908.0	628.5
Specific Conductance	µmhos	2	1945	1880	2010	92
Total Dissolved Solids	mg/L	2	1245	1180	1310	92
Total Hardness as ($CaCO_3$)	mg/L	2	207	186	227	29
Hydroxide (OH)	mg/L	2	1.0[1]	1.0[1]	1.0[1]	0.0
Iron (Fe)	mg/L	2	0.321	0.226	0.416	0.134
Magnesium (Mg)	mg/L	2	42.5	37.3	47.6	7.3
Nitrate + Nitrite as N	mg/L	2	0.030[1]	0.030[1]	0.030[1]	0.000
Total Kjeldahl Nitrogen as N	mg/L	2	3.350	2.870	3.830	0.679
Total Nitrogen as N	mg/L	2	3.380	2.900	3.860	0.679
pH		2	9.38	9.20	9.56	0.25
Total Phosphorus as P	mg/L	2	0.117	0.091	0.143	0.037
Potassium (K)	mg/L	2	18.1	15.5	20.7	3.7
Sodium (Na)	mg/L	2	426.0	403.0	449.0	32.5
Sulfate (SO4)	mg/L	2	241	232	250	13

[1]Equal to the lower reporting limit

Limiting Nutrients: The two water quality samples results for Buffalo Lake define the waterbody as being phosphorus limited (Figure 7). The limiting nutrient assessment is based on the assumption that either nitrogen or phosphorus is limiting algal growth with the water body, and that the ratio of total nitrogen as N to total phosphorus as P (N:P), by weight in the average algae, is approximately 15 to 1. When the N:P ratio is less than 15:1, nitrogen is assumed to be the limiting nutrient and when it exceeds 15:1, the limiting nutrient is assumed to be phosphorus.

Trophic Status Assessment: Based on the chlorophyll-a, secchi disk transparency, and total phosphorus data collected in 2008, Buffalo Lake's trophic is estimated as hypeutrophic. The trophic Status Index scores ranged from a low of 60 to a high of 97 based on chlorophyll-a (Figure 8).

Table 2. Statistical Summary of Water Quality Data[2] Collected from Reservoirs and Impoundments in the Cultivated Plains Ecological Region of North Dakota

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	400	261	88	891	99
Total Ammonia as N	mg/L	567	0.145	0.001[1]	2.070	0.208
Bicarbonate (HCO_3)	mg/L	400	294	91	951	110
Calcium (Ca)	mg/L	402	66.7	19.4	169.0	22.7
Carbonate (CO_3)	mg/L	382	13	1[1]	93	16
Chloride (Cl)	mg/L	400	21	3[1]	113	17
Chlorophyll-a	µg/L	445	19.9	1.5[1]	388.0	30.2
Specific Conductance	µmhos	400	1025	217	3140	501
Total Dissolved Solids	mg/L	392	671	127	2300	375
Total Hardness as ($CaCO_3$)	mg/L	402	341	95	1090	119
Hydroxide (OH)	mg/L	339	1.0	0.0[1]	1.0	0.2
Iron (Fe)	mg/L	400	0.143	0.007	3.190	0.220
Magnesium (Mg)	mg/L	402	42.3	11.2	161.0	19.6
Nitrate + Nitrite as N	mg/L	560	0.112	0.001[1]	2.060	0.213
Total Kjeldahl Nitrogen as N	mg/L	480	1.470	0.206	4.410	0.648
Total Nitrogen as N	mg/L	419	1.520	0.418	3.950	0.617
pH		401	8.34	1.76	9.40	0.54
Total Phosphorus as P	mg/L	569	0.327	0.002[1]	2.270	0.290
Potassium (K)	mg/L	402	11.6	2.7	34.5	5.4
Sodium (Na)	mg/L	402	96.8	2.2	582.0	102.9
Sulfate (SO4)	mg/L	400	272	1[1]	1350	210

[1]Equal to the lower reporting limit
[2]Data collected from 45 reservoirs between 1991 and 2010

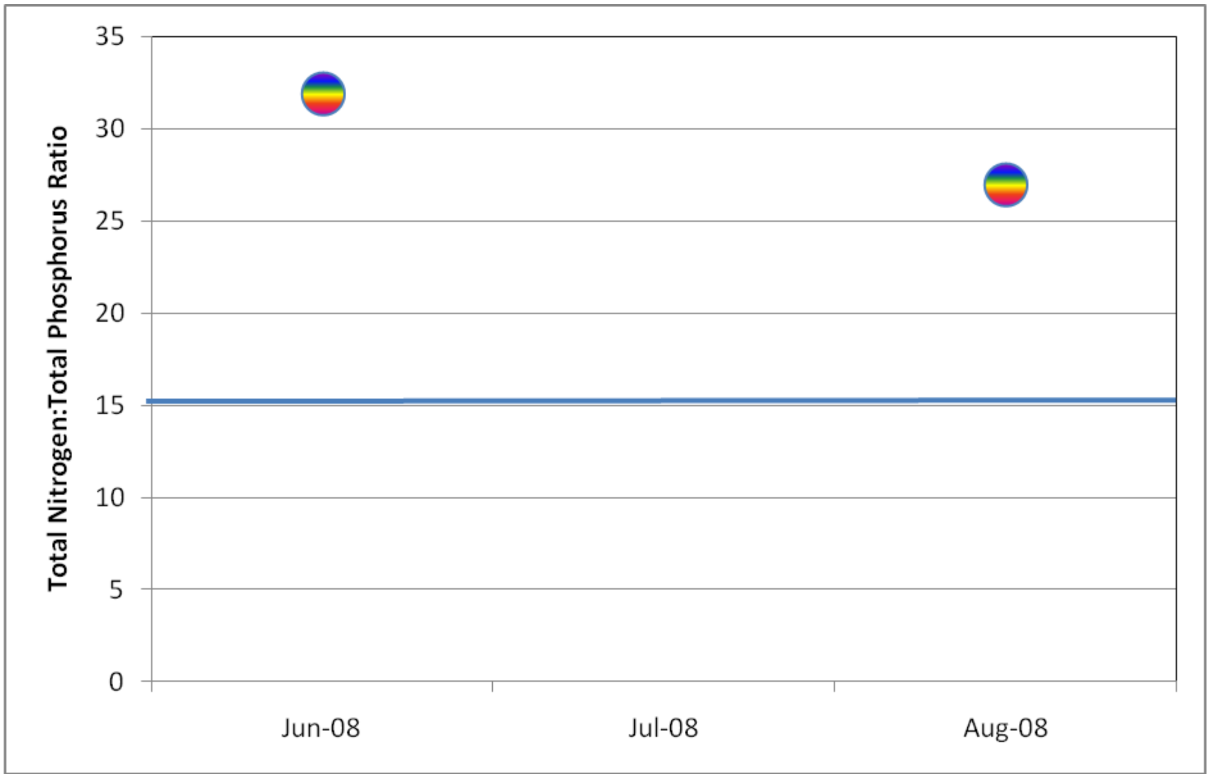

Figure 7. Buffalo Lake's Total Nitrogen to Total Phosphorus Ratio

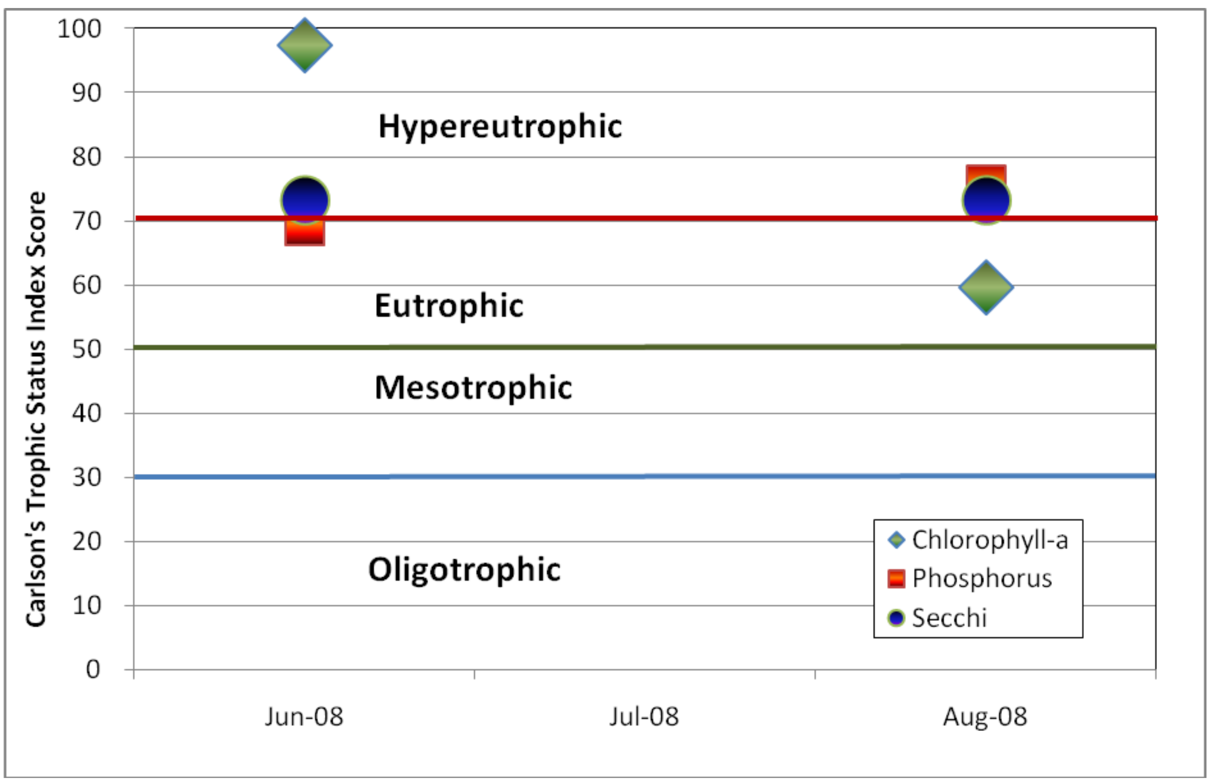

Figure 8. Buffalo Lake's TSI Scores

Cavanaugh Lake, Ramsey County

BACKGROUND

Location: Cavanaugh Lake is a glacial lake located in Ramsey County nine miles north and one mile west of Devils Lake, North Dakota (Figure 1). The fishery is managed by the North Dakota Game and Fish. Fish species managed for are northern pike and yellow perch.

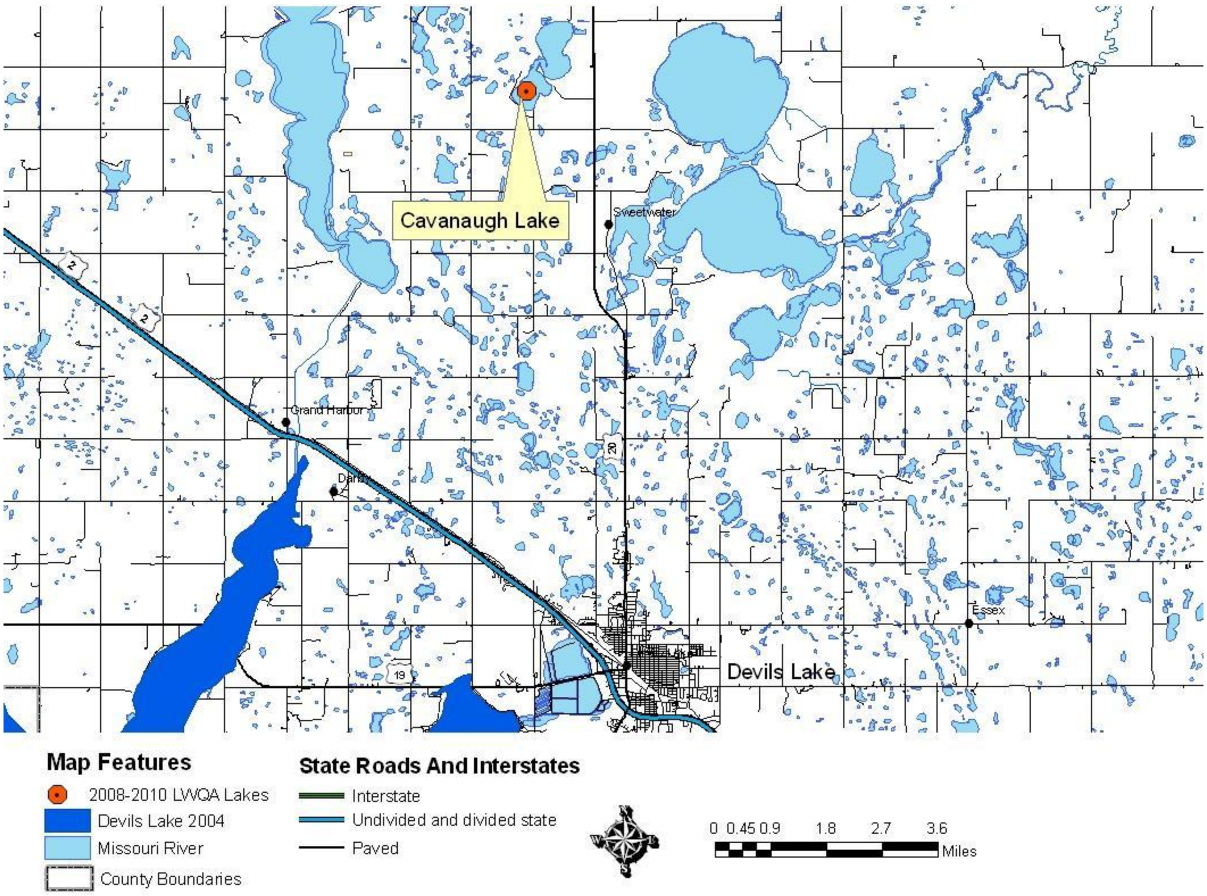

Figure 1. Location of Cavanaugh Lake

Physiographic/Ecological Setting: Cavanaugh Lake has a surface area of 423.9 acres and a maximum depth of 13.8 ft and an average depth of 6.9 ft (Figure 2). The lake is located within the Northern Glaciated Plains Level III Ecoregion, which is part of the broader Cultivated Plains region (Figures 3 and 4).

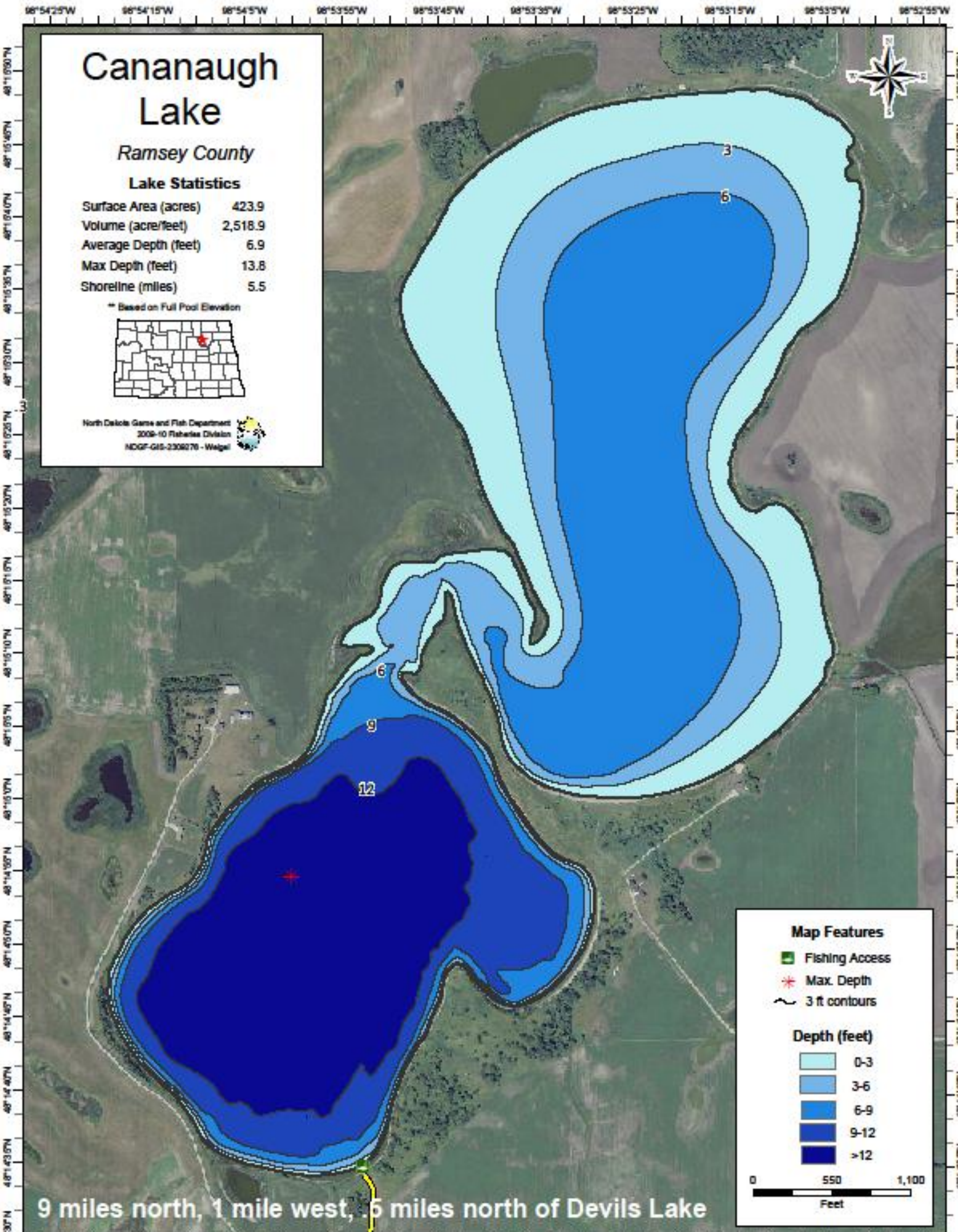

Figure 2. Contour Map of Cavanaugh Lake (Map Courtesy of North Dakota Game and Fish Department)

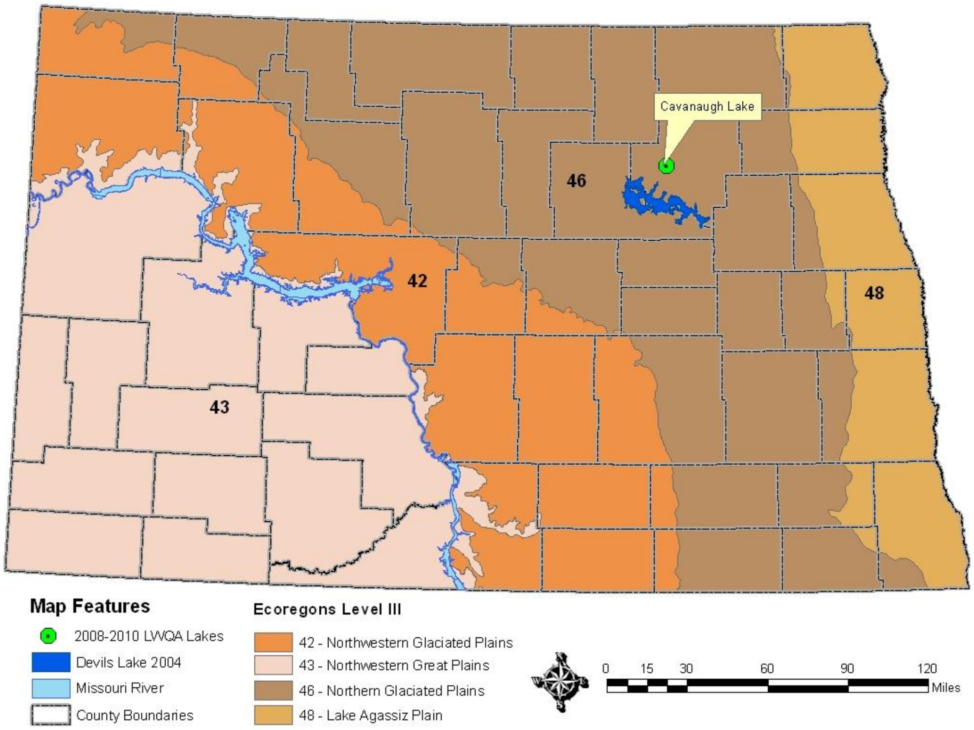

Figure 3. Cavanaugh Lake's Location and the Level III Ecoregions

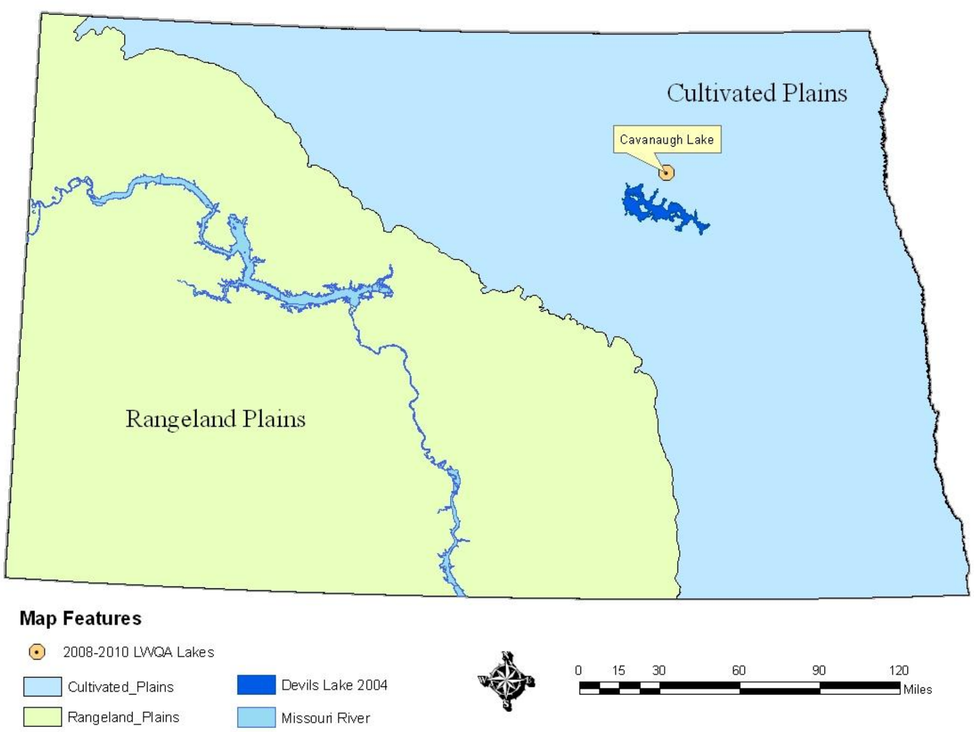

Figure 4. Cavanaugh Lake Location and the Cultivated and Rangeland Plans Regions

Recreational Facilities: There are no recreational facilities at Cavanaugh Lake. Access is off a steep grassed bank that is not for the inexperienced.

Water Quality Standards Classification: Cavanaugh Lake is classified in the state "Standards of Quality for Waters of the State" (NDDoH, 2011) as a class 3 lake. Class 3 lakes or reservoirs are defined as a "warm water fishery" or "waters capable of supporting natural reproduction and growth of warm water fishes (e.g., largemouth bass and bluegill) and associated aquatic biota. Some cool water species may also be present."

Historical Water Quality Sampling: No historical water quality data.

WATER QUALITY MONITORING RESULTS

The water quality assessment for Cavanaugh Lake is presented in four general categories: 1) temperature and dissolved oxygen profile results; 2) general water quality characterization; 3) nutrient limitation; and 4) trophic status. Additionally, where appropriate, results have been compared to regional data.

Temperature and Dissolved Oxygen Profile Results: There are three temperature and dissolved oxygen profiles for Cavanaugh Lake collected in 2009 (Figures 5 and 6). The profile data shows that Cavanaugh Lake was not thermally stratification during the open water period. Additionally during the open water period the lake remained well enough oxygenated to support aquatic Life.

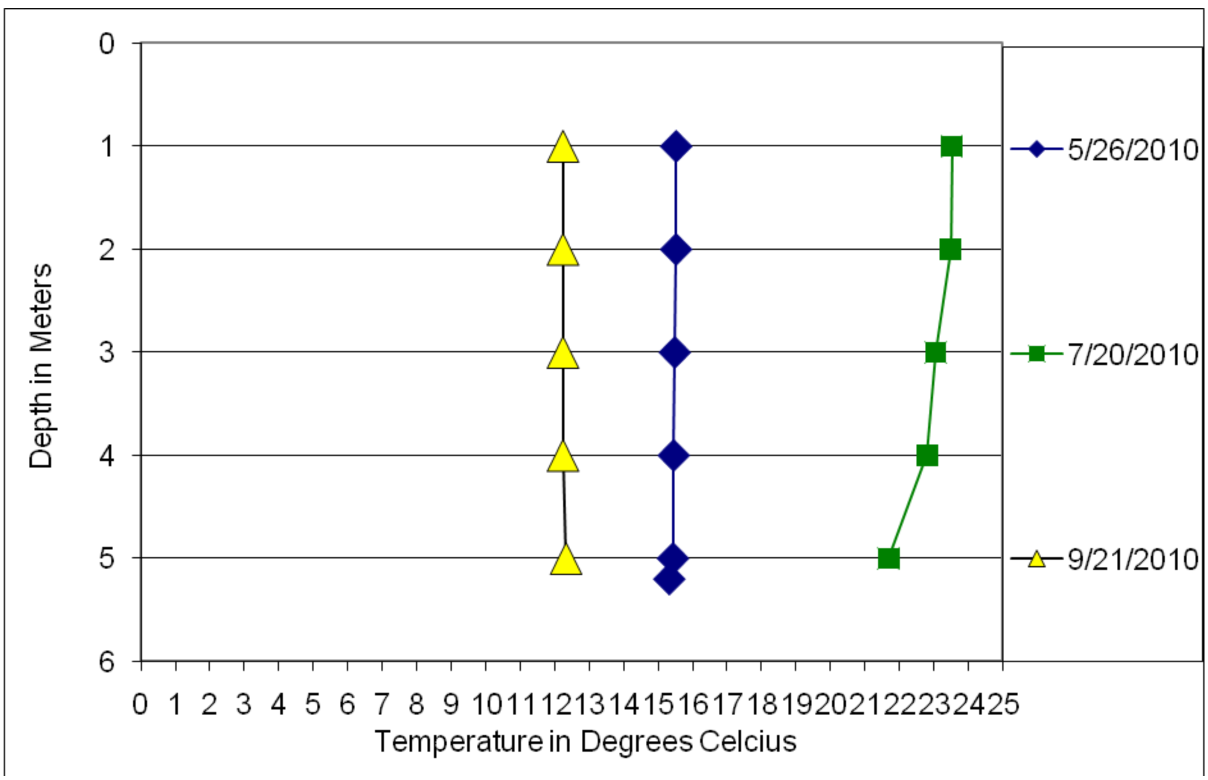

Figure 5. Temperature Profiles for Cavanaugh Lake

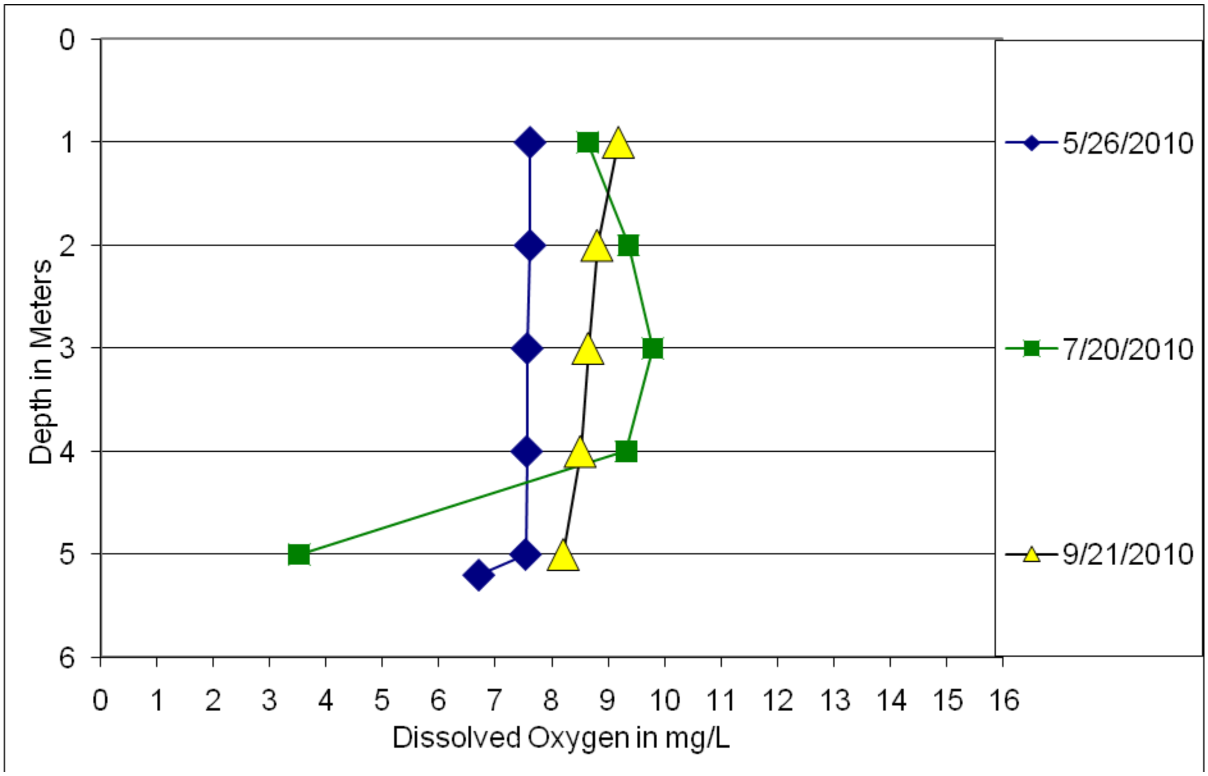

Figure 6. Dissolved Oxygen Profiles for Cavanaugh Lake

General Water Quality: Data collected in 2010 indicate that Cavanaugh Lake is well buffered with total alkalinity as $CaCO_3$ concentrations averaging 248 mg/L (Table 1). The lake is sodium sulfate dominated with an average sodium concentration of 128 mg/L and an average sulfate concentration of 344 mg/L. The average total dissolved solids concentration and specific conductance measurement for 2009 sampling period were 782 mg/L and 1220 µmhos/cm respectively, and the average total nitrogen as N and total phosphorus as P concentrations were 1.943 mg/L and 0.097 mg/L respectively.

When compared to the regional average water quality for natural lakes in the Cultivated Plans Ecoregion, Cavanaugh Lake has a few more dissolved solids, but is about average in nutrient richness (Table 3). For example, the regional average TDS, total nitrogen, and total phosphorus concentrations are 507 mg/L, 1.486 mg/L and 0.090 mg/L, respectively, compared to Cavanaugh Lake's average TDS, total nitrogen, and total phosphorus concentrations of 782 mg/L, 1.943 mg/L, and 0.097 mg/L.

Table 1. Statistical Summary of Cavanaugh Lake's 2010 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	2	248	248	248	0
Total Ammonia as N	mg/L	3	0.191	0.170	0.234	0.037
Bicarbonate (HCO_3)	mg/L	2	255	230	280	35
Calcium (Ca)	mg/L	3	45.8	44.3	47.3	1.5
Carbonate (CO_3)	mg/L	2	24	11	36	18
Chloride (Cl)	mg/L	2	37	35	38	2
Chlorophyll-a	µg/L	3	44.9	6.0	108.0	55.1
Specific Conductance	µmhos	2	1220	1210	1230	14
Total Dissolved Solids	mg/L	2	782	778	786	6
Total Hardness as ($CaCO_3$)	mg/L	3	342	328	354	13
Hydroxide (OH)	mg/L	2	1.0[1]	1.0[1]	1.0[1]	0.0
Iron (Fe)	mg/L	3	0.275	0.107	0.500	0.203
Magnesium (Mg)	mg/L	3	55.2	52.8	58.2	2.8
Nitrate + Nitrite as N	mg/L	3	0.030	0.030	0.030	0.000
Total Kjeldahl Nitrogen as N	mg/L	3	1.913	1.640	2.240	0.304
Total Nitrogen as N	mg/L	3	1.943	1.670	2.270	0.304
pH		3	6.38	1.78	8.85	3.99
Total Phosphorus as P	mg/L	3	0.097	0.068	0.140	0.038
Potassium (K)	mg/L	3	24.4	24.0	24.7	0.4
Sodium (Na)	mg/L	3	128.0	126.0	131.0	2.6
Sulfate (SO4)	mg/L	2	344	338	349	8

[1]Equal to the lower reporting limit

Limiting Nutrients: The three water quality samples collected in 2010, define Cavanaugh Lake's as being phosphorus limited (Figure 7). The limiting nutrient assessment is based on the assumption that either nitrogen or phosphorus is limiting algal growth with the water body, and that the ratio of total nitrogen as N to total phosphorus as P (N:P), by weight in the average algae, is approximately 15 to 1. When the N:P ratio is less than 15:1, nitrogen is assumed to be the limiting nutrient and when it exceeds 15:1, the limiting nutrient is assumed to be phosphorus.

Trophic Status Assessment: Based on the chlorophyll-a, secchi disk transparency, and total phosphorus data collected in 2008, Cavanaugh Lake's trophic is estimated as eutrophic. The trophic Status Index scores ranged from a low of 48 to a high of 77 based on chlorophyll-a (Figure 8).

Table 2. Statistical Summary of Water Quality Data[2] Collected from Natural and Enhanced Natural Lakes in the Cultivated Plains Ecological Region of North Dakota

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	191	340	166	1120	181
Total Ammonia as N	mg/L	281	0.106	0.001	1.620	0.198
Bicarbonate (HCO_3)	mg/L	191	355	171	1040	154
Calcium (Ca)	mg/L	193	53.7	12.6	210.0	33.1
Carbonate (CO_3)	mg/L	188	30	1[1]	220	41
Chloride (Cl)	mg/L	191	90	3[1]	1260	206
Chlorophyll-a	µg/L	233	16.4	1.5[1]	908.0	61.8
Specific Conductance	µmhos	210	1742	361	11500	1879
Total Dissolved Solids	mg/L	192	1285	191	9880	1593
Total Hardness as ($CaCO_3$)	mg/L	193	507	173	1820	273
Hydroxide (OH)	mg/L	167	1.0	0.0[1]	1.0	0.2
Iron (Fe)	mg/L	189	0.162	0.007	1.620	0.226
Magnesium (Mg)	mg/L	193	90.6	28.4	413.0	63.1
Nitrate + Nitrite as N	mg/L	272	0.052	0.001[1]	0.680	0.086
Total Kjeldahl Nitrogen as N	mg/L	179	1.497	0.080	4.110	0.632
Total Nitrogen as N	mg/L	154	1.486	0.523	3.860	0.566
pH		193	8.48	1.78	9.56	0.76
Total Phosphorus as P	mg/L	283	0.090	0.002[1]	1.460	0.144
Potassium (K)	mg/L	193	27.7	2.2	179.0	35.6
Sodium (Na)	mg/L	193	227.8	4.5	2570.0	441.5
Sulfate (SO4)	mg/L	191	555	7	3880	728

[1]Equal to the lower reporting limit
[2]Data collected from 53 natural lakes between 1991 and 2010

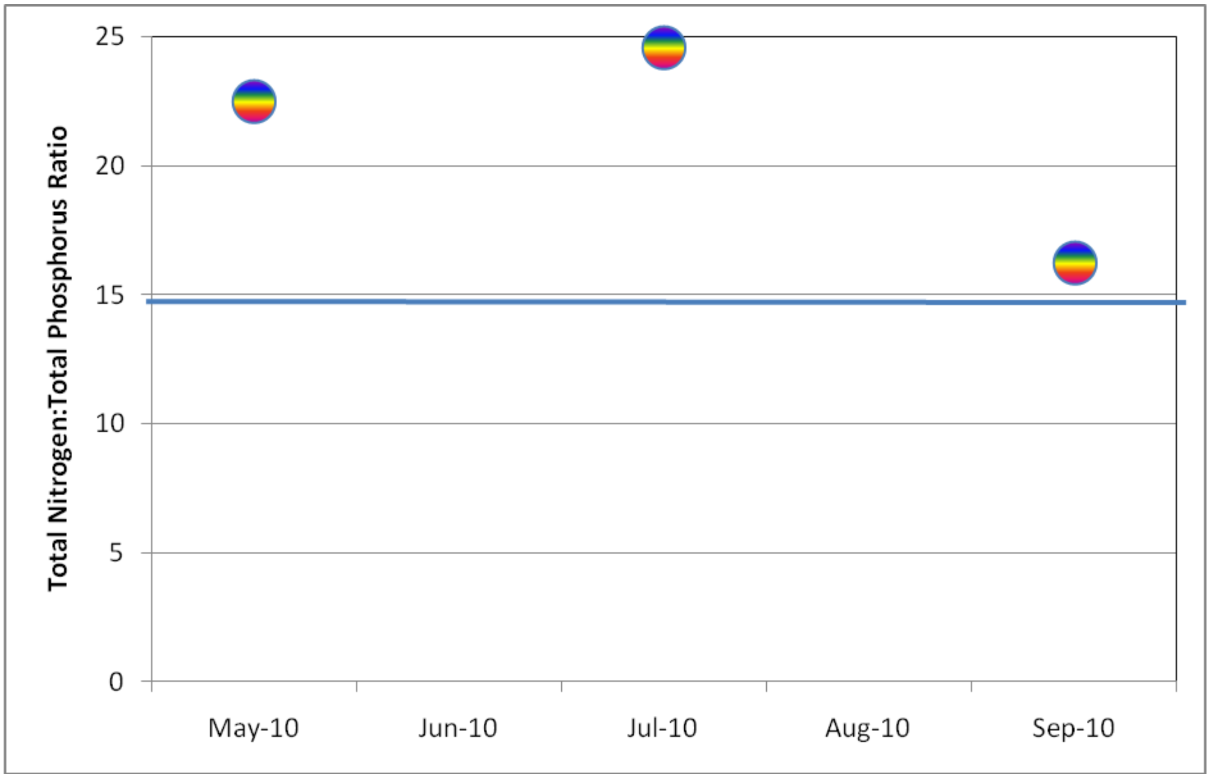

Figure 7. Cavanaugh Lake's Total Nitrogen to Total Phosphorus Ratio

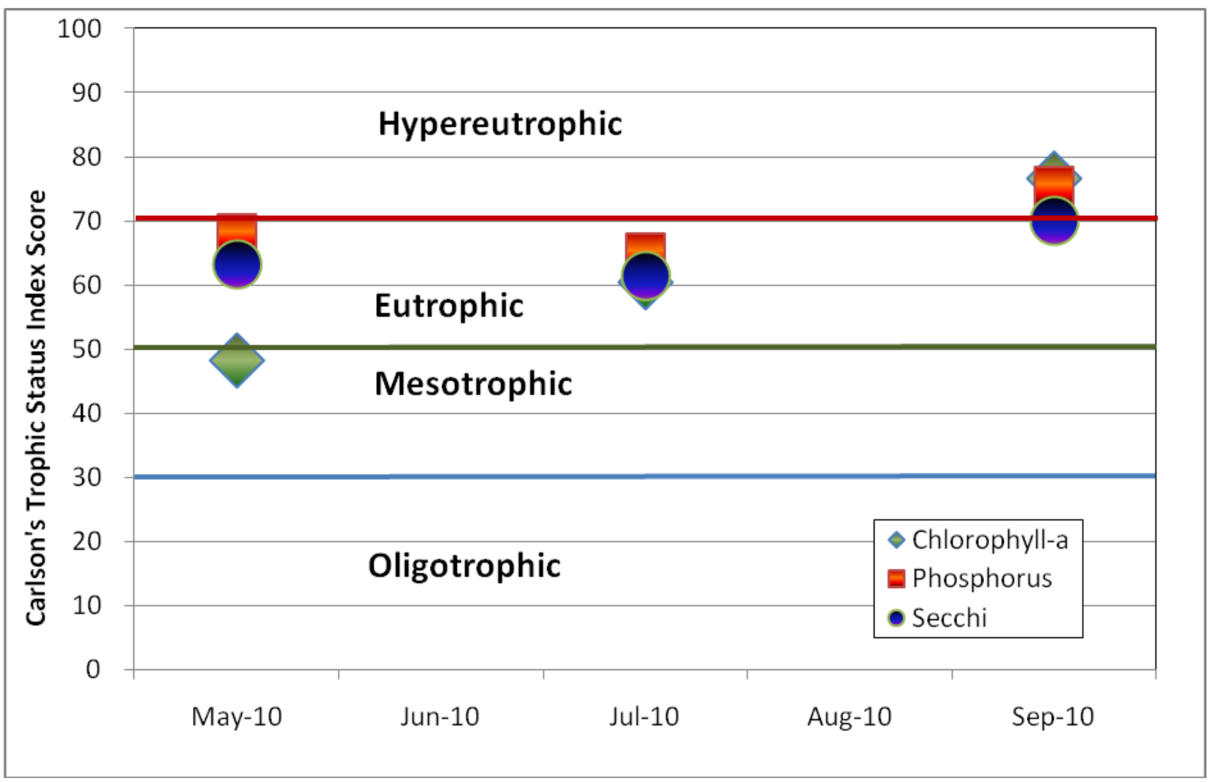

Figure 8. Cavanaugh Lake's TSI Scores

Lake Elsie, Richland County

BACKGROUND

Location: Lake Elsie is located on the southwest edge of the town of Hankinson, North Dakota (Figure 1). It is a significant source of aquatic recreation to the local community as well as the surrounded area. The fishery is managed by the North Dakota Game and Fish Department. Fish species stocked in recent years are northern pike and walleye.

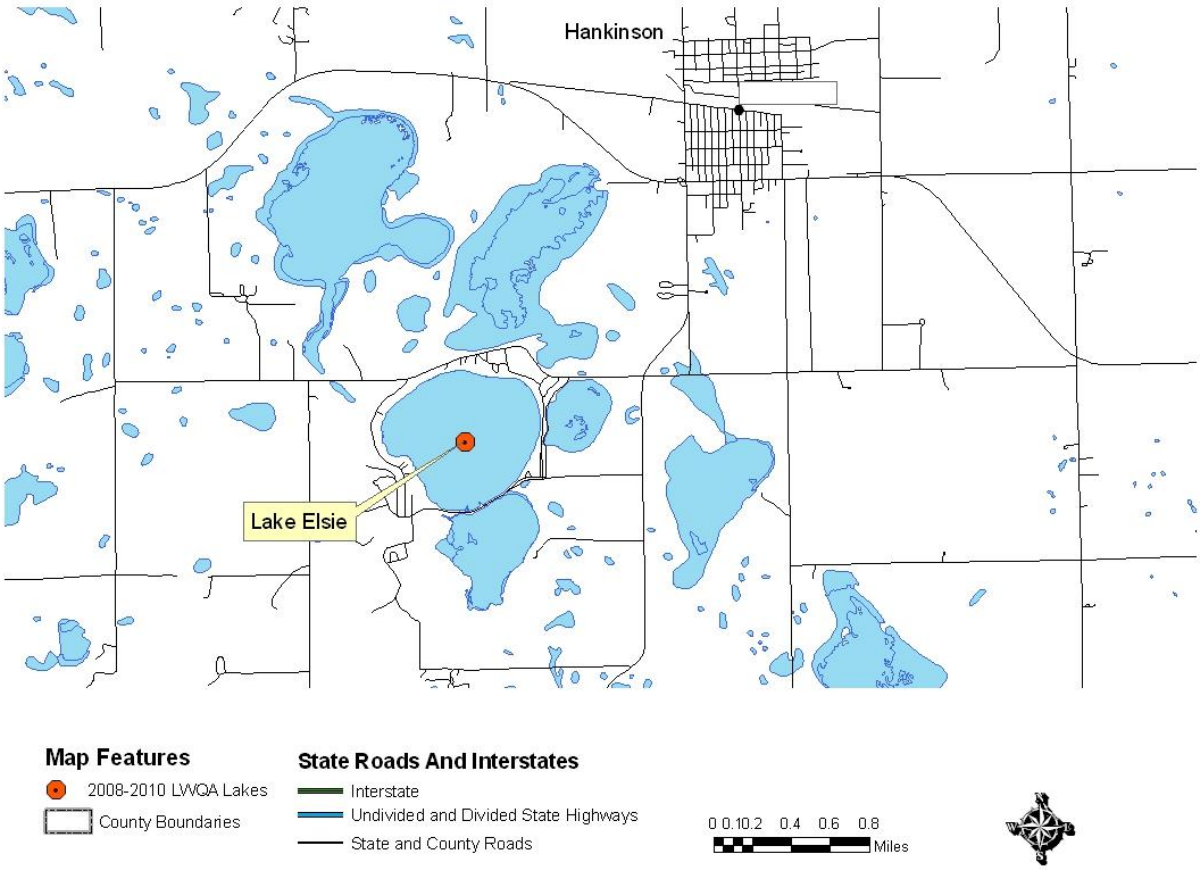

Figure 1. Location of Lake Elsie

Physiographic/Ecological Setting: Lake Elsie has a surface area of 376.8 acres, a maximum depth of 23.6 ft, and an average depth of 8.4 ft. The lake is round, relatively deep with a nice sand and gravel bottom. The reservoir is located in the Northern Glaciated Plains Level III Ecoregion, which is part of the broader Rangeland Plains Region (Figures 3 and 4).

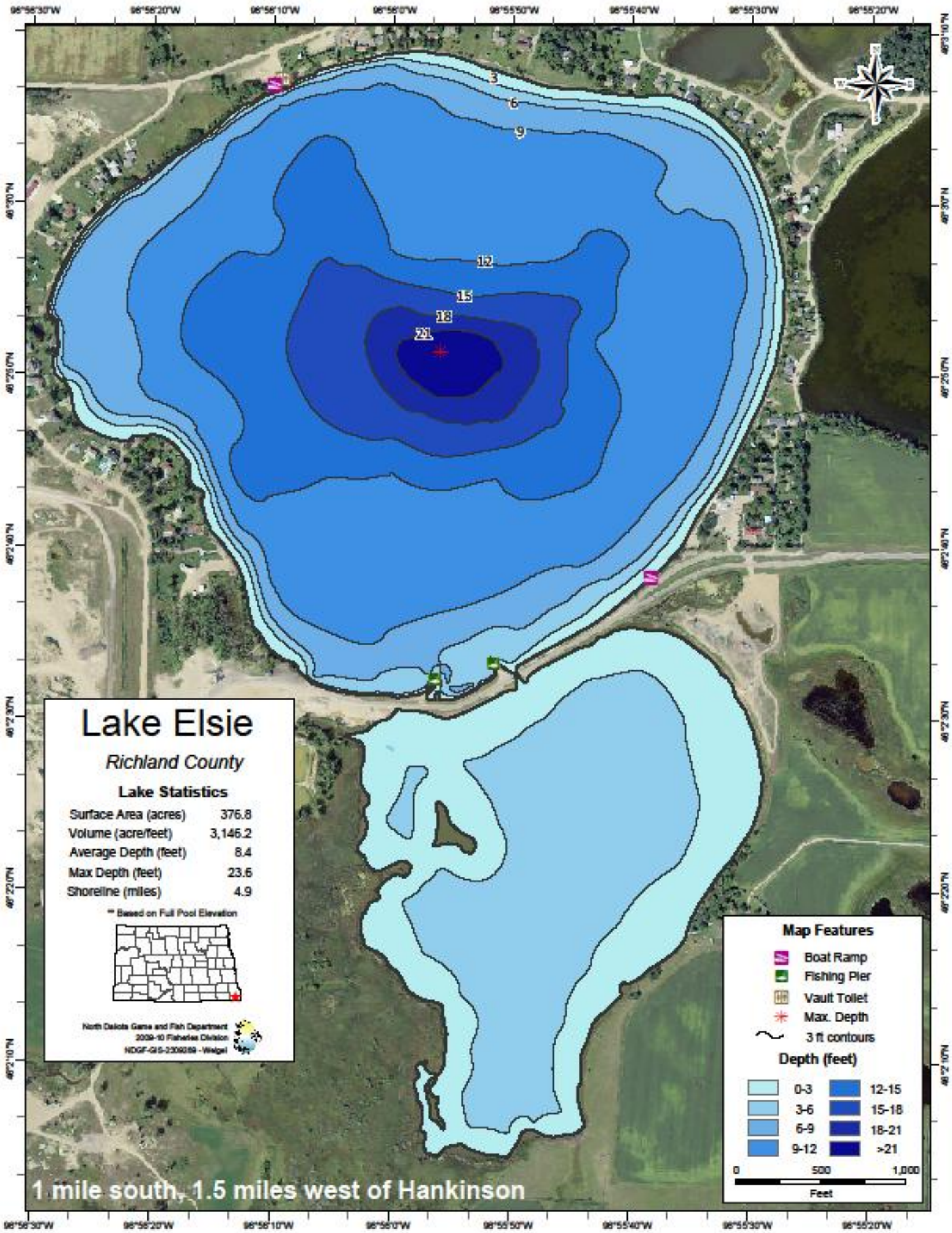

Figure 2. Contour Map of Lake Elsie (Courtesy of the North Dakota Game and Fish Department)

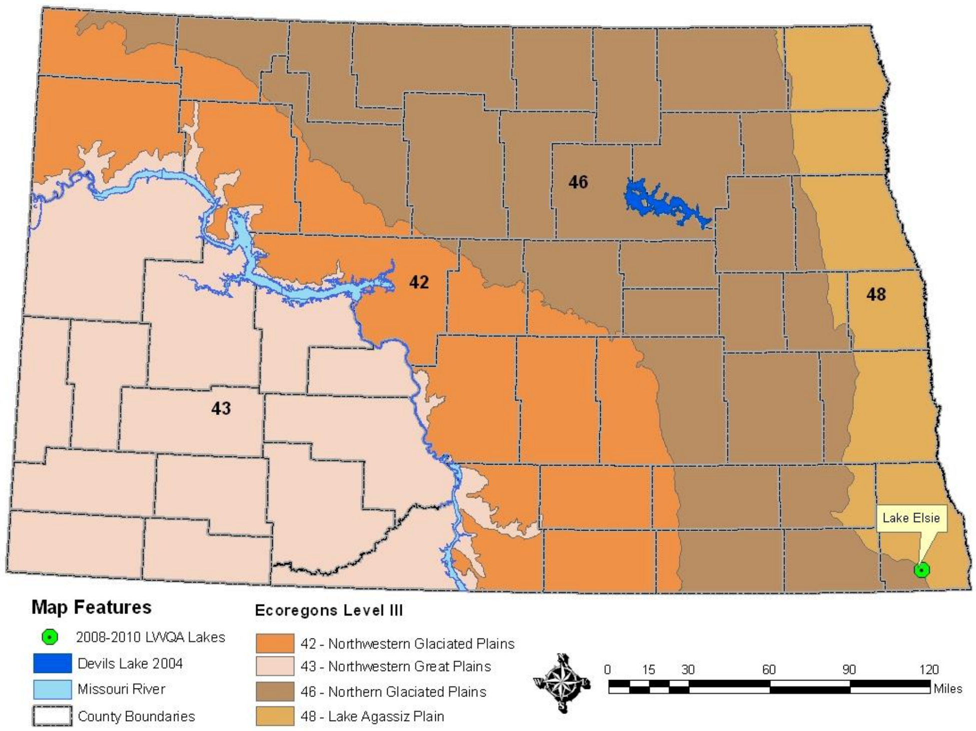

Figure 3. Lake Elsie's Location and the Level III Ecoregions

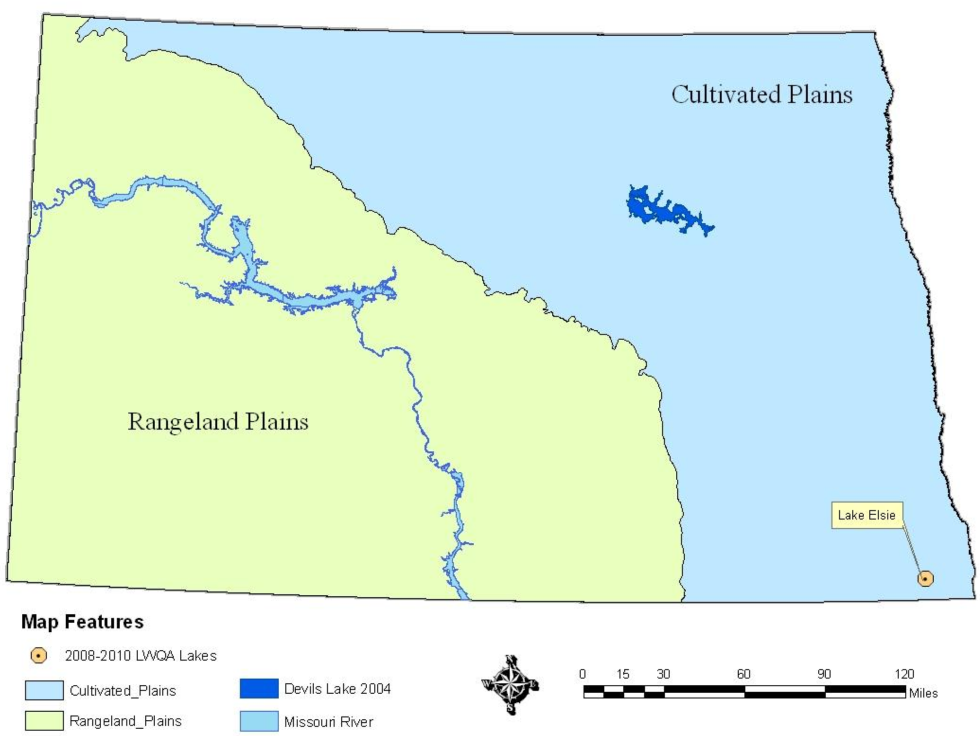

Figure 4. Lake Elsies's Location and the Cultivated and Rangeland Plans Regions

Recreational Facilities: Recreational facilities include a cement boat dock, courtesy dock, a fishing pier, two rock fishing points, and a nice public swim beach and outdoor toilets (Figure 2).

Water Quality Standards Classification: Lake Elsie is classified in the state "Standards of Quality for Waters of the State" (NDDoH, 2011) as a class 3 Lake. Class 3 lakes or reservoirs are defined as a "warm water fisheries" or "waters capable of supporting natural reproduction and growth of warm water fishes (e.g., largemouth bass and bluegill) and associated aquatic biota. Some cool water species may also be present.

Historical Water Quality Sampling: Historical water quality data include three samples collected in 1992-1993 and 4 in 2005-2006.

WATER QUALITY MONITORING RESULTS

The water quality assessment for Lake Isabel is presented in four general categories: 1) temperature and dissolved oxygen profile results; 2) general water quality characterization; 3) nutrient limitation; and 4) trophic status. Where appropriate, results have been compared to the historical and regional data.

Temperature and Dissolved Oxygen Profile Results: There are ten temperature and dissolved oxygen profiles for Lake Elsie collected in three periods 1992-93, 2005-2006 and 2010 (Figures 5 and 6). The profile data show that the water body does weakly thermally stratify occasionally, and that in response dissolved oxygen decline though not rapidly or completely. Of note, the decline in dissolved oxygen appears to have improved between 1992-1993 and 2005-2006 and even more so between 2005-2006 and 2010 (Figure 6). During the entire period of record (1992-2010) only once, on March 2, 1993, was the lakes dissolved oxygen profiles below the States standard concentration of 5 mg/L.

General Water Quality: Data collected in 2010 indicate that Lake Elsie is well buffered with total alkalinity as $CaCO_3$ concentrations ranging from 178 to 195 mg/L (Table 1). The reservoir is nearly evenly dominated by both sodium sulfate and sodium bicarbonate with average sodium, sulfate and bicarbonate concentration of 15.6 mg/L, 225 mg/L and 226 mg/L, respectively. The average total dissolved solids concentration and specific conductance measurements for the 2010 sampling period were 491 mg/L, and 773 µmhos/cm, respectively, and the average total nitrogen as N and total phosphorus as P concentrations were 0.740 mg/L and 0.0.013 mg/L respectively.

When compared to the water quality for natural lakes in the Cultivated Plans region, Lake Elsie is generally fresher and less eutrophic than most (Table 3). For example, the average regional concentrations for TDS, total nitrogen, and total phosphorus concentrations are 507 mg/L, 1.486 mg/L, and 0.090 mg/L respectively, compared to Lake Elsie's average TDS, total nitrogen, and total phosphorus concentrations of 491 mg/L, 0.740 mg/L and 0.031 mg/L respectively.

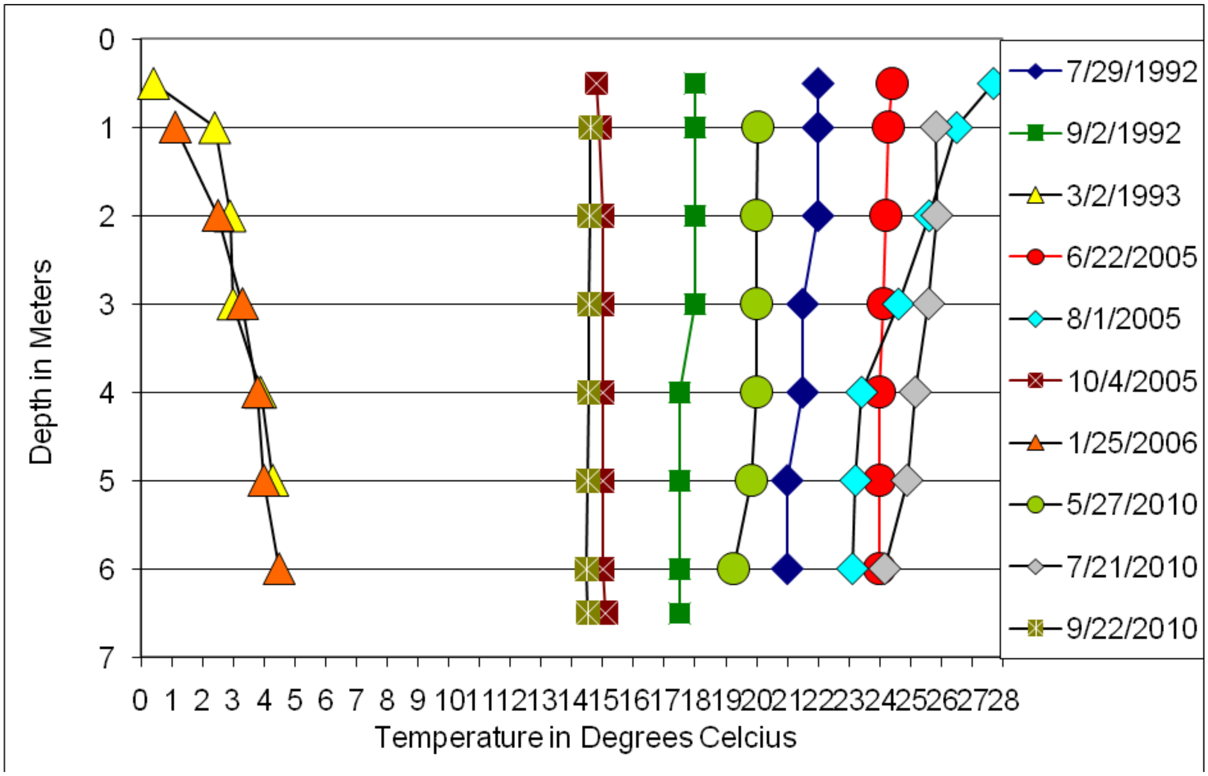

Figure 5. Temperature Profiles for Lake Elsie

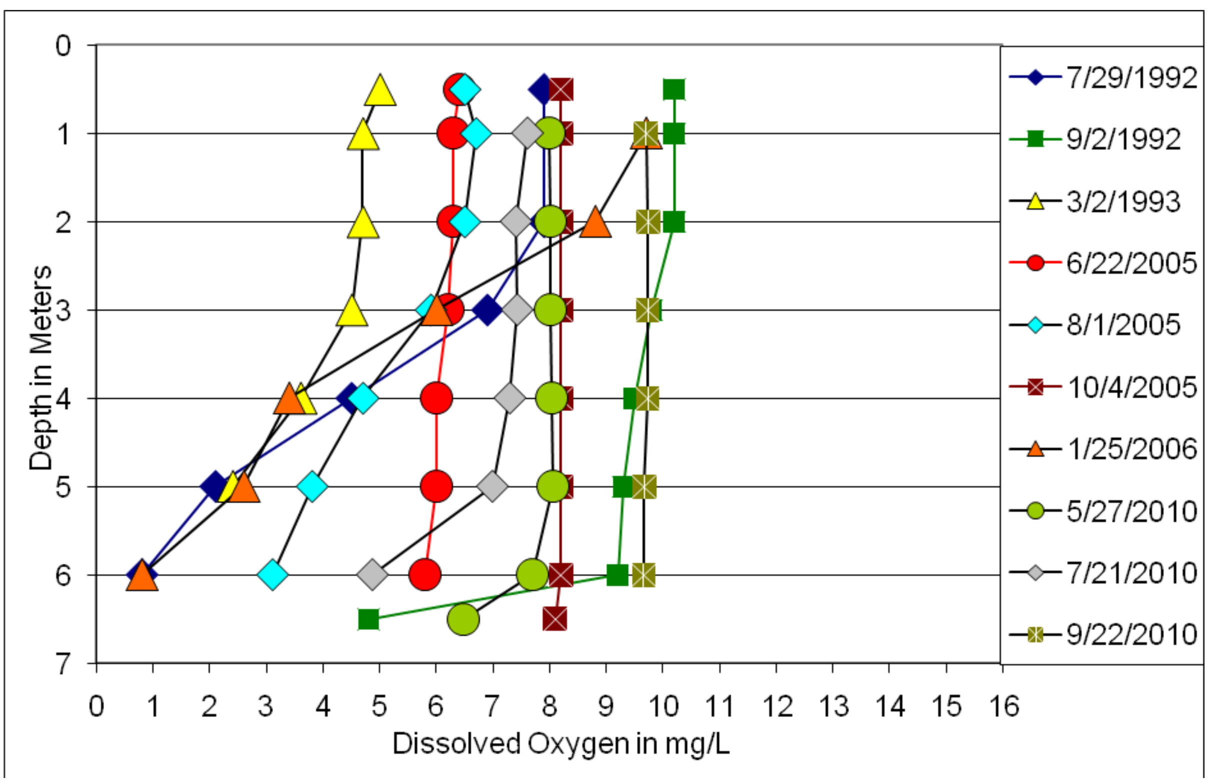

Figure 6. Dissolved Oxygen Profiles for Lake Elsie

Table 1. Statistical Summary of Lake Elsie's 2010 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	3	188	178	195	9
Total Ammonia as N	mg/L	3	0.169	0.054	0.284	0.115
Bicarbonate (HCO_3)	mg/L	3	226	209	236	15
Calcium (Ca)	mg/L	3	75.4	69.2	80.0	5.6
Carbonate (CO_3)	mg/L	3	2	1[1]	4	2
Chloride (Cl)	mg/L	3	6	5	6	0
Chlorophyll-a	µg/L	3	2.5	1.5	3.0	0.9
Specific Conductance	µmhos	3	773	764	786	12
Total Dissolved Solids	mg/L	3	491	472	507	18
Total Hardness as ($CaCO_3$)	mg/L	3	385	380	395	8
Hydroxide (OH)	mg/L	3	1.0[1]	1.0[1]	1.0[1]	0.0
Iron (Fe)	mg/L	3	0.100	0.053	0.130	0.041
Magnesium (Mg)	mg/L	3	47.8	45.7	50.2	2.3
Nitrate + Nitrite as N	mg/L	3	0.103	0.040	0.160	0.060
Total Kjeldahl Nitrogen as N	mg/L	3	0.636	0.483	0.813	0.166
Total Nitrogen as N	mg/L	3	0.740	0.523	0.923	0.202
pH		3	8.30	8.24	8.37	0.07
Total Phosphorus as P	mg/L	3	0.013	0.004[1]	0.030	0.014
Potassium (K)	mg/L	3	6.1	5.7	6.4	0.4
Sodium (Na)	mg/L	3	15.6	15.3	15.9	0.3
Sulfate (SO4)	mg/L	3	225	217	233	8

[1]Equal to the lower reporting limit

When comparing historical water quality data (1992-1993 and 2005-2006) to the 2010 water quality data, it appears that Lake Elsie's water quality is improving. For example, the historical average bicarbonate, sulfate and sodium concentrations were 242 mg/L, 336 mg/L and 28.6 mg/L, respectively, compared to the 2010 averages of 226 mg/L, 225 mg/L and 15.6 mg/L (Tables 1 and 2). The decline in sodium sulfate has been enough that the lake is close to switching from being sodium sulfate dominated to sodium bicarbonate dominated. While not conclusive, reductions in sulfate concentrations are often associated with reductions in pollution impacts and should be viewed optimistically.

Like dissolved solids, nutrient concentrations also appear to be trending downward with total nitrogen and total phosphorus concentrations decreasing from 0.911 mg/L and 0.034 mg/L to 0.740 mg/L and 0.031 mg/L in 2010. The reductions in nutrient concentrations also support a hypothesis that the lake is experiencing a reduction in pollution or is recovering from past pollution impacts.

Table 2. Statistical Summary of Lake Elsie's 1992-2006 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	7	205	179	236	18
Total Ammonia as N	mg/L	7	0.248	0.011	0.648	0.207
Bicarbonate (HCO_3)	mg/L	7	242	204	288	28
Calcium (Ca)	mg/L	7	81.0	61.6	99.7	14.1
Carbonate (CO_3)	mg/L	6	5	1[1]	10	4
Chloride (Cl)	mg/L	7	10	8	14	2
Chlorophyll-a	µg/L	6	9.9	1.5	31.0	11.8
Specific Conductance	µmhos	7	999	750	1410	261
Total Dissolved Solids	mg/L	7	662	475	918	188
Total Hardness as ($CaCO_3$)	mg/L	7	496	347	660	133
Hydroxide (OH)	mg/L	5	1.0[1]	1.0[1]	1.0[1]	0.0
Iron (Fe)	mg/L	7	0.090	0.042	0.204	0.058
Magnesium (Mg)	mg/L	7	71.3	47.0	99.7	24.0
Nitrate + Nitrite as N	mg/L	7	0.147	0.017	0.520	0.174
Total Kjeldahl Nitrogen as N	mg/L	6	1.004	0.503	1.640	0.485
Total Nitrogen as N	mg/L	4	0.911	0.703	1.240	0.231
pH		7	8.28	7.76	8.49	0.26
Total Phosphorus as P	mg/L	7	0.034	0.007	0.053	0.017
Potassium (K)	mg/L	7	11.1	7.7	15.0	3.4
Sodium (Na)	mg/L	7	28.6	17.1	42.1	10.4
Sulfate (SO4)	mg/L	7	336	224	506	132

[1]Equal to the lower reporting limit

Limiting Nutrients: The ten water quality samples collected between 1992 and 2010 indicate that Lake Elsie is phosphorus limited (Figure 7). The limiting nutrient assessment is based on the assumption that either nitrogen or phosphorus is limiting algal growth and that the ratio of total nitrogen as N to total phosphorus as P (N:P), by weight in the average algae is approximately 15 to 1. When the N:P ratio is less than 15:1, nitrogen is assumed to be the limiting nutrient and when it exceeds 15:1, the limiting nutrient is assumed to be phosphorus.

Trophic Status Assessment: Based on the chlorophyll-a, Secchi disk transparency, and total phosphorus data collected in 2010, Lake Elsie's trophic status is mesotrophic. The trophic status index (TSI) scores ranged from a low of 24 based on total phosphorus concentrations to a high of 60 based on secchi disk transparency (Figure 8).

Trends: A total of ten total phosphorus samples, nine chlorophyll-a samples, and nine Secchi disk transparency measurements collected during the sampling periods of 1992-93 and 2010 were available to evaluate trends in the trophic status of Lake Elsie. In viewing all the data, it would be difficult to come up with any conclusion other than Lake Elsie is improving in general water quality and trophic condition. This is clearly demonstrated in Figure 8 when TSI scores ranged from eutrophic to hypereutrophic in 1992-1993 to oligotrophic to eutrophic in 2010.

Table 3. Statistical Summary of Water Quality Data[2] Collected from Natural and Enhanced Natural Lakes in the Cultivated Plains Ecological Region of North Dakota

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	191	340	166	1120	181
Total Ammonia as N	mg/L	281	0.106	0.001	1.620	0.198
Bicarbonate (HCO_3)	mg/L	191	355	171	1040	154
Calcium (Ca)	mg/L	193	53.7	12.6	210.0	33.1
Carbonate (CO_3)	mg/L	188	30	1[1]	220	41
Chloride (Cl)	mg/L	191	90	3[1]	1260	206
Chlorophyll-a	µg/L	233	16.4	1.5[1]	908.0	61.8
Specific Conductance	µmhos	210	1742	361	11500	1879
Total Dissolved Solids	mg/L	192	1285	191	9880	1593
Total Hardness as ($CaCO_3$)	mg/L	193	507	173	1820	273
Hydroxide (OH)	mg/L	167	1.0	0.0[1]	1.0	0.2
Iron (Fe)	mg/L	189	0.162	0.007	1.620	0.226
Magnesium (Mg)	mg/L	193	90.6	28.4	413.0	63.1
Nitrate + Nitrite as N	mg/L	272	0.052	0.001[1]	0.680	0.086
Total Kjeldahl Nitrogen as N	mg/L	179	1.497	0.080	4.110	0.632
Total Nitrogen as N	mg/L	154	1.486	0.523	3.860	0.566
pH		193	8.48	1.78	9.56	0.76
Total Phosphorus as P	mg/L	283	0.090	0.002[1]	1.460	0.144
Potassium (K)	mg/L	193	27.7	2.2	179.0	35.6
Sodium (Na)	mg/L	193	227.8	4.5	2570.0	441.5
Sulfate (SO4)	mg/L	191	555	7	3880	728

[1]Equal to the lower reporting limit
[2]Data collected from 53 natural lakes between 1991 and 2010

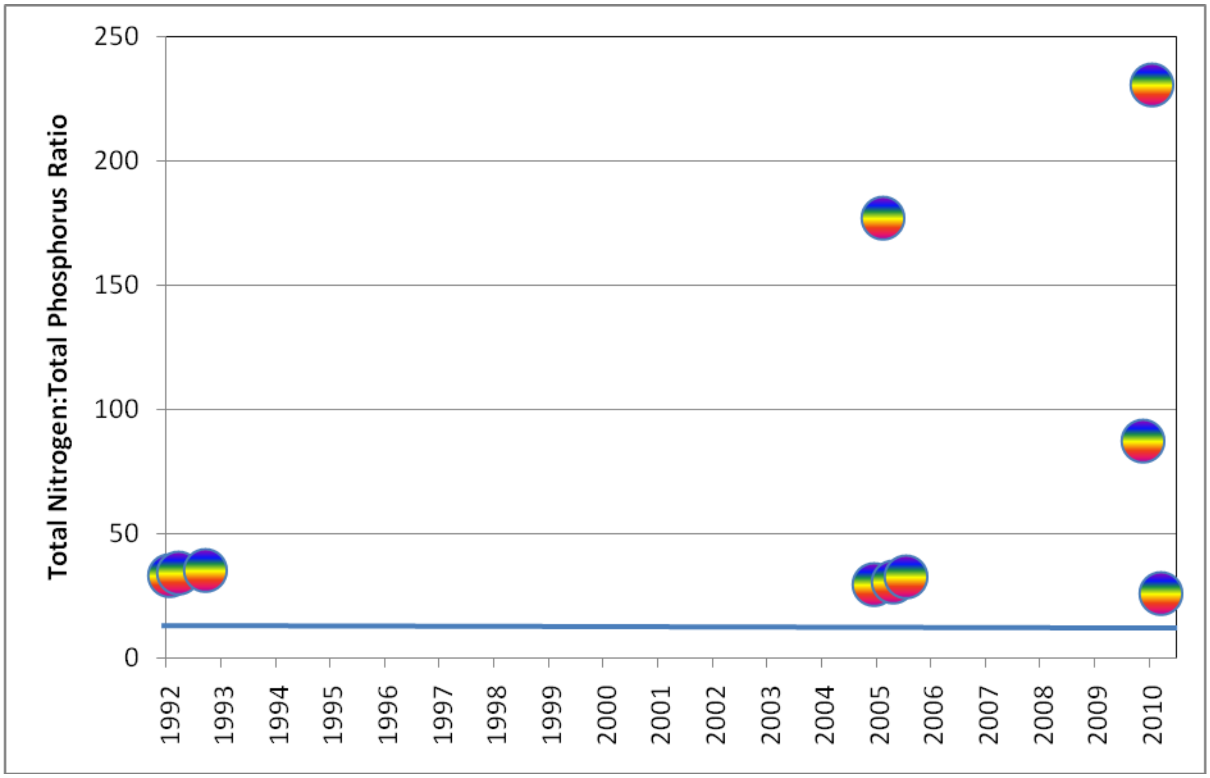

Figure 7. Lake Elsie's Total Nitrogen to Total Phosphorus Ratio

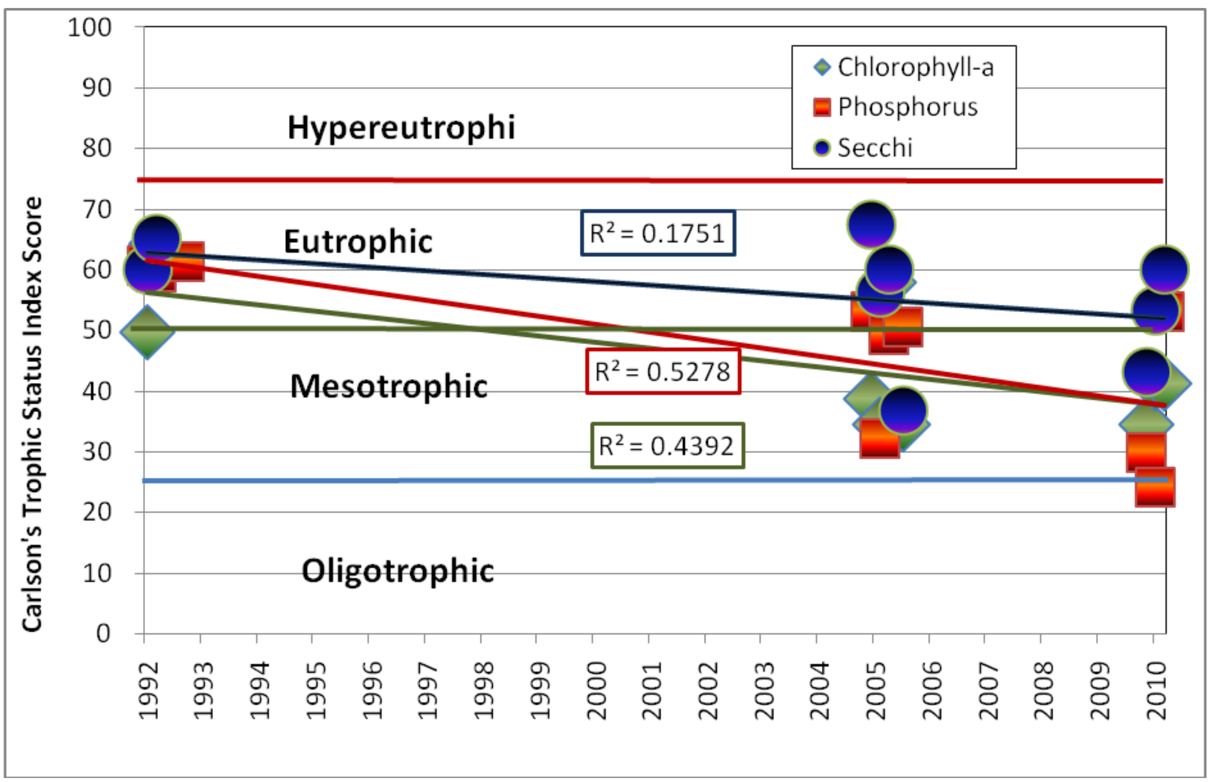

Figure 8. Lake Elsie's TSI Scores

Buffalo Lake, Sargent County

BACKGROUND

Location: Buffalo Lake is a glacial lake located in Sargent County 4 miles north and 5 mile west of Cayuga, North Dakota (Figure 1). The fishery is managed by the North Dakota Game and Fish. Fish species managed for are northern pike and walleye.

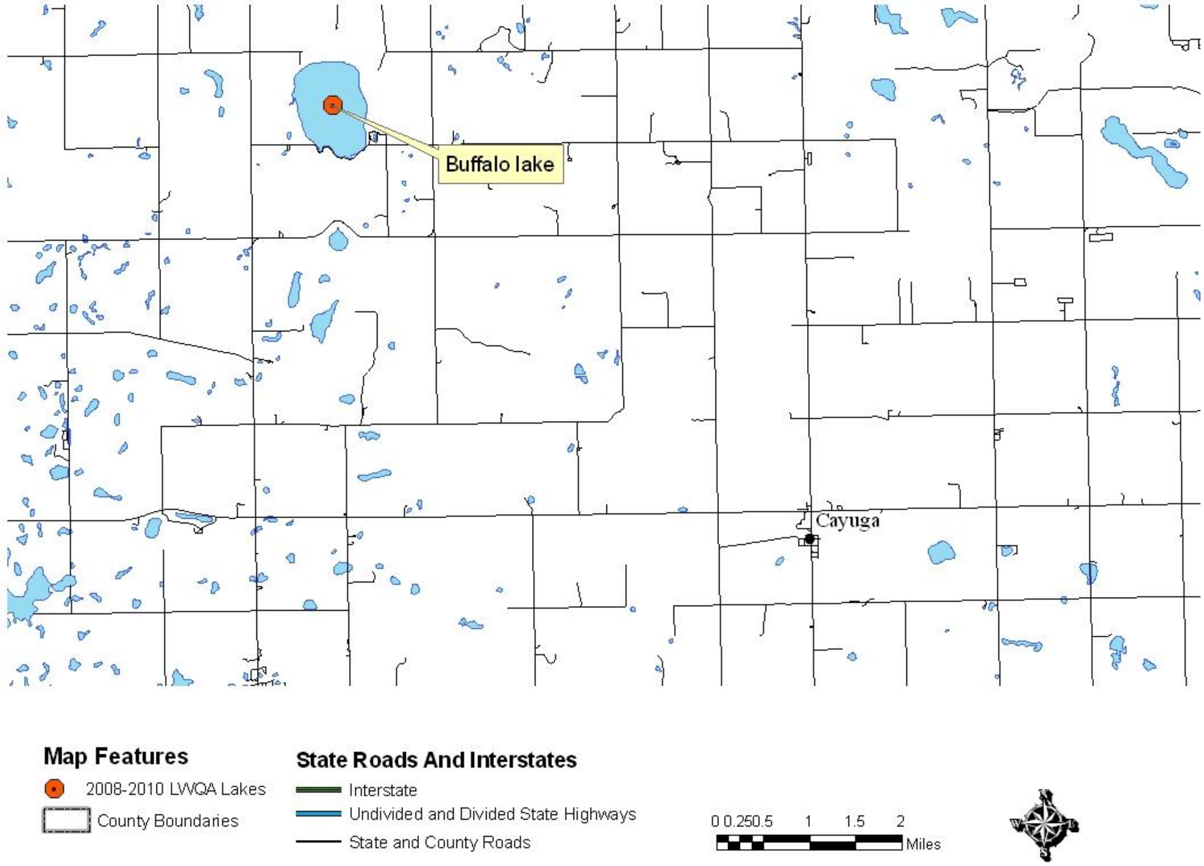

Figure 1. Location of Buffalo Lake

Physiographic/Ecological Setting: Buffalo Lake has a surface area of 4101 acres a maximum depth of 19.5 ft and an average depth of 16.4 ft (Figure 2). The lake is located within the Northern Glaciated Plains Level III Ecoregion, which is part of the broader Cultivated Plains region (Figures 3 and 4).

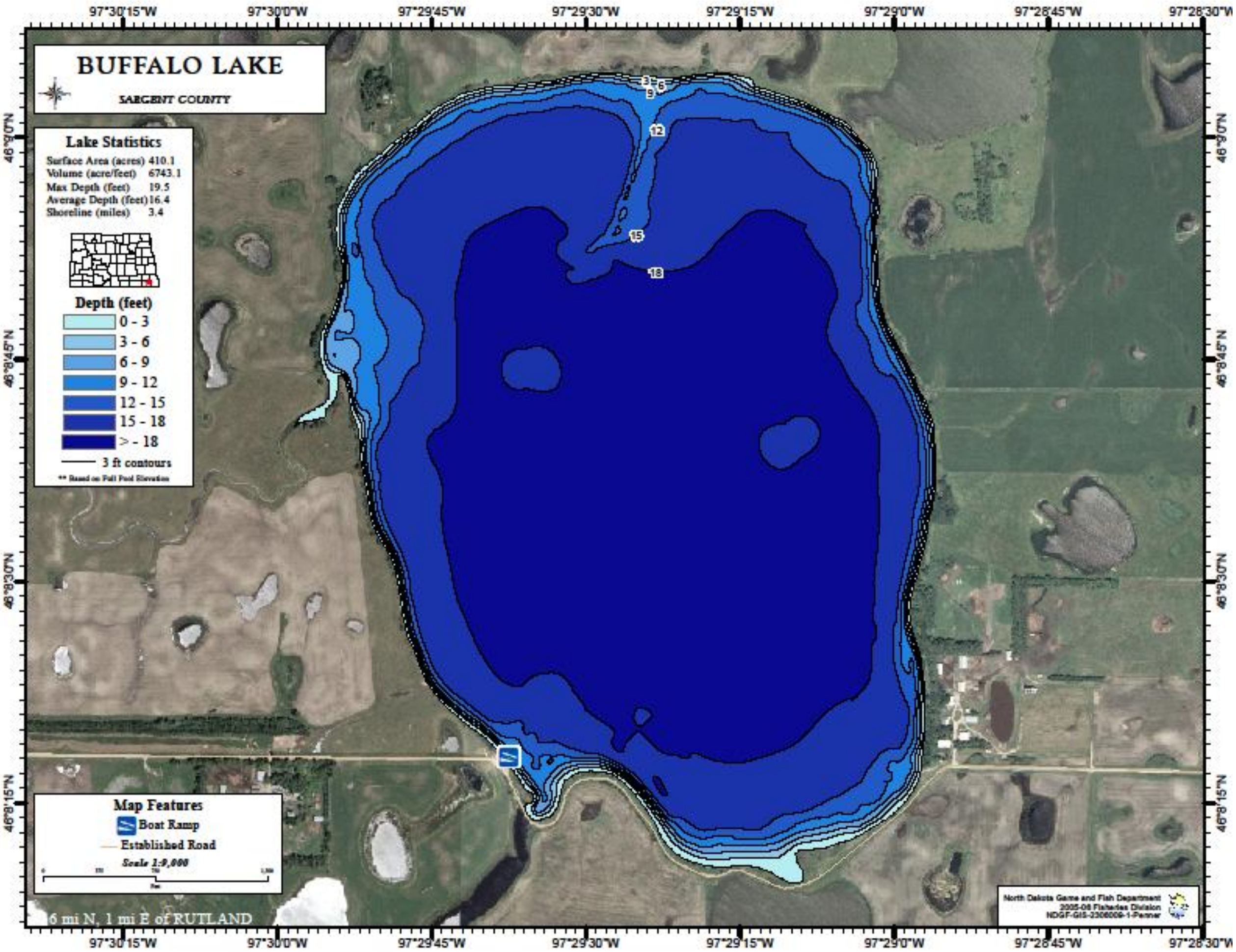

Figure 2. Contour Map of Buffalo Lake (Map Courtesy of North Dakota Game and Fish Department)

Recreational Facilities: Recreational facilities at Buffalo Lake include a cement boat ramp, courtesy dock and outdoor toilet.

Water Quality Standards Classification: Buffalo Lake is classified in the state "Standards of Quality for Waters of the State" (NDDoH, 2011) as a class 3 lake. Class 3 lakes or reservoirs are defined as a "warm water fishery" or "waters capable of supporting natural reproduction and growth of warm water fishes (e.g., largemouth bass and bluegill) and associated aquatic biota. Some cool water species may also be present."

Historical Water Quality Sampling: No historical water quality data.

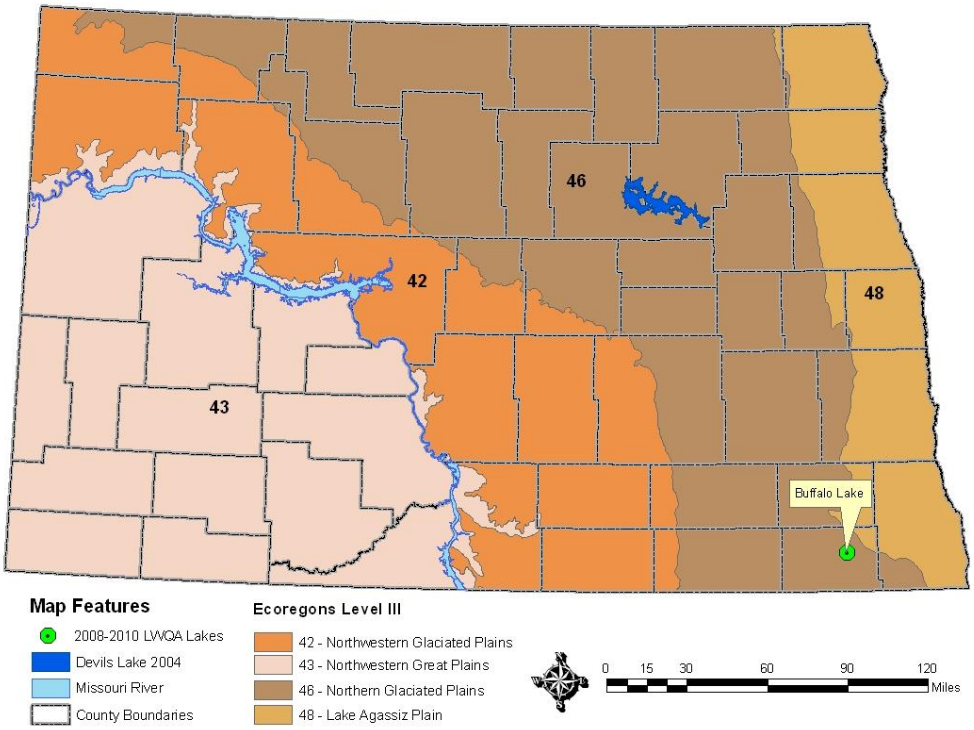

Figure 3. Buffalo Lake's Location and the Level III Ecoregions

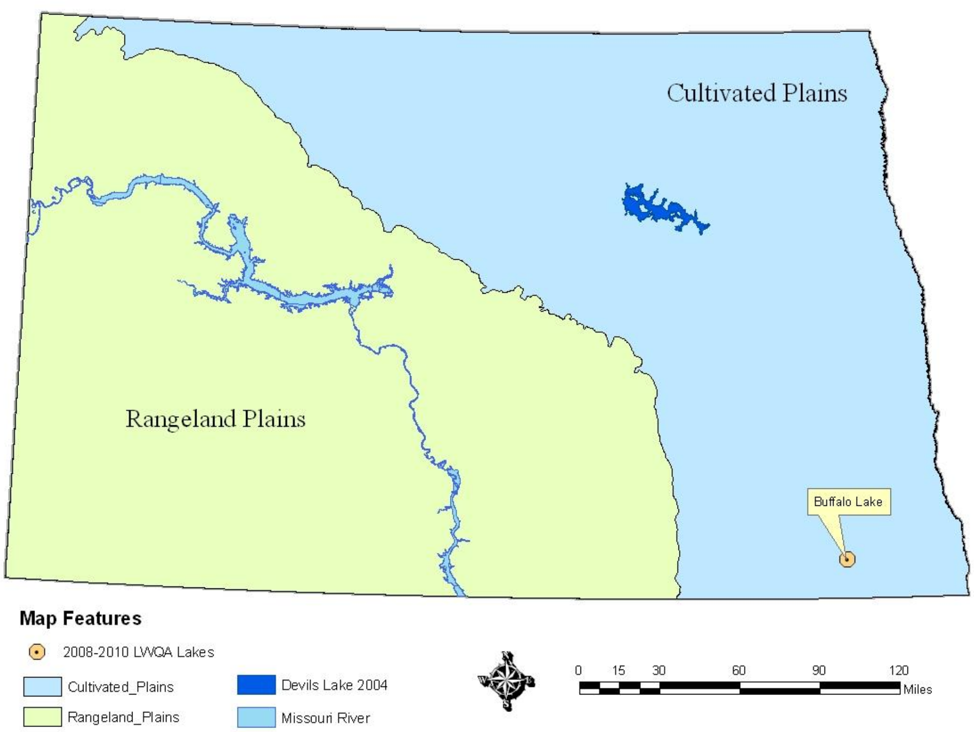

Figure 4. Buffalo Lake Location and the Cultivated and Rangeland Plans Regions

WATER QUALITY MONITORING RESULTS

The water quality assessment for Buffalo Lake is presented in four general categories: 1) temperature and dissolved oxygen profile results; 2) general water quality characterization; 3) nutrient limitation; and 4) trophic status. Additionally, where appropriate, results have been compared to regional data.

Temperature and Dissolved Oxygen Profile Results: There are three temperature and dissolved oxygen profiles for Buffalo Lake collected in 2010 (Figures 5 and 6). The profile data shows that Buffalo Lake was weakly thermally stratified at 4 meters of depth in July and September visits.

During periods of thermal stratification Buffalo Lake's dissolved oxygen concentrations declined. The decline was only below the thermally stratified layer and was not complete. This allowed aquatic life access to adequate dissolved oxygen throughout the entire monitoring period (Figure 6).

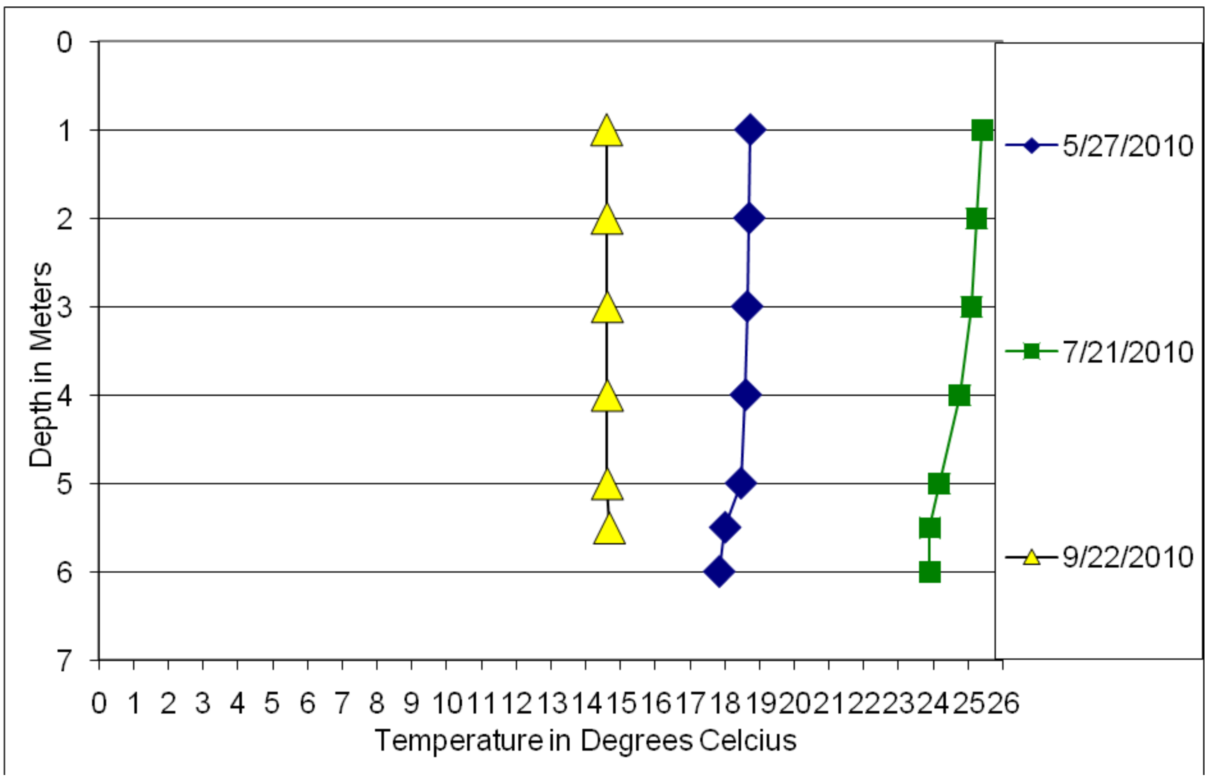

Figure 5. Temperature Profiles for Buffalo Lake

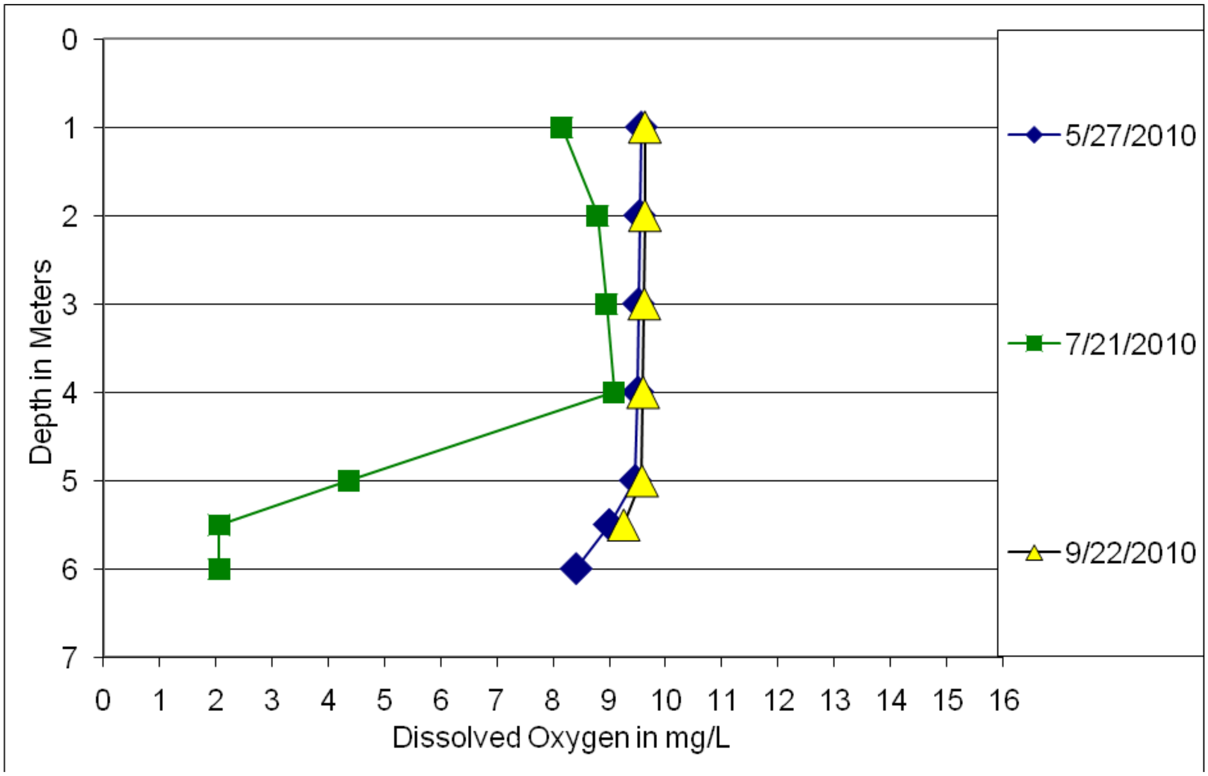

Figure 6. Dissolved Oxygen Profiles for Buffalo Lake

General Water Quality: Data collected in 2010 indicate that Buffalo Lake is well buffered with total alkalinity as $CaCO_3$ concentrations averaging 275 mg/L (Table 1). The lake is sodium bicarbonate dominated with an average sodium concentration of 33.7 mg/L and an average bicarbonate concentration of 270 mg/L. The average total dissolved solids concentration and specific conductance measurement for 2010 sampling period were 451 mg/L and 916 µmhos/cm respectively, and the average total nitrogen as N and total phosphorus as P concentrations were 1.563 mg/L and 0.548 mg/L respectively.

When compared to water quality from natural lakes in the Cultivated Plans region, Buffalo Lake is fairly average with the exception of higher total phosphorus concentrations than most (Table 3). For example, the regional average TDS, total nitrogen, and total phosphorus concentrations are 507 mg/L, 1.486 mg/L and 0.090 mg/L, respectively, compared to Buffalo Lake's average TDS, total nitrogen, and total phosphorus concentrations of 451 mg/L, 1.563 mg/L, and 0.548 mg/L.

Table 1. Statistical Summary of Buffalo Lake's (Sargent County) 2010 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	3	275	255	291	18
Total Ammonia as N	mg/L	3	0.206	0.170	0.279	0.063
Bicarbonate (HCO_3)	mg/L	3	270	241	296	28
Calcium (Ca)	mg/L	3	79.2	73.2	83.4	5.4
Carbonate (CO_3)	mg/L	3	32	7	56	25
Chloride (Cl)	mg/L	3	21	20	21	1
Chlorophyll-a	µg/L	3	11.1	3.0	21.9	9.7
Specific Conductance	µmhos	3	916	865	947	44
Total Dissolved Solids	mg/L	3	589	555	609	29
Total Hardness as ($CaCO_3$)	mg/L	3	451	413	483	35
Hydroxide (OH)	mg/L	3	1.0[1]	1.0[1]	1.0[1]	0.0
Iron (Fe)	mg/L	3	0.219	0.085	0.473	0.220
Magnesium (Mg)	mg/L	3	61.6	56.0	66.7	5.4
Nitrate + Nitrite as N	mg/L	3	0.073	0.030[1]	0.150	0.067
Total Kjeldahl Nitrogen as N	mg/L	3	1.490	1.160	1.720	0.293
Total Nitrogen as N	mg/L	3	1.563	1.190	1.870	0.345
pH		3	8.74	8.39	9.03	0.32
Total Phosphorus as P	mg/L	3	0.548	0.466	0.672	0.109
Potassium (K)	mg/L	3	17.0	16.1	17.5	0.8
Sodium (Na)	mg/L	3	33.7	31.3	35.6	2.2
Sulfate (SO4)	mg/L	3	210	203	216	7

[1]Equal to the lower reporting limit

Limiting Nutrients: The three water quality samples, collected in 2010, define Buffalo Lake as a nitrogen limited waterbody (Figure 7). The limiting nutrient assessment is based on the assumption that either nitrogen or phosphorus is limiting algal growth with the water body, and that the ratio of total nitrogen as N to total phosphorus as P (N:P), by weight in the average algae, is approximately 15 to 1. When the N:P ratio is less than 15:1, nitrogen is assumed to be the limiting nutrient and when it exceeds 15:1, the limiting nutrient is assumed to be phosphorus.

Trophic Status Assessment: Based on the chlorophyll-a, secchi disk transparency, and total phosphorus data collected in 2010, Buffalo Lake's trophic is estimated as eutrophic. The trophic status index scores ranged from a low of 41 based on chlorophyll-a to a high of 98 based on total phosphorus (Figure 8).

Table 2. Statistical Summary of Water Quality Data[2] Collected from Natural and Enhanced Natural Lakes in the Cultivated Plains Ecological Region of North Dakota

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	191	340	166	1120	181
Total Ammonia as N	mg/L	281	0.106	0.001	1.620	0.198
Bicarbonate (HCO_3)	mg/L	191	355	171	1040	154
Calcium (Ca)	mg/L	193	53.7	12.6	210.0	33.1
Carbonate (CO_3)	mg/L	188	30	1[1]	220	41
Chloride (Cl)	mg/L	191	90	3[1]	1260	206
Chlorophyll-a	µg/L	233	16.4	1.5[1]	908.0	61.8
Specific Conductance	µmhos	210	1742	361	11500	1879
Total Dissolved Solids	mg/L	192	1285	191	9880	1593
Total Hardness as ($CaCO_3$)	mg/L	193	507	173	1820	273
Hydroxide (OH)	mg/L	167	1.0	0.0[1]	1.0	0.2
Iron (Fe)	mg/L	189	0.162	0.007	1.620	0.226
Magnesium (Mg)	mg/L	193	90.6	28.4	413.0	63.1
Nitrate + Nitrite as N	mg/L	272	0.052	0.001[1]	0.680	0.086
Total Kjeldahl Nitrogen as N	mg/L	179	1.497	0.080	4.110	0.632
Total Nitrogen as N	mg/L	154	1.486	0.523	3.860	0.566
pH		193	8.48	1.78	9.56	0.76
Total Phosphorus as P	mg/L	283	0.090	0.002[1]	1.460	0.144
Potassium (K)	mg/L	193	27.7	2.2	179.0	35.6
Sodium (Na)	mg/L	193	227.8	4.5	2570.0	441.5
Sulfate (SO4)	mg/L	191	555	7	3880	728

[1]Equal to the lower reporting limit
[2]Data collected from 53 natural lakes between 1991 and 2010

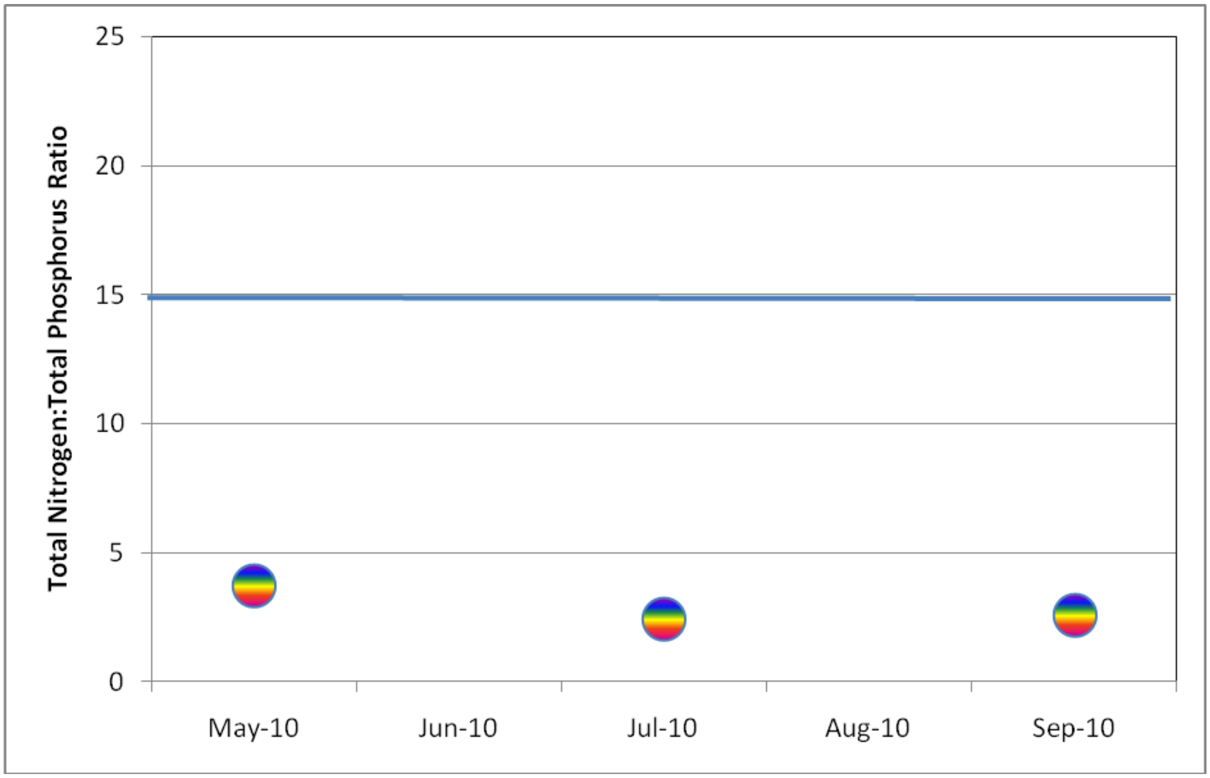

Figure 7. Buffalo Lake's Total Nitrogen to Total Phosphorus Ratio

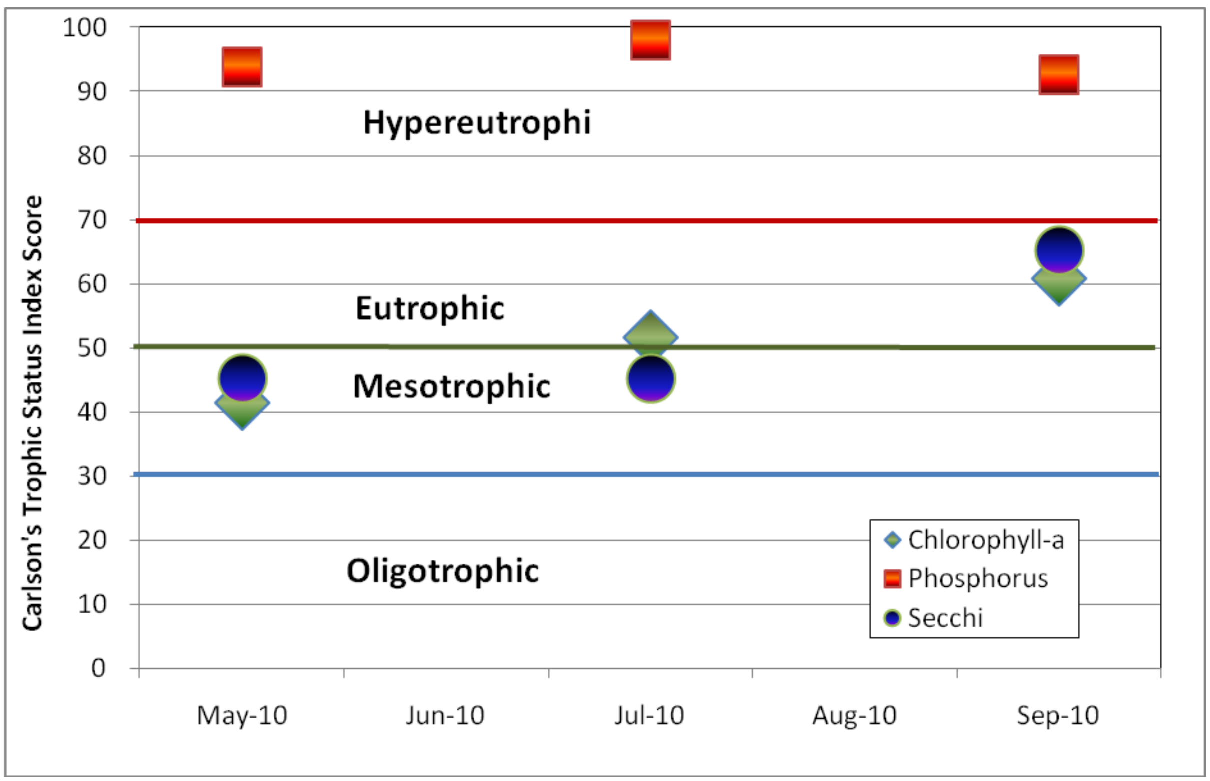

Figure 8. Buffalo Lake's TSI Scores

Lake Tewaukon, Sargent County

BACKGROUND

Location: Lake Tewaukon is a shallow windswept basin on the Tewaukon National Wild Life Refuge. Located 5 miles south of Cayuga, North Dakota (Figure 1), the lake's elevation is enhanced and stabilized with a control structure on the Wild Rice River. The control structure is on the north end of the lake near the public access area (Figure 2). The fishery is managed by the North Dakota Game and Fish. Fish species most recently stocked included northern pike, walleye and black crappie.

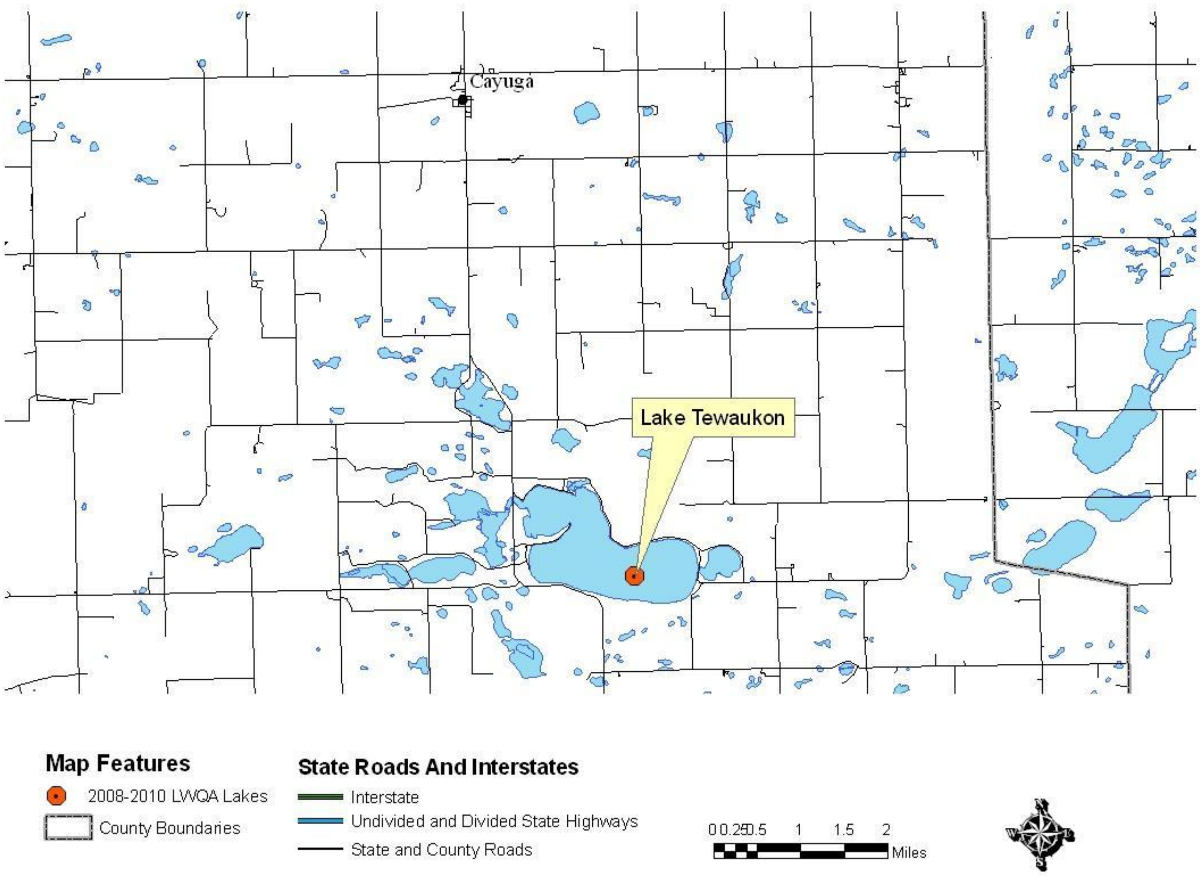

Figure 1. Location of Lake Tewaukon

Physiographic/Ecological Setting: Lake Tewaukon has a surface area of 1038.3 acres a maximum depth of 11.8 ft and an average depth of 10 ft (Figure 2). The lake is located within the Northern Glaciated Plains Level III Ecoregion, which is part of the broader Cultivated Plains region (Figures 3 and 4).

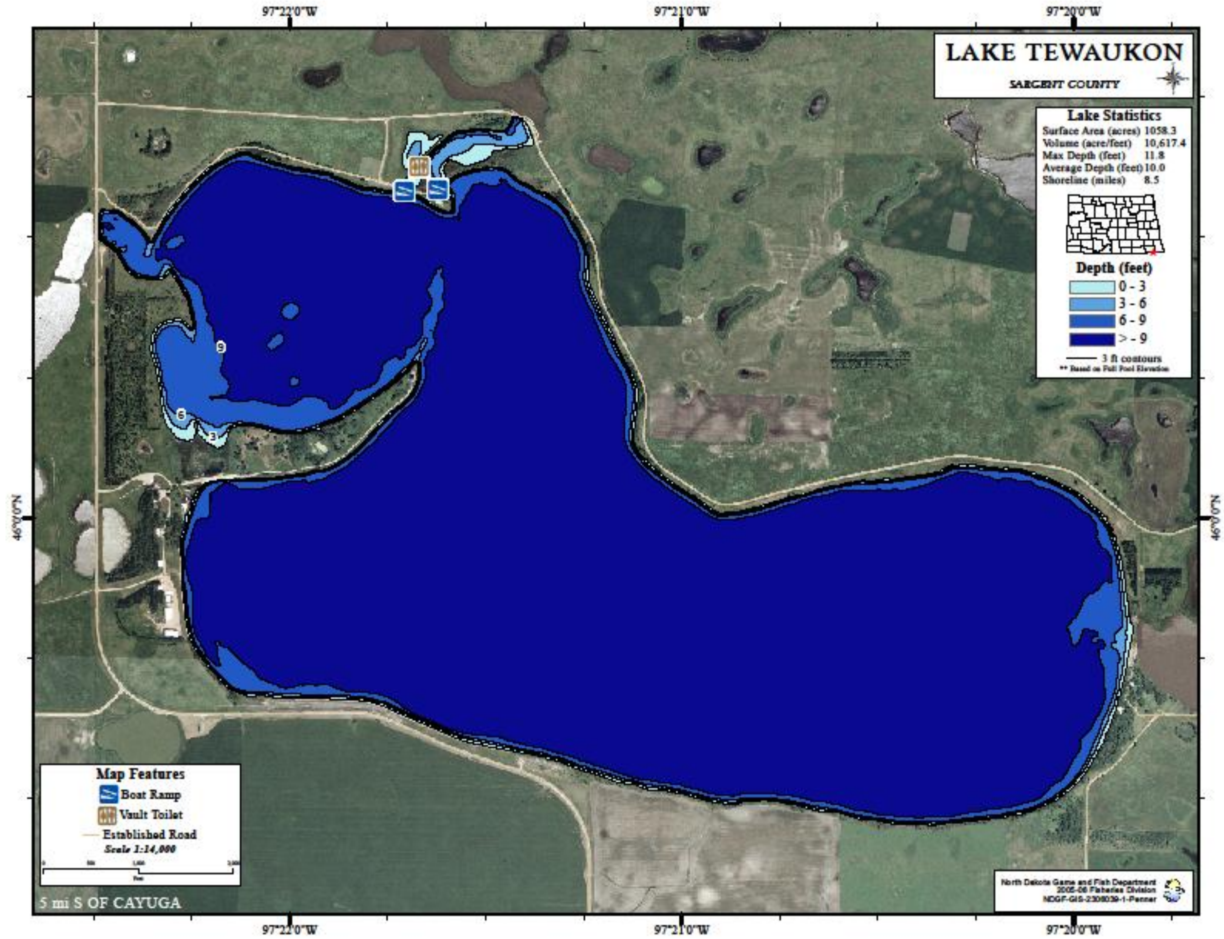

Figure 2. Contour Map of Lake Tewaukon (Map Courtesy of North Dakota Game and Fish Department)

Recreational Facilities: Recreational facilities at Lake Tewaukon include a cement boat ramp, courtesy dock, information board and outdoor toilet.

Water Quality Standards Classification: Lake Tewaukon is classified in the state "Standards of Quality for Waters of the State" (NDDoH, 2011) as a class 3 lake. Class 3 lakes or reservoirs are defined as a "warm water fishery" or "waters capable of supporting natural reproduction and growth of warm water fishes (e.g., largemouth bass and bluegill) and associated aquatic biota. Some cool water species may also be present."

Historical Water Quality Sampling: No historical water quality data.

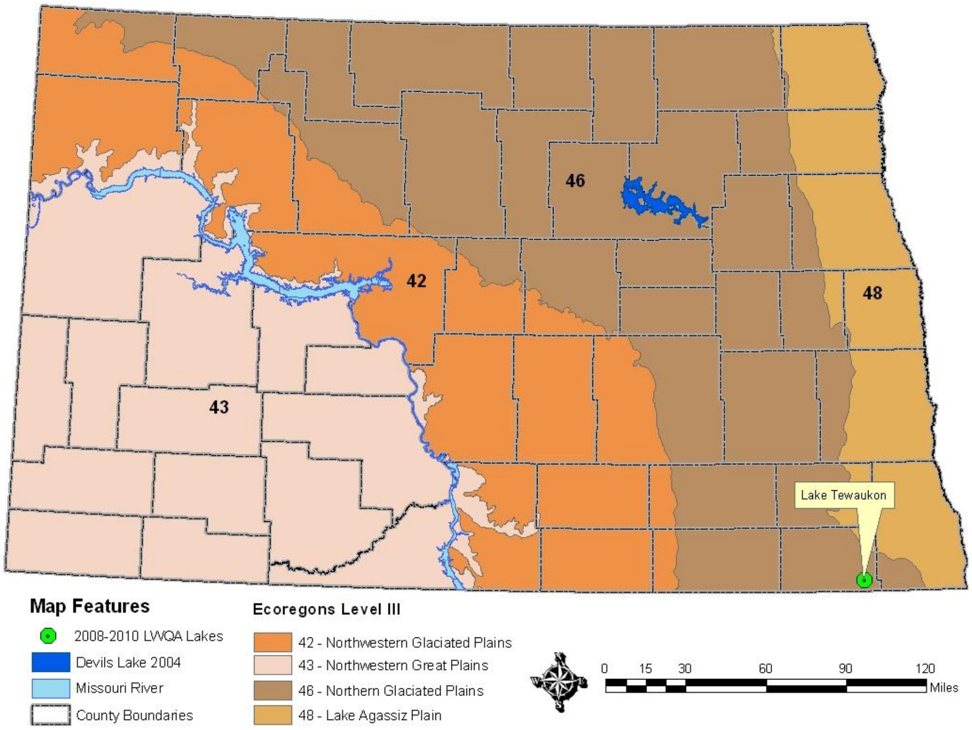

Figure 3. Lake Tewaukon's Location and the Level III Ecoregions

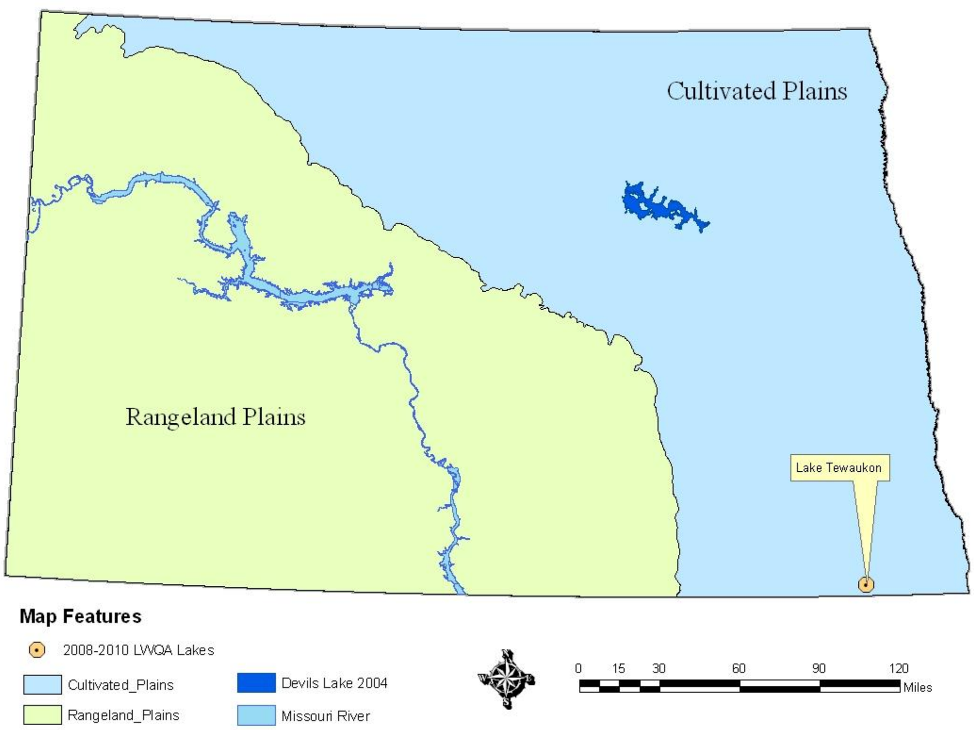

Figure 4. Lake Tewaukon Location and the Cultivated and Rangeland Plans Regions

WATER QUALITY MONITORING RESULTS

The water quality assessment for Lake Tewaukon is presented in four general categories: 1) temperature and dissolved oxygen profile results; 2) general water quality characterization; 3) nutrient limitation; and 4) trophic status. Additionally, where appropriate, results have been compared to regional data.

Temperature and Dissolved Oxygen Profile Results: There are three temperature and dissolved oxygen profiles for Lake Tewaukon collected in 2010 (Figures 5 and 6). The profile data shows that Lake Tewaukon was not thermally stratified during any of the sampling times (Figure 5). Additionally the profiles showed that Lake Tewaukon had adequate dissolved oxygen to support fish and associated biota of a warm water fishery (Figure 6).

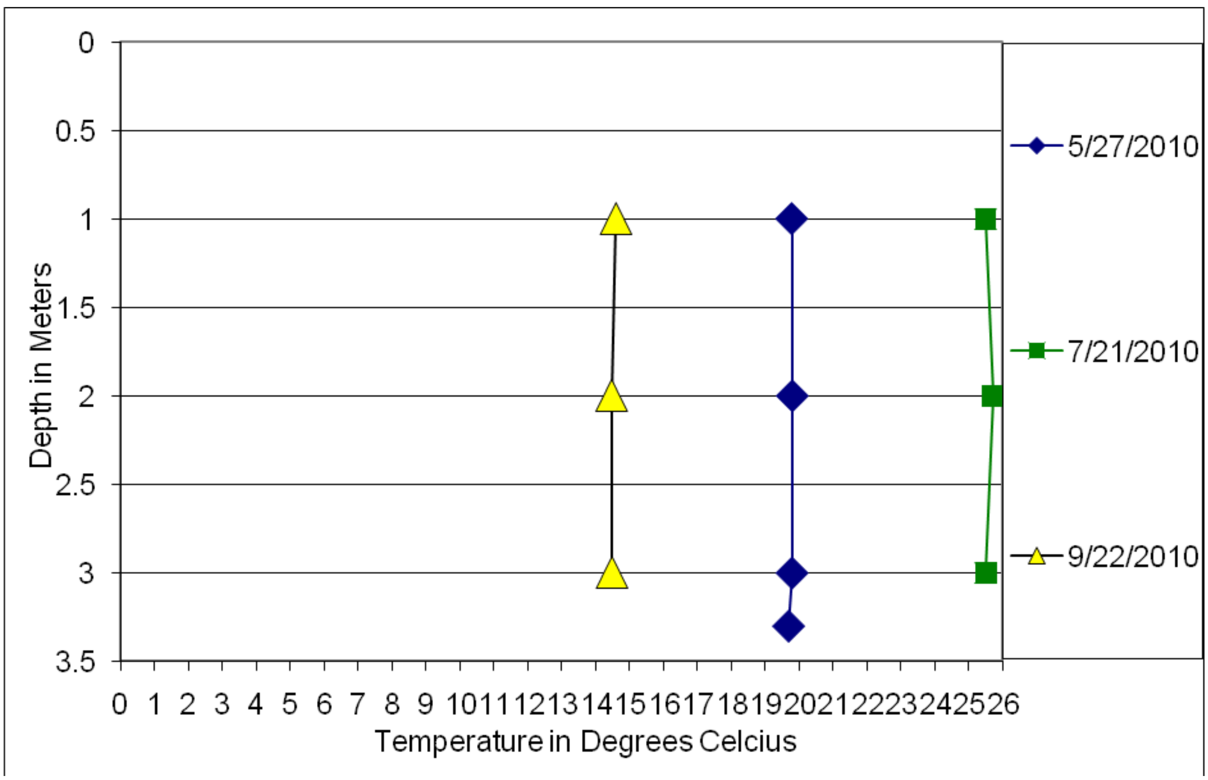

Figure 5. Temperature Profiles for Lake Tewaukon

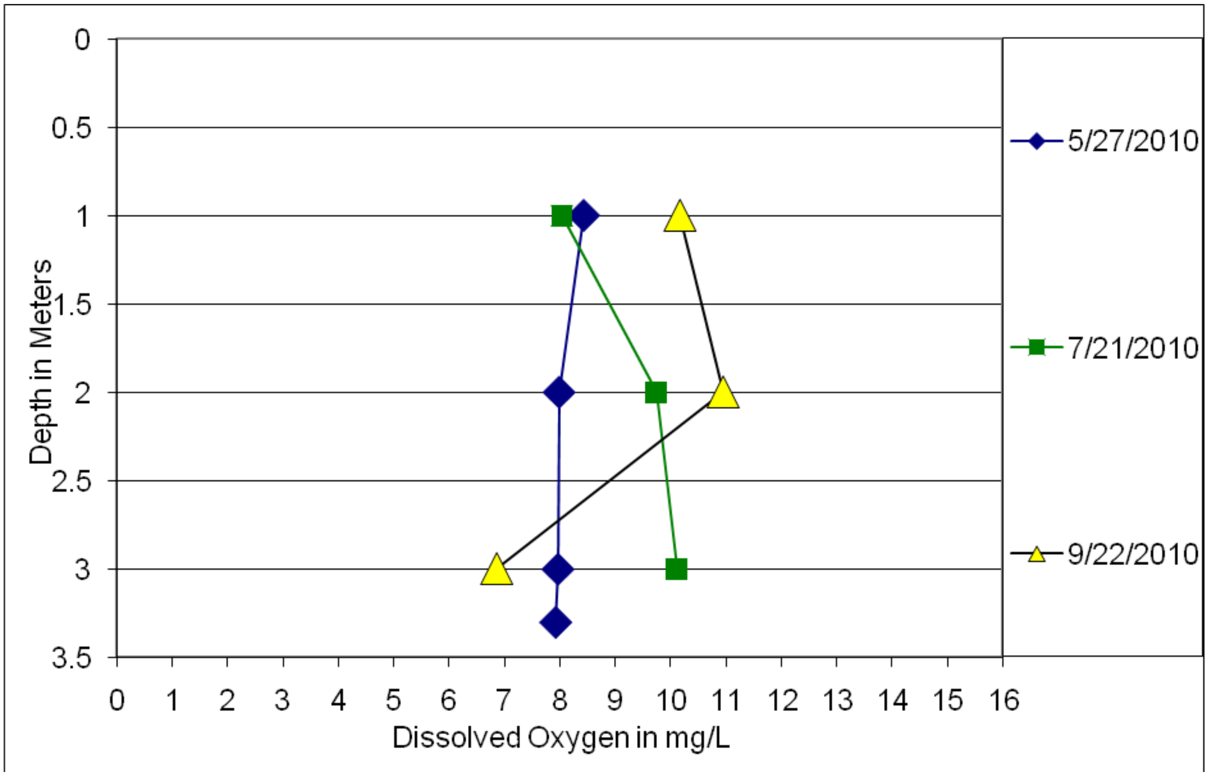

Figure 6. Dissolved Oxygen Profiles for Lake Tewaukon

General Water Quality: Data collected in 2010 indicate that Lake Tewaukon is well buffered with total alkalinity as $CaCO_3$ concentrations averaging 265 mg/L (Table 1). The lake is sodium sulfate dominated with an average sodium concentration of 83.5 mg/L and an average sulfate concentration of 557 mg/L. The average total dissolved solids concentration and specific conductance measurement for 2010 sampling period were 1060 mg/L and 1470 µmhos/cm respectively, and the average total nitrogen as N and total phosphorus as P concentrations were 1.25 mg/L and 0.351 mg/L respectively.

When compared to water quality for natural lakes in the Cultivated Plans region, Lake Tewaukon has more dissolved solids and is more eutrophic than most (Table 3). For example, the regional average TDS, total nitrogen, and total phosphorus concentrations are 507 mg/L, 1.486 mg/L and 0.090 mg/L, respectively, compared to Lake Tewaukon's average TDS, total nitrogen, and total phosphorus concentrations of 1060 mg/L and 0.351 mg/L.

Table 1. Statistical Summary of Lake Tewaukon 2010 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	3	263	262	265	2
Total Ammonia as N	mg/L	3	0.127	0.041	0.170	0.074
Bicarbonate (HCO_3)	mg/L	3	274	253	305	28
Calcium (Ca)	mg/L	3	119.3	110.0	127.0	8.6
Carbonate (CO_3)	mg/L	3	23	7	35	15
Chloride (Cl)	mg/L	3	24	22	27	3
Chlorophyll-a	µg/L	3	34.6	6.0	56.1	25.8
Specific Conductance	µmhos	3	1470	1420	1520	50
Total Dissolved Solids	mg/L	3	1060	1030	1110	44
Total Hardness as ($CaCO_3$)	mg/L	3	707	680	754	41
Hydroxide (OH)	mg/L	3	1.0[1]	1.0[1]	1.0[1]	0.0
Iron (Fe)	mg/L	3	0.533	0.443	0.673	0.123
Magnesium (Mg)	mg/L	3	99.2	91.7	106.0	7.2
Nitrate + Nitrite as N	mg/L	3	0.100	0.030[1]	0.230	0.113
Total Kjeldahl Nitrogen as N	mg/L	3	1.150	0.970	1.280	0.161
Total Nitrogen as N	mg/L	3	1.250	1.200	1.310	0.056
pH		3	8.58	8.35	8.76	0.21
Total Phosphorus as P	mg/L	3	0.351	0.106	0.814	0.401
Potassium (K)	mg/L	3	14.9	14.1	16.2	1.2
Sodium (Na)	mg/L	3	83.5	70.8	89.8	11.0
Sulfate (SO4)	mg/L	3	557	536	586	26

[1]Equal to the lower reporting limit

Limiting Nutrients: The three water quality samples, collected in 2010 defined Lake Tewaukon as a nitrogen limited waterbody (Figure 7). The limiting nutrient assessment is based on the assumption that either nitrogen or phosphorus is limiting algal growth with the water body, and that the ratio of total nitrogen as N to total phosphorus as P (N:P), by weight in the average algae, is approximately 15 to 1. When the N:P ratio is less than 15:1, nitrogen is assumed to be the limiting nutrient and when it exceeds 15:1, the limiting nutrient is assumed to be phosphorus.

Trophic Status Assessment: Based on the chlorophyll-a, secchi disk transparency, and total phosphorus data collected in 2010, Lake Tewaukon's trophic is hypereutrophic. The trophic Status Index scores ranged from a low of 48 based on chlorophyll-a to a high of 101 based on total phosphorus (Figure 8).

Table 2. Statistical Summary of Water Quality Data[2] Collected from Natural and Enhanced Natural Lakes in the Cultivated Plains Ecological Region of North Dakota

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	191	340	166	1120	181
Total Ammonia as N	mg/L	281	0.106	0.001	1.620	0.198
Bicarbonate (HCO_3)	mg/L	191	355	171	1040	154
Calcium (Ca)	mg/L	193	53.7	12.6	210.0	33.1
Carbonate (CO_3)	mg/L	188	30	1[1]	220	41
Chloride (Cl)	mg/L	191	90	3[1]	1260	206
Chlorophyll-a	µg/L	233	16.4	1.5[1]	908.0	61.8
Specific Conductance	µmhos	210	1742	361	11500	1879
Total Dissolved Solids	mg/L	192	1285	191	9880	1593
Total Hardness as ($CaCO_3$)	mg/L	193	507	173	1820	273
Hydroxide (OH)	mg/L	167	1.0	0.0[1]	1.0	0.2
Iron (Fe)	mg/L	189	0.162	0.007	1.620	0.226
Magnesium (Mg)	mg/L	193	90.6	28.4	413.0	63.1
Nitrate + Nitrite as N	mg/L	272	0.052	0.001[1]	0.680	0.086
Total Kjeldahl Nitrogen as N	mg/L	179	1.497	0.080	4.110	0.632
Total Nitrogen as N	mg/L	154	1.486	0.523	3.860	0.566
pH		193	8.48	1.78	9.56	0.76
Total Phosphorus as P	mg/L	283	0.090	0.002[1]	1.460	0.144
Potassium (K)	mg/L	193	27.7	2.2	179.0	35.6
Sodium (Na)	mg/L	193	227.8	4.5	2570.0	441.5
Sulfate (SO4)	mg/L	191	555	7	3880	728

[1]Equal to the lower reporting limit
[2]Data collected from 53 natural lakes between 1991 and 2010

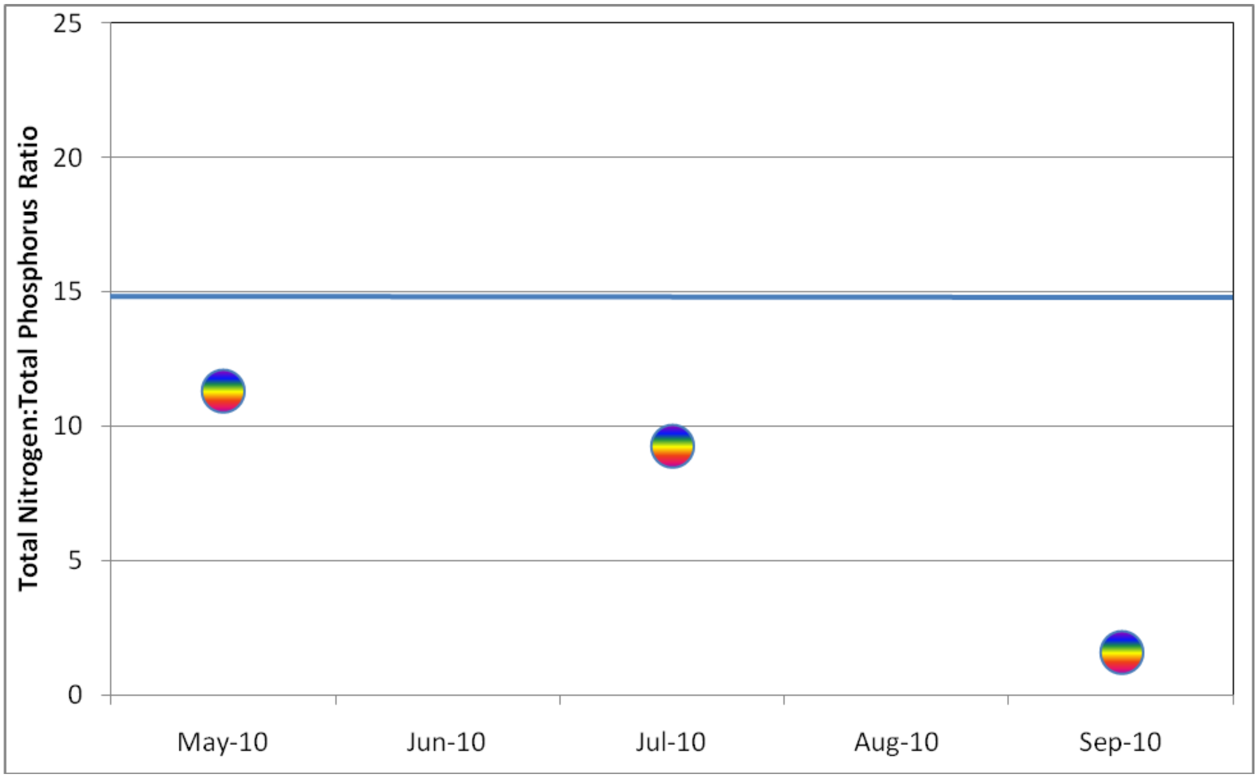

Figure 7. Lake Tewaukon's Total Nitrogen to Total Phosphorus Ratio

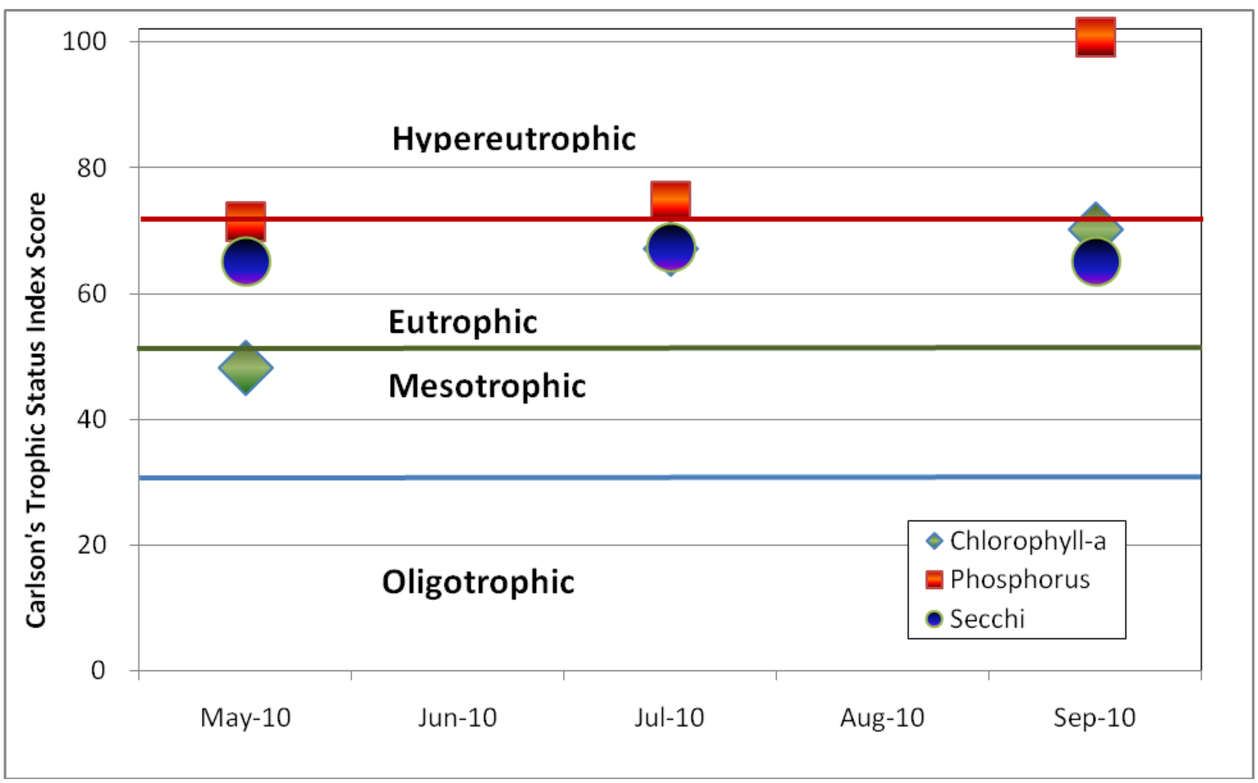

Figure 8. Lake Tewaukon's TSI Scores

Sprague Lake, Sargent County

BACKGROUND

Location: Sprague Lake is a shallow windswept basin on the Tewaukon National Wild Life Refuge system. Located 2 miles south and 1 mile west of Rutland, North Dakota (Figure 1), the lake's elevation is enhanced and stabilized with a control structure on the north shore near the railroad embankment (Figure 2). The fishery is managed by the North Dakota Game and Fish. Fish species most recently stocked included northern pike, walleye and black crappie.

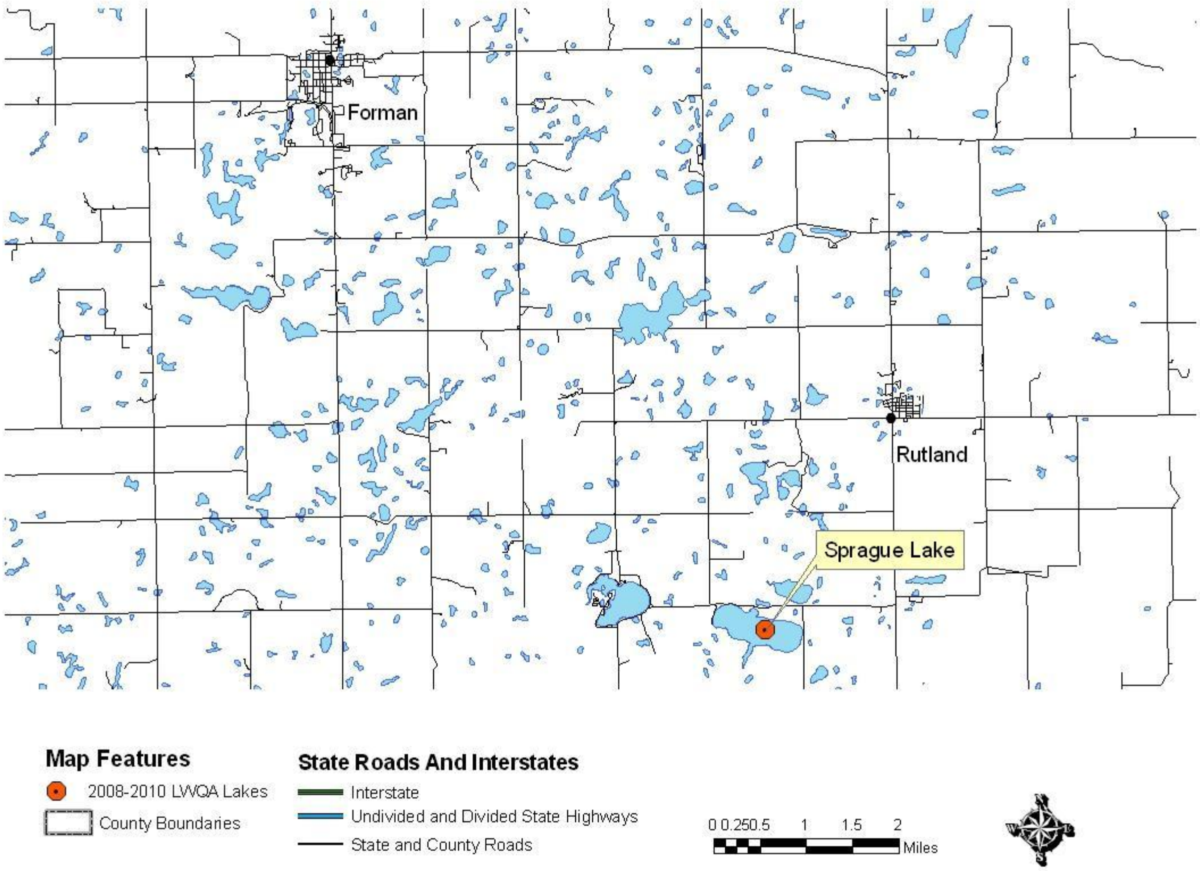

Figure 1. Location of Sprague Lake

Physiographic/Ecological Setting: Sprague Lake has a surface area of 192.1 acres a maximum depth of 10.8 ft and an average depth of 8.3ft (Figure 2). The lake is located within the Northern Glaciated Plains Level III Ecoregion, which is part of the broader Cultivated Plains region (Figures 3 and 4).

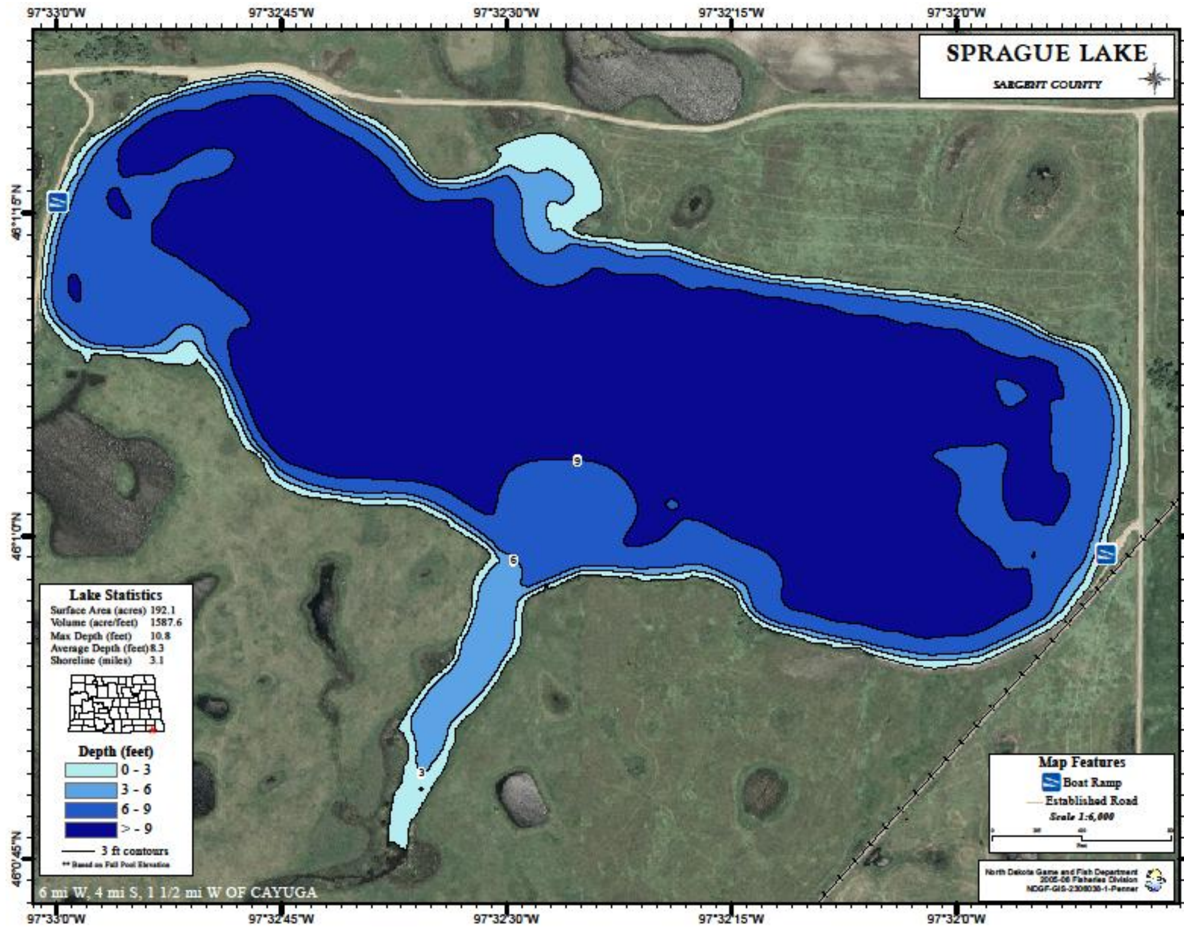

Figure 2. Contour Map of Sprague Lake (Map Courtesy of North Dakota Game and Fish Department)

Recreational Facilities: Recreational facilities at Sprague Lake include a cement boat ramp, courtesy dock, and information board.

Water Quality Standards Classification: Sprague Lake is classified in the state "Standards of Quality for Waters of the State" (NDDoH, 2011) as a class 3 lake. Class 3 lakes or reservoirs are defined as a "warm water fishery" or "waters capable of supporting natural reproduction and growth of warm water fishes (e.g., largemouth bass and bluegill) and associated aquatic biota. Some cool water species may also be present."

Historical Water Quality Sampling: No historical water quality data.

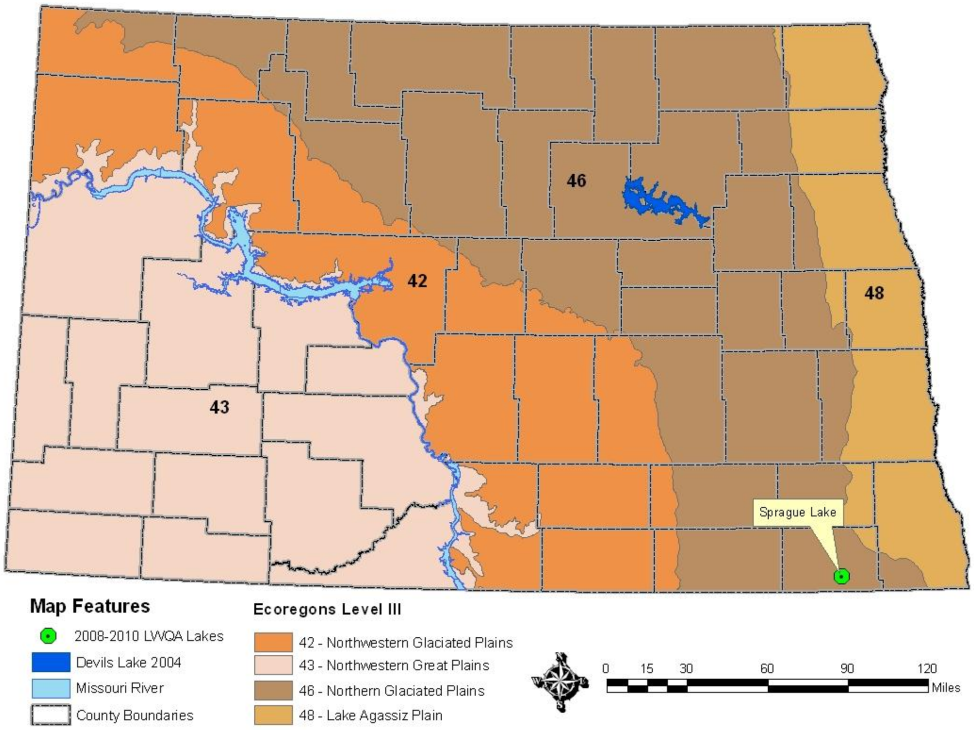

Figure 3. Sprague Lake's Location and the Level III Ecoregions

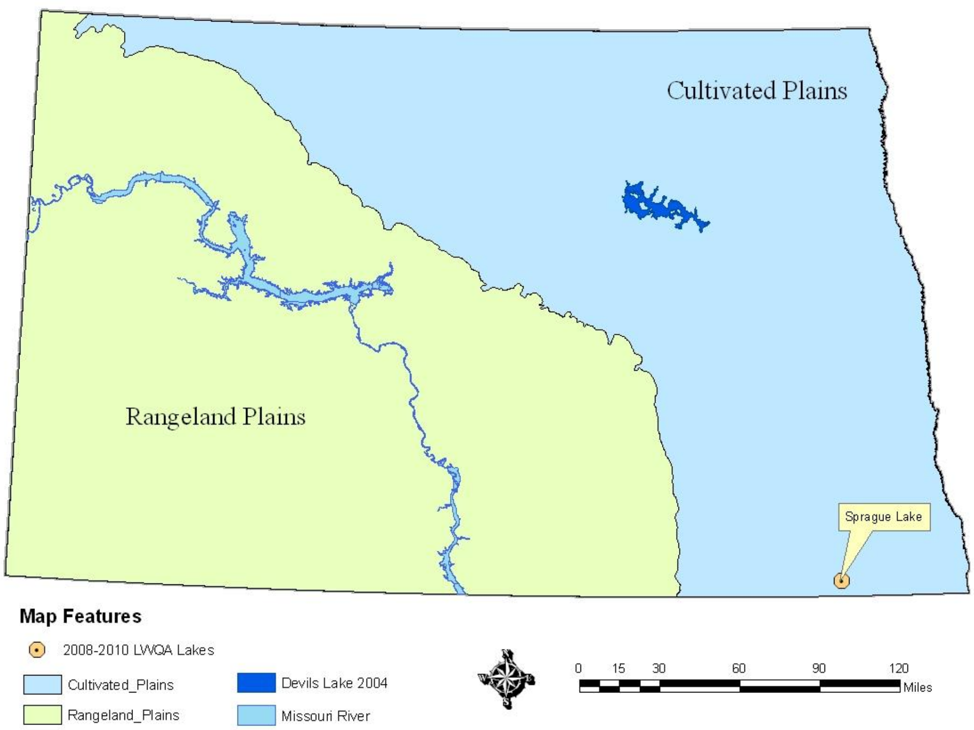

Figure 4. Sprague Lake Location and the Cultivated and Rangeland Plans Regions

WATER QUALITY MONITORING RESULTS

The water quality assessment for Sprague Lake is presented in four general categories: 1) temperature and dissolved oxygen profile results; 2) general water quality characterization; 3) nutrient limitation; and 4) trophic status. Additionally, where appropriate, results have been compared to regional data.

Temperature and Dissolved Oxygen Profile Results: There are three temperature and dissolved oxygen profiles for Sprague Lake collected in 2010 (Figures 5 and 6). The profile data shows that Sprague Lake was not thermally stratified during any of the sampling times (Figure 5). Additionally the profiles showed that Sprague Lake had adequate dissolved oxygen to support fish and associated biota of a warm water fishery (Figure 6).

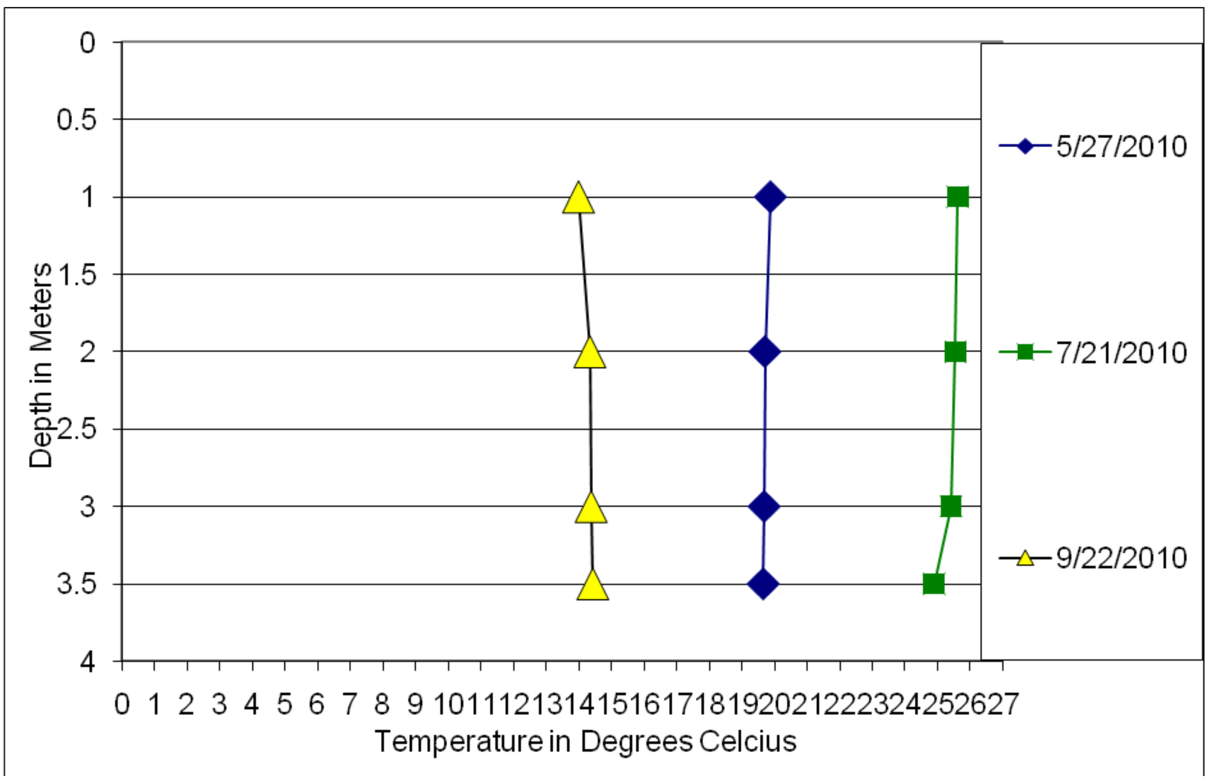

Figure 5. Temperature Profiles for Sprague Lake

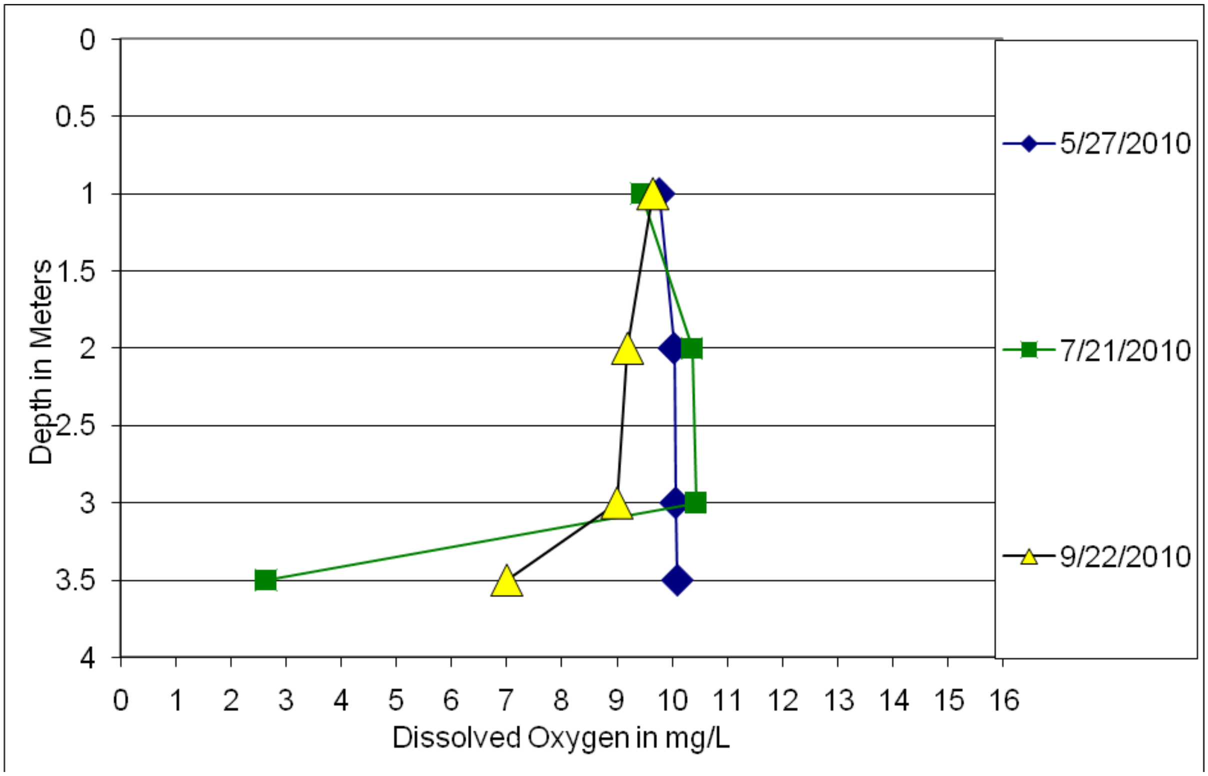

Figure 6. Dissolved Oxygen Profiles for Sprague Lake

General Water Quality: Data collected in 2010 indicate that Sprague Lake is well buffered with total alkalinity as $CaCO_3$ concentrations ranging from 172 to 230 mg/L (Table 1). The lake is sodium sulfate dominated with an average sodium concentration of 78.2 mg/L and an average sulfate concentration of 1031 mg/L. The average total dissolved solids concentration and specific conductance measurement for 2010 sampling period were 1620 mg/L and 2003 µmhos/cm respectively, and the average total nitrogen as N and total phosphorus as P concentrations were 1.025 mg/L and 0.105 mg/L respectively.

When compared to water quality for natural lakes in the Cultivated Plans region, Sprague Lake contains higher concentrations of dissolved solids and is more eutrophic than most (Table 3). For example, the regional average TDS, total nitrogen, and total phosphorus concentrations are 507 mg/L, 1.486 mg/L and 0.090 mg/L, respectively, compared to Sprague Lake's average TDS, total nitrogen and total phosphorus concentrations of 1620 mg/L, 1.025 mg/L and 0.105 mg/L.

Table 1. Statistical Summary of Sprague Lake's 2010 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	3	204	172	230	29
Total Ammonia as N	mg/L	3	0.123	0.030[1]	0.170	0.081
Bicarbonate (HCO_3)	mg/L	3	230	192	260	35
Calcium (Ca)	mg/L	3	204.3	194.0	210.0	9.0
Carbonate (CO_3)	mg/L	3	9	8	10	1
Chloride (Cl)	mg/L	3	11	11	11	0
Chlorophyll-a	µg/L	3	33.2	3.0	65.7	31.4
Specific Conductance	µmhos	3	2003	1940	2080	71
Total Dissolved Solids	mg/L	3	1620	1540	1700	80
Total Hardness as ($CaCO_3$)	mg/L	3	1173	1060	1270	106
Hydroxide (OH)	mg/L	3	1.0[1]	1.0[1]	1.0[1]	0.0
Iron (Fe)	mg/L	3	0.578	0.126	1.170	0.536
Magnesium (Mg)	mg/L	3	161.0	140.0	182.0	21.0
Nitrate + Nitrite as N	mg/L	3	0.047	0.030[1]	0.070	0.021
Total Kjeldahl Nitrogen as N	mg/L	3	0.979	0.823	1.150	0.164
Total Nitrogen as N	mg/L	3	1.025	0.893	1.190	0.151
pH		3	8.44	8.40	8.50	0.05
Total Phosphorus as P	mg/L	3	0.105	0.044	0.164	0.060
Potassium (K)	mg/L	3	9.1	7.6	10.2	1.4
Sodium (Na)	mg/L	3	78.2	68.1	85.7	9.1
Sulfate (SO4)	mg/L	3	1031	984	1090	54

[1]Equal to the lower reporting limit

Limiting Nutrients: The three water quality samples collected in 2010, defined Sprague Lake as a nitrogen limited water body (Figure 7). The limiting nutrient assessment is based on the assumption that either nitrogen or phosphorus is limiting algal growth with the water body, and that the ratio of total nitrogen as N to total phosphorus as P (N:P), by weight in the average algae, is approximately 15 to 1. When the N:P ratio is less than 15:1, nitrogen is assumed to be the limiting nutrient and when it exceeds 15:1, the limiting nutrient is assumed to be phosphorus.

Trophic Status Assessment: Based on the chlorophyll-a, secchi disk transparency, and total phosphorus data collected in 2010, Sprague Lake's trophic is estimated as eutrophic. The trophic Status Index scores ranged from a low of 41 based on chlorophyll-a to a high of 78 based on total phosphorus (Figure 8).

Table 2. Statistical Summary of Water Quality Data[2] Collected from Natural and Enhanced Natural Lakes in the Cultivated Plains Ecological Region of North Dakota

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	191	340	166	1120	181
Total Ammonia as N	mg/L	281	0.106	0.001	1.620	0.198
Bicarbonate (HCO_3)	mg/L	191	355	171	1040	154
Calcium (Ca)	mg/L	193	53.7	12.6	210.0	33.1
Carbonate (CO_3)	mg/L	188	30	1[1]	220	41
Chloride (Cl)	mg/L	191	90	3[1]	1260	206
Chlorophyll-a	µg/L	233	16.4	1.5[1]	908.0	61.8
Specific Conductance	µmhos	210	1742	361	11500	1879
Total Dissolved Solids	mg/L	192	1285	191	9880	1593
Total Hardness as ($CaCO_3$)	mg/L	193	507	173	1820	273
Hydroxide (OH)	mg/L	167	1.0	0.0[1]	1.0	0.2
Iron (Fe)	mg/L	189	0.162	0.007	1.620	0.226
Magnesium (Mg)	mg/L	193	90.6	28.4	413.0	63.1
Nitrate + Nitrite as N	mg/L	272	0.052	0.001[1]	0.680	0.086
Total Kjeldahl Nitrogen as N	mg/L	179	1.497	0.080	4.110	0.632
Total Nitrogen as N	mg/L	154	1.486	0.523	3.860	0.566
pH		193	8.48	1.78	9.56	0.76
Total Phosphorus as P	mg/L	283	0.090	0.002[1]	1.460	0.144
Potassium (K)	mg/L	193	27.7	2.2	179.0	35.6
Sodium (Na)	mg/L	193	227.8	4.5	2570.0	441.5
Sulfate (SO4)	mg/L	191	555	7	3880	728

[1]Equal to the lower reporting limit
[2]Data collected from 53 natural lakes between 1991 and 2010

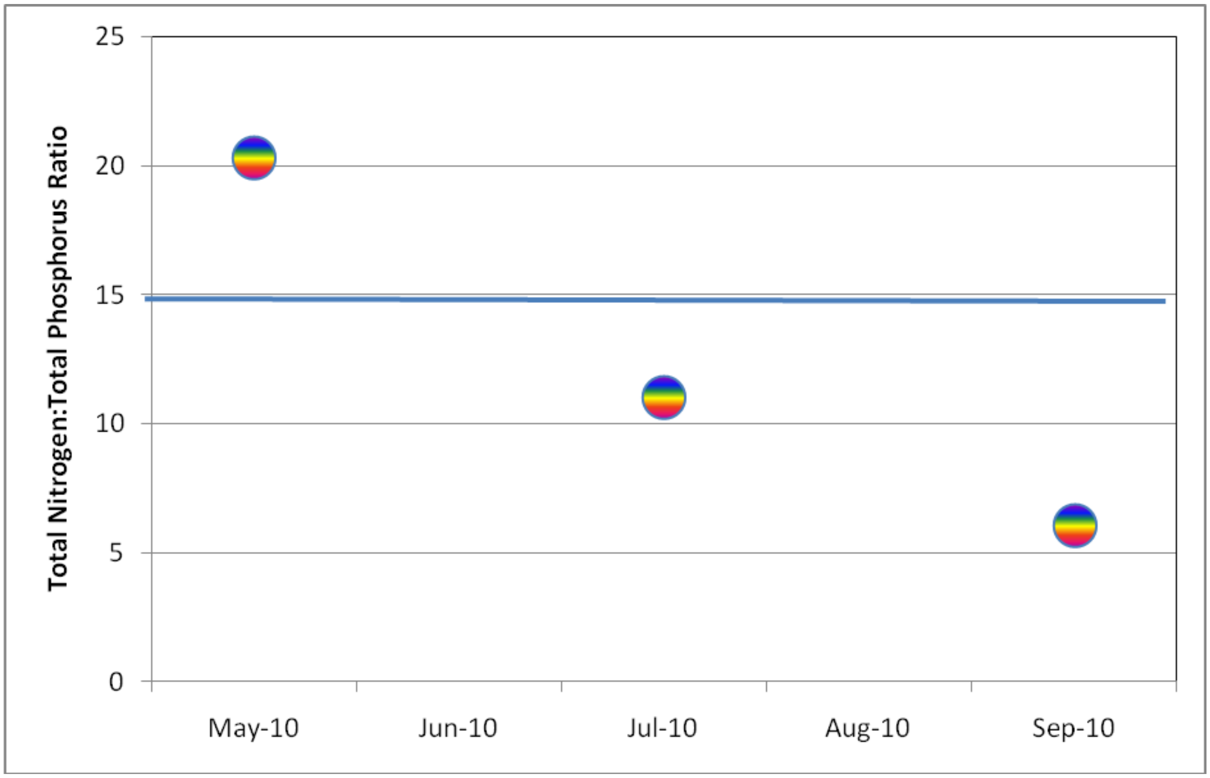

Figure 7. Sprague Lake's Total Nitrogen to Total Phosphorus Ratio

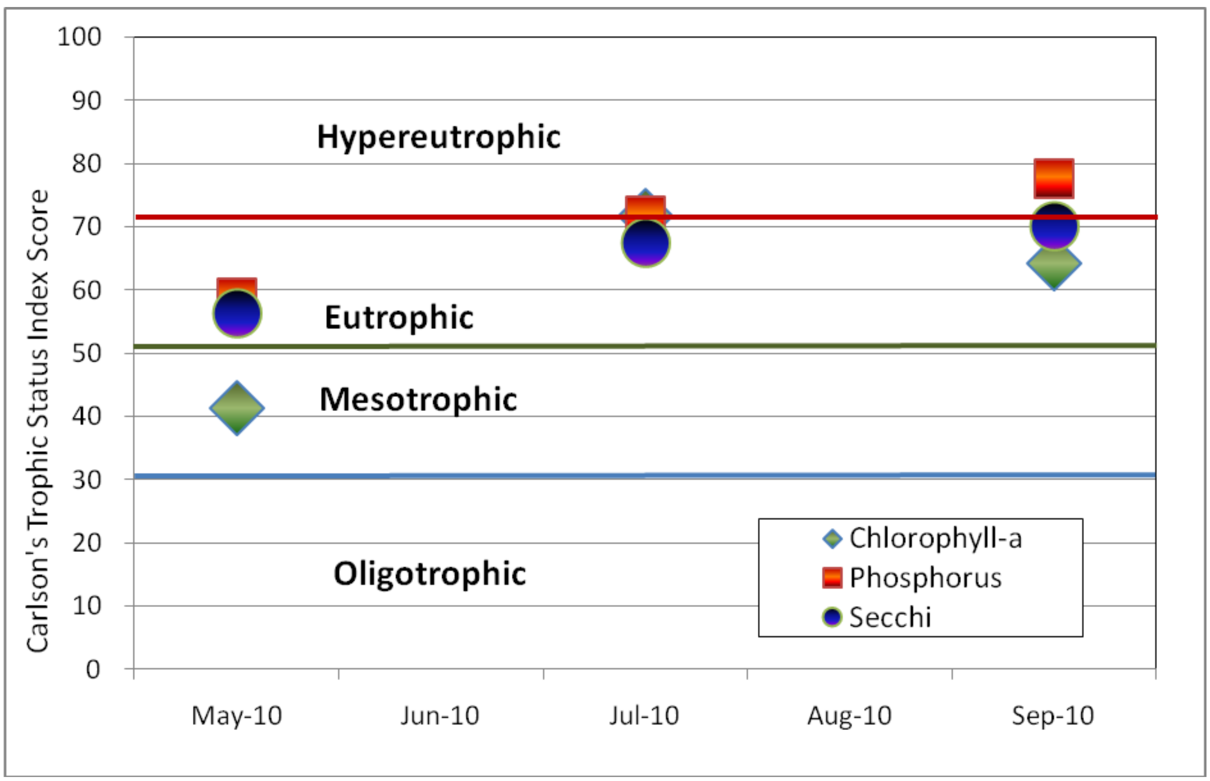

Figure 8. Sprague Lake's TSI Scores

South McClusky (Hoffer) Lake, Sheridan County

BACKGROUND

Location: South McClusky (Hoffer) Lake is a natural basin along the McClusky Cannel in southwest Sheridan County. The lake is located 2 miles north and 1 mile west of McClusky, North Dakota (Figure 1), the lake's elevation is enhanced with a permanent supply of water from the canal and a control structure on the north (outlet end) of the lake (Figure 2). The fishery is managed by the North Dakota Game and Fish. Fish species most recently stocked included northern pike and yellow perch.

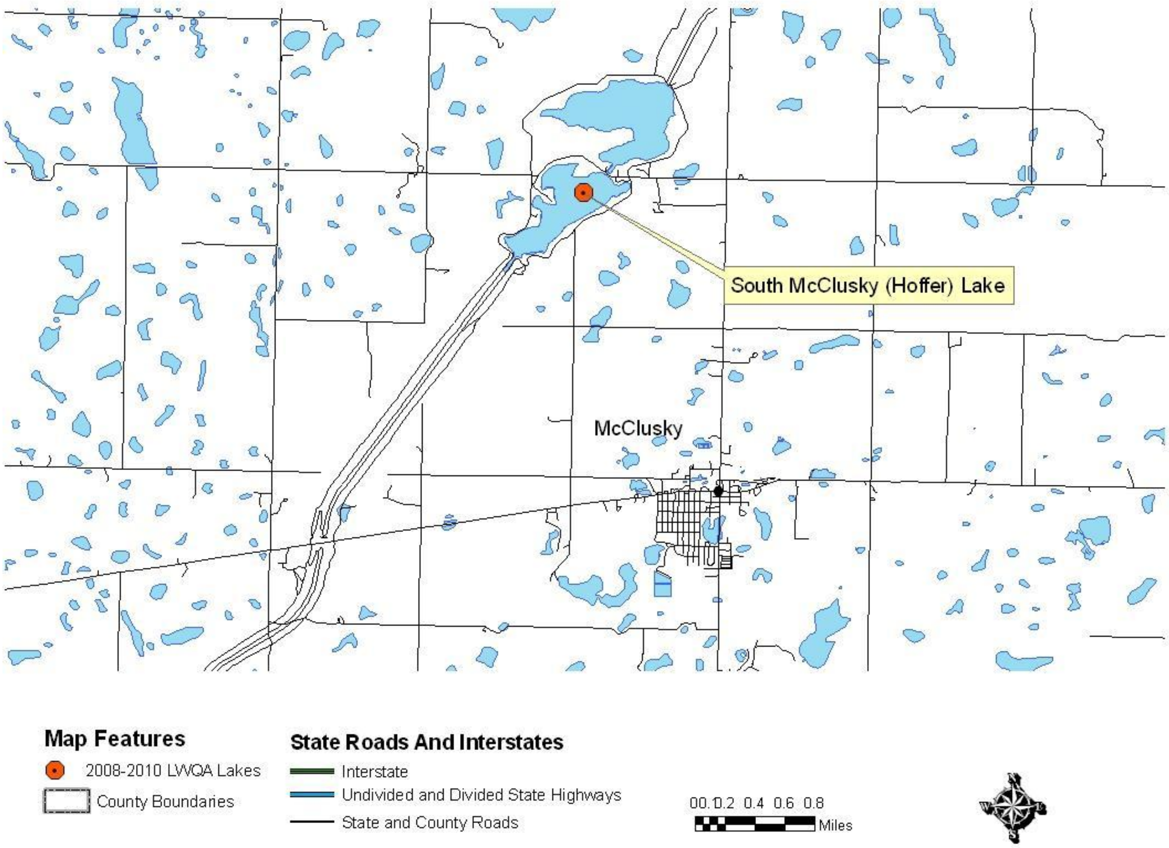

Figure 1. Location of South McClusky (Hoffer) Lake

Physiographic/Ecological Setting: South McClusky (Hoffer) Lake has a surface area of 129.7 acres a maximum depth of 19.8 ft and an average depth of 10.2 ft (Figure 2). The lake is located within the Northwestern Glaciated Plains Level III Ecoregion, which is part of the broader Rangeland Plains region (Figures 3 and 4).

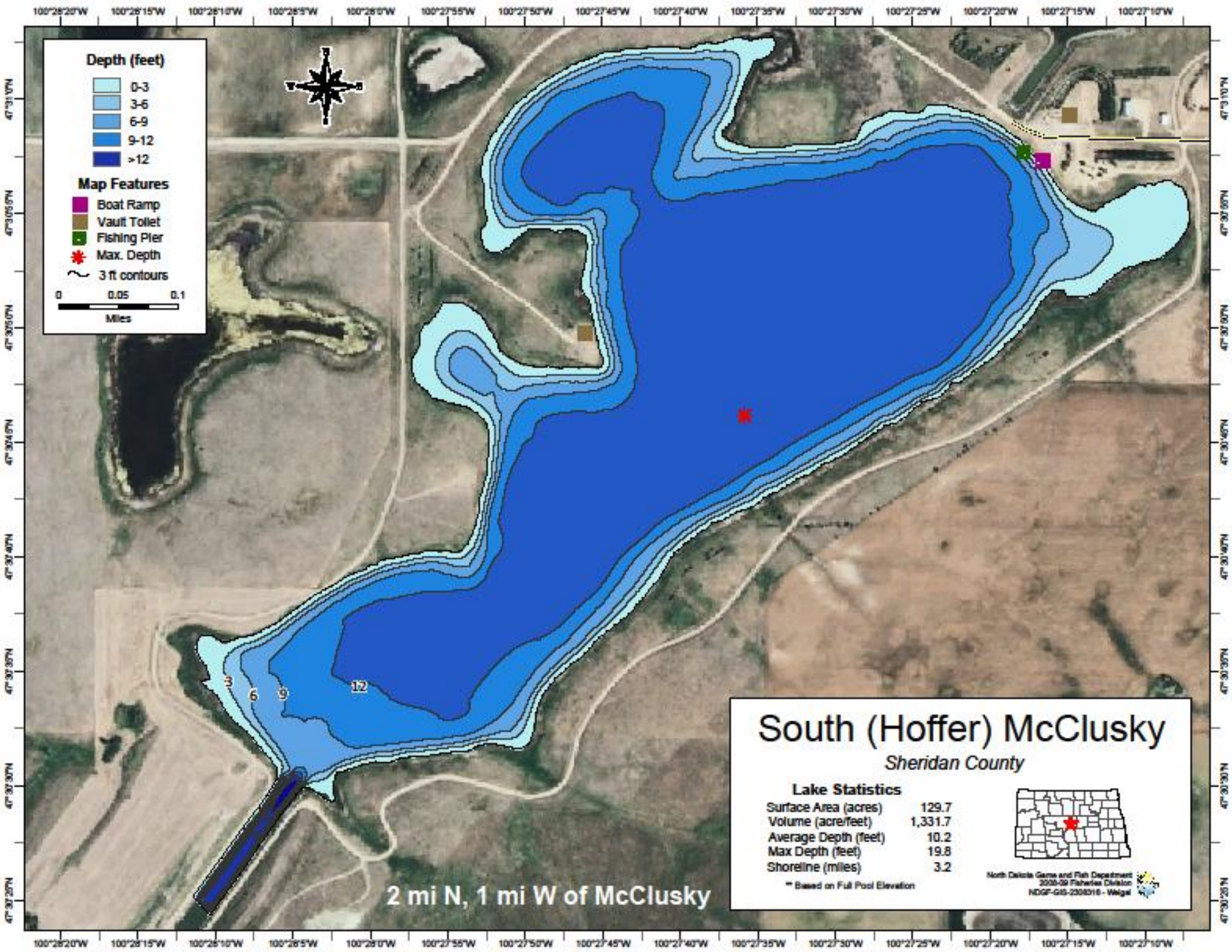

Figure 2. Contour Map of South McClusky (Hoffer) Lake (Map Courtesy of North Dakota Game and Fish Department)

Recreational Facilities: Recreational facilities at South McClusky (Hoffer) Lake include a cement boat ramp, courtesy dock, fishing pier, Camping and picnic areas, information board and vault toilet.

Water Quality Standards Classification: South McClusky (Hoffer) Lake is classified in the state "Standards of Quality for Waters of the State" (NDDoH, 2011) as a class 2 lake. Class 2 lakes or reservoirs are defined as a "cool water fishery" or "waters capable of supporting natural reproduction and growth of cool water fishes (e.g., northern pike and walleye) and associated aquatic biota. Some cold water species may also be present."

Historical Water Quality Sampling: No historical water quality data.

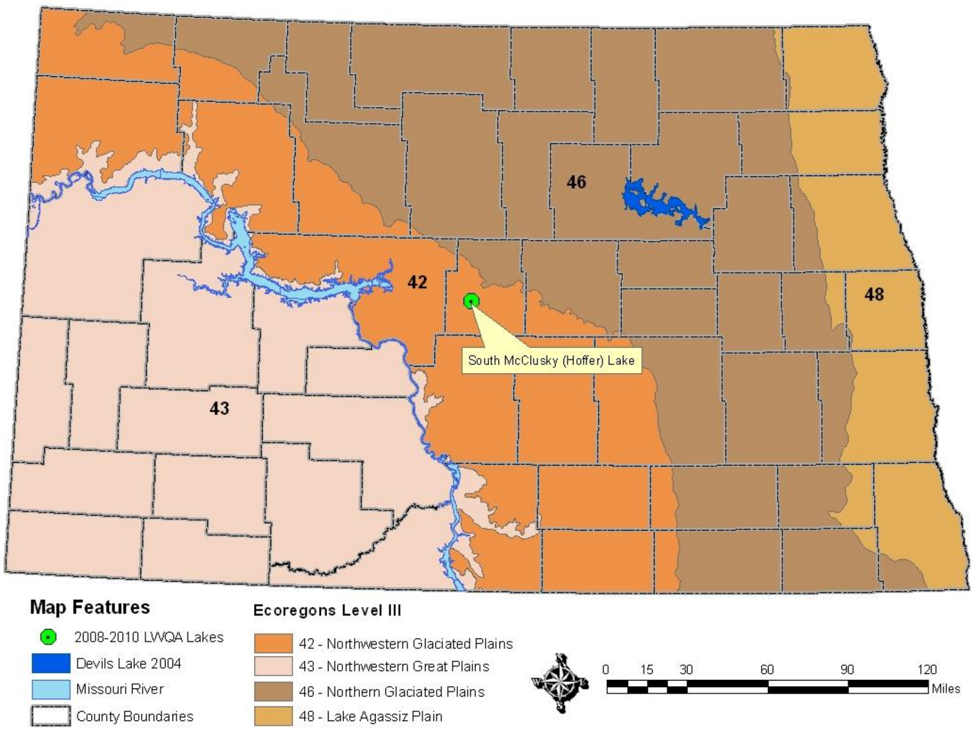

Figure 3. South McClusky (Hoffer) Lake's Location and the Level III Ecoregions

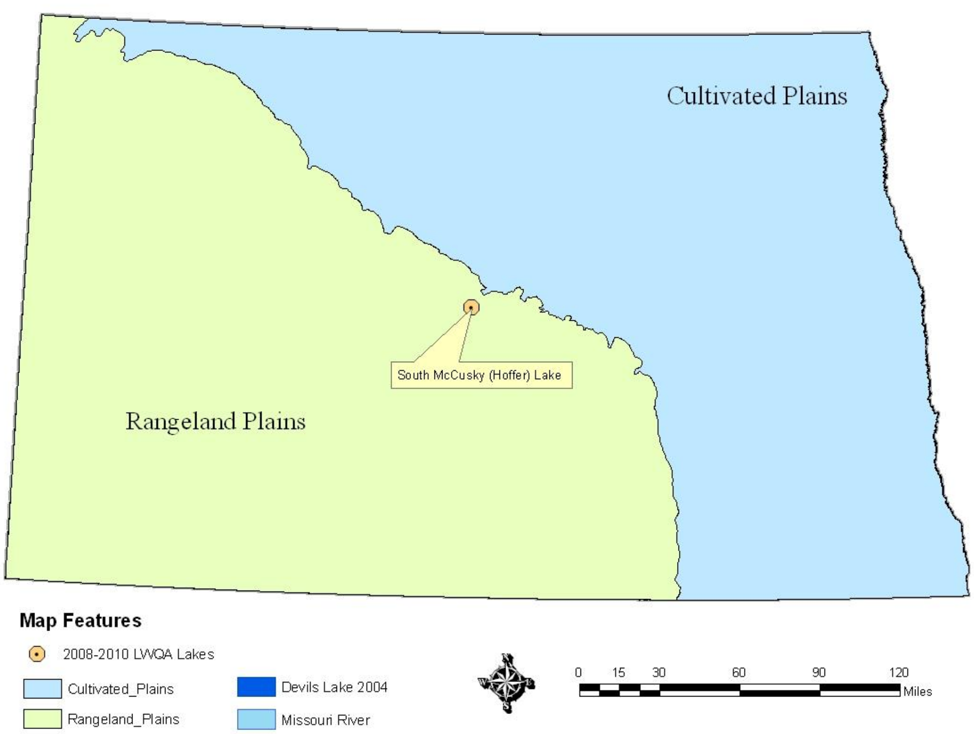

Figure 4. South McClusky (Hoffer) Lake Location and the Cultivated and Rangeland Plans Regions

WATER QUALITY MONITORING RESULTS

The water quality assessment for South McClusky (Hoffer) Lake is presented in four general categories: 1) temperature and dissolved oxygen profile results; 2) general water quality characterization; 3) nutrient limitation; and 4) trophic status. Additionally, where appropriate, results have been compared to regional data.

Temperature and Dissolved Oxygen Profile Results: There are three temperature and dissolved oxygen profiles for South McClusky (Hoffer) Lake collected in 2010 (Figures 5 and 6). The profile data shows that South McClusky (Hoffer) Lake was not thermally stratified during any of the sampling times (Figure 5). Additionally the profiles showed that South McClusky (Hoffer) Lake had adequate dissolved oxygen to support fish and associated biota of a cool water fishery (Figure 6).

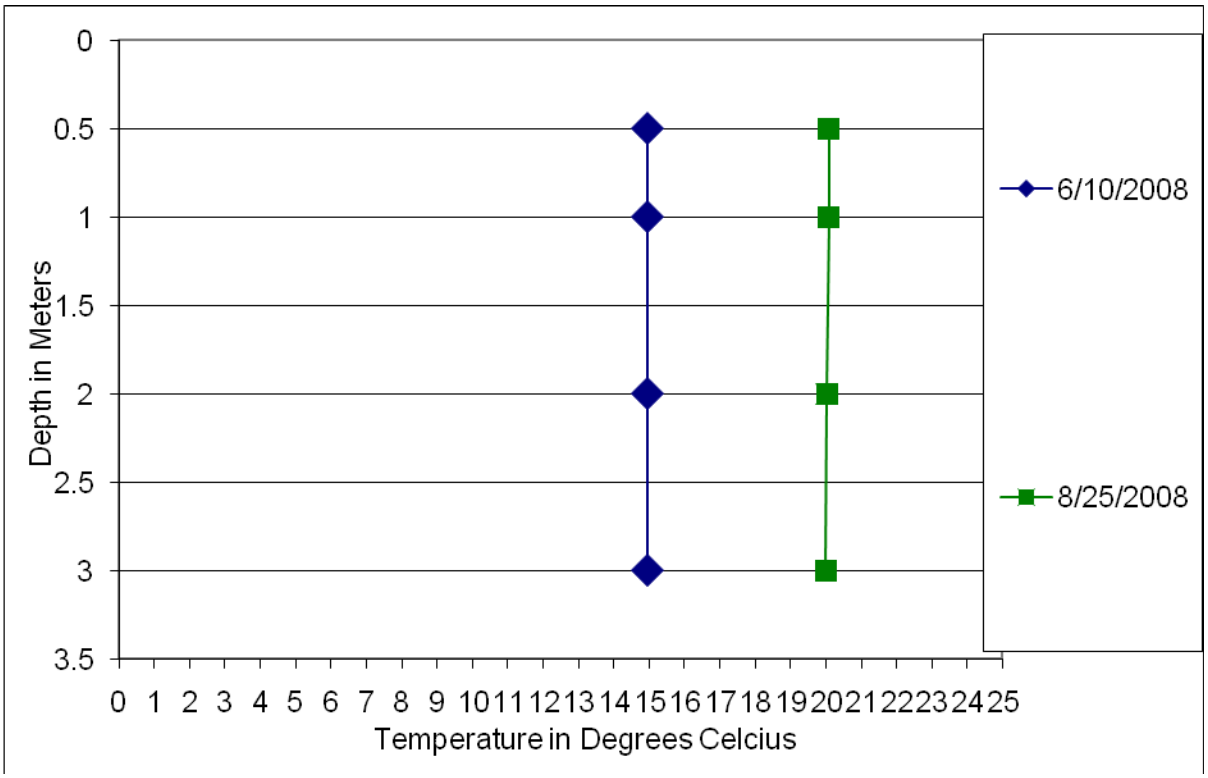

Figure 5. Temperature Profiles for South McClusky (Hoffer) Lake

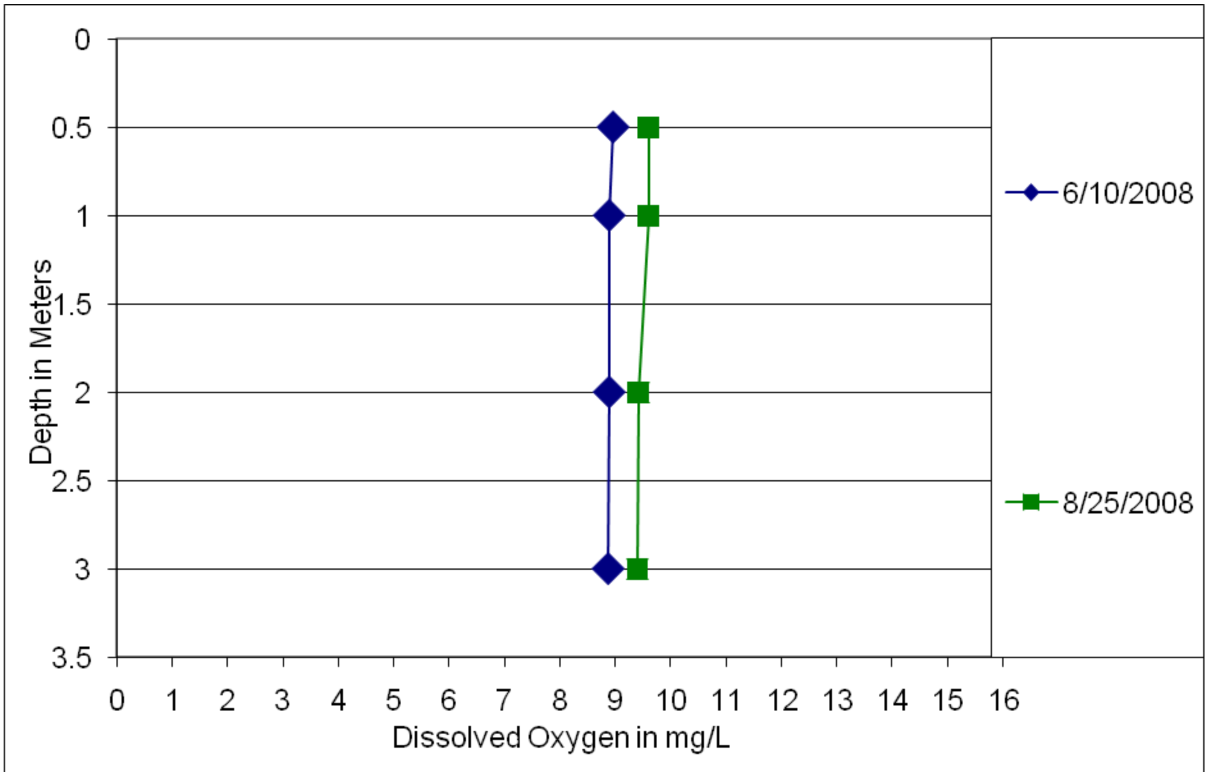

Figure 6. Dissolved Oxygen Profiles for South McClusky (Hoffer) Lake

General Water Quality: Data collected in 2008 indicate that South McClusky (Hoffer) Lake is well buffered with total alkalinity as $CaCO_3$ concentrations averaging 352 mg/L (Table 1). The lake is sodium sulfate dominated with an average sodium concentration of 439 mg/L and an average sulfate concentration of 1615 mg/L. The average total dissolved solids concentration and specific conductance measurement for 2008 sampling period were 2640 mg/L and 3340 µmhos/cm respectively, and the average total nitrogen as N and total phosphorus as P concentrations were 1.430 mg/L and 0.032 mg/L respectively.

When compared to water quality for natural lakes in the Rangeland Plans Ecoregion, South McClusky (Hoffer) Lake is more mineralized but much less eutrophic than most (Table 3). For example, the regional average TDS, total nitrogen, and total phosphorus concentrations are 1466 mg/L, 1.794 mg/L and 0.233 mg/L, respectively, compared to South McClusky (Hoffer) Lake's average TDS, total nitrogen, and total phosphorus concentrations of 2640 mg/L, 1.430 mg/L and 0.032 mg/L.

Table 1. Statistical Summary of South McClusky (Hoffer) Lake's 2008 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	2	352	347	357	7
Total Ammonia as N	mg/L	2	0.076	0.056	0.096	0.028
Bicarbonate (HCO_3)	mg/L	2	385	365	404	28
Calcium (Ca)	mg/L	2	94.1	91.7	96.5	3.4
Carbonate (CO_3)	mg/L	2	22	10	34	17
Chloride (Cl)	mg/L	2	40	37	42	4
Chlorophyll-a	µg/L	2	10.0	2.8	17.1	10.1
Specific Conductance	µmhos	2	3340	3270	3410	99
Total Dissolved Solids	mg/L	2	2640	2550	2730	127
Total Hardness as ($CaCO_3$)	mg/L	2	1080	1010	1150	99
Hydroxide (OH)	mg/L	2	1.0[1]	1.0[1]	1.0[1]	0.0
Iron (Fe)	mg/L	2	0.259	0.206	0.312	0.075
Magnesium (Mg)	mg/L	2	205.5	189.0	222.0	23.3
Nitrate + Nitrite as N	mg/L	2	0.065	0.050	0.080	0.021
Total Kjeldahl Nitrogen as N	mg/L	2	1.365	1.350	1.380	0.021
Total Nitrogen as N	mg/L	2	1.430	1.430	1.430	0.000
pH		2	8.53	8.37	8.69	0.23
Total Phosphorus as P	mg/L	2	0.032	0.021	0.043	0.016
Potassium (K)	mg/L	2	38.2	33.9	42.5	6.1
Sodium (Na)	mg/L	2	439.0	422.0	456.0	24.0
Sulfate (SO4)	mg/L	2	1615	1570	1660	64

[1]Equal to the lower reporting limit

Limiting Nutrient: The water quality results define South McClusky (Hoffer) Lake as a phopshorus limited waterbody (Figure 7). The limiting nutrient assessment is based on the assumption that either nitrogen or phosphorus is limiting algal growth with the water body, and that the ratio of total nitrogen as N to total phosphorus as P (N:P), by weight in the average algae, is approximately 15 to 1. When the N:P ratio is less than 15:1, nitrogen is assumed to be the limiting nutrient and when it exceeds 15:1, the limiting nutrient is assumed to be phosphorus.

Trophic Status Assessment: Based on the chlorophyll-a, secchi disk transparency, and total phosphorus data collected in 2008, South McClusky (Hoffer) Lake's trophic is eutrophic. The trophic Status Index scores ranged from a low of 41 based on chlorophyll-a to a high of 63 based on secchi disk transparency (Figure 8).

Table 2. Statistical Summary of Water Quality Data[2] Collected from Natural and Enhanced Lakes in the Rangeland Plains Ecological Region of North Dakota

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	383	513	111	4770	487
Total Ammonia as N	mg/L	494	0.105	0.001[1]	2.230	0.229
Bicarbonate (HCO_3)	mg/L	383	469	60	2990	320
Calcium (Ca)	mg/L	384	41.1	0.5	282.0	34.4
Carbonate (CO_3)	mg/L	377	79	1[1]	1420	148
Chloride (Cl)	mg/L	383	44	3[1]	1070	103
Chlorophyll-a	µg/L	346	22.5	1.5[1]	292.0	37.4
Specific Conductance	µmhos	383	2028	424	20100	1976
Total Dissolved Solids	mg/L	383	1466	227	18200	1717
Total Hardness as ($CaCO_3$)	mg/L	384	529	74	2370	295
Hydroxide (OH)	mg/L	322	1.0	0.0[1]	1.0	0.2
Iron (Fe)	mg/L	385	0.245	0.001[1]	7.070	0.543
Magnesium (Mg)	mg/L	384	103.6	8.5	567.0	70.9
Nitrate + Nitrite as N	mg/L	491	0.040	0.001[1]	0.54	0.054
Total Kjeldahl Nitrogen as N	mg/L	463	1.876	0.080	8.500	1.073
Total Nitrogen as N	mg/L	401	1.794	0.240	5.520	0.897
pH		383	8.80	7.40	9.87	0.36
Total Phosphorus as P	mg/L	501	0.233	0.002[1]	1.940	0.336
Potassium (K)	mg/L	384	34.0	3.1	356.0	37.0
Sodium (Na)	mg/L	384	299.6	16.9	4680.0	514.5
Sulfate (SO4)	mg/L	383	625	34	10500	885

[1]Equal to the lower reporting limit
[2]Data collected from 64 natural and enhanced Lakes between 1991 and 2010

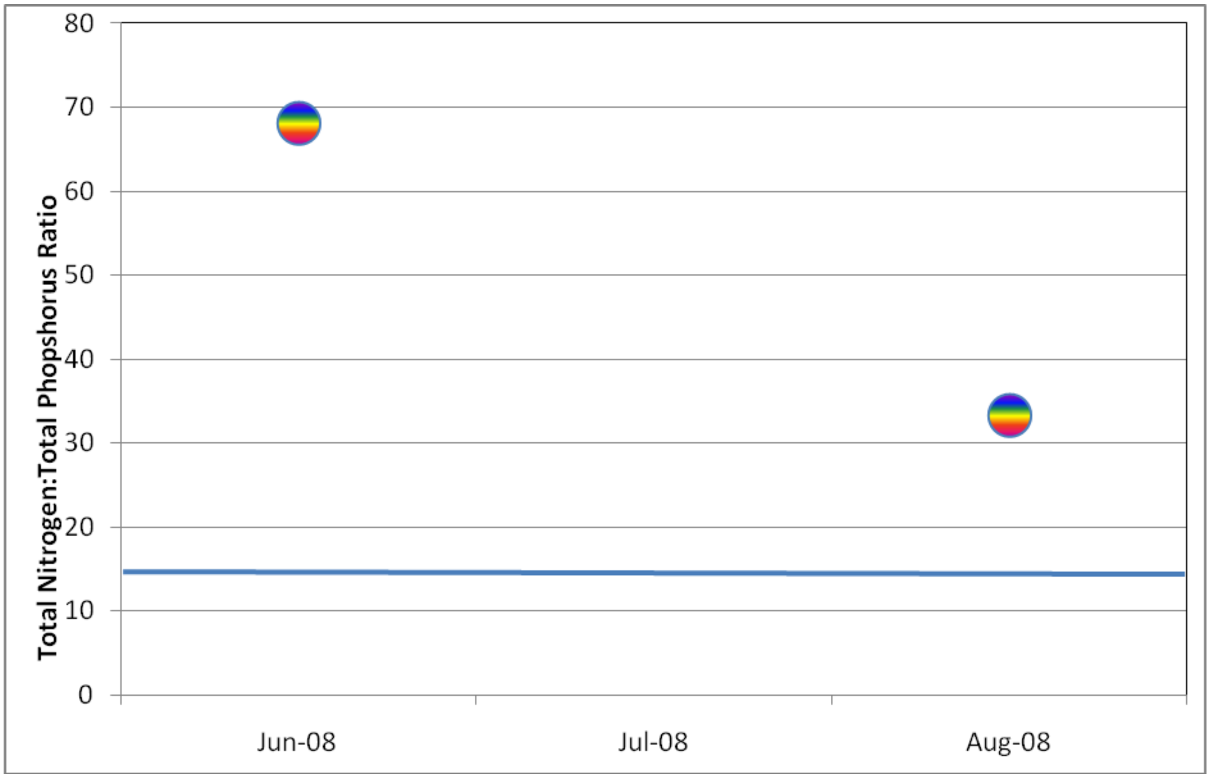

Figure 7. South McClusky (Hoffer) Lake's Total Nitrogen to Total Phosphorus Ratio

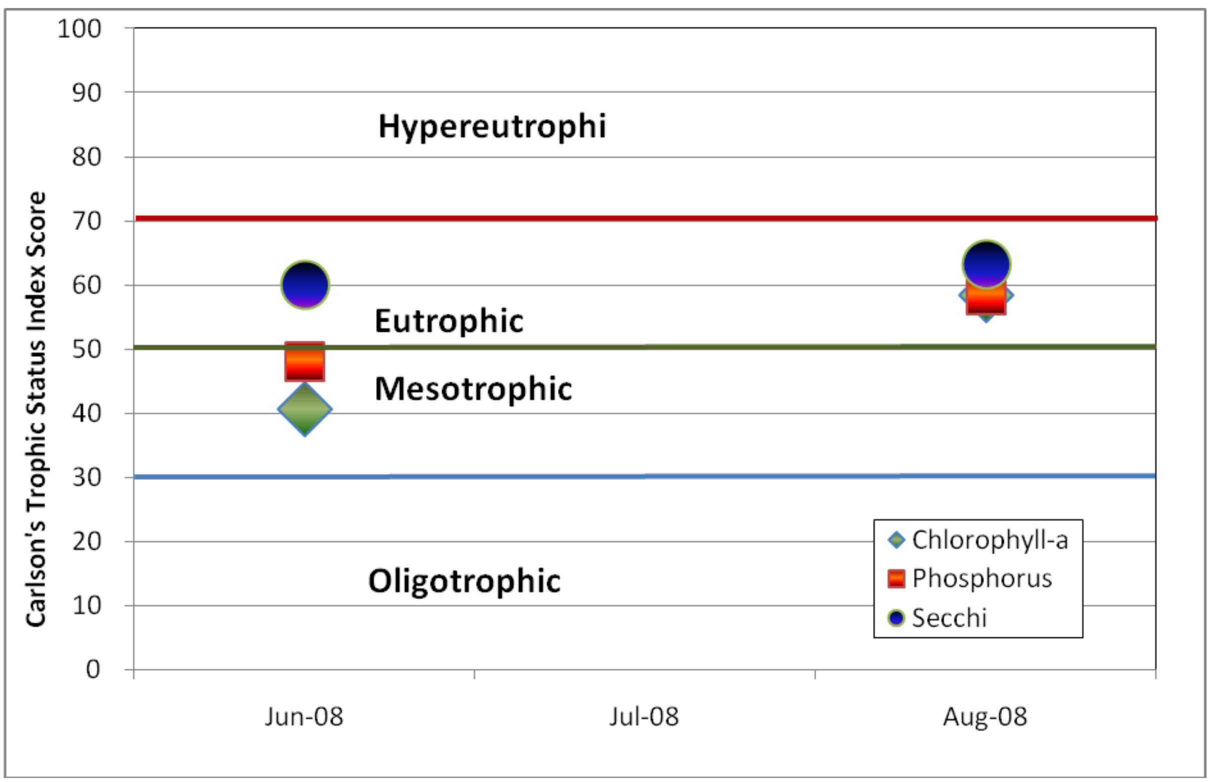

Figure 8. South McClusky (Hoffer) Lake's TSI Scores

Stewart Lake, Slope County

BACKGROUND

Location: Stewart Lake is a shallow hypereutrophic reservoir on an unnamed tributary to Deep Creek in central Slope County. The lake is relatively isolated 11 miles north and 6 mile west of Amidon, North Dakota (Figure 1). Originally built for water based recreation with boat access and rock picnic shelters it is now a National Waterfowl Refuge easement and no longer managed for recreation (Figure 2).

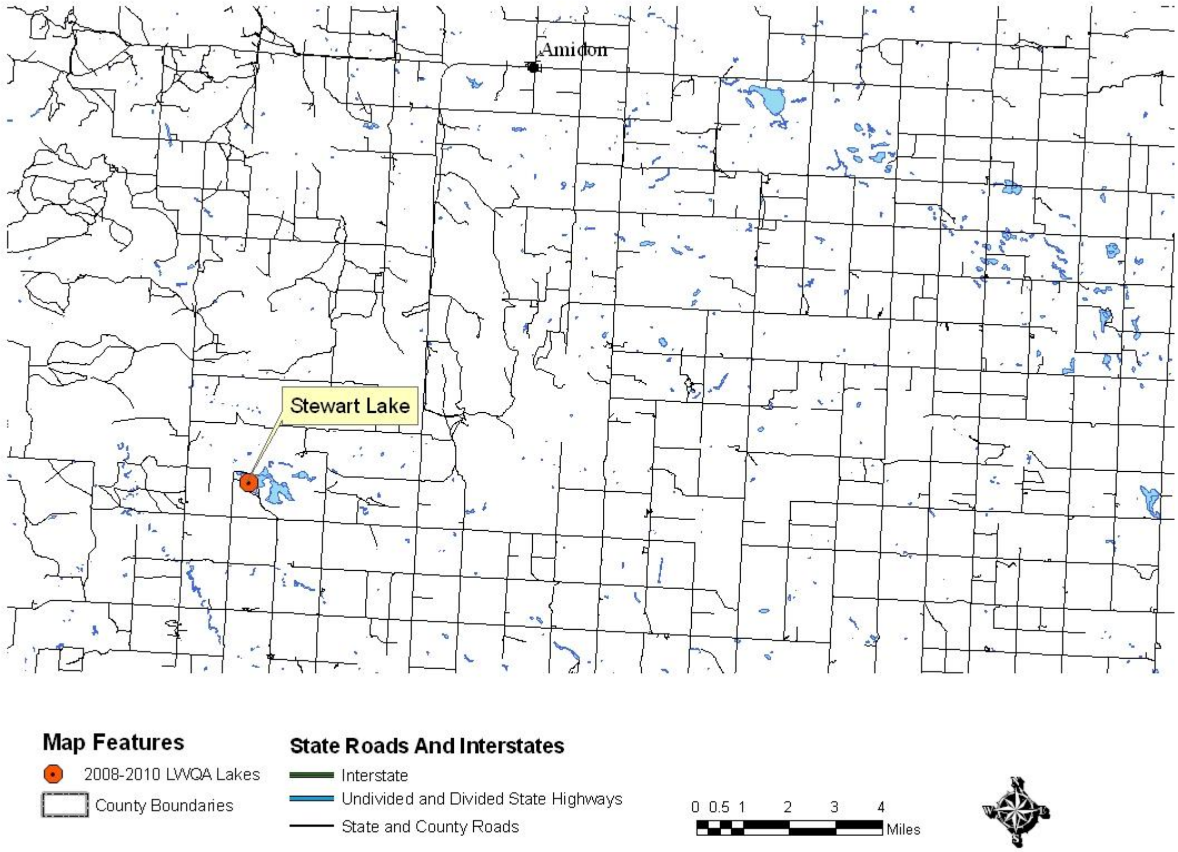

Figure 1. Location of Stewart Lake

Physiographic/Ecological Setting: Stewart Lake has a surface area of approximately 84 acres, a maximum depth of 4 ft and an average depth of 2 ft (Figure 2). The lake is located within the Northwestern Great Plains Level III Ecoregion, which is part of the broader Rangeland Plains region (Figures 3 and 4).

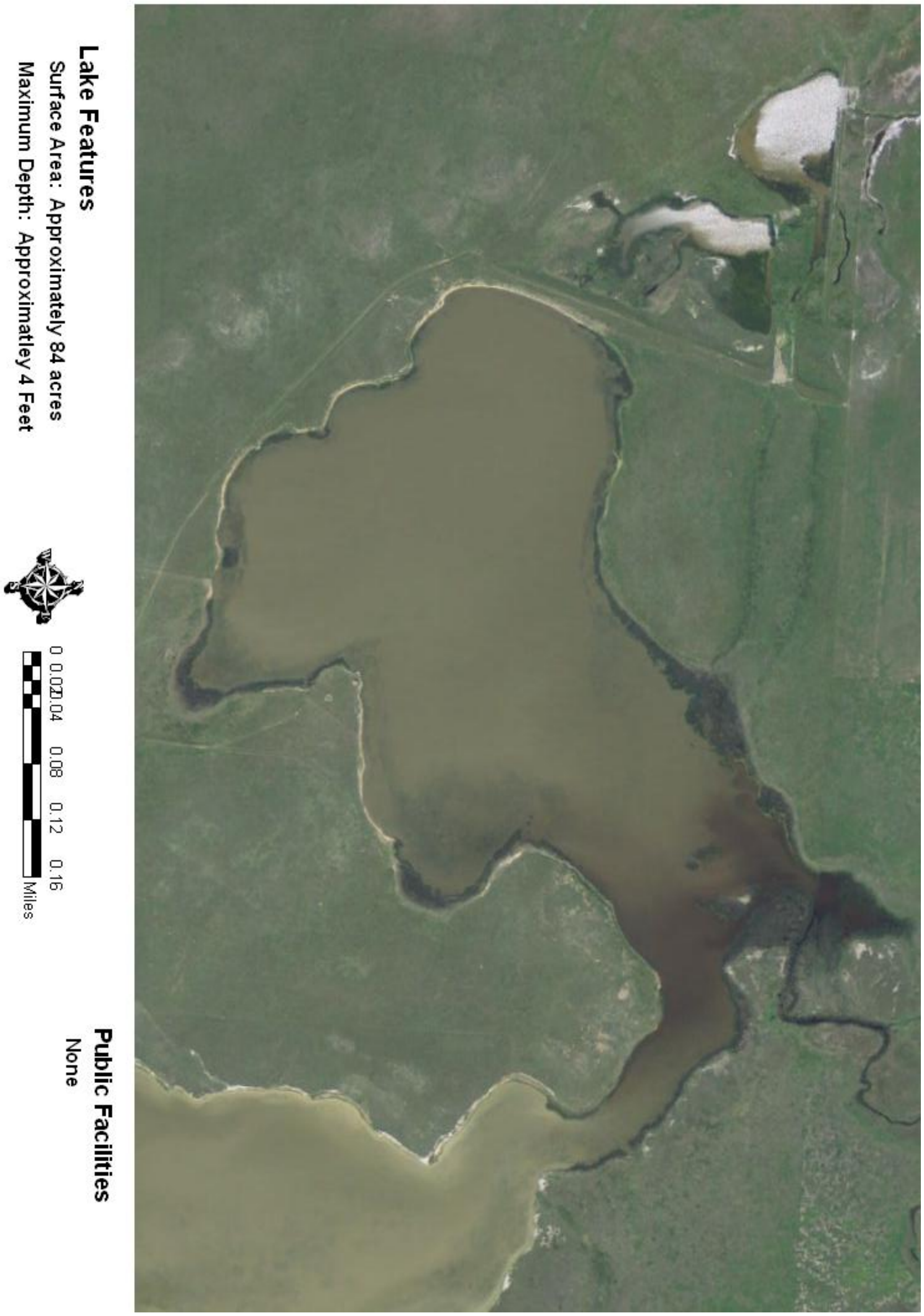

Figure 2. Aerial Map of Stewart Lake

Recreational Facilities: There are no recreational facilities at Stewart Lake. Access is controlled by the US Fish and Wildlife Service.

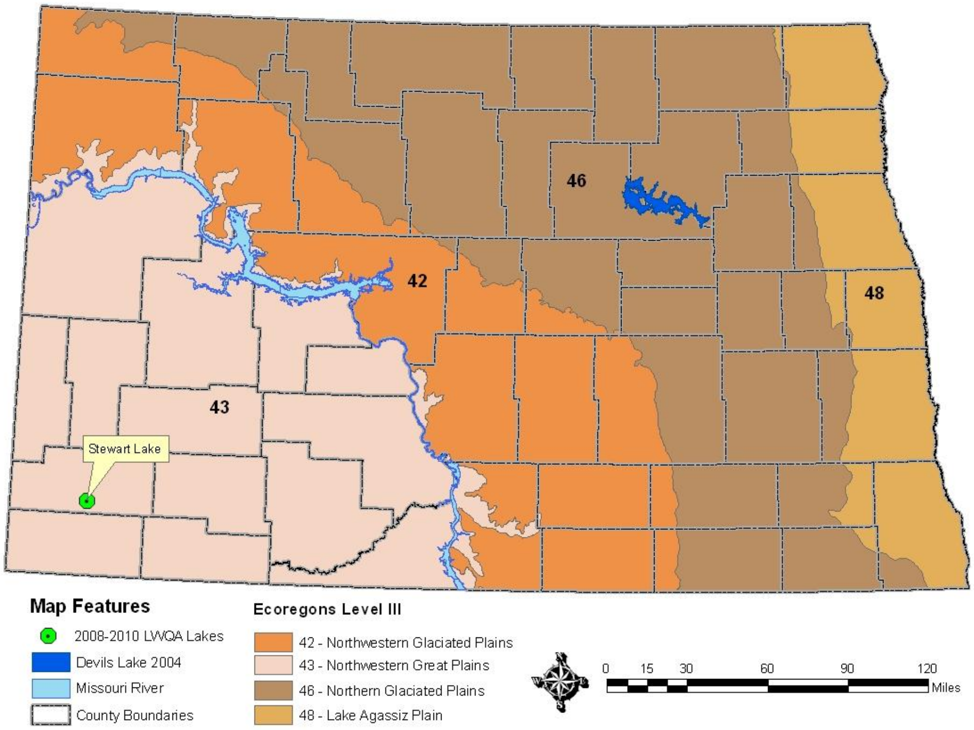

Figure 3. Stewart Lake's Location and the Level III Ecoregions

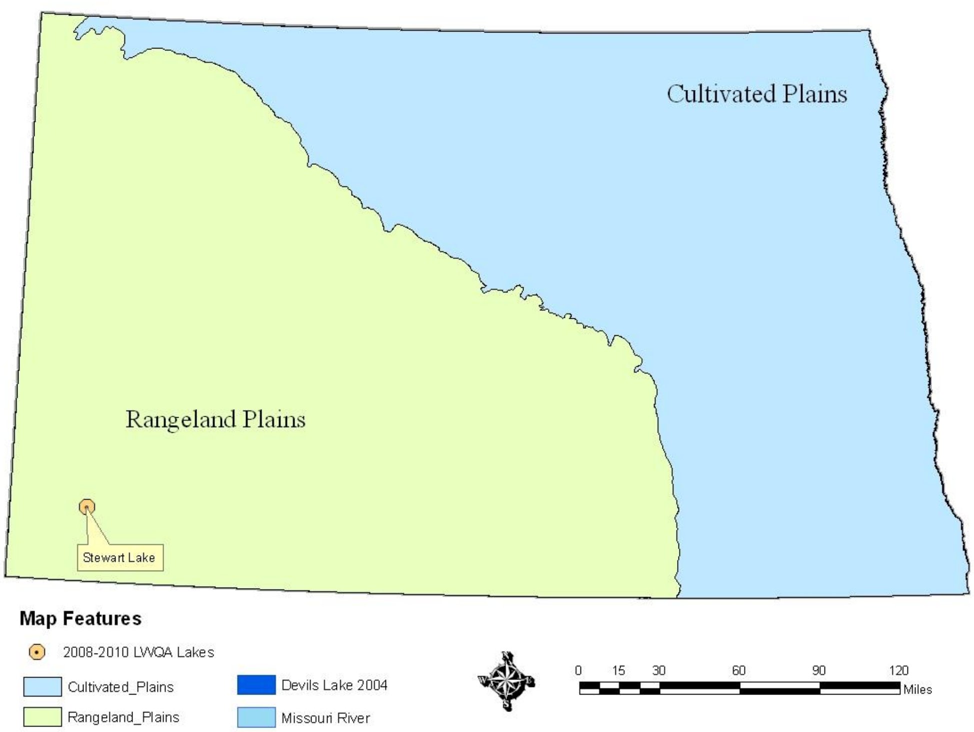

Figure 4. Stewart Lake Location and the Cultivated and Rangeland Plans Regions

Water Quality Standards Classification: Stewart Lake is miss-classified in the state "Standards of Quality for Waters of the State" (NDDoH, 2011) as a class 3 lake. Class 3 lakes or reservoirs are defined as a "warm water fishery" or "waters capable of supporting natural reproduction and growth of warm water fishes (e.g., largemouth bass and bluegill) and associated aquatic biota. Some cool water species may also be present." However the reservoir should be classified as a class 4 lake. Class 4 lakes or reservoirs are capable of supporting a fishery on a short term or seasonal basis (generally a "put and take" fishery).

Historical Water Quality Sampling: No historical water quality data.

WATER QUALITY MONITORING RESULTS

The water quality assessment for Stewart Lake is presented in four general categories: 1) temperature and dissolved oxygen profile results; 2) general water quality characterization; 3) nutrient limitation; and 4) trophic status. Additionally, where appropriate, results have been compared to regional data.

Temperature and Dissolved Oxygen Profile Results: There are three temperature and dissolved oxygen profiles for Stewart Lake collected in 2009 (Figures 5 and 6). The profile data shows that Stewart Lake was not thermally stratified during any of the sampling times (Figure 5). Additionally the profiles showed that Stewart Lake had adequate dissolved oxygen to support fish and associated biota of a warm water fishery (Figure 6).

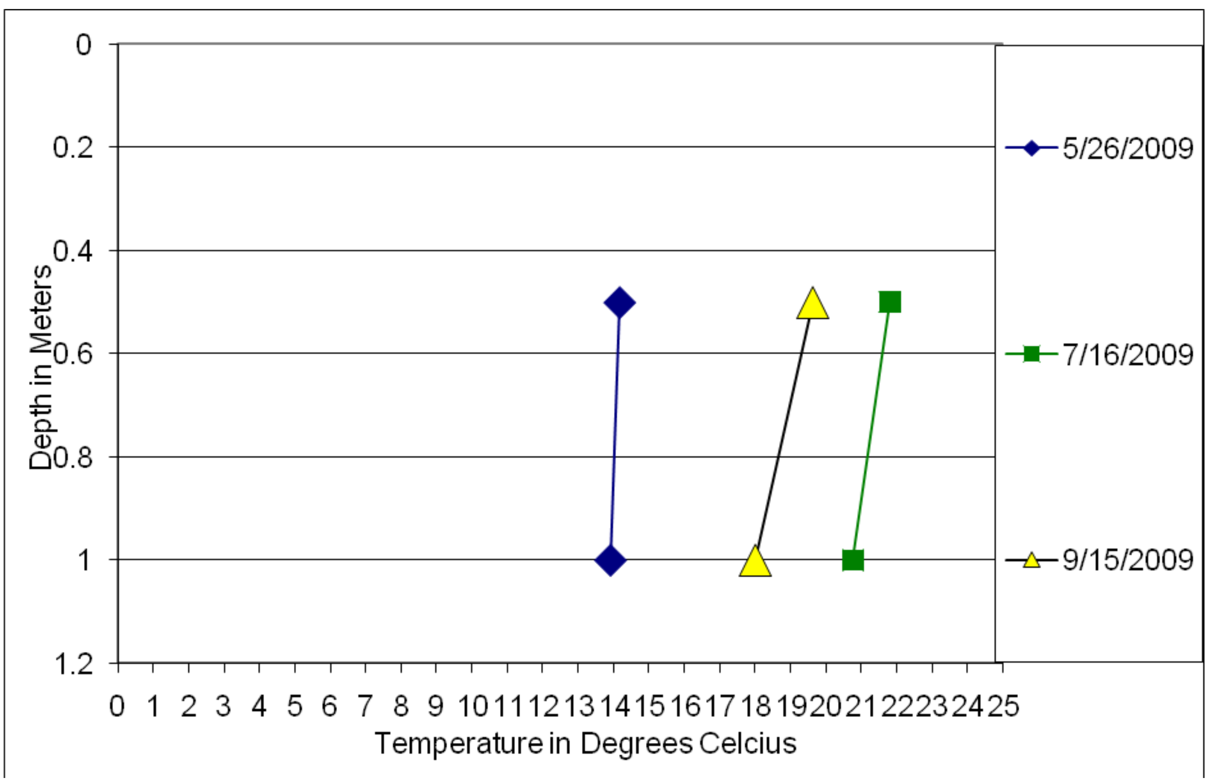

Figure 5. Temperature Profiles for Stewart Lake

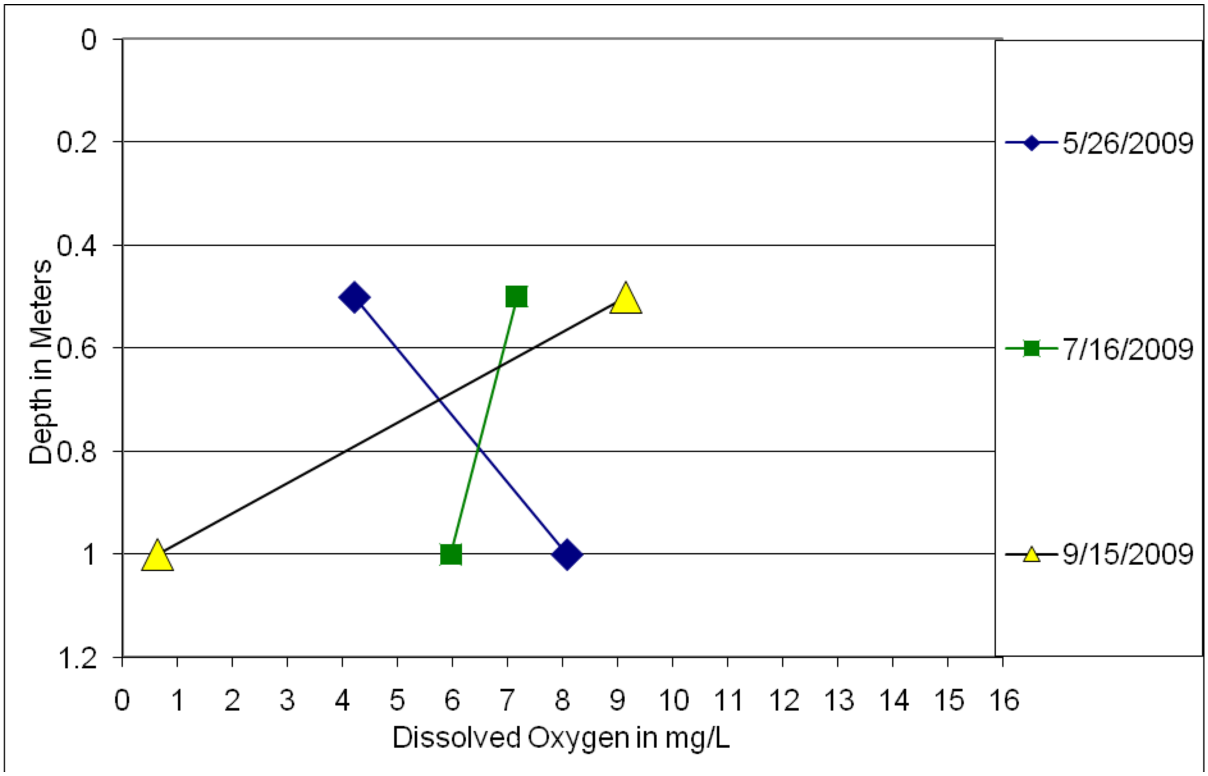

Figure 6. Dissolved Oxygen Profiles for Stewart Lake

General Water Quality: Data collected in 2009 indicate that Stewart Lake is well buffered with total alkalinity as $CaCO_3$ concentrations averaging 401 mg/L (Table 1). The lake is sodium sulfate dominated with an average sodium concentration of 343.7 mg/L and an average sulfate concentration of 470 mg/L. The average total dissolved solids concentration and specific conductance measurement for 2009 sampling period were 1120 mg/L and 1690 µmhos/cm respectively, and the average total nitrogen as N and total phosphorus as P concentrations were 1.807 mg/L and 0.269 mg/L respectively.

When compared to water quality for natural lakes in the Rangeland Plans region, Stewart Lake is fairly average for dissolved solids but measurably more eutrophic (Table 3). For example, the regional average TDS, total nitrogen, and total phosphorus concentrations are 1107 mg/L, 1.314 mg/L and 0.123 mg/L, respectively, compared to Stewart Lake's average TDS, total nitrogen, and total phosphorus concentrations of 1120 mg/L, 1.807 mg/L and 0.269 mg/L.

Table 1. Statistical Summary of Stewart Lake's 2009 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	3	401	274	517	122
Total Ammonia as N	mg/L	3	0.212	0.094	0.357	0.134
Bicarbonate (HCO_3)	mg/L	3	360	323	408	44
Calcium (Ca)	mg/L	3	23.0	19.9	25.0	2.7
Carbonate (CO_3)	mg/L	3	63	6	138	68
Chloride (Cl)	mg/L	3	7	5	9	2
Chlorophyll-a	µg/L	3	6.0	6.0	6.0	0.0
Specific Conductance	µmhos	3	1690	1150	2200	526
Total Dissolved Solids	mg/L	3	1120	751	1460	355
Total Hardness as ($CaCO_3$)	mg/L	3	150	129	163	18
Hydroxide (OH)	mg/L	3	1.0[1]	1.0[1]	1.0[1]	0.0
Iron (Fe)	mg/L	3	2.343	1.050	3.460	1.215
Magnesium (Mg)	mg/L	3	22.4	16.1	26.0	5.5
Nitrate + Nitrite as N	mg/L	3	0.060	0.030[1]	0.080	0.026
Total Kjeldahl Nitrogen as N	mg/L	3	1.747	1.220	2.070	0.460
Total Nitrogen as N	mg/L	3	1.807	1.250	2.150	0.486
pH		3	8.97	8.45	9.39	0.48
Total Phosphorus as P	mg/L	3	0.269	0.173	0.367	0.097
Potassium (K)	mg/L	3	13.5	10.0	16.5	3.3
Sodium (Na)	mg/L	3	343.7	219.0	456.0	119.0
Sulfate (SO4)	mg/L	3	470	309	624	158

[1]Equal to the lower reporting limit

Limiting Nutrients: Water quality samples collected in 2009 define Stewart Lake as a nitrogen limited waterbody (Figure 7). The limiting nutrient assessment is based on the assumption that either nitrogen or phosphorus is limiting algal growth with the water body, and that the ratio of total nitrogen as N to total phosphorus as P (N:P), by weight in the average algae, is approximately 15 to 1. When the N:P ratio is less than 15:1, nitrogen is assumed to be the limiting nutrient and when it exceeds 15:1, the limiting nutrient is assumed to be phosphorus.

Trophic Status Assessment: Based on the chlorophyll-a, Secchi disk transparency, and total phosphorus data collected in 2009, Stewart Lake's trophic is hypereutrophic. The trophic Status Index scores ranged from a low of 41 based on chlorophyll-a to a high of 89 based on total phosphorus (Figure 8).

Table 2. **Statistical Summary of Water Quality Data[2] Collected from Reservoirs and Impoundments in the Rangeland Plains Ecological Region of North Dakota**

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	522	283	54	982	131
Total Ammonia as N	mg/L	593	0.092	0.001[1]	2.440	0.183
Bicarbonate (HCO_3)	mg/L	522	295	14	1040	145
Calcium (Ca)	mg/L	522	52.3	4.7	163.0	27.3
Carbonate (CO_3)	mg/L	520	25	1[1]	197	29
Chloride (Cl)	mg/L	522	13	3[1]	75	9
Chlorophyll-a	µg/L	415	20.1	1.5[1]	218.0	27.0
Specific Conductance	µmhos	542	1621	173	5880	988
Total Dissolved Solids	mg/L	523	1107	100	5110	782
Total Hardness as ($CaCO_3$)	mg/L	522	396	45	2100	279
Hydroxide (OH)	mg/L	465	1.0	0.0[1]	1.0	0.2
Iron (Fe)	mg/L	523	0.193	0.007	4.110	0.349
Magnesium (Mg)	mg/L	522	64.5	5.6	412.0	54.0
Nitrate + Nitrite as N	mg/L	592	0.060	0.001[1]	0.790	0.102
Total Kjeldahl Nitrogen as N	mg/L	483	1.375	0.108	7.720	0.789
Total Nitrogen as N	mg/L	426	1.314	0.178	4.840	0.605
pH		542	8.55	6.73	9.87	0.55
Total Phosphorus as P	mg/L	599	0.128	0.004[1]	3.160	0.190
Potassium (K)	mg/L	522	13.8	2.6	39.2	6.5
Sodium (Na)	mg/L	522	217.2	3.0	932.0	171.6
Sulfate (SO4)	mg/L	520	573	1[1]	3210	519

[1]Equal to the lower reporting limit
[2]Data collected from 76 reservoirs between 1991 and 2010

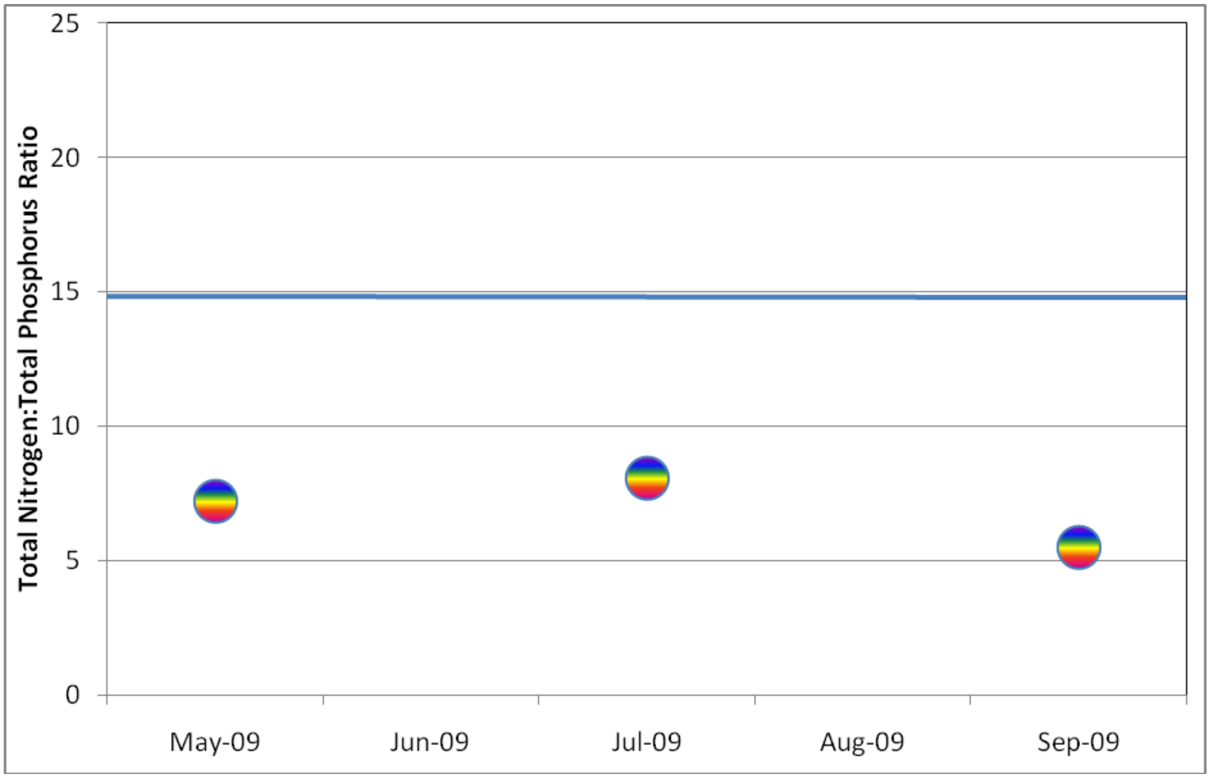

Figure 7. Stewart Lake's Total Nitrogen to Total Phosphorus Ratio

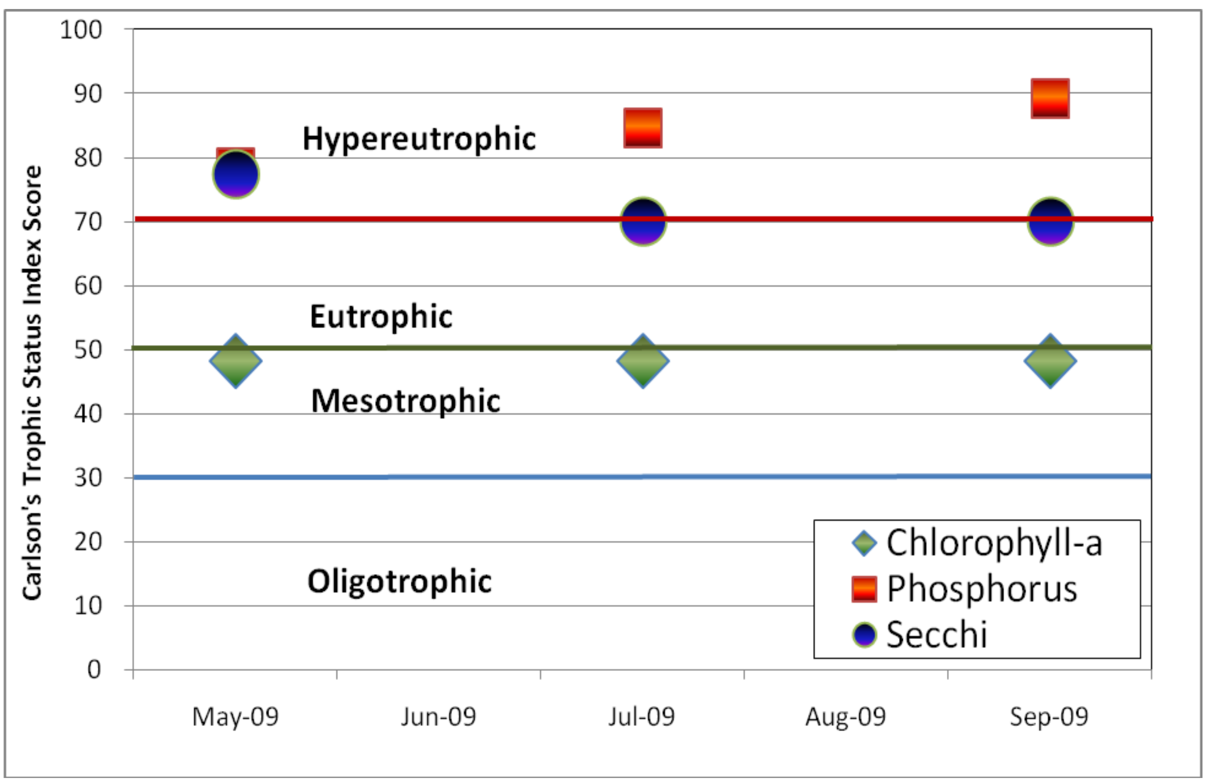

Figure 8. Stewart Lake's TSI Scores

South Golden Lake, Steele County

BACKGROUND

Location: South Golden Lake is located nine miles east and two miles north of Finley, North Dakota (Figure 1). It is a significant source of aquatic recreation to the local community as well as the surrounded area. The fishery is managed by the North Dakota Game and Fish Department. Fish species stocked in recent years are northern pike and walleye.

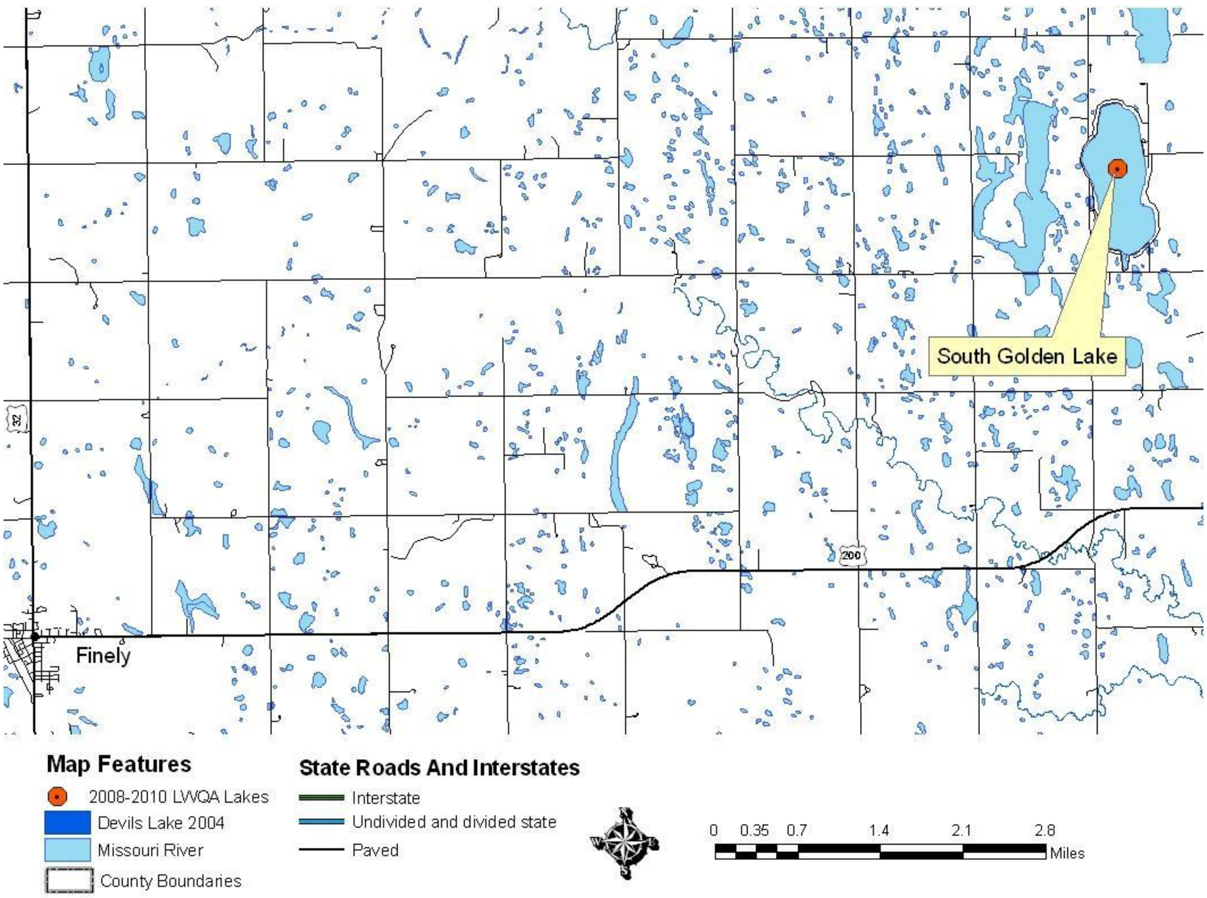

Figure 1. Location of South Golden Lake

Physiographic/Ecological Setting: South Golden Lake has a surface area of 327.1 acres, a maximum depth of 18 ft, and an average depth of 12.6 ft. The lake is oblong, setting north to south, shallow with a nice sand bottom. The lake is located in the Northern Glaciated Plains Level III Ecoregion, which is part of the broader Cultivated Plains Region (Figures 3 and 4).

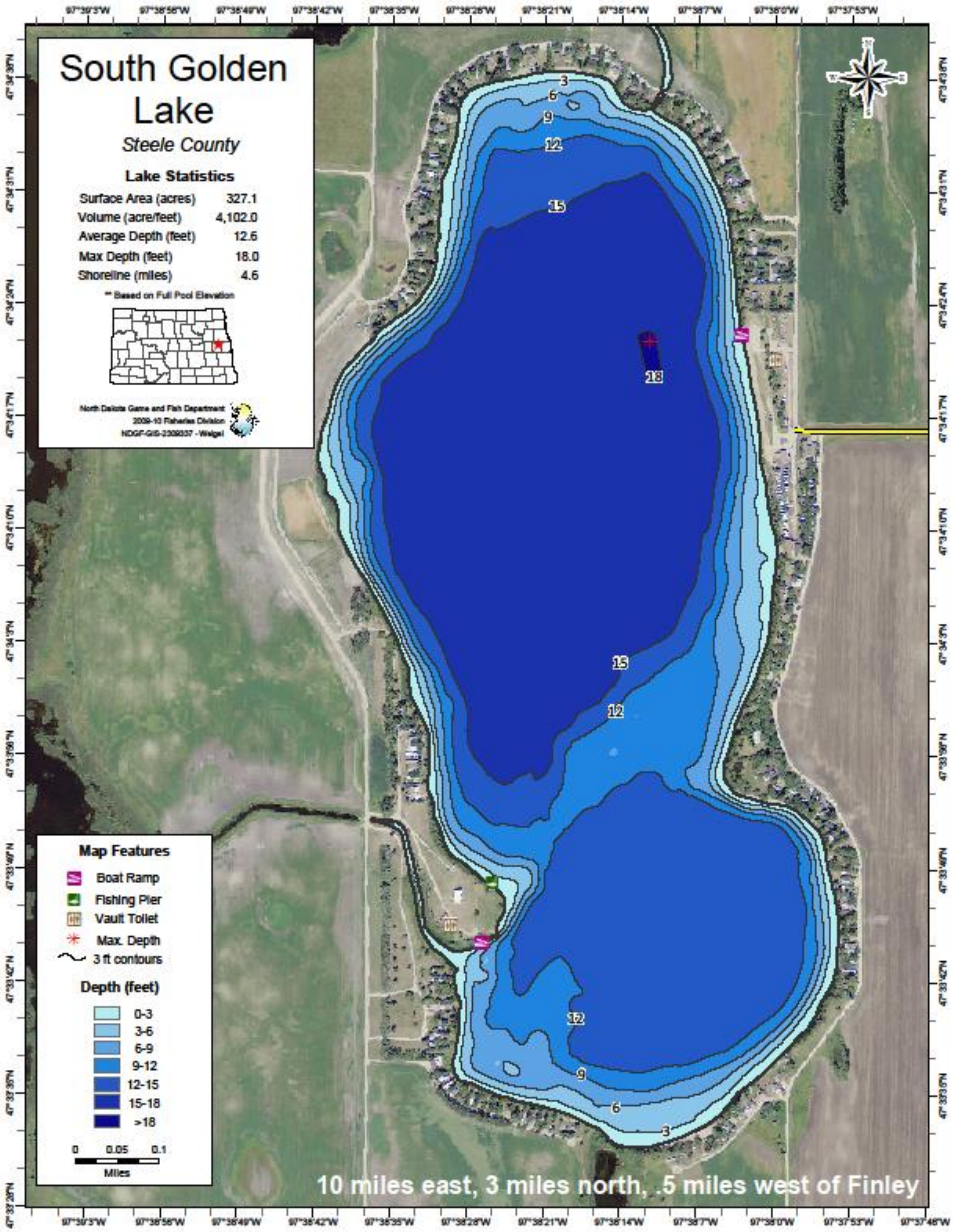

Figure 2. Contour Map of South Golden Lake (Courtesy of the North Dakota Game and Fish Department)

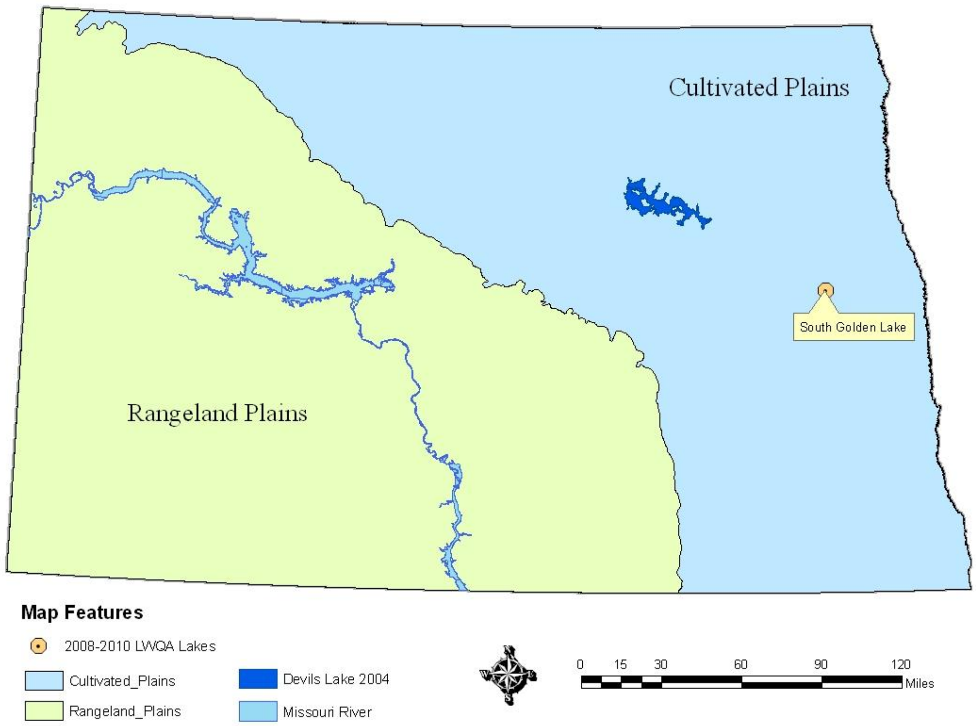

Figure 3. South Golden Lake's Location and the Level III Ecoregions

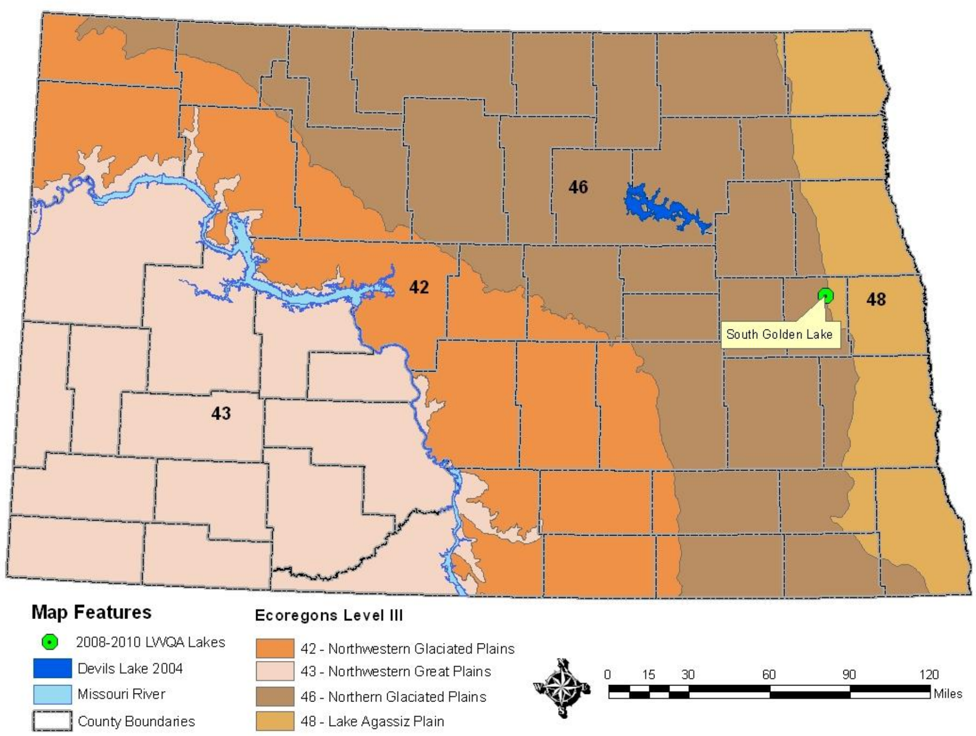

Figure 4. South Golden Lakes's Location and the Cultivated and Rangeland Plans Regions

Recreational Facilities: Recreational facilities include a cement boat dock, courtesy dock, a fishing pier, two rock fishing points, and a nice public swim beach and outdoor toilets (Figure 2).

Water Quality Standards Classification: South Golden Lake is classified in the state "Standards of Quality for Waters of the State" (NDDoH, 2011) as a class 3 Lake. Class 3 lakes or reservoirs are defined as a "warm water fisheries" or "waters capable of supporting natural reproduction and growth of warm water fishes (e.g., largemouth bass and bluegill) and associated aquatic biota. Some cool water species may also be present.

Historical Water Quality Sampling: Historical water quality data include (depending on parameter) 12 to 32 samples collected in two clusters between 1992-1993 and 2005-2006.

WATER QUALITY MONITORING RESULTS

The water quality assessment for South Golden Lake is presented in four general categories: 1) temperature and dissolved oxygen profile results; 2) general water quality characterization; 3) nutrient limitation; and 4) trophic status. Where appropriate, results have been compared to the historical and regional data.

Temperature and Dissolved Oxygen Profile Results: There are eight temperature and dissolved oxygen profiles for South Golden Lake collected in three periods 1992-93, 2005-2006 and 2010 (Figures 5 and 6). The temperature profile data show that the water body was not thermally stratified at anytime during sampling.

The dissolved oxygen profiles show that South Golden Lake maintains sufficient oxygen to maintain warm water aquatic life. Of note, there is some decay of dissolved oxygen with increasing depth that appears to have improved between 1992-1993 and 2010 (Figure 6). It should also be noted that between these two dates the South Golden Lake Improvement Association initiated and implemented a Lake Improvement project.

General Water Quality: Data collected in 2010 indicates that South Golden Lake is well buffered with total alkalinity as $CaCO_3$ concentrations ranging from 195 to 203 mg/L (Table 1). The lake is dominated by sodium sulfate with average sodium and sulfate concentration of 89.3 mg/L and 567 mg/L, respectively. The average total dissolved solids concentration and specific conductance measurements for the 2010 sampling period were 1000 mg/L and 1417 µmhos/cm, respectively, and the average total nitrogen as N and total phosphorus as P concentrations were 0.929 mg/L and 0.041 mg/L respectively.

When compared to water quality for natural lakes in the Cultivated Plains region, South Golden contains more dissolved solids but is less eutrophic than most (Table 3). For example, the average regional concentrations for TDS, total nitrogen, and total phosphorus concentrations are 507 mg/L, 1.486 mg/L, and 0.090 mg/L respectively, compared to South Golden Lake's average hardness, TDS, total nitrogen, and total phosphorus concentrations of 612 mg/L, 1,000 mg/L, 0.929 mg/L and 0.041 mg/L respectively.

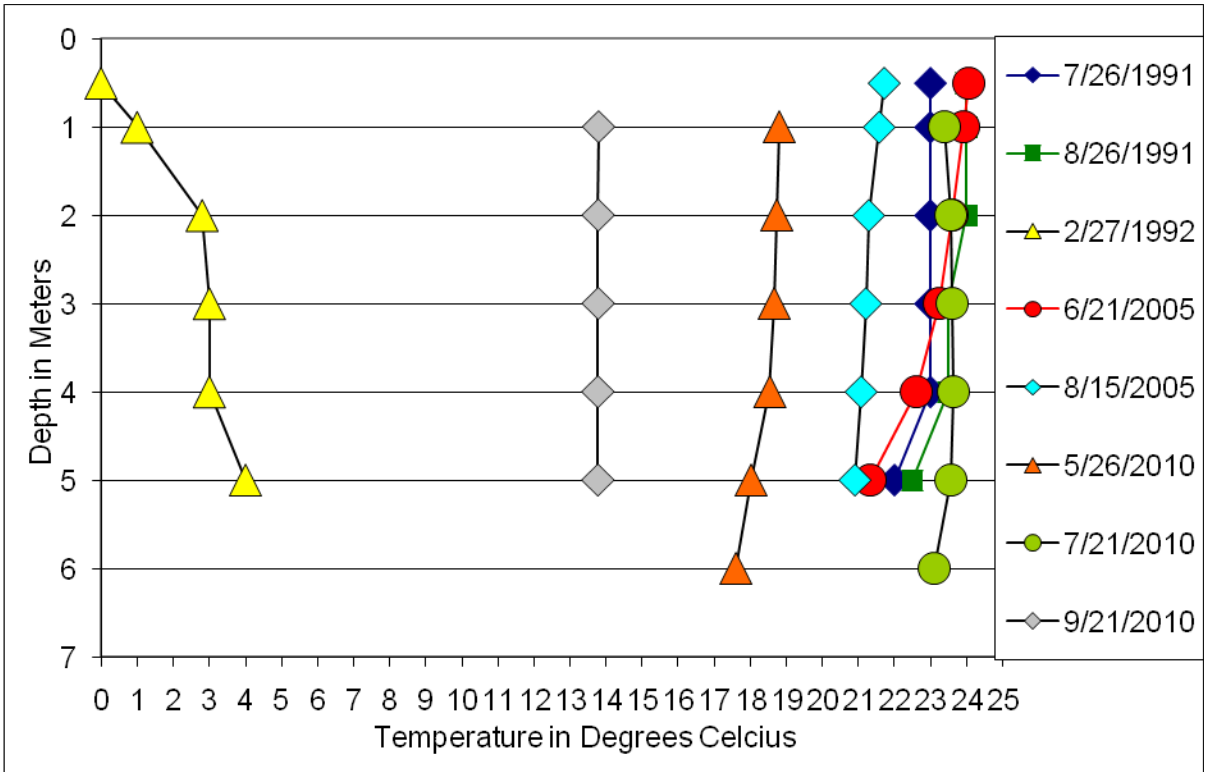

Figure 5. Temperature Profiles for South Golden Lake

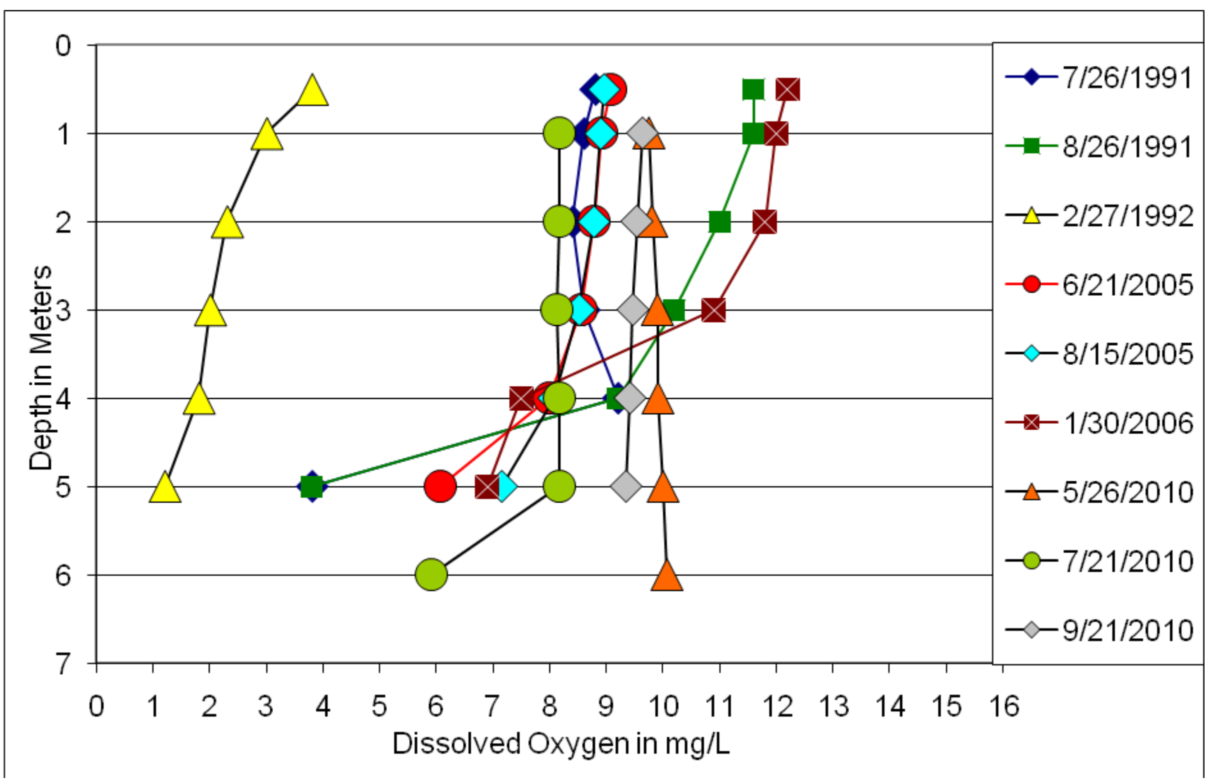

Figure 6. Dissolved Oxygen Profiles for South Golden Lake

Table 1. Statistical Summary of South Golden Lake's 2010 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	3	199	195	203	4
Total Ammonia as N	mg/L	3	0.123	0.030[1]	0.170	0.081
Bicarbonate (HCO_3)	mg/L	3	231	224	235	6
Calcium (Ca)	mg/L	3	99.1	95.9	102.0	3.1
Carbonate (CO_3)	mg/L	3	6	5	7	1
Chloride (Cl)	mg/L	3	21	20	22	1
Chlorophyll-a	µg/L	3	8.4	3.0[1]	13.1	5.1
Specific Conductance	µmhos	3	1417	1400	1430	15
Total Dissolved Solids	mg/L	3	1000	981	1020	20
Total Hardness as ($CaCO_3$)	mg/L	3	612	595	621	15
Hydroxide (OH)	mg/L	3	1.0[1]	1.0[1]	1.0[1]	0.0
Iron (Fe)	mg/L	3	0.080	0.050	0.109	0.030
Magnesium (Mg)	mg/L	3	88.5	86.4	90.5	2.1
Nitrate + Nitrite as N	mg/L	3	0.033	0.030[1]	0.040	0.006
Total Kjeldahl Nitrogen as N	mg/L	3	0.895	0.823	1.040	0.125
Total Nitrogen as N	mg/L	3	0.929	0.853	1.080	0.131
pH		3	8.39	8.36	8.44	0.05
Total Phosphorus as P	mg/L	3	0.041	0.032	0.052	0.010
Potassium (K)	mg/L	3	14.2	12.9	15.2	1.2
Sodium (Na)	mg/L	3	89.3	82.8	95.3	6.3
Sulfate (SO4)	mg/L	3	567	555	590	20

[1]Equal to the lower reporting limit

When comparing historical water quality data (1992-1993 and 2005-2006) to the 2010 water quality data, it appears that South Golden Lake's water quality is fairly stable. For example, the historical average bicarbonate, sulfate and sodium concentrations were 237 mg/L, 531 mg/L and 110 mg/L, respectively, compared to the 2010 averages of 231 mg/L, 567 mg/L and 89.3 mg/L (Tables 1 and 2).

Unlike the dissolved solids, nutrient concentrations appear to be improving or trending downward with total nitrogen and total phosphorus average concentrations decreasing from 1.322 mg/L and 0.105 mg/L to 0.929 mg/L and 0.041 mg/L in 2010. The reductions in nutrient concentrations also support the goal of the lake improvement project of reducing non-point source pollution and it appears to be reaping the rewards for past hard work.

Table 2. Statistical Summary of South Golden Lake's 1991-2005 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	12	212	175	259	21
Total Ammonia as N	mg/L	32	0.066	0.010[1]	0.925	0.163
Bicarbonate (HCO_3)	mg/L	12	237	191	316	37
Calcium (Ca)	mg/L	12	84.8	61.2	105.0	16.1
Carbonate (CO_3)	mg/L	11	12	1[1]	29	10
Chloride (Cl)	mg/L	12	29	24	37	4
Chlorophyll-a	µg/L	29	20.4	3.0	167.0	30.8
Specific Conductance	µmhos	31	1296	967	1670	149
Total Dissolved Solids	mg/L	13	968	756	1190	139
Total Hardness as ($CaCO_3$)	mg/L	12	559	422	703	99
Hydroxide (OH)	mg/L	6	1.0[1]	1.0[1]	1.0[1]	0.0
Iron (Fe)	mg/L	12	0.095	0.023	0.194	0.060
Magnesium (Mg)	mg/L	12	84.4	65.3	107.0	14.7
Nitrate + Nitrite as N	mg/L	31	0.027	0.006	0.120	0.023
Total Kjeldahl Nitrogen as N	mg/L	24	1.565	0.921	4.110	0.696
Total Nitrogen as N	mg/L	18	1.322	0.942	2.090	0.300
pH		12	8.40	7.80	8.80	0.29
Total Phosphorus as P	mg/L	32	0.105	0.020[1]	0.299	0.075
Potassium (K)	mg/L	12	18.5	15.3	23.1	2.1
Sodium (Na)	mg/L	12	110.6	84.6	141.0	14.8
Sulfate (SO4)	mg/L	12	531	390	677	93

[1]Equal to the lower reporting limit

Limiting Nutrients: The water quality samples collected between 1992 and 2010 indicate that South Golden Lake was phosphorus limited with the exception of very late summer when nitrogen uptake exceeds supply and the nitrogen fixing algae bloom (Figure 7). The limiting nutrient assessment is based on the assumption that either nitrogen or phosphorus is limiting algal growth and that the ratio of total nitrogen as N to total phosphorus as P (N:P), by weight in the average algae is approximately 15 to 1. When the N:P ratio is less than 15:1, nitrogen is assumed to be the limiting nutrient and when it exceeds 15:1, the limiting nutrient is assumed to be phosphorus.

Trophic Status Assessment: Based on the chlorophyll-a, secchi disk transparency, and total phosphorus data collected in 2010, South Golden Lake's trophic status is eutrophic trending towards mesotrophic. The trophic status index (TSI) scores ranged from a high of 81 in 1991 and a low of low of 37 based on secchi disk transparency in 2010 (Figure 8).

Table 3. Statistical Summary of Water Quality Data[2] Collected from Natural and Enhanced Natural Lakes in the Cultivated Plains Ecological Region of North Dakota

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	191	340	166	1120	181
Total Ammonia as N	mg/L	281	0.106	0.001	1.620	0.198
Bicarbonate (HCO_3)	mg/L	191	355	171	1040	154
Calcium (Ca)	mg/L	193	53.7	12.6	210.0	33.1
Carbonate (CO_3)	mg/L	188	30	1[1]	220	41
Chloride (Cl)	mg/L	191	90	3[1]	1260	206
Chlorophyll-a	µg/L	233	16.4	1.5[1]	908.0	61.8
Specific Conductance	µmhos	210	1742	361	11500	1879
Total Dissolved Solids	mg/L	192	1285	191	9880	1593
Total Hardness as ($CaCO_3$)	mg/L	193	507	173	1820	273
Hydroxide (OH)	mg/L	167	1.0	0.0[1]	1.0	0.2
Iron (Fe)	mg/L	189	0.162	0.007	1.620	0.226
Magnesium (Mg)	mg/L	193	90.6	28.4	413.0	63.1
Nitrate + Nitrite as N	mg/L	272	0.052	0.001[1]	0.680	0.086
Total Kjeldahl Nitrogen as N	mg/L	179	1.497	0.080	4.110	0.632
Total Nitrogen as N	mg/L	154	1.486	0.523	3.860	0.566
pH		193	8.48	1.78	9.56	0.76
Total Phosphorus as P	mg/L	283	0.090	0.002[1]	1.460	0.144
Potassium (K)	mg/L	193	27.7	2.2	179.0	35.6
Sodium (Na)	mg/L	193	227.8	4.5	2570.0	441.5
Sulfate (SO4)	mg/L	191	555	7	3880	728

[1]Equal to the lower reporting limit
[2]Data collected from 53 natural lakes between 1991 and 2010

Trends: A total of 32 total phosphorus samples, 29 chlorophyll-a samples and 7 Secchi disk transparency measurements collected between 1991 and 2010 were available to evaluate trends in the trophic status of South Golden Lake. In viewing all the data, it would be difficult to come up with any conclusion other than South Golden Lake is improving in general water quality and trophic condition (Figure 8). This is clearly demonstrated in Figure 8 when TSI scores ranged from eutrophic to hypereutrophic in 1991-1992 to the boarder of mesotrophic in 2010 and a slope of approximately 14 percent.

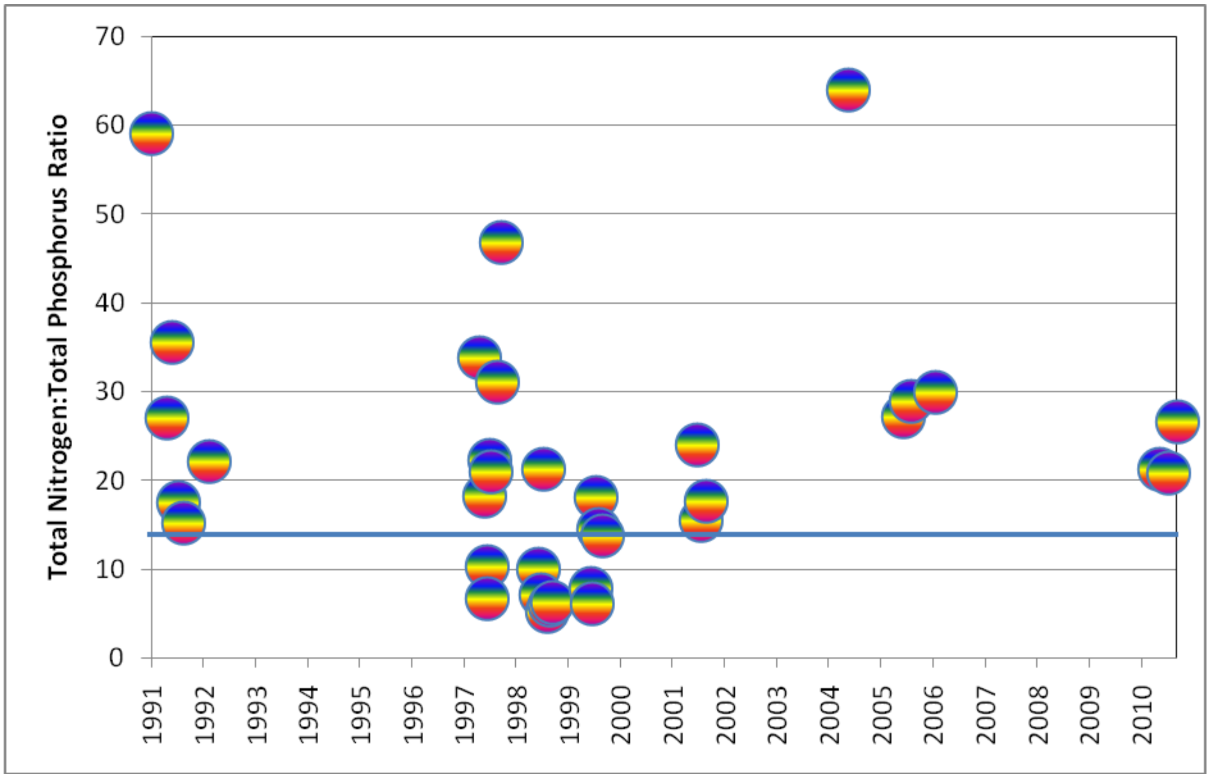

Figure 7. South Golden Lake's Total Nitrogen to Total Phosphorus Ratio

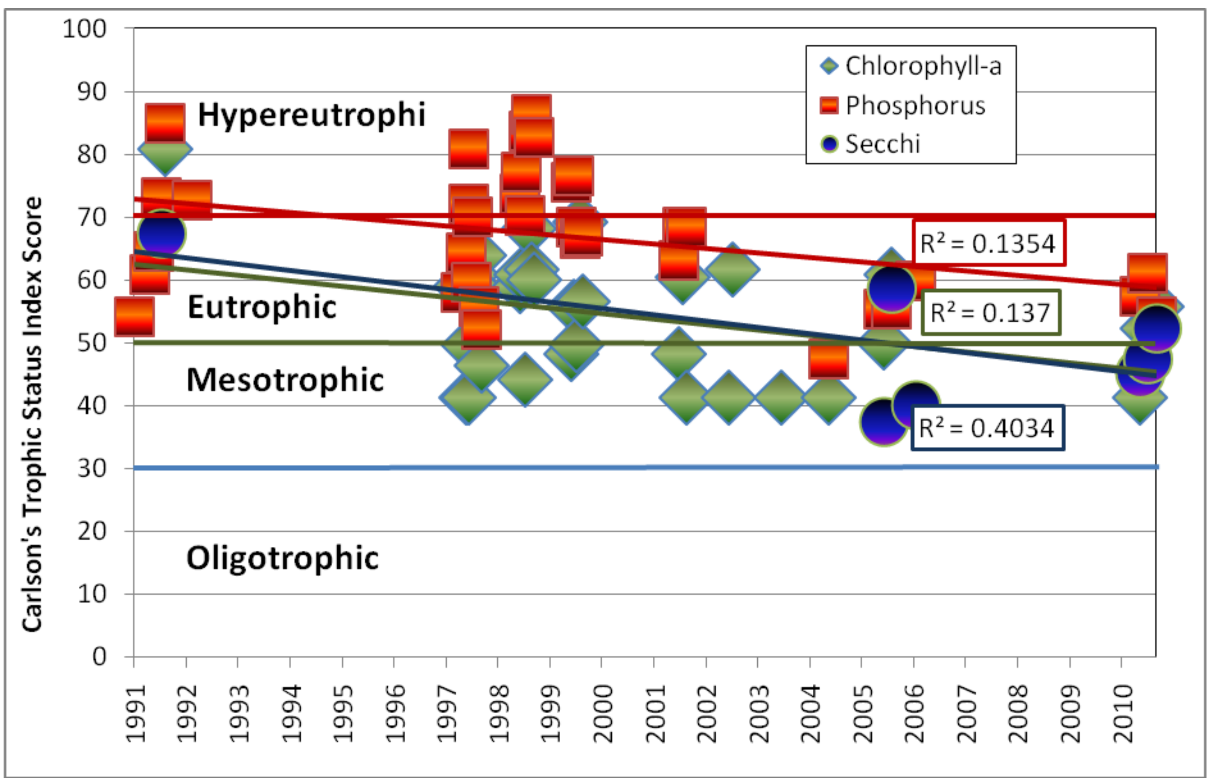

Figure 8. South Golden Lake's TSI Scores

Bader Lake, Stutsman County

BACKGROUND

Location: Bader Lake is a shallow glacial lake four miles south and one mile east of Medina, North Dakota (Figure 1). The fishery is managed by the North Dakota Game and Fish. Fish species managed for are crappie, northern pike and walleye.

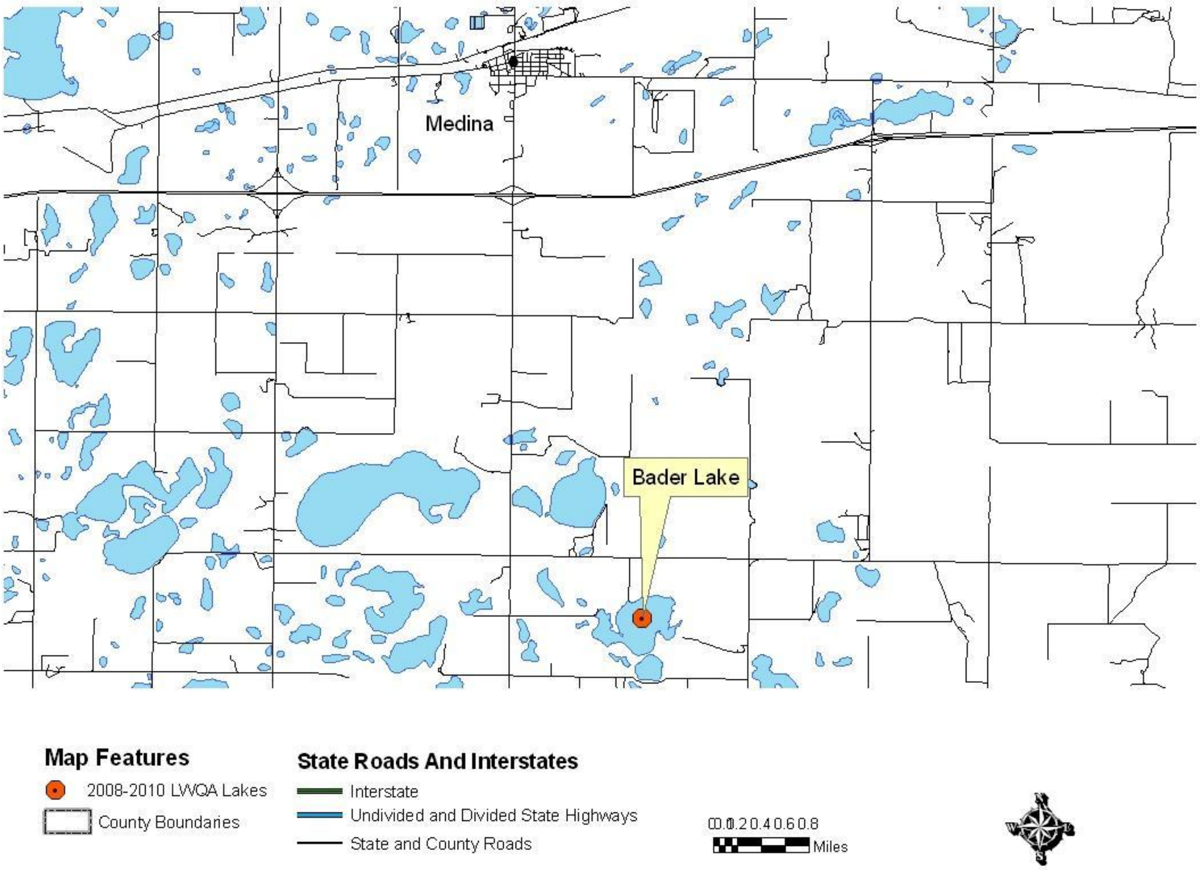

Figure 1. Location of Bader Lake

Physiographic/Ecological Setting: Bader Lake has a surface area of 137.6 acres, a maximum depth of 14.6 ft and an average depth 10.9 ft (Figure 2). The lake is located within the Northwestern Glaciated Plains Level III Ecoregion, which is part of the broader Rangeland Plains region (Figures 3 and 4).

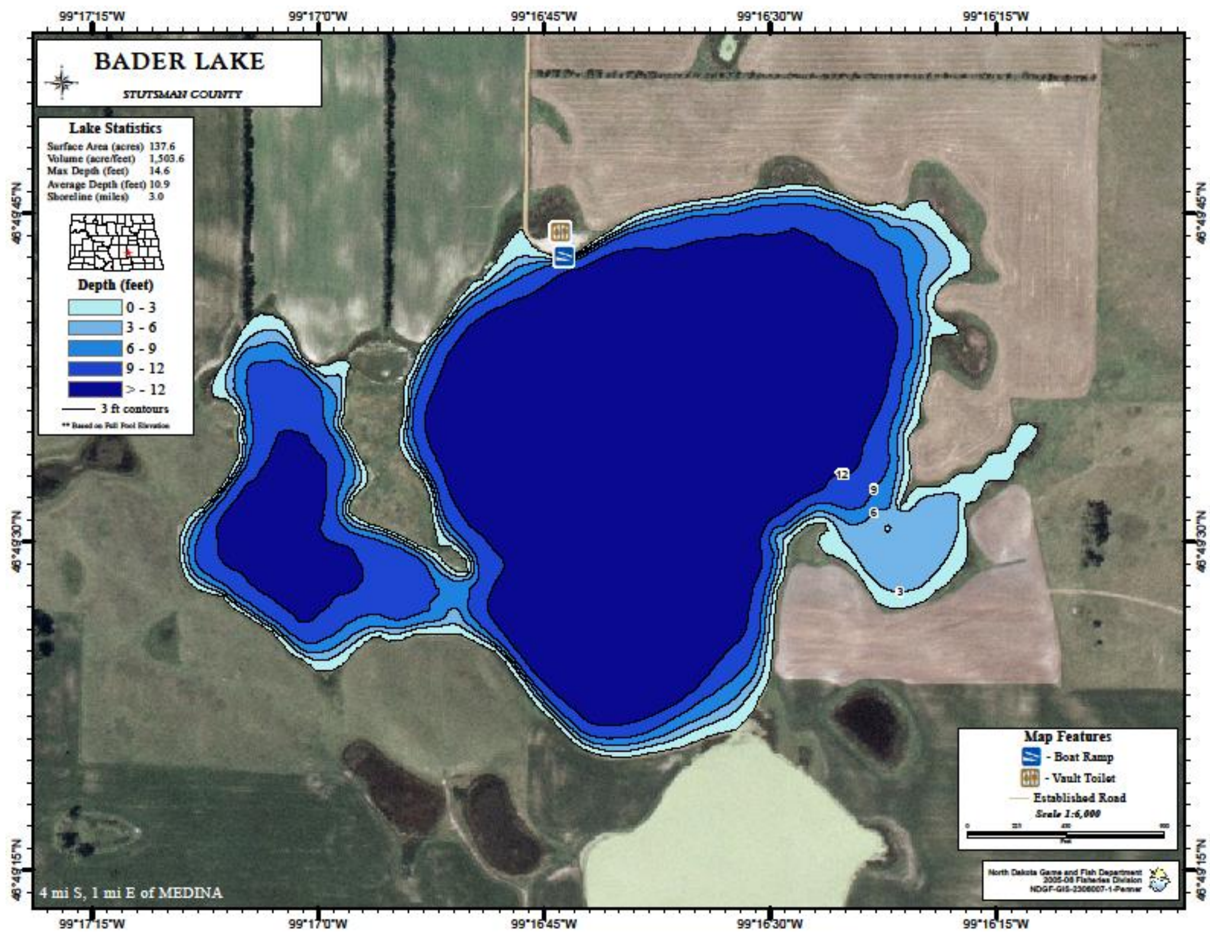

Figure 2. Contour Map of Bader Lake (Map Courtesy of North Dakota Game and Fish Department)

Recreational Facilities: Recreational facilities at Bader Lake include a cement boat ramp, courtesy dock, vault toilets and vehicle parking.

Water Quality Standards Classification: Bader Lake is classified in the state "Standards of Quality for Waters of the State" (NDDoH, 2011) as a class 3 lake. Class 3 lakes or reservoirs are defined as a "warm water fishery" or "waters capable of supporting natural reproduction and growth of warm water fishes (e.g., largemouth bass and bluegill) and associated aquatic biota. Some cool water species may also be present."

Historical Water Quality Sampling: No historical water quality data.

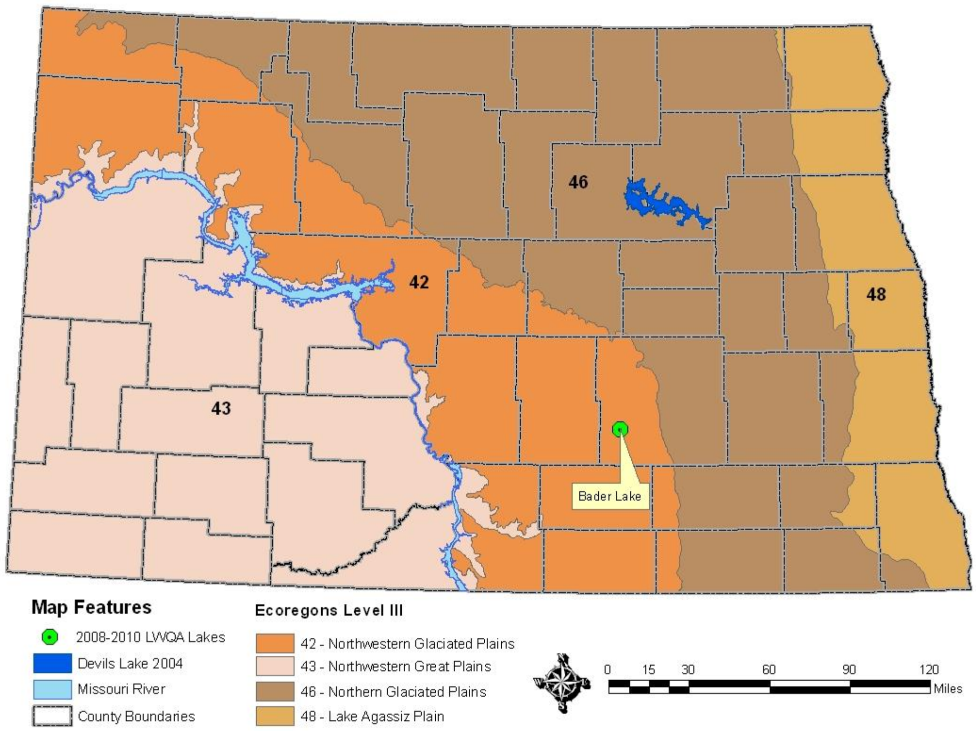

Figure 3. Bader Lake's Location and the Level III Ecoregions

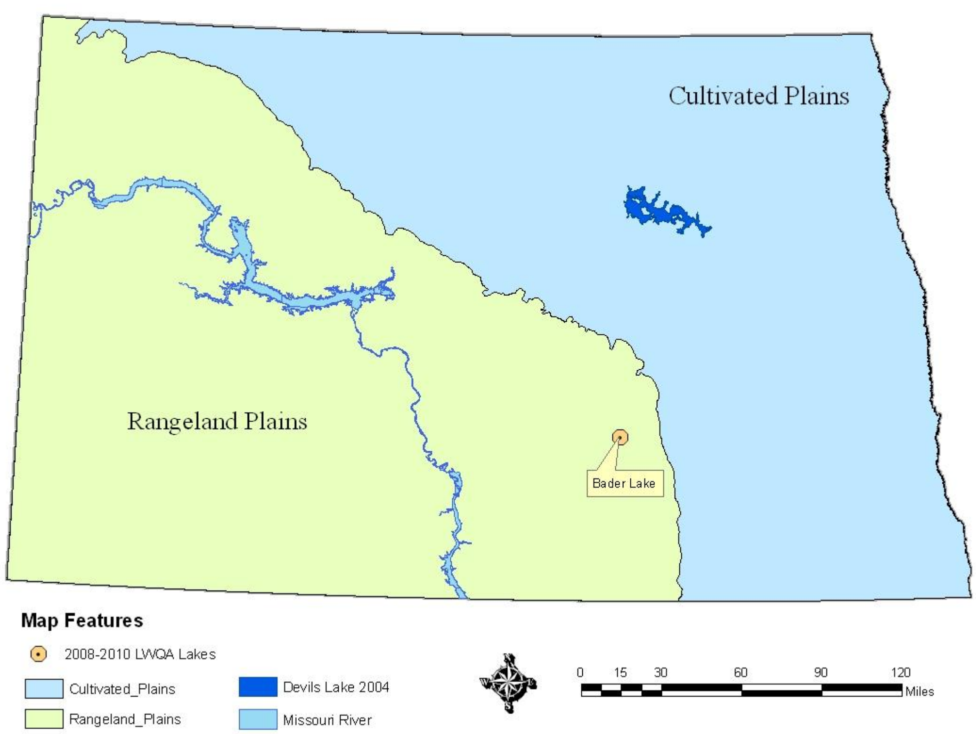

Figure 4. Bader Lake Location and the Cultivated and Rangeland Plans Regions

WATER QUALITY MONITORING RESULTS

The water quality assessment for Bader Lake is presented in four general categories: 1) temperature and dissolved oxygen profile results; 2) general water quality characterization; 3) nutrient limitation; and 4) trophic status. Additionally where appropriate, results have been compared to regional data.

Temperature and Dissolved Oxygen Profile Results: There are two temperature and dissolved oxygen profiles for Bader Lake collected in 2008 (Figures 5 and 6). The profile data shows that Bader Lake was not thermally stratified during the open water period. Additionally during the open water period the lake remained well enough oxygenated to support aquatic Life.

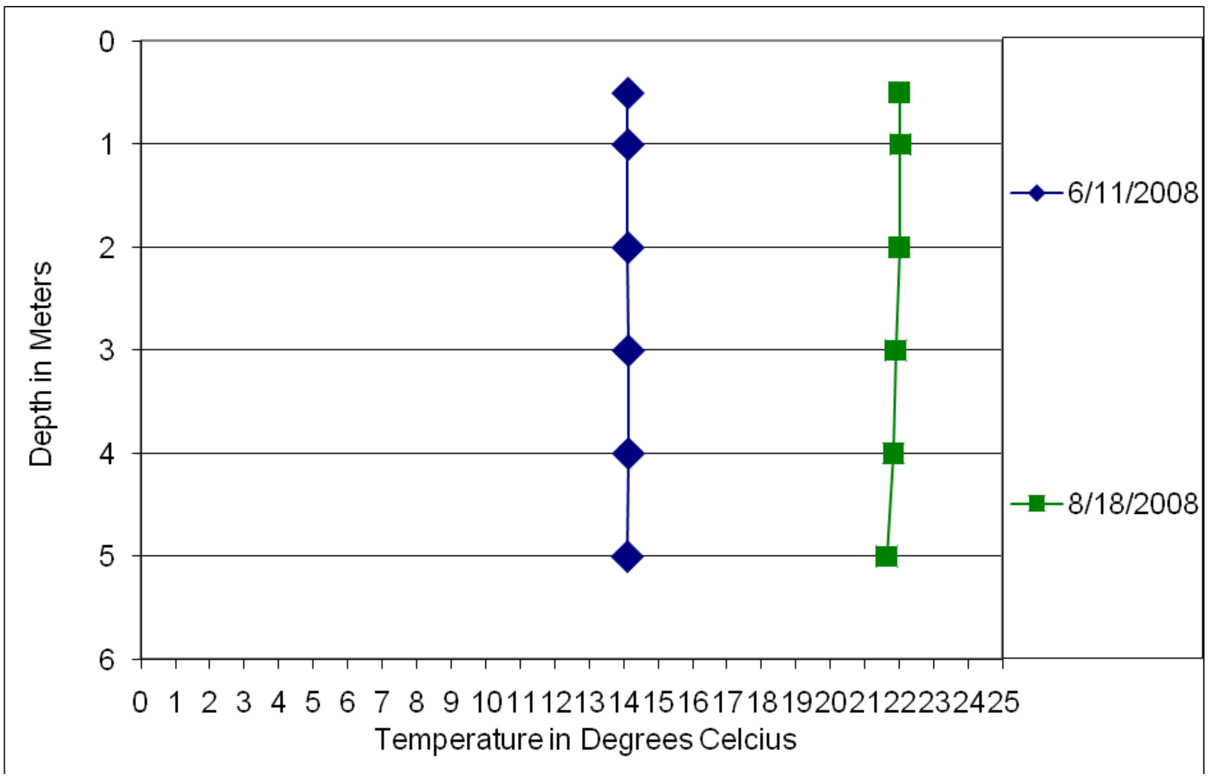

Figure 5. Temperature Profiles for Bader Lake

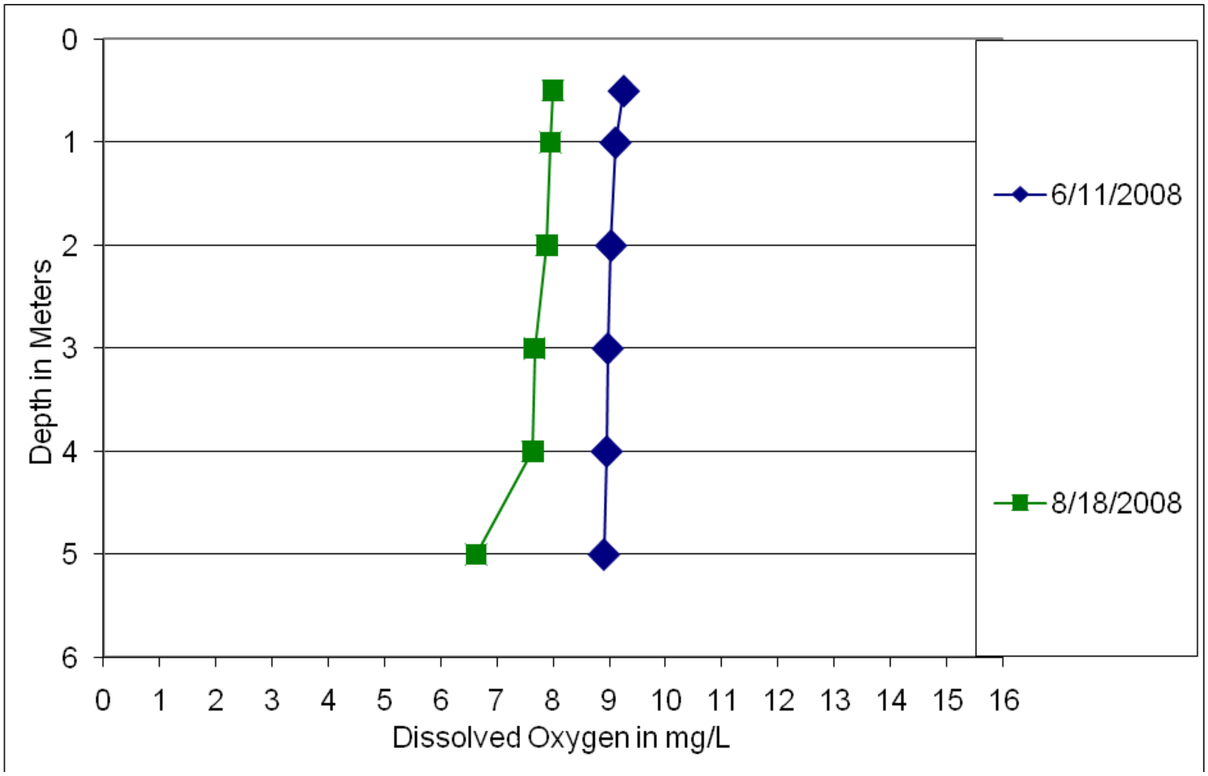

Figure 6. Dissolved Oxygen Profiles for Bader Lake

General Water Quality: Data collected in 2008 indicate that Bader Lake is very well buffered with total alkalinity as $CaCO_3$ concentrations ranging from 437 to 478 mg/L (Table 1). The lake is sodium bicarbonate dominated with an average sodium concentration of 424 mg/L and an average bicarbonate concentration of 470 mg/L. The average total dissolved solids concentration and specific conductance measurement for 2008 sampling period were 2410 mg/L and 3165 µmhos/cm respectively, and the average total nitrogen as N and total phosphorus as P concentrations were 2.055 mg/L and 0.092 mg/L respectively.

When compared to water quality for natural lakes in the Rangeland Plans region, Bader Lake is more mineralized than most but is less eutrophic (Table 3). For example, the regional average concentrations in natural lakes for TDS and total phosphorus concentrations are 1466 mg/L and 0.233 mg/L respectively, compared to Bader Lake's average TDS and total phosphorus concentrations of 2410 mg/L and 0.092 mg/L respectively.

Table 1. Statistical Summary of Bader Lake's 2008 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	2	458	437	478	29
Total Ammonia as N	mg/L	2	0.039	0.030[1]	0.048	0.013
Bicarbonate (HCO_3)	mg/L	2	470	427	513	61
Calcium (Ca)	mg/L	2	45.5	38.0	52.9	10.5
Carbonate (CO_3)	mg/L	2	44	35	52	12
Chloride (Cl)	mg/L	2	97	97	98	1
Chlorophyll-a	µg/L	2	1.5[1]	1.5[1]	1.5[1]	0.0
Specific Conductance	µmhos	2	3165	3150	3180	21
Total Dissolved Solids	mg/L	2	2410	2360	2460	71
Total Hardness as ($CaCO_3$)	mg/L	2	995	939	1050	78
Hydroxide (OH)	mg/L	2	1.0[1]	1.0[1]	1.0[1]	0.0
Iron (Fe)	mg/L	2	0.108	0.087	0.129	0.030
Magnesium (Mg)	mg/L	2	214.5	196.0	233.0	26.2
Nitrate + Nitrite as N	mg/L	2	0.030[1]	0.030[1]	0.030[1]	0.000
Total Kjeldahl Nitrogen as N	mg/L	2	2.025	1.770	2.280	0.361
Total Nitrogen as N	mg/L	2	2.055	1.800	2.310	0.361
pH		2	8.68	8.59	8.77	0.13
Total Phosphorus as P	mg/L	2	0.092	0.075	0.109	0.024
Potassium (K)	mg/L	2	66.4	58.5	74.3	11.2
Sodium (Na)	mg/L	2	424.0	411.0	437.0	18.4
Sulfate (SO4)	mg/L	2	1290	1260	1320	42

[1]Equal to the lower reporting limit

Limiting Nutrients: The two water quality samples define Bader Lake limiting nutrient as phosphorus (Figure 7). The limiting nutrient assessment is based on the assumption that either nitrogen or phosphorus is limiting algal growth with the water body, and that the ratio of total nitrogen as N to total phosphorus as P (N:P), by weight in the average algae, is approximately 15 to 1. When the N:P ratio is less than 15:1, nitrogen is assumed to be the limiting nutrient and when it exceeds 15:1, the limiting nutrient is assumed to be phosphorus.

Trophic Status Assessment: Based on the chlorophyll-a, secchi disk transparency, and total phosphorus data collected in 2008, Bader Lake's trophic is eutrophic. The trophic Status Index scores ranged from a low of 35 based on chlorophyll-a to a high of 72 based on total phosphorus (Figure 8).

Table 2. Statistical Summary of Water Quality Data[2] Collected from Natural and Enhanced Lakes in the Rangeland Plains Ecological Region of North Dakota

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	383	513	111	4770	487
Total Ammonia as N	mg/L	494	0.105	0.001[1]	2.230	0.229
Bicarbonate (HCO_3)	mg/L	383	469	60	2990	320
Calcium (Ca)	mg/L	384	41.1	0.5	282.0	34.4
Carbonate (CO_3)	mg/L	377	79	1[1]	1420	148
Chloride (Cl)	mg/L	383	44	3[1]	1070	103
Chlorophyll-a	µg/L	346	22.5	1.5[1]	292.0	37.4
Specific Conductance	µmhos	383	2028	424	20100	1976
Total Dissolved Solids	mg/L	383	1466	227	18200	1717
Total Hardness as ($CaCO_3$)	mg/L	384	529	74	2370	295
Hydroxide (OH)	mg/L	322	1.0	0.0[1]	1.0	0.2
Iron (Fe)	mg/L	385	0.245	0.001[1]	7.070	0.543
Magnesium (Mg)	mg/L	384	103.6	8.5	567.0	70.9
Nitrate + Nitrite as N	mg/L	491	0.04046	0.001[1]	0.54	0.054
Total Kjeldahl Nitrogen as N	mg/L	463	1.876	0.080	8.500	1.073
Total Nitrogen as N	mg/L	401	1.794	0.240	5.520	0.897
pH		383	8.80	7.40	9.87	0.36
Total Phosphorus as P	mg/L	501	0.233	0.002[1]	1.940	0.336
Potassium (K)	mg/L	384	34.0	3.1	356.0	37.0
Sodium (Na)	mg/L	384	299.6	16.9	4680.0	514.5
Sulfate (SO4)	mg/L	383	625	34	10500	885

[1]Equal to the lower reporting limit
[2]Data collected from 64 natural and enhanced Lakes between 1991 and 2010

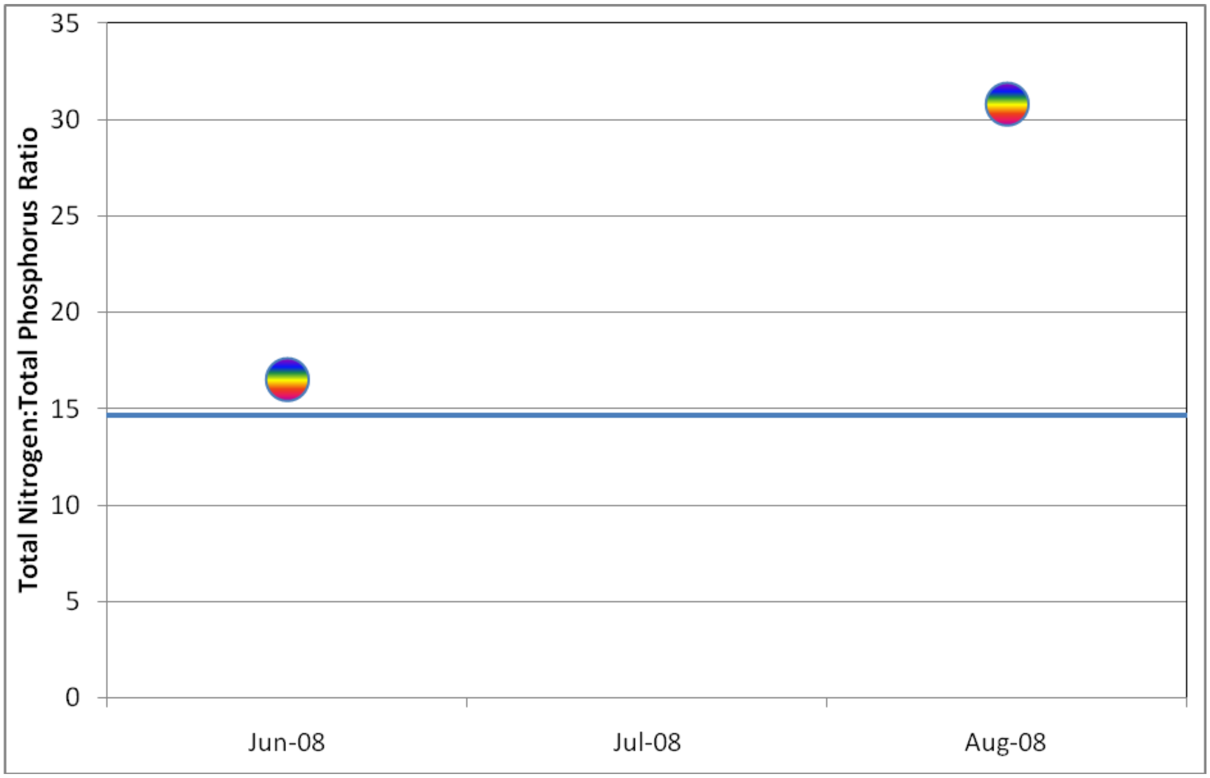

Figure 7. Bader Lake's Total Nitrogen to Total Phosphorus Ratio

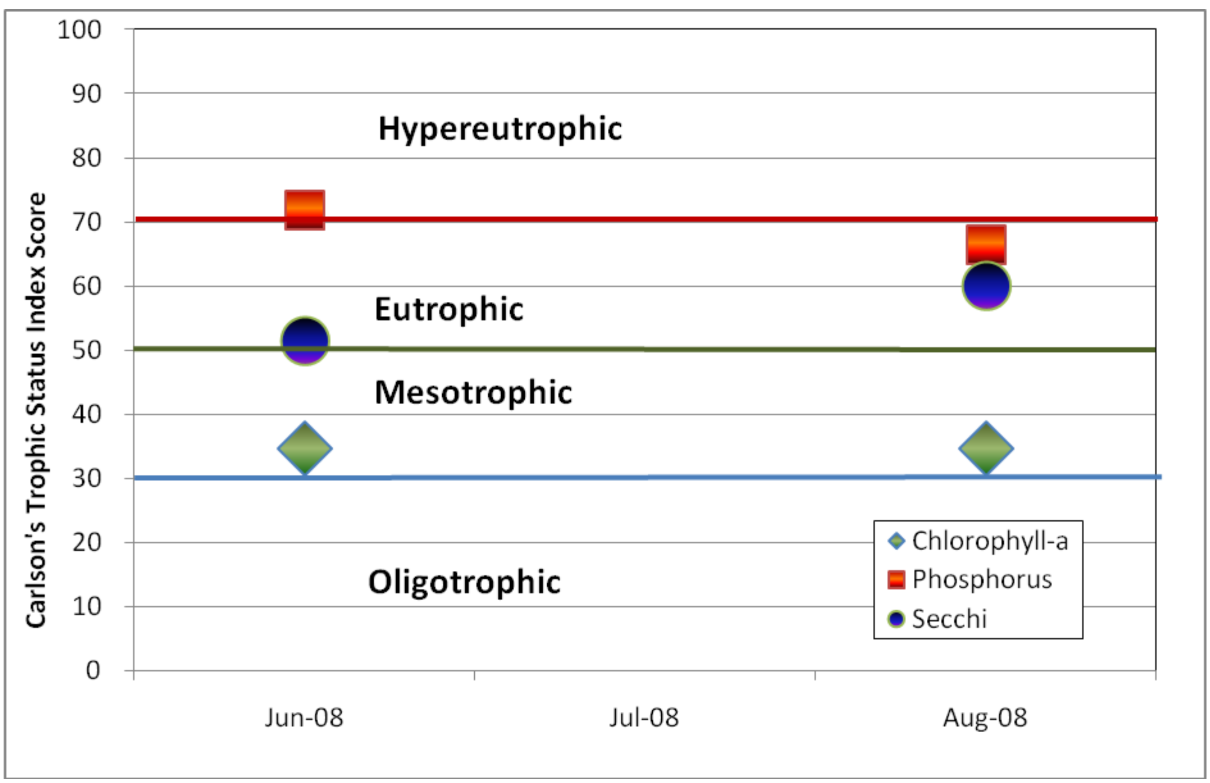

Figure 8. Bader Lake's TSI Scores

Barnes Lake, Stutsman County

BACKGROUND

Location: Barnes Lake is a shallow glacial lake a 5 miles north and 1 mile east of Woodworth, North Dakota (Figure 1). The fishery is managed by the North Dakota Game and Fish. Fish species managed for are northern pike, walleye and yellow perch.

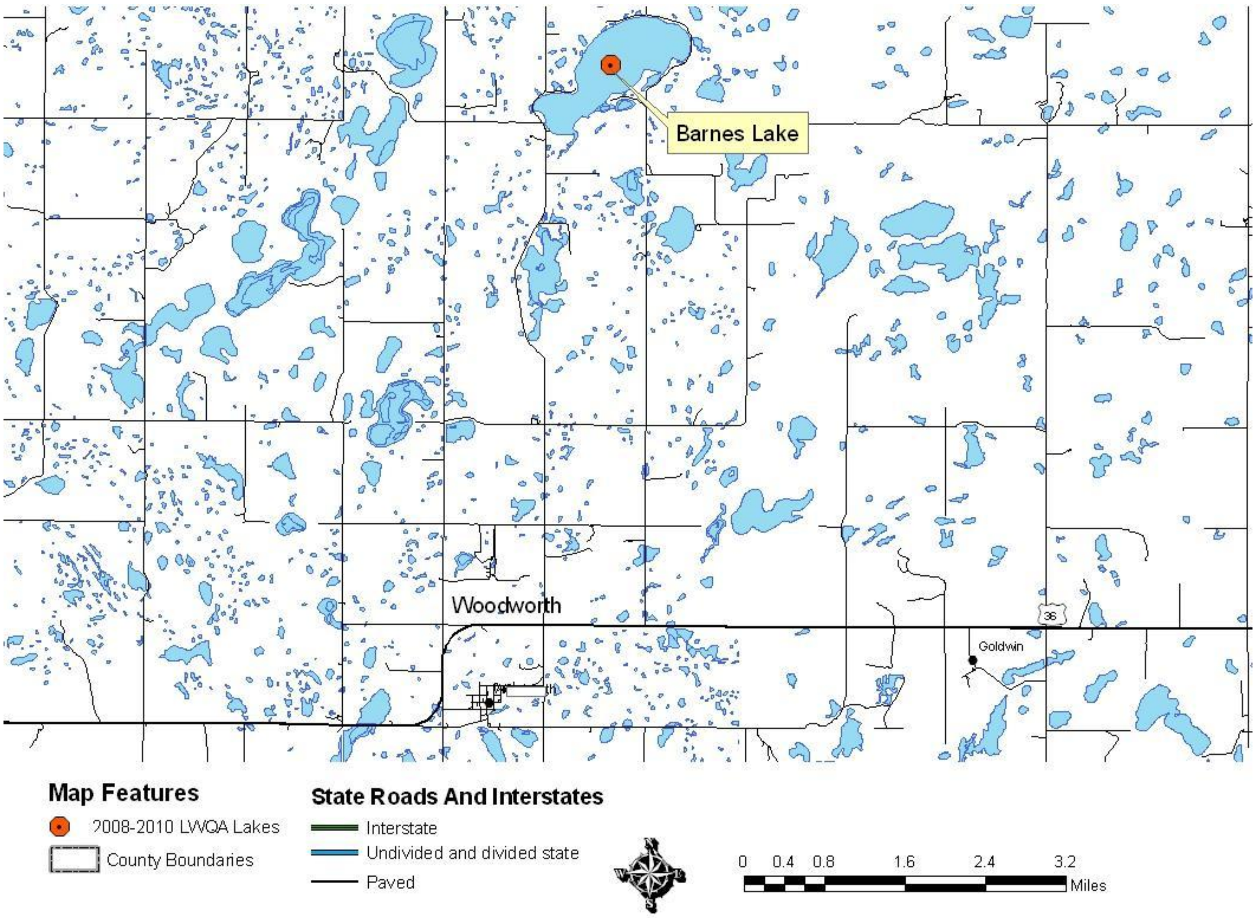

Figure 1. Location of Barnes Lake

Physiographic/Ecological Setting: Barnes Lake has a surface area of 525.7 acres, a maximum depth of 11.5 ft and an average depth 9 ft (Figure 2). The lake is located within the Northwestern Glaciated Plains Level III Ecoregion, which is part of the broader Rangeland Plains Ecoregion (Figures 3 and 4).

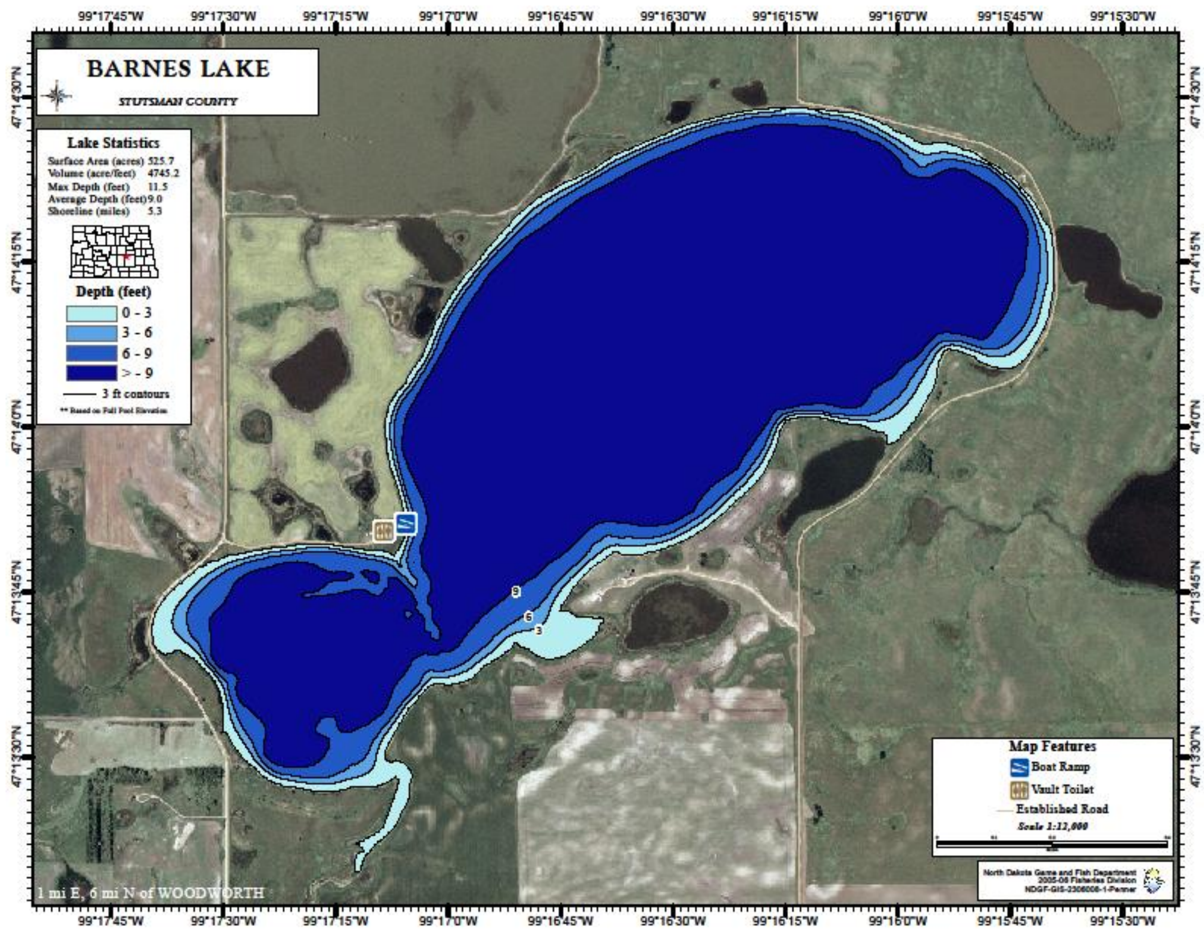

Figure 2. Contour Map of Barnes Lake (Map Courtesy of North Dakota Game and Fish Department)

Recreational Facilities: Recreational facilities at Barnes Lake include a cement boat ramp, courtesy dock, vault toilets and vehicle parking.

Water Quality Standards Classification: Barnes Lake is classified in the state "Standards of Quality for Waters of the State" (NDDoH, 2011) as a class 3 lake. Class 3 lakes or reservoirs are defined as a "warm water fishery" or "waters capable of supporting natural reproduction and growth of warm water fishes (e.g., largemouth bass and bluegill) and associated aquatic biota. Some cool water species may also be present."

Historical Water Quality Sampling: No historical water quality data.

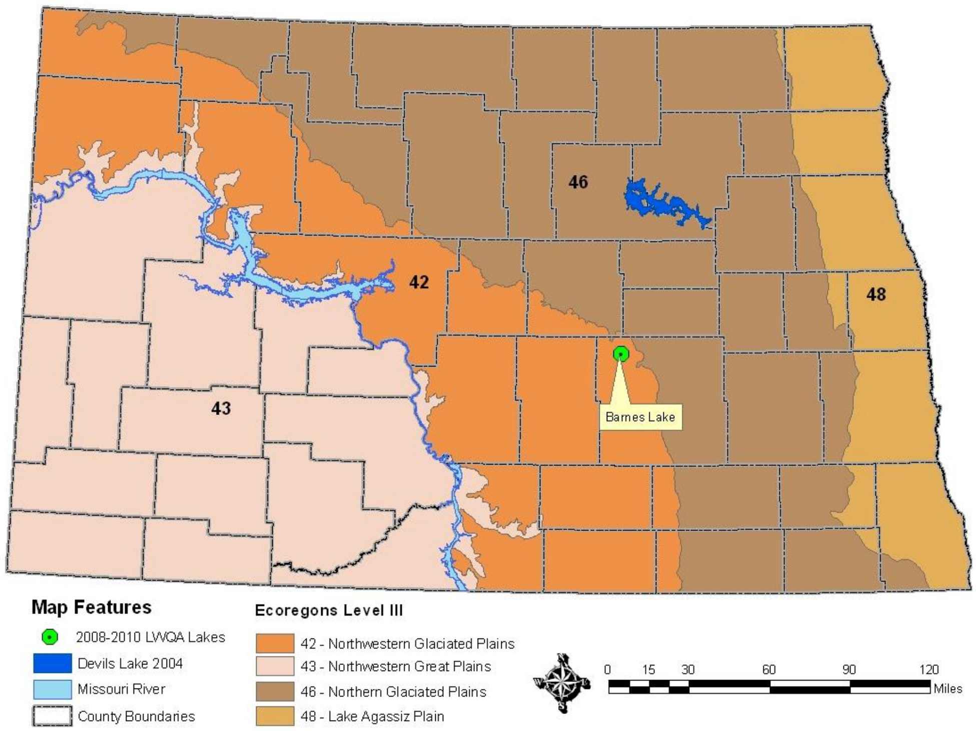

Figure 3. Barnes Lake's Location and the Level III Ecoregions

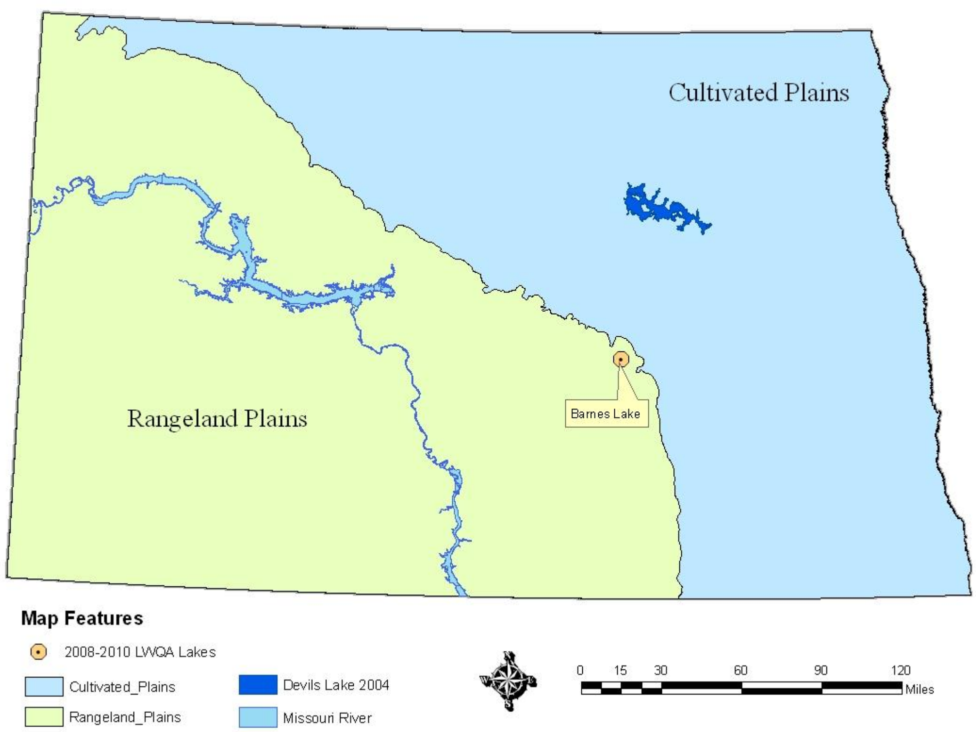

Figure 4. Barnes Lake Location and the Cultivated and Rangeland Plans Regions

WATER QUALITY MONITORING RESULTS

The water quality assessment for Barnes Lake is presented in four general categories: 1) temperature and dissolved oxygen profile results; 2) general water quality characterization; 3) nutrient limitation; and 4) trophic status. Additionally where appropriate, results have been compared to regional data.

Temperature and Dissolved Oxygen Profile Results: There are 2 temperature and dissolved oxygen profiles for Barnes Lake collected in 2008 (Figures 5 and 6). The profile data shows that Barnes Lake was not thermally stratification during the open water period. Additionally during the open water period the lake remained well enough oxygenated to support aquatic Life.

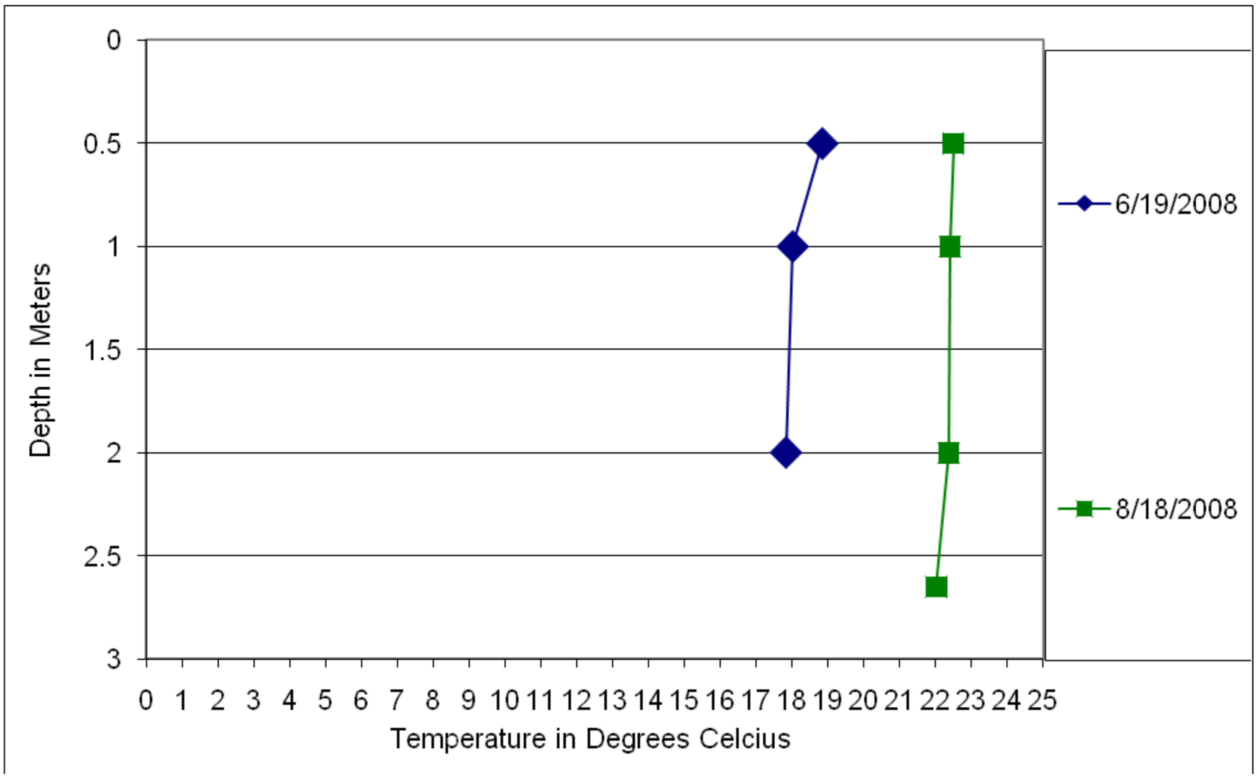

Figure 5. Temperature Profiles for Barnes Lake

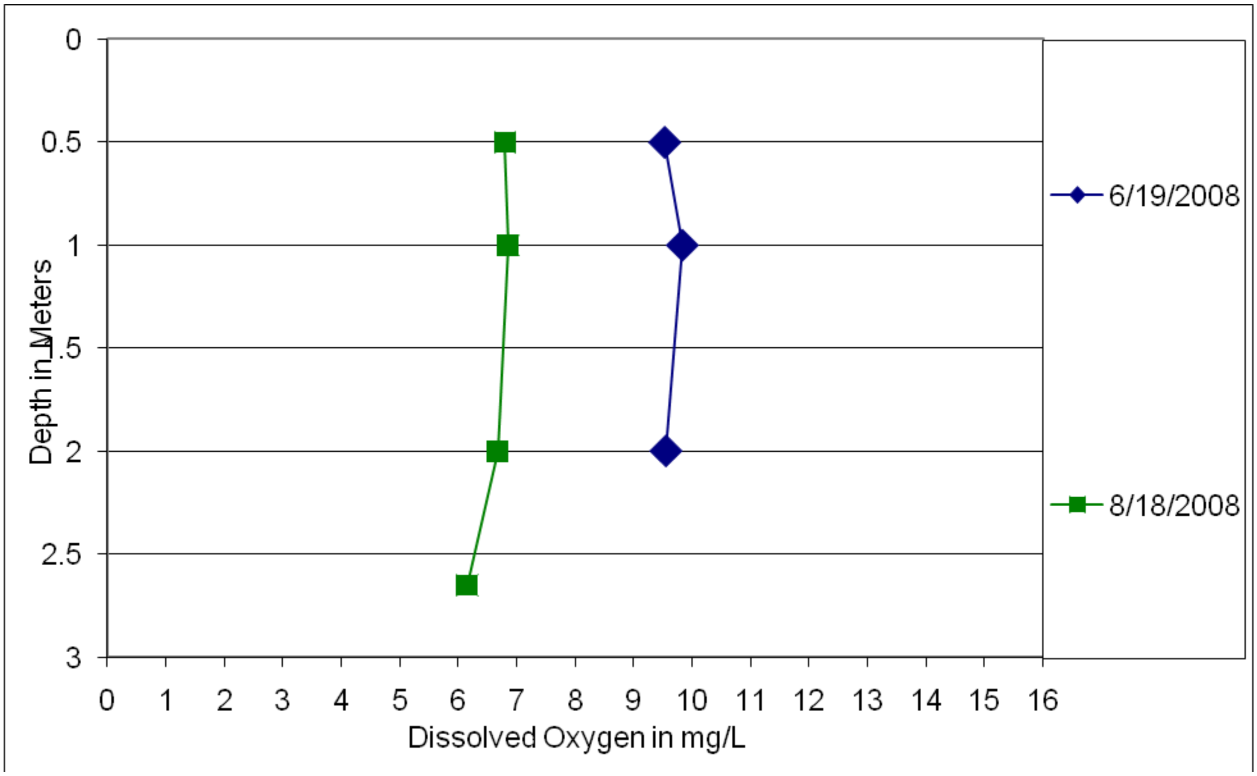

Figure 6. Dissolved Oxygen Profiles for Barnes Lake

General Water Quality: Data collected in 2008 indicate that Barnes Lake is very well buffered with total alkalinity as $CaCO_3$ concentrations ranging from 296 to 342 mg/L (Table 1). The lake is sodium sulfate dominated with an average sodium concentration of 222 mg/L and an average sulfate concentration of 1022 mg/L. The average total dissolved solids concentration and specific conductance measurement for 2008 sampling period were 1775 mg/L and 2360 µmhos/cm respectively, and the average total nitrogen as N and total phosphorus as P concentrations are 2.42 mg/L and 0.350 mg/L respectively.

When compared to the regional average water quality for natural lakes in the Rangeland Plans Ecoregion, Barnes Lake is more mineralized and more eutrophic than most (Table 3). For example, the regional average concentrations in natural lakes for TDS and total phosphorus concentrations are 1466 mg/L and 0.233 mg/L respectively, compared to Barnes Lake's average TDS and total phosphorus concentrations of 1775 mg/L and 0.350 mg/L respectively.

Table 1. Statistical Summary of Barnes Lake's 2008 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	2	319	296	342	33
Total Ammonia as N	mg/L	2	0.207	0.030[1]	0.383	0.250
Bicarbonate (HCO_3)	mg/L	2	284	238	329	64
Calcium (Ca)	mg/L	2	90.5	89.5	91.4	1.3
Carbonate (CO_3)	mg/L	2	52	43	61	13
Chloride (Cl)	mg/L	2	46	43	49	4
Chlorophyll-a	µg/L	2	1.5[1]	1.5[1]	1.5[1]	0.0
Specific Conductance	µmhos	2	2360	2340	2380	28
Total Dissolved Solids	mg/L	2	1775	1750	1800	35
Total Hardness as ($CaCO_3$)	mg/L	2	901	895	907	8
Hydroxide (OH)	mg/L	2	1.0[1]	1.0[1]	1.0[1]	0.0
Iron (Fe)	mg/L	2	0.085	0.066	0.104	0.027
Magnesium (Mg)	mg/L	2	164.0	162.0	166.0	2.8
Nitrate + Nitrite as N	mg/L	2	0.040	0.030[1]	0.050	0.014
Total Kjeldahl Nitrogen as N	mg/L	2	2.380	2.010	2.750	0.523
Total Nitrogen as N	mg/L	2	2.420	2.040	2.800	0.537
pH		2	8.91	8.78	9.04	0.18
Total Phosphorus as P	mg/L	2	0.350	0.349	0.351	0.001
Potassium (K)	mg/L	2	38.4	35.9	40.9	3.5
Sodium (Na)	mg/L	2	222.0	220.0	224.0	2.8
Sulfate (SO4)	mg/L	2	1022	983	1060	54

[1]Equal to the lower reporting limit

Limiting Nutrients: The 2 water quality samples define Barnes Lake limiting nutrient as nitrogen (Figure 7). The limiting nutrient analysis is based on the assumption that either nitrogen or phosphorus is limiting algal growth with the water body, and that the ratio of total nitrogen as N to total phosphorus as P (N:P), by weight in the average algae, is approximately 15 to 1. When the N:P ratio is less than 15:1, nitrogen is assumed to be the limiting nutrient and when it exceeds 15:1, the limiting nutrient is assumed to be phosphorus.

Trophic Status Assessment: Based on the chlorophyll-a, Secchi disk transparency, and total phosphorus data collected in 2008, Barnes Lake's trophic is eutrophic. The trophic Status Index scores ranged from a low of 35 based on chlorophyll-a to a high of 89 based on total phosphorus (Figure 8).

Table 2. Statistical Summary of Water Quality Data[2] Collected from Natural and Enhanced Lakes in the Rangeland Plains Ecological Region of North Dakota

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	383	513	111	4770	487
Total Ammonia as N	mg/L	494	0.105	0.001[1]	2.230	0.229
Bicarbonate (HCO_3)	mg/L	383	469	60	2990	320
Calcium (Ca)	mg/L	384	41.1	0.5	282.0	34.4
Carbonate (CO_3)	mg/L	377	79	1[1]	1420	148
Chloride (Cl)	mg/L	383	44	3[1]	1070	103
Chlorophyll-a	µg/L	346	22.5	1.5[1]	292.0	37.4
Specific Conductance	µmhos	383	2028	424	20100	1976
Total Dissolved Solids	mg/L	383	1466	227	18200	1717
Total Hardness as ($CaCO_3$)	mg/L	384	529	74	2370	295
Hydroxide (OH)	mg/L	322	1.0	0.0[1]	1.0	0.2
Iron (Fe)	mg/L	385	0.245	0.001[1]	7.070	0.543
Magnesium (Mg)	mg/L	384	103.6	8.5	567.0	70.9
Nitrate + Nitrite as N	mg/L	491	0.04046	0.001[1]	0.54	0.054
Total Kjeldahl Nitrogen as N	mg/L	463	1.876	0.080	8.500	1.073
Total Nitrogen as N	mg/L	401	1.794	0.240	5.520	0.897
pH		383	8.80	7.40	9.87	0.36
Total Phosphorus as P	mg/L	501	0.233	0.002[1]	1.940	0.336
Potassium (K)	mg/L	384	34.0	3.1	356.0	37.0
Sodium (Na)	mg/L	384	299.6	16.9	4680.0	514.5
Sulfate (SO4)	mg/L	383	625	34	10500	885

[1]Equal to the lower reporting limit
[2]Data collected from 64 natural and enhanced Lakes between 1991 and 2010

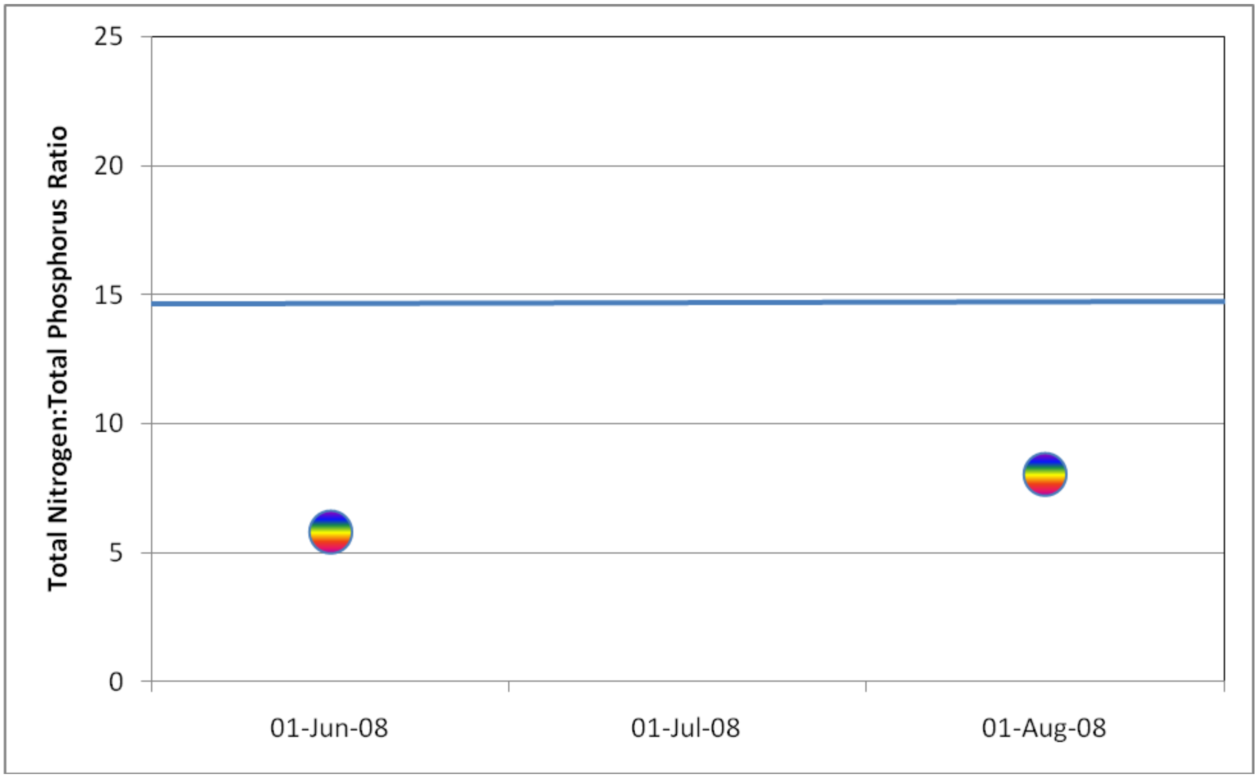

Figure 7. Barnes Lake's Total Nitrogen to Total Phosphorus Ratio

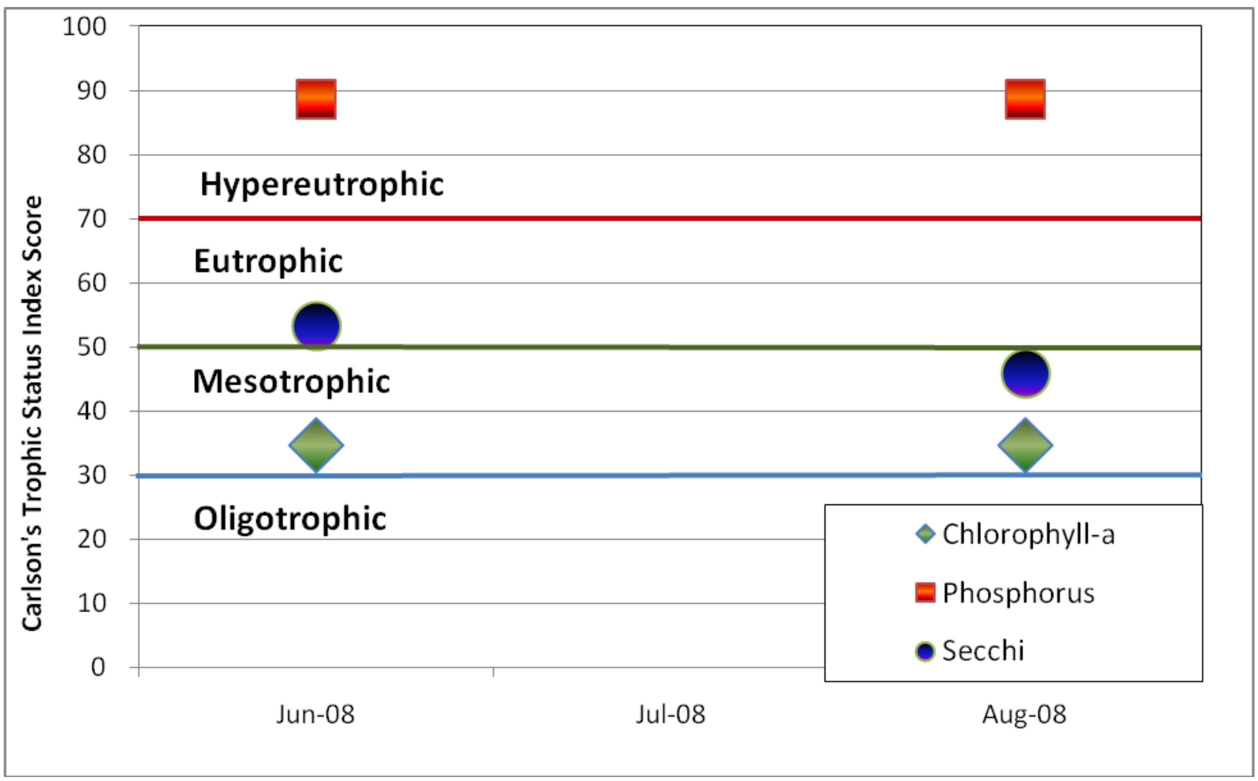

Figure 8. Barnes Lake's TSI Scores

Clark Lake, Stutsman County

BACKGROUND

Location: Clark Lake is a shallow glacial lake located two miles north and five miles west of Woodworth, North Dakota (Figure 1). The fishery is managed by the North Dakota Game and Fish. Fish species managed for are northern pike, walleye and yellow perch.

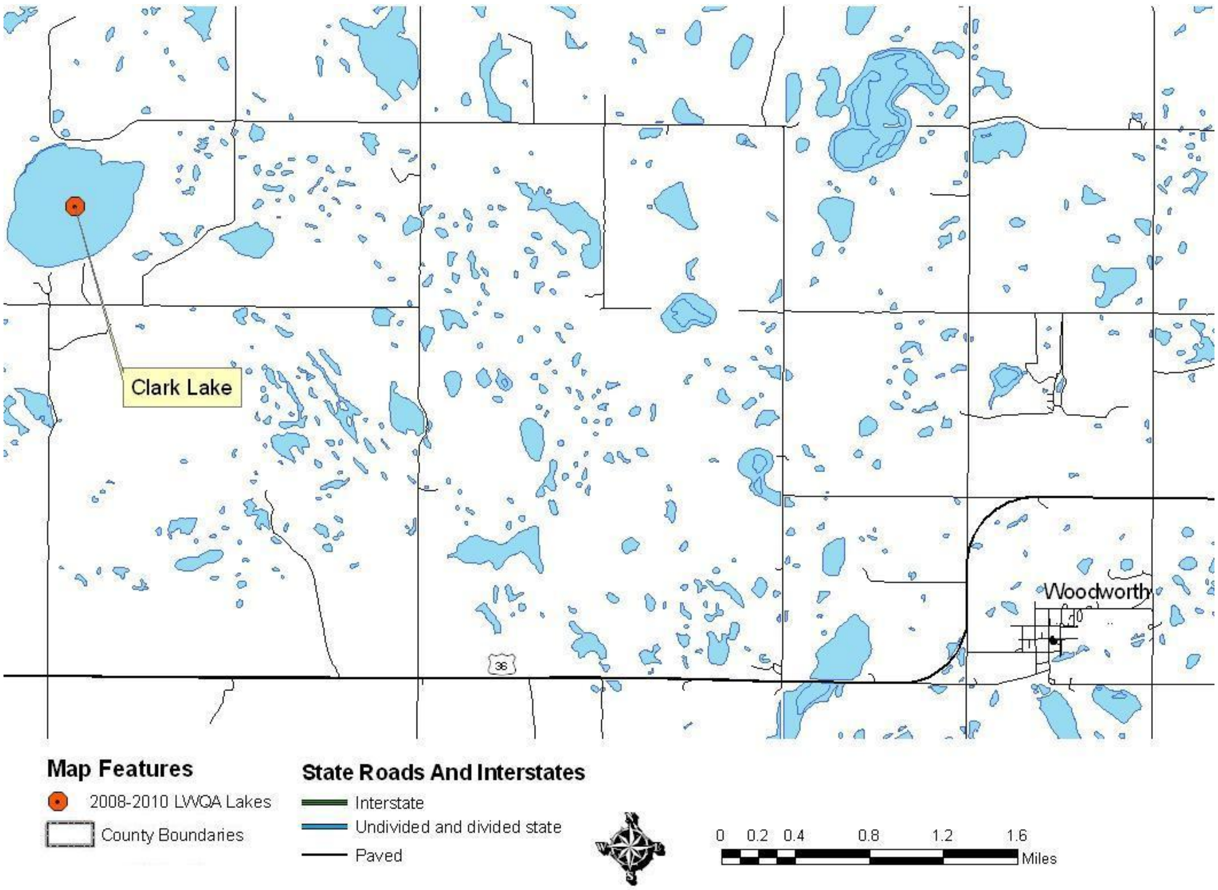

Figure 1. Location of Clark Lake

Physiographic/Ecological Setting: Clark Lake has a surface area of 284.5 acres, a maximum depth of 24.6 ft and an average depth 18 ft (Figure 2). The lake is located within the Northwestern Glaciated Plains Level III Ecoregion, which is part of the broader Rangeland Plains region (Figures 3 and 4).

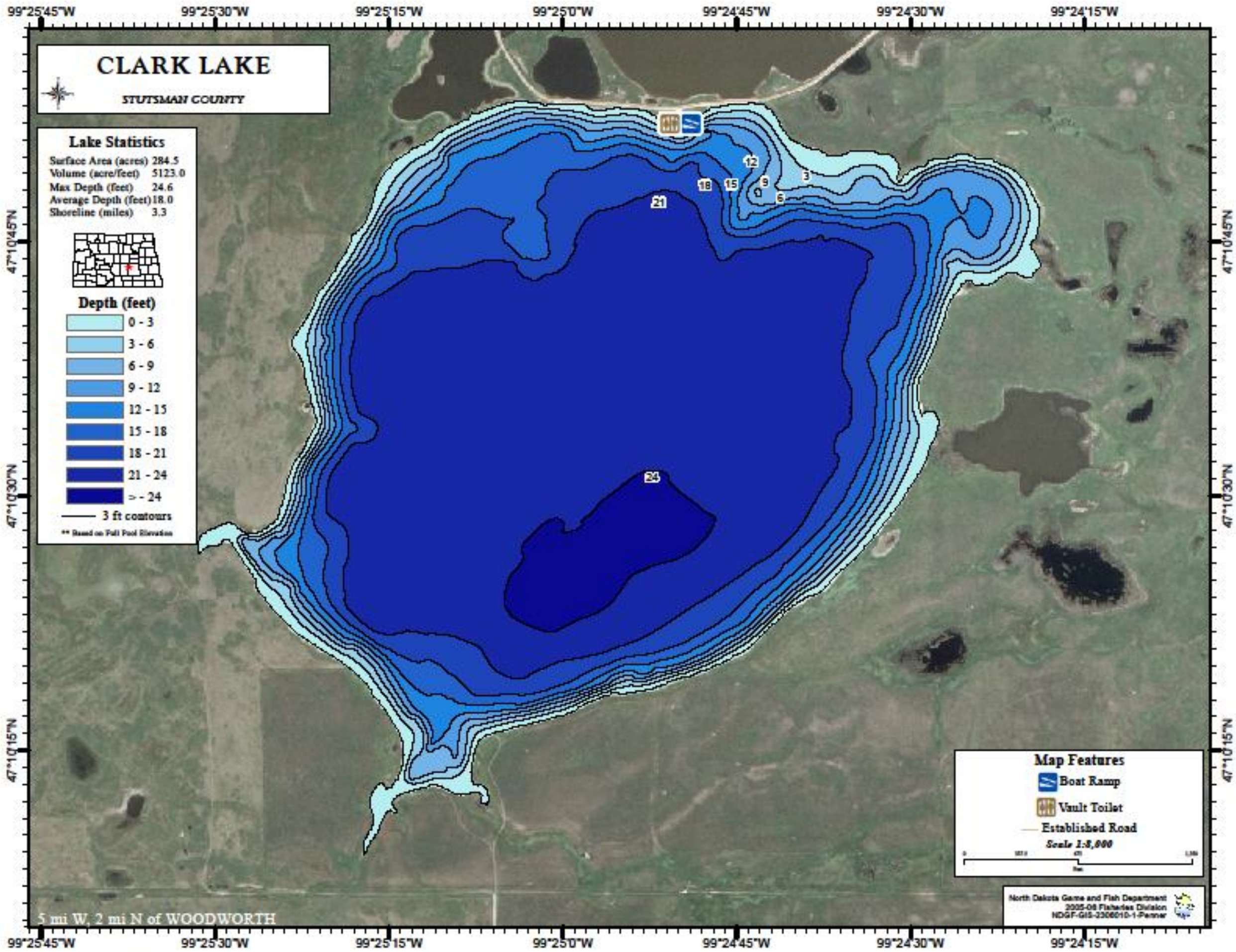

Figure 2. Contour Map of Clark Lake (Map Courtesy of North Dakota Game and Fish Department)

Recreational Facilities: Recreational facilities at Clark Lake include a cement boat ramp, courtesy dock, and limited vehicle parking.

Water Quality Standards Classification: Clark Lake is classified in the state "Standards of Quality for Waters of the State" (NDDoH, 2011) as a class 3 lake. Class 3 lakes or reservoirs are defined as a "warm water fishery" or "waters capable of supporting natural reproduction and growth of warm water fishes (e.g., largemouth bass and bluegill) and associated aquatic biota. Some cool water species may also be present."

Historical Water Quality Sampling: No historical water quality data.

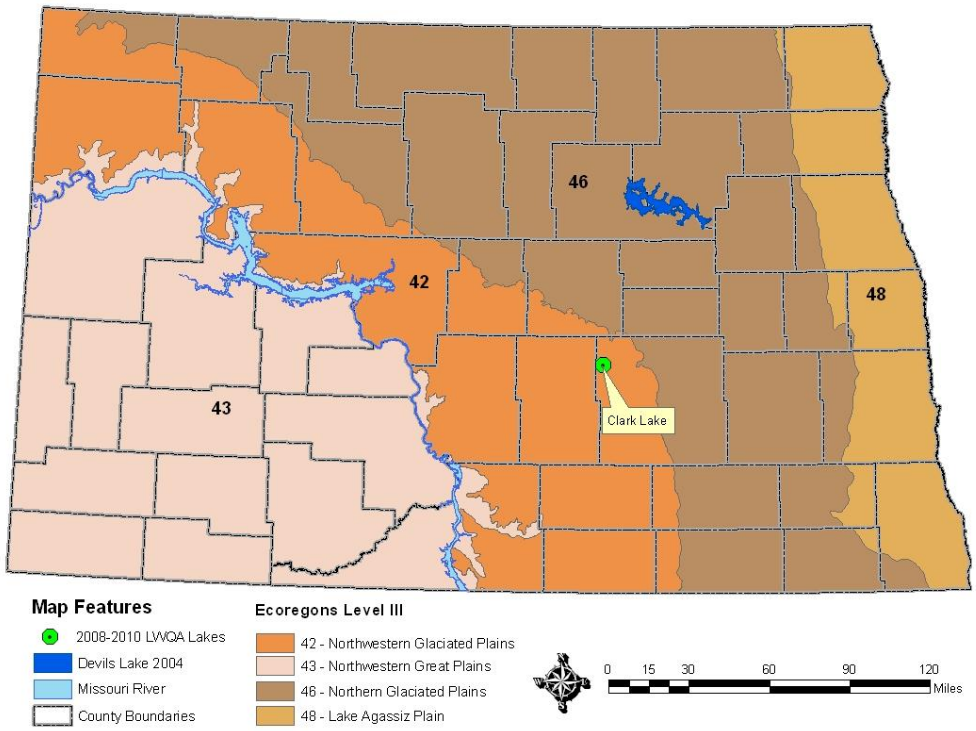

Figure 3. Clark Lake's Location and the Level III Ecoregions

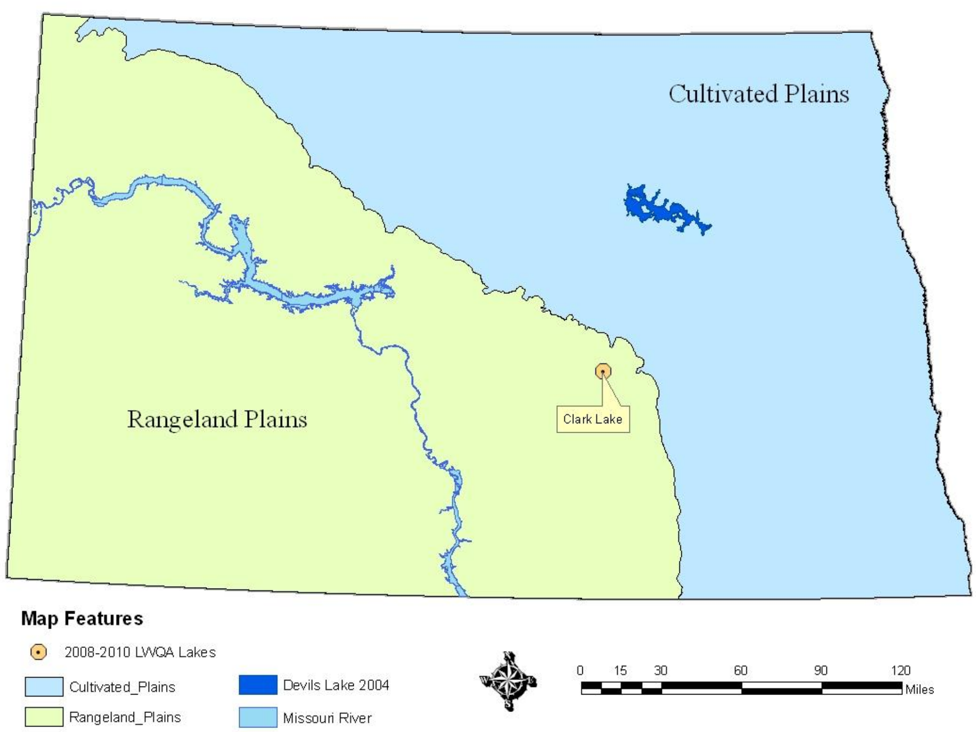

Figure 4. Clark Lake Location and the Cultivated and Rangeland Plans Regions

WATER QUALITY MONITORING RESULTS

The water quality assessment for Clark Lake is presented in four general categories: 1) temperature and dissolved oxygen profile results; 2) general water quality characterization; 3) nutrient limitation; and 4) trophic status. Additionally where appropriate, results have been compared to regional data.

Temperature and Dissolved Oxygen Profile Results: There are two temperature and dissolved oxygen profiles for Clark Lake collected in 2008 (Figures 5 and 6). The profile data shows that Clark Lake was not thermally stratification during the open water period. Additionally during the open water period the lake remained well enough oxygenated to support aquatic Life.

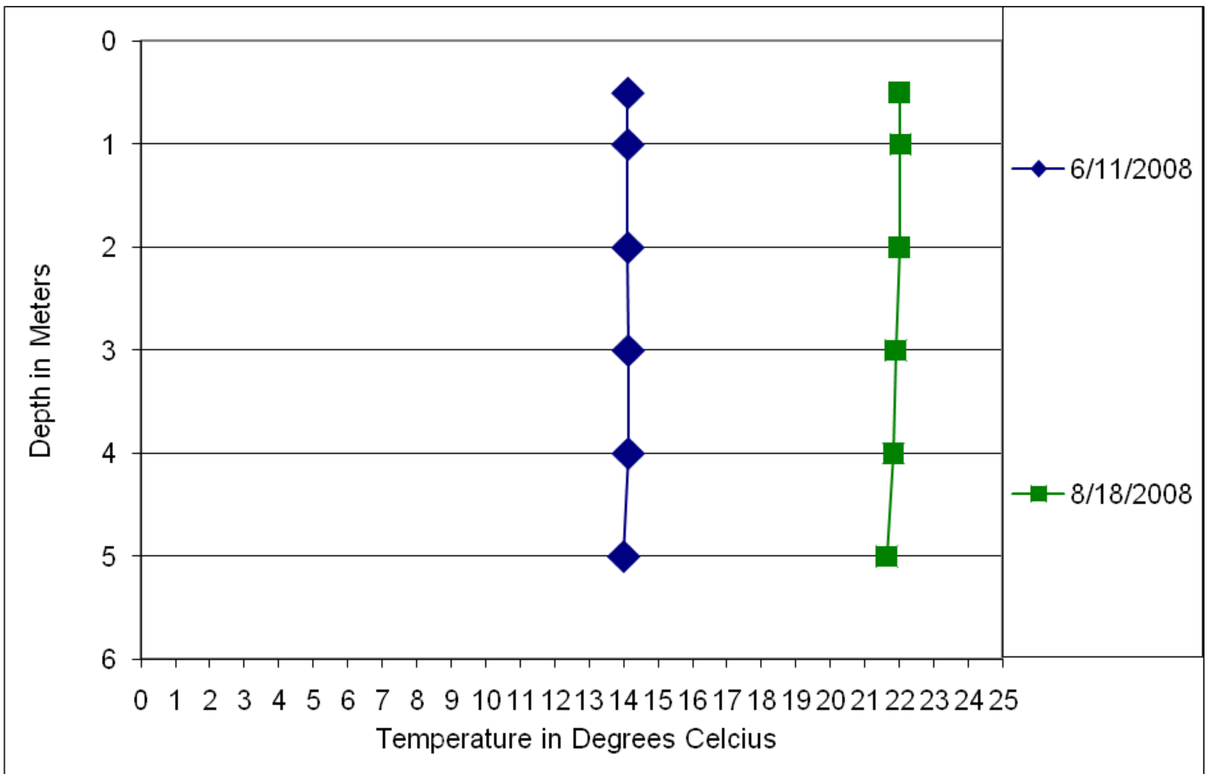

Figure 5. Temperature Profiles for Clark Lake

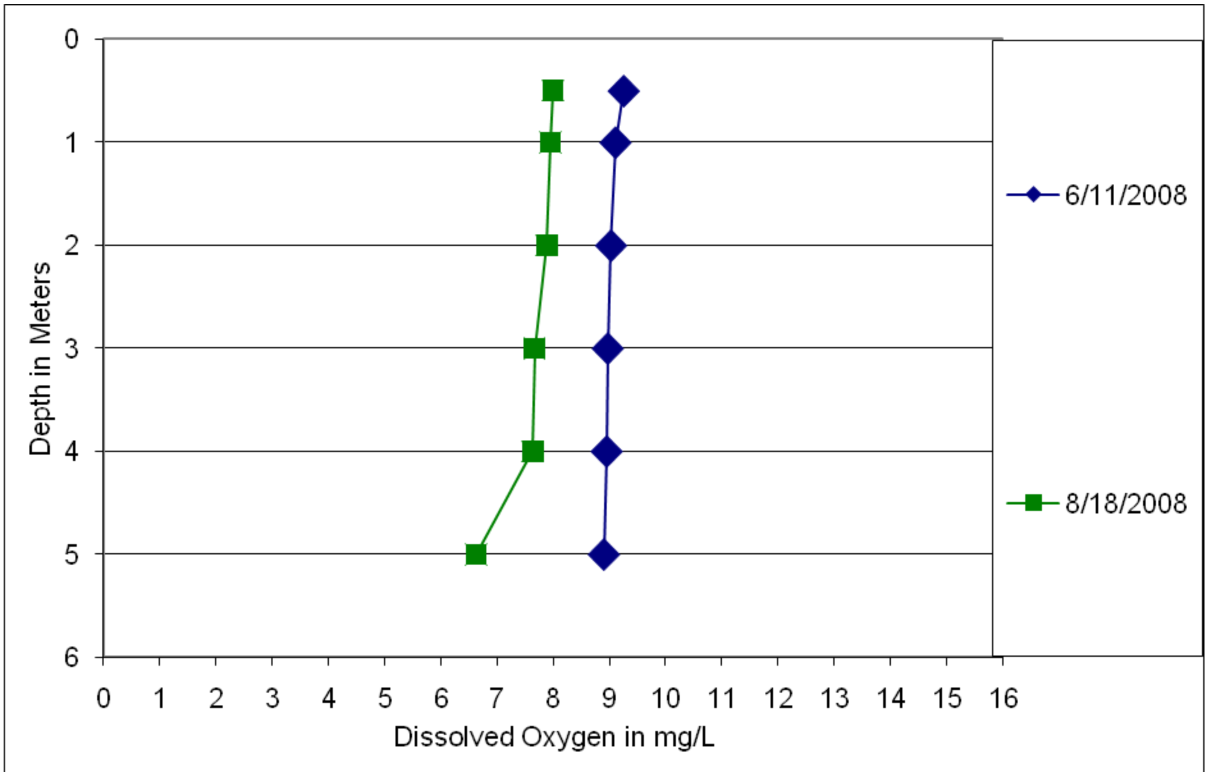

Figure 6. Dissolved Oxygen Profiles for Clark Lake

General Water Quality: Data collected in 2008 indicate that Clark Lake is very well buffered with total alkalinity as $CaCO_3$ concentrations ranging from 412 to 424 mg/L (Table 1). The lake is sodium sulfate dominated with an average sodium concentration of 294 mg/L and an average sulfate concentration of 1140 mg/L. The average total dissolved solids concentration and specific conductance measurement for 2008 sampling period are 2075 mg/L and 2795 µmhos/cm respectively, and the average total nitrogen as N and total phosphorus as P concentrations are 2.040 mg/L and 0.140 mg/L respectively.

When compared to water quality for natural lakes in the Rangeland Plans region, Clark Lake is more mineralized and but less eutrophic than most (Table 3). For example, the regional average concentrations in natural lakes for TDS and total phosphorus concentrations are 1466 mg/L and 0.233 mg/L respectively, compared to Clark Lake's average TDS and total phosphorus concentrations of 2075 mg/L and 0.350 mg/L respectively.

Table 1. Statistical Summary of Clark Lake's 2008 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	2	418	412	424	8
Total Ammonia as N	mg/L	2	0.034	0.030[1]	0.038	0.006
Bicarbonate (HCO_3)	mg/L	2	414	404	424	14
Calcium (Ca)	mg/L	2	52.2	48.7	55.7	4.9
Carbonate (CO_3)	mg/L	2	47	38	56	13
Chloride (Cl)	mg/L	2	72	70	75	4
Chlorophyll-a	µg/L	2	3.8	1.9	5.6	2.6
Specific Conductance	µmhos	2	2795	2750	2840	64
Total Dissolved Solids	mg/L	2	2075	2040	2110	49
Total Hardness as ($CaCO_3$)	mg/L	2	927	875	979	74
Hydroxide (OH)	mg/L	2	1.0[1]	1.0[1]	1.0[1]	0.0
Iron (Fe)	mg/L	2	0.057	0.050	0.064	0.010
Magnesium (Mg)	mg/L	2	193.5	183.0	204.0	14.8
Nitrate + Nitrite as N	mg/L	2	0.030[1]	0.030[1]	0.030[1]	0.000
Total Kjeldahl Nitrogen as N	mg/L	2	2.010	1.840	2.180	0.240
Total Nitrogen as N	mg/L	2	2.040	1.870	2.210	0.240
pH		2	8.73	8.65	8.81	0.11
Total Phosphorus as P	mg/L	2	0.140	0.087	0.193	0.075
Potassium (K)	mg/L	2	68.0	62.0	74.0	8.5
Sodium (Na)	mg/L	2	294.5	275.0	314.0	27.6
Sulfate (SO4)	mg/L	2	1140	1110	1170	42

[1]Equal to the lower reporting limit

Limiting Nutrients: The two water quality samples define Clark Lake limiting nutrient as phosphorus (Figure 7). The limiting nutrient assessment is based on the assumption that either nitrogen or phosphorus is limiting algal growth with the water body, and that the ratio of total nitrogen as N to total phosphorus as P (N:P), by weight in the average algae, is approximately 15 to 1. When the N:P ratio is less than 15:1, nitrogen is assumed to be the limiting nutrient and when it exceeds 15:1, the limiting nutrient is assumed to be phosphorus.

Trophic Status Assessment: Based on the chlorophyll-a, secchi disk transparency, and total phosphorus data collected in 2008, Clark Lake's trophic is eutrophic. The trophic Status Index scores ranged from a low of 37 based on chlorophyll-a to a high of 80 based on total phosphorus (Figure 8).

Table 2. Statistical Summary of Water Quality Data[2] Collected from Natural and Enhanced Lakes in the Rangeland Plains Ecological Region of North Dakota

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	383	513	111	4770	487
Total Ammonia as N	mg/L	494	0.105	0.001[1]	2.230	0.229
Bicarbonate (HCO_3)	mg/L	383	469	60	2990	320
Calcium (Ca)	mg/L	384	41.1	0.5	282.0	34.4
Carbonate (CO_3)	mg/L	377	79	1[1]	1420	148
Chloride (Cl)	mg/L	383	44	3[1]	1070	103
Chlorophyll-a	µg/L	346	22.5	1.5[1]	292.0	37.4
Specific Conductance	µmhos	383	2028	424	20100	1976
Total Dissolved Solids	mg/L	383	1466	227	18200	1717
Total Hardness as ($CaCO_3$)	mg/L	384	529	74	2370	295
Hydroxide (OH)	mg/L	322	1.0	0.0[1]	1.0	0.2
Iron (Fe)	mg/L	385	0.245	0.001[1]	7.070	0.543
Magnesium (Mg)	mg/L	384	103.6	8.5	567.0	70.9
Nitrate + Nitrite as N	mg/L	491	0.04046	0.001[1]	0.54	0.054
Total Kjeldahl Nitrogen as N	mg/L	463	1.876	0.080	8.500	1.073
Total Nitrogen as N	mg/L	401	1.794	0.240	5.520	0.897
pH		383	8.80	7.40	9.87	0.36
Total Phosphorus as P	mg/L	501	0.233	0.002[1]	1.940	0.336
Potassium (K)	mg/L	384	34.0	3.1	356.0	37.0
Sodium (Na)	mg/L	384	299.6	16.9	4680.0	514.5
Sulfate (SO4)	mg/L	383	625	34	10500	885

[1]Equal to the lower reporting limit
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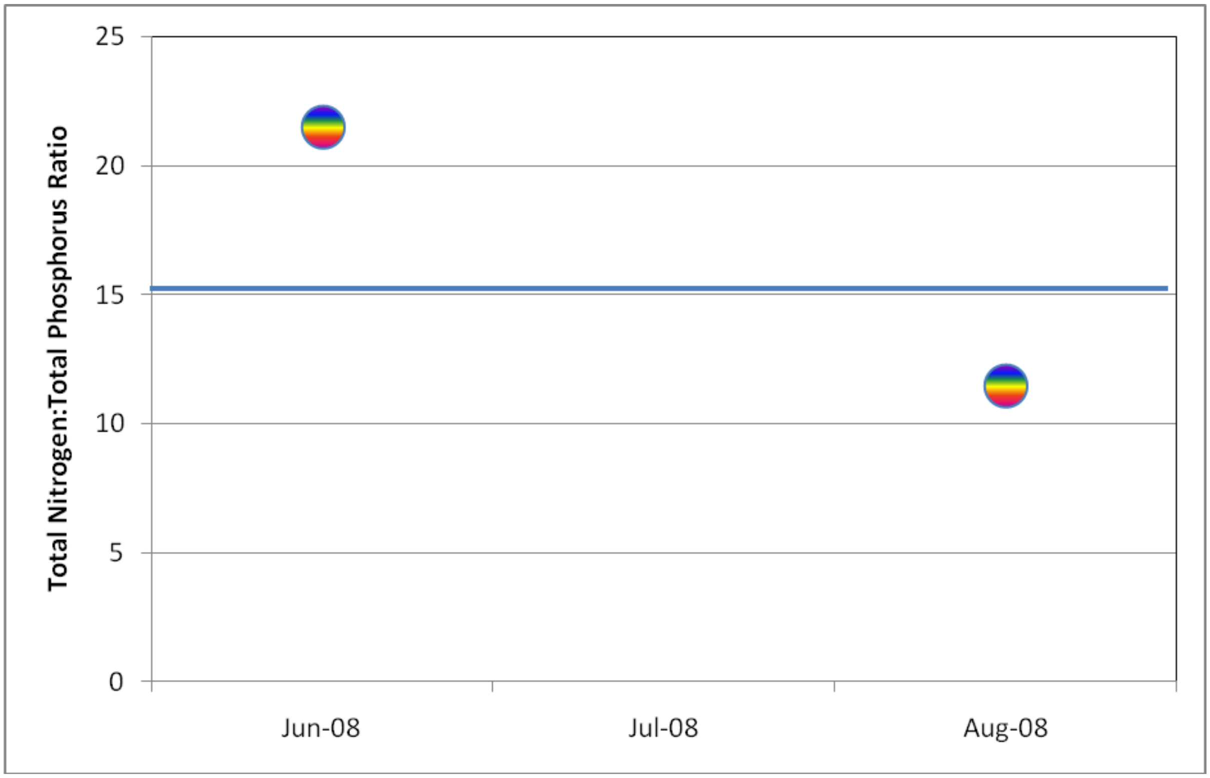

Figure 7. Clark Lake's Total Nitrogen to Total Phosphorus Ratio

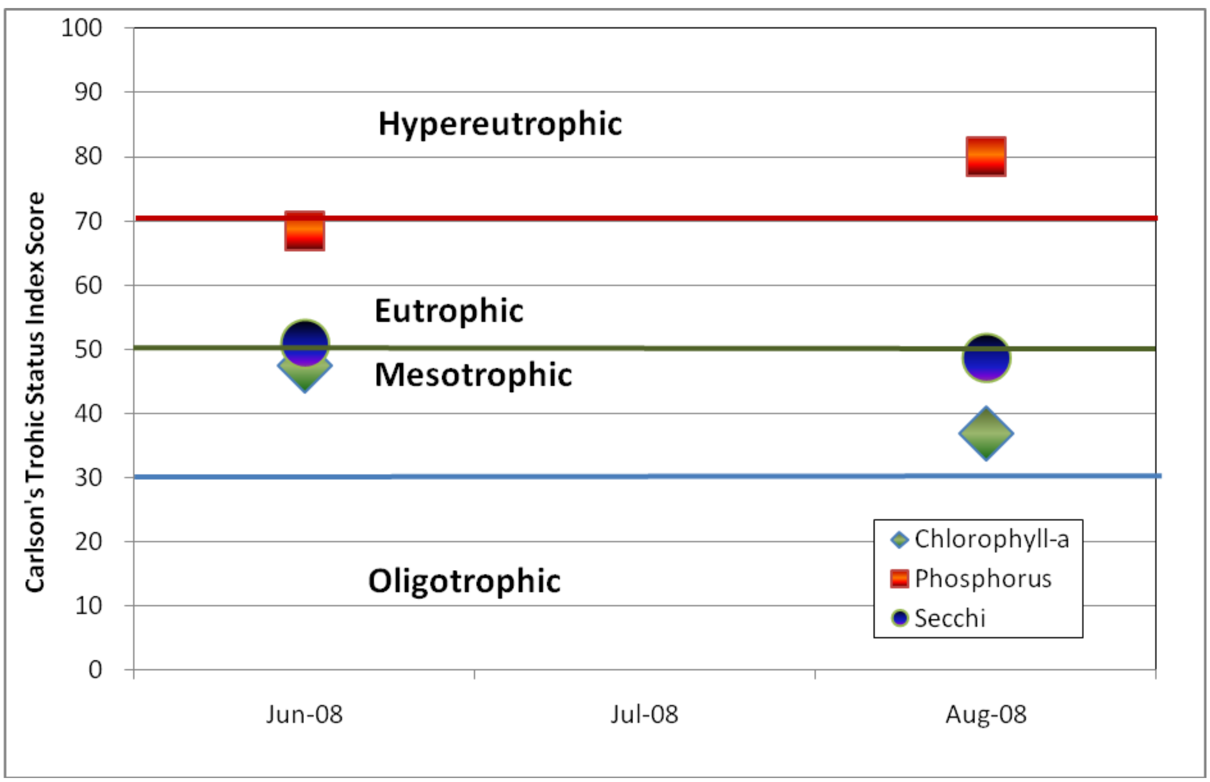

Figure 8. Clark Lake's TSI Scores

Matejcek Dam, Walsh County

BACKGROUND

Location: Matejcek Dam is small reservoir on the Middle Branch of the Forest River, a tributary of the Red River of the North. It is located six miles west of Fordville in Welsh County North Dakota (Figure 1).

Matejcek Dam's fishery is managed by the North Dakota game and Fish Department (NDG&F). The most recent stocking to Matejcek Dam included the fish species yellow perch and northern pike.

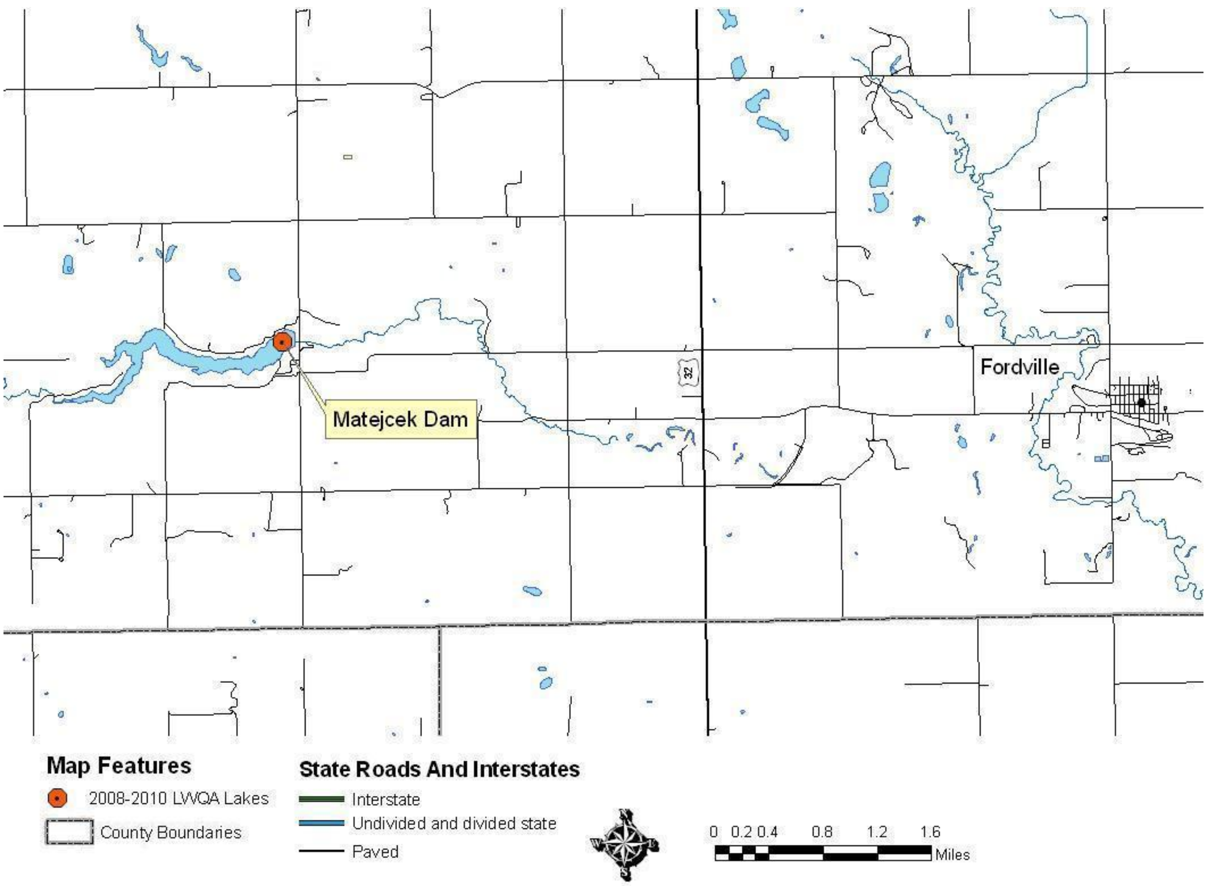

Figure 1. Location of Matejcek Dam

Physiographic/Ecological Setting: Matejcek Dam has a surface area of 129.1 acres a maximum depth of 43.5 ft and an average depth of 19.2 ft (Figure 2). The reservoir is located in the Northern Glaciated Plains Level III Ecoregion, which is part of the broader Cultivated Plains Region (Figures 3 and 4).

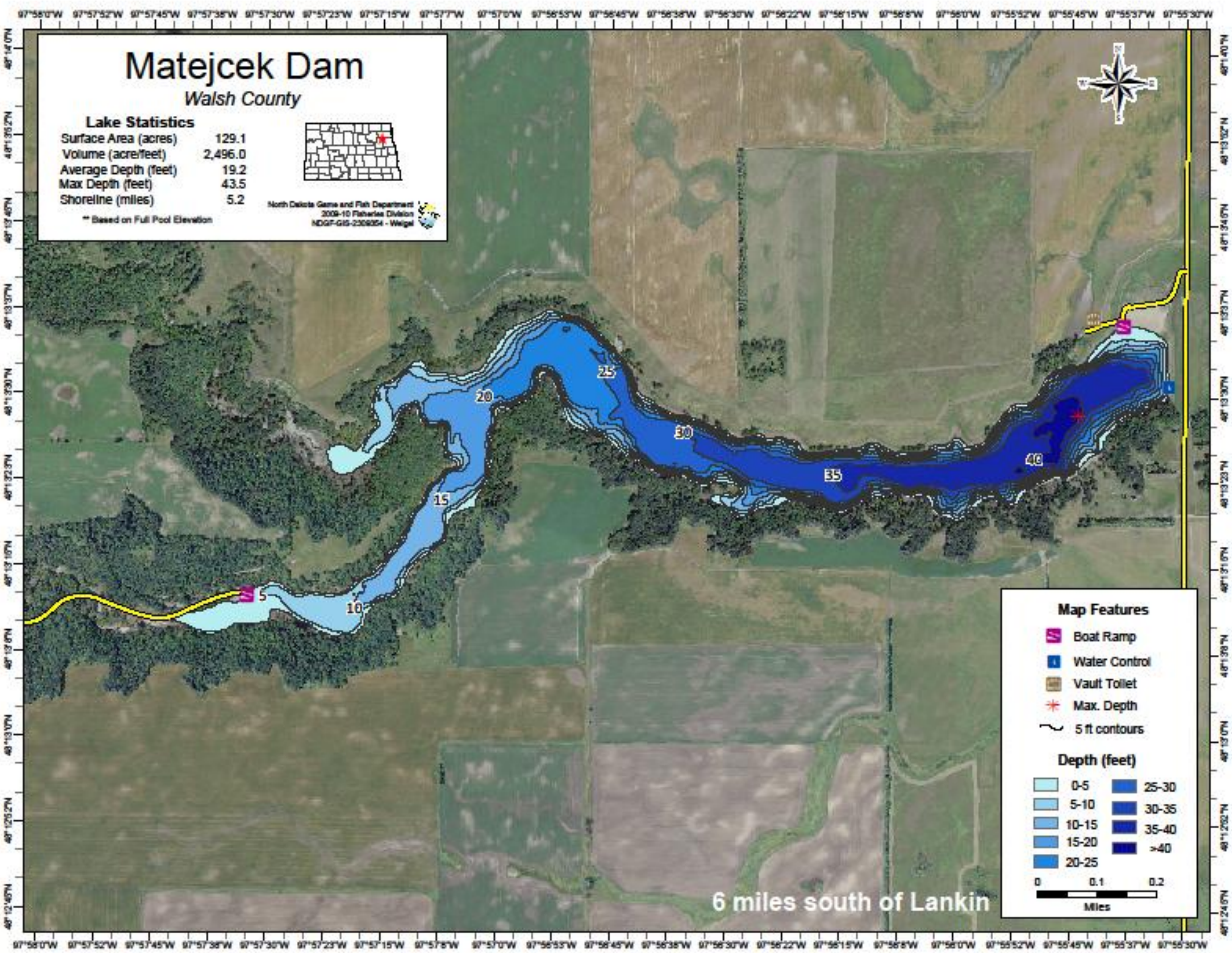

Figure 2. Contour Map of Matejcek Dam (Map Courtesy of North Dakota Game and Fish Department)

Recreational Facilities: Recreational facilities at Matejcek Dam include a cement boat ramp. The boat ramp is primitive, shallowly sloped and crowded by an oil field water pump.

Water Quality Standards Classification: Matejcek Dam is classified in the state "Standards of Quality for Waters of the State" (NDDoH, 2011) as a class 3 lake. Class 3 lakes or impoundments are defined as a "warm water fishery" or "waters capable of supporting natural reproduction and growth of warm water fishes (e.g., largemouth bass and bluegills).

Historical Water Quality Sampling: No historical water quality data.

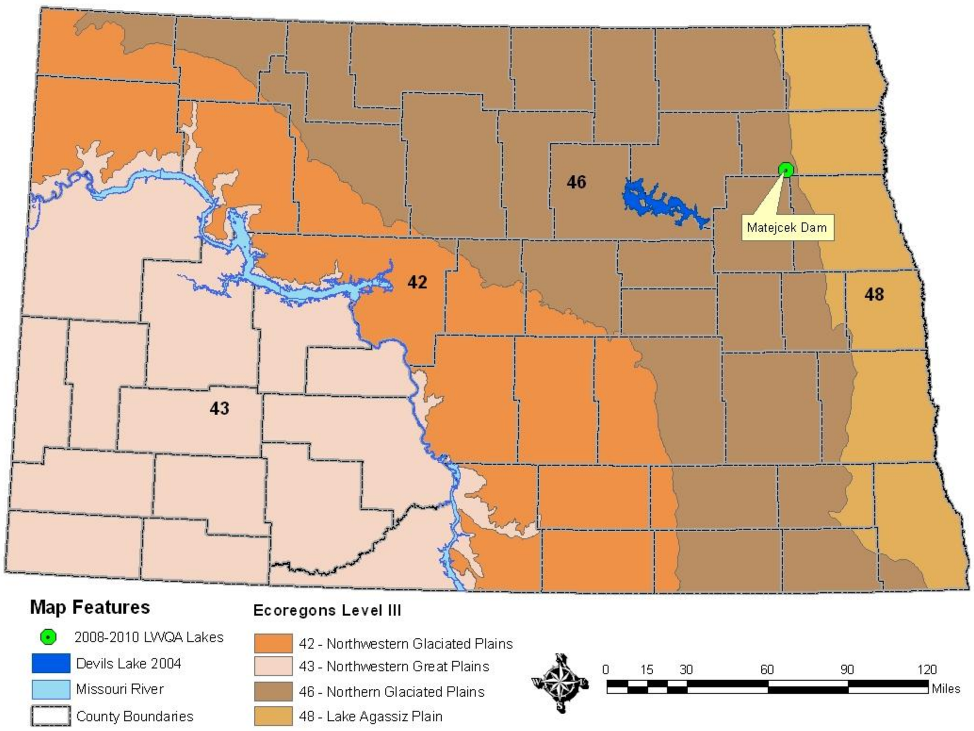

Figure 3. Matejcek Dam's Location and the Level III Ecoregions

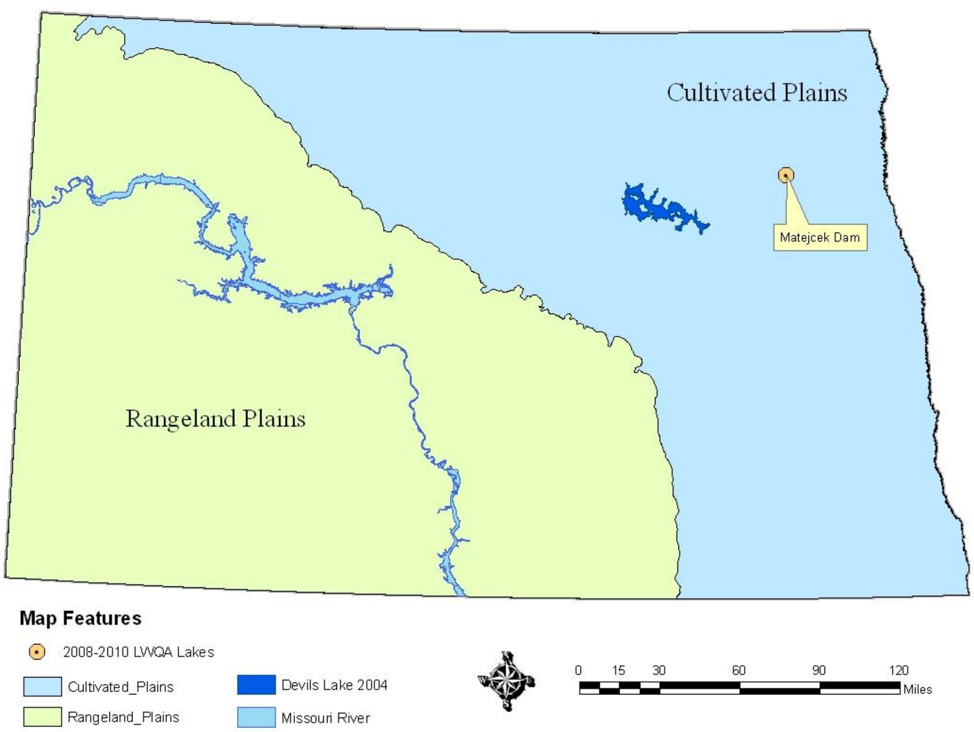

Figure 4. Matejcek Dam's Location and the Cultivated and Rangeland Plans Regions

WATER QUALITY MONITORING RESULTS

The water quality assessment for Matejcek Dam is presented in four general categories: 1) temperature and dissolved oxygen profile results; 2) general water quality characterization; 3) nutrient limitation; and 4) trophic status. Where appropriate, results have been compared to the regional and historical water quality data.

Temperature and Dissolved Oxygen Profile Results: There are six temperature and dissolved oxygen profiles for Matejcek Dam collected in two periods 1991-92 and 2010 (Figures 5 and 6).

The profile data shows that Matejcek Dam weakly thermally stratify periodically throughout the year. During thermal stratification dissolved oxygen concentrations rapidly decay so that within 1 to 4 meters below the thermocline the water column is anoxic. While anoxia does occur regularly from 4 meters of depth and below the reservoir does maintain sufficient dissolved oxygen concentrations above to support a warm water fishery and associate aquatic biota.

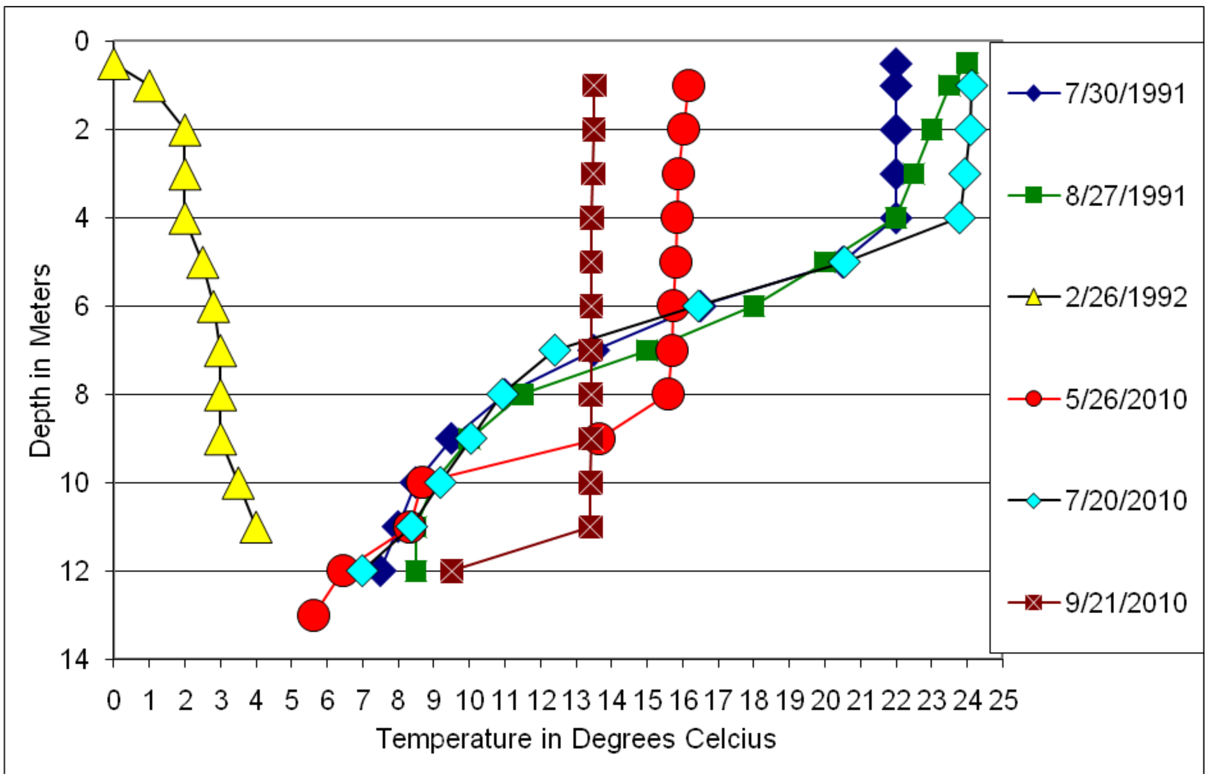

Figure 5. Temperature Profiles for Matejcek Dam

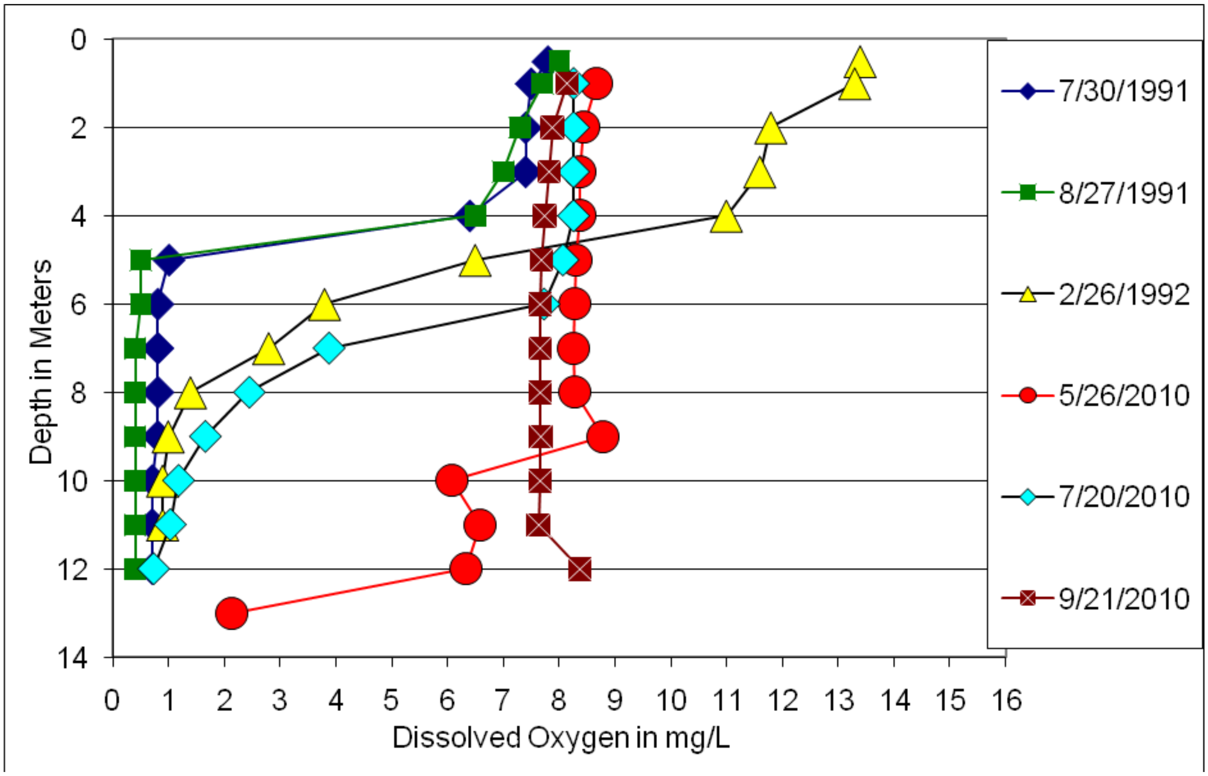

Figure 6. Dissolved Oxygen Profiles for Matejcek Dam

General Water Quality: Data collected in 2010 indicate that Matejcek Dam is well buffered with total alkalinity as $CaCO_3$ concentrations ranging from 172 to 359 mg/L (Table 1). The reservoir is sodium sulfate dominated with average sodium and sulfate concentrations of 144.1 mg/L, 435 mg/L, respectively. The average total dissolved solids concentration and specific conductance measurements for the 2010 sampling period were 934 mg/L and 1390 µmhos/cm, respectively, and the average total nitrogen as N and total phosphorus as P concentrations were 2.303 mg/L and 0.347 mg/L respectively.

When compared to water quality for reservoirs in the Cultivated Plans region, Matejcek Dam has more dissolved solids and nitrogen but less phosphorus than most (Table 3). For example, the average regional concentrations for TDS, total nitrogen, and total phosphorus concentrations are 671 mg/L, 1.52 mg/L, and 0.327 mg/L, respectively, compared to Matejcek Dam's average TDS, total nitrogen, and total phosphorus concentrations of 934 mg/L, 2.303 mg/L and 0.347 mg/L respectively.

Table 1. Statistical Summary of Matejcek Dam's 2010 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	3	271	172	359	94
Total Ammonia as N	mg/L	3	0.274	0.170	0.442	0.147
Bicarbonate (HCO_3)	mg/L	3	321	209	411	103
Calcium (Ca)	mg/L	3	79.6	62.6	90.5	14.9
Carbonate (CO_3)	mg/L	3	5	1[1]	13	7
Chloride (Cl)	mg/L	3	32	17	43	13
Chlorophyll-a	µg/L	3	9.8	9.6	10.0	0.2
Specific Conductance	µmhos	3	1390	1030	1650	322
Total Dissolved Solids	mg/L	3	934	683	1100	221
Total Hardness as ($CaCO_3$)	mg/L	3	453	326	542	113
Hydroxide (OH)	mg/L	3	1.0[1]	1.0[1]	1.0[1]	0.0
Iron (Fe)	mg/L	3	0.584	0.108	1.510	0.802
Magnesium (Mg)	mg/L	3	61.7	41.2	76.7	18.4
Nitrate + Nitrite as N	mg/L	3	0.680	0.080	1.500	0.735
Total Kjeldahl Nitrogen as N	mg/L	3	1.623	1.170	1.990	0.417
Total Nitrogen as N	mg/L	3	2.303	2.070	2.670	0.321
pH		3	8.19	7.86	8.44	0.30
Total Phosphorus as P	mg/L	3	0.347	0.260	0.490	0.125
Potassium (K)	mg/L	3	13.8	10.6	16.3	2.9
Sodium (Na)	mg/L	3	144.1	98.4	171.0	39.8
Sulfate (SO4)	mg/L	3	435	341	486	82

[1]Equal to the lower reporting limit

When comparing historical water quality data (1991-1992) to the 2010 water quality data it appears that the water quality has declined with increases in nearly all constitutes including dissolved solids and nutrients. For example the 1991-1992 averages for sulfates and sodium concentrations were 186 mg/L and 70.3 mg/L and in 2010 they are 435 mg/L and 144.1 mg/L (Tables 1 and 2). Like dissolved solids, total nitrogen and phosphorus also appear to be trending upward from the 1991-1992 averages of 1.26 mg/L and 0.271 mg/L to 2.303 mg/L and 0.347 mg/L in 2010.

Limiting Nutrients: The six water quality samples collected between 1991 and 2010 indicate that Matejcek Dam is nitrogen limited (Figure 7). The limiting nutrient assessment is based on the assumption that either nitrogen or phosphorus is limiting algal growth and that the ratio of total nitrogen as N to total phosphorus as P (N:P), by weight in the average algae is approximately 15 to 1. When the N:P ratio is less than 15:1, nitrogen is assumed to be the limiting nutrient and when it exceeds 15:1, the limiting nutrient is assumed to be phosphorus.

Table 2. Statistical Summary of Matejcek Dam's 1991-1992 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	3	225	207	259	29
Total Ammonia as N	mg/L	2	0.025	0.012	0.037	0.018
Bicarbonate (HCO_3)	mg/L	3	252	238	279	23
Calcium (Ca)	mg/L	3	73.4	68.2	82.1	7.6
Carbonate (CO_3)	mg/L	3	11	6	18	6
Chloride (Cl)	mg/L	3	19	18	22	2
Chlorophyll-a	µg/L	2	3.0	3.0	3.0	0.0
Specific Conductance	µmhos	3	839	778	931	81
Total Dissolved Solids	mg/L	3	528	497	570	38
Total Hardness as ($CaCO_3$)	mg/L	3	320	298	357	32
Hydroxide (OH)	mg/L	0				
Iron (Fe)	mg/L	3	0.047	0.041	0.059	0.010
Magnesium (Mg)	mg/L	3	33.2	31.0	36.8	3.2
Nitrate + Nitrite as N	mg/L	2	0.007	0.006	0.007	0.001
Total Kjeldahl Nitrogen as N	mg/L	3	1.253	1.090	1.530	0.241
Total Nitrogen as N	mg/L	3	1.260	1.096	1.537	0.242
pH		3	8.43	8.30	8.50	0.12
Total Phosphorus as P	mg/L	3	0.271	0.255	0.280	0.014
Potassium (K)	mg/L	3	10.9	10.7	11.1	0.2
Sodium (Na)	mg/L	3	70.3	67.8	74.9	4.0
Sulfate (SO4)	mg/L	3	186	174	196	11

[1]Equal to the lower reporting limit

Trophic Status Assessment: Based on the chlorophyll-a, secchi disk transparency, and total phosphorus data collected in 2010, Matejcek Dam's trophic status is eutrophic. The trophic status index (TSI) scores ranged from a low of 46 based on secchi disk to a high of 86 based on total phosphorus concentrations (Figure 8).

Trends: A total of six total phosphorus samples, five chlorophyll-a samples and five Secchi disk transparency measurements collected during the sampling periods of 1991-93 and 2010 were available to evaluate trends in the trophic status of Matejcek Dam. While it would be difficult to make a conclusive assessment on water quality trends, the increasing concentrations of total phosphorus and chlorophyll-a and decreasing transparency does suggest the reservoir is not improving (Figures 7 and 8).

Table 3. Statistical Summary of Water Quality Data[2] Collected from Reservoirs and Impoundments in the Cultivated Plains Ecological Region of North Dakota

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	400	261	88	891	99
Total Ammonia as N	mg/L	567	0.145	0.001[1]	2.070	0.208
Bicarbonate (HCO_3)	mg/L	400	294	91	951	110
Calcium (Ca)	mg/L	402	66.7	19.4	169.0	22.7
Carbonate (CO_3)	mg/L	382	13	1[1]	93	16
Chloride (Cl)	mg/L	400	21	3[1]	113	17
Chlorophyll-a	µg/L	445	19.9	1.5[1]	388.0	30.2
Specific Conductance	µmhos	400	1025	217	3140	501
Total Dissolved Solids	mg/L	392	671	127	2300	375
Total Hardness as ($CaCO_3$)	mg/L	402	341	95	1090	119
Hydroxide (OH)	mg/L	339	1.0	0.0[1]	1.0	0.2
Iron (Fe)	mg/L	400	0.143	0.007	3.190	0.220
Magnesium (Mg)	mg/L	402	42.3	11.2	161.0	19.6
Nitrate + Nitrite as N	mg/L	560	0.112	0.001[1]	2.060	0.213
Total Kjeldahl Nitrogen as N	mg/L	480	1.470	0.206	4.410	0.648
Total Nitrogen as N	mg/L	419	1.520	0.418	3.950	0.617
pH		401	8.34	1.76	9.40	0.54
Total Phosphorus as P	mg/L	569	0.327	0.002[1]	2.270	0.290
Potassium (K)	mg/L	402	11.6	2.7	34.5	5.4
Sodium (Na)	mg/L	402	96.8	2.2	582.0	102.9
Sulfate (SO4)	mg/L	400	272	1[1]	1350	210

[1]Equal to the lower reporting limit
[2]Data collected from 45 reservoirs between 1991 and 2010

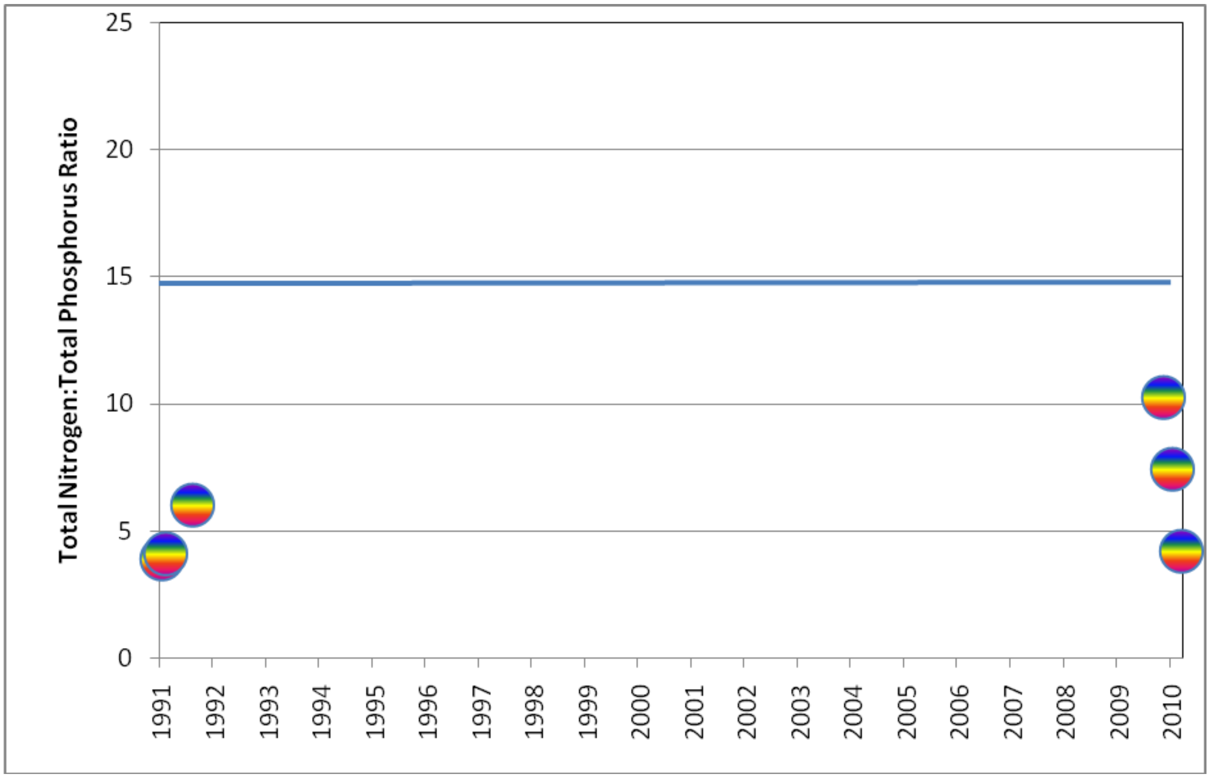

Figure 7. Matejcek Dam's Total Nitrogen to Total Phosphorus Ratio

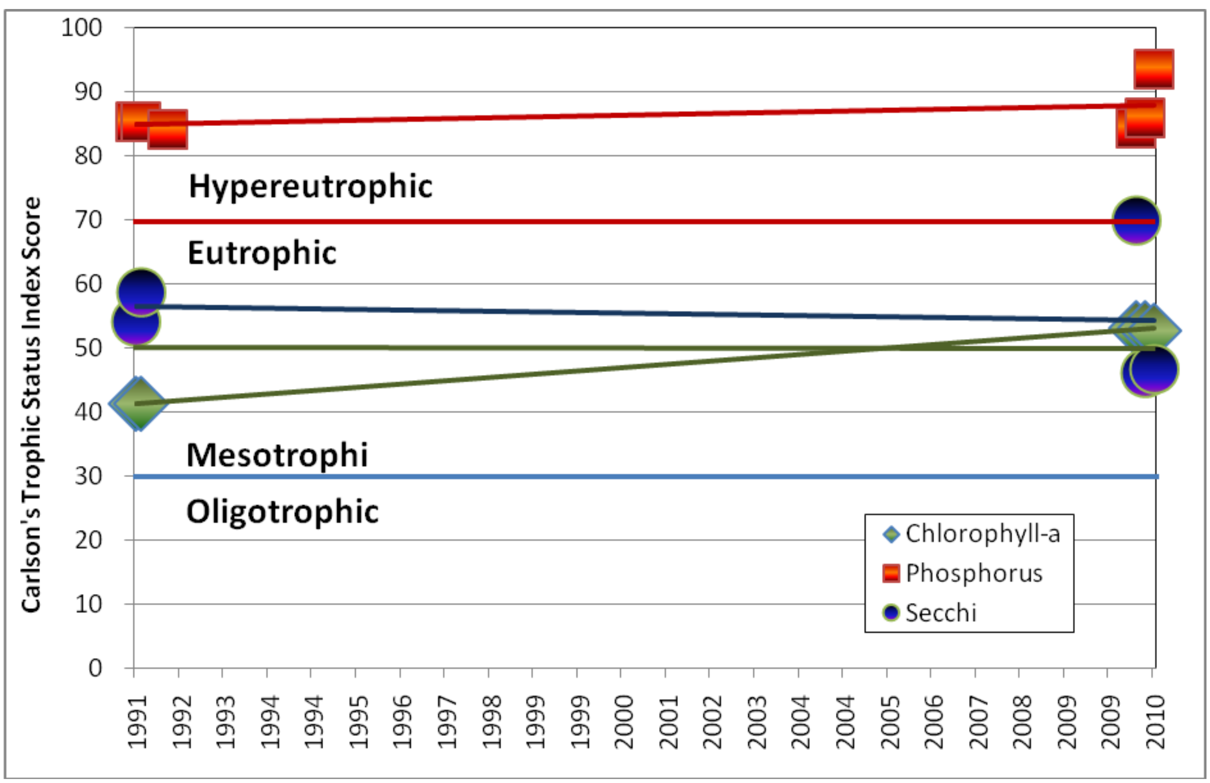

Figure 8. Matejcek Dam's TSI Scores

Cottonwood Lake, Williams County

BACKGROUND

Location: Cottonwood Lake is a shallow glacial lake on the northeast edge of Alamo, North Dakota (Figure 1). The fishery is managed by the North Dakota Game and Fish. Fish species managed for are northern pike and yellow perch.

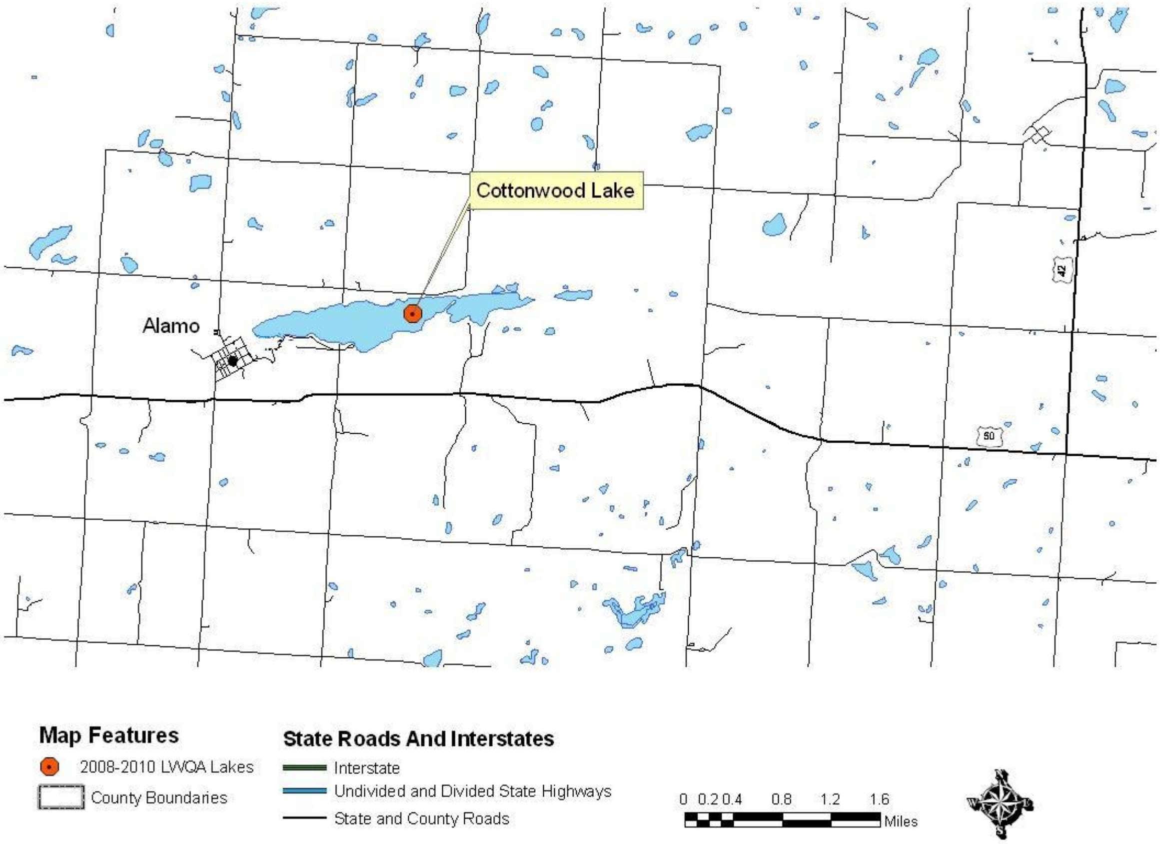

Figure 1. Location of Cottonwood Lake

Physiographic/Ecological Setting: Cottonwood Lake has a surface area of 305.8 acres and a maximum depth of 13.4 ft and an average depth of 9.2 ft (Figure 2). The lake is located within the Northwestern Glaciated Plains Level III Ecoregion, which is part of the broader Rangeland Plains region (Figures 3 and 4).

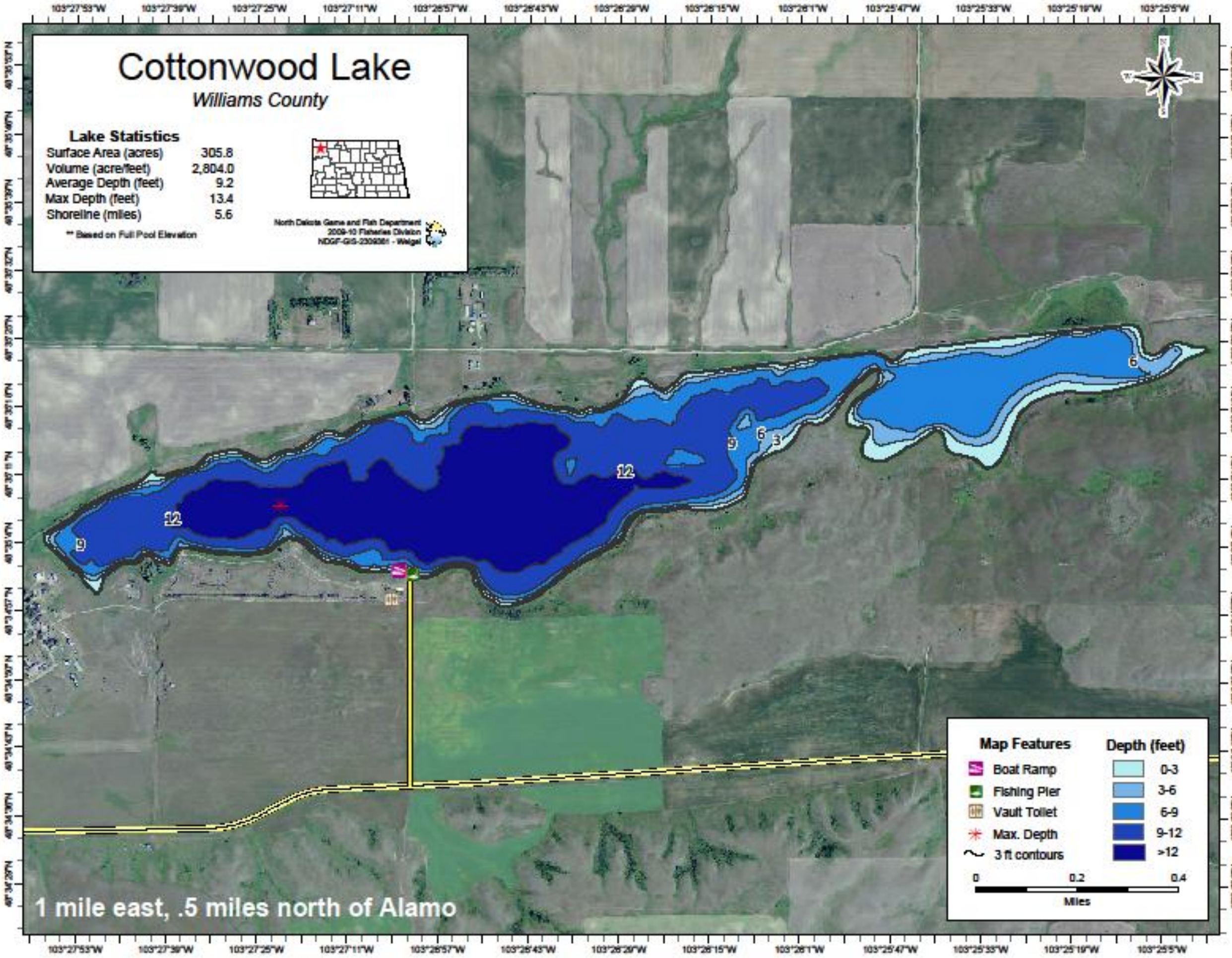

Figure 2. Aerial Map of Cottonwood Lake (Map Courtesy of North Dakota Game and Fish Department)

Recreational Facilities: Recreational facilities at Cottonwood Lake include a cement boat ramp and courtesy dock, parking, vault toilet and small picnic area. The lake is an excellent location for viewing wetland species of birds such as long billed curlew, avocets, willets, and marbled godwits. Access is good from the south off State highway 50.

Water Quality Standards Classification: Cottonwood Lake is classified in the state "Standards of Quality for Waters of the State" (NDDoH, 2011) as a class 3 lake. Class 3 lakes or reservoirs are defined as a "warm water fishery" or "waters capable of supporting natural reproduction and growth of warm water fishes (e.g., largemouth bass and bluegill) and associated aquatic biota. Some cool water species may also be present."

Historical Water Quality Sampling: No historical water quality data.

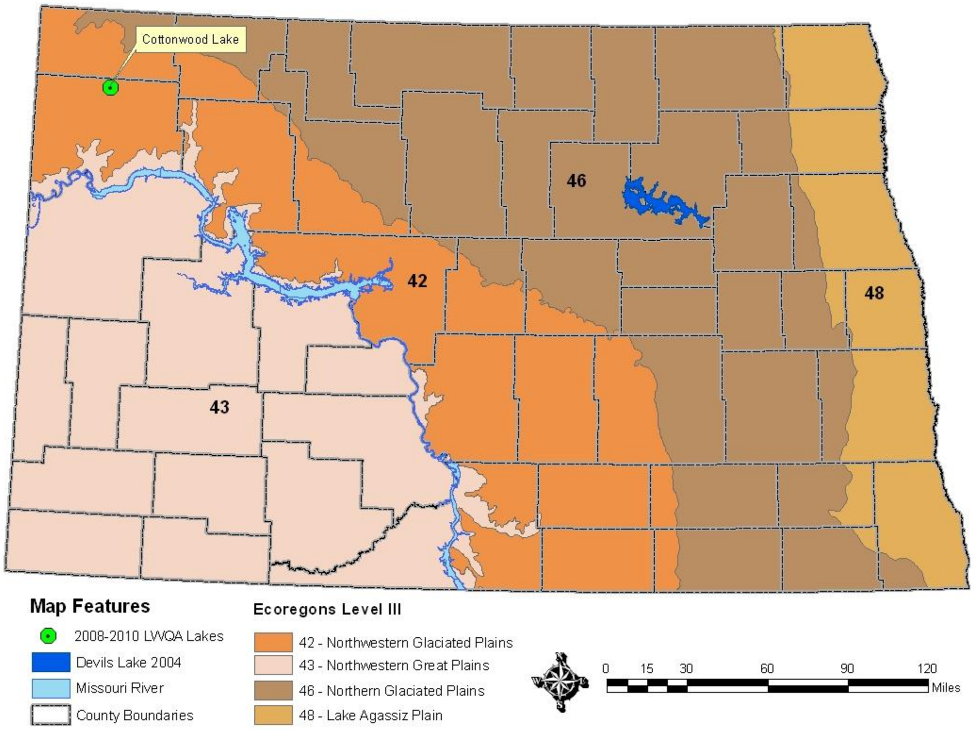

Figure 3. Cottonwood Lake's Location and the Level III Ecoregions

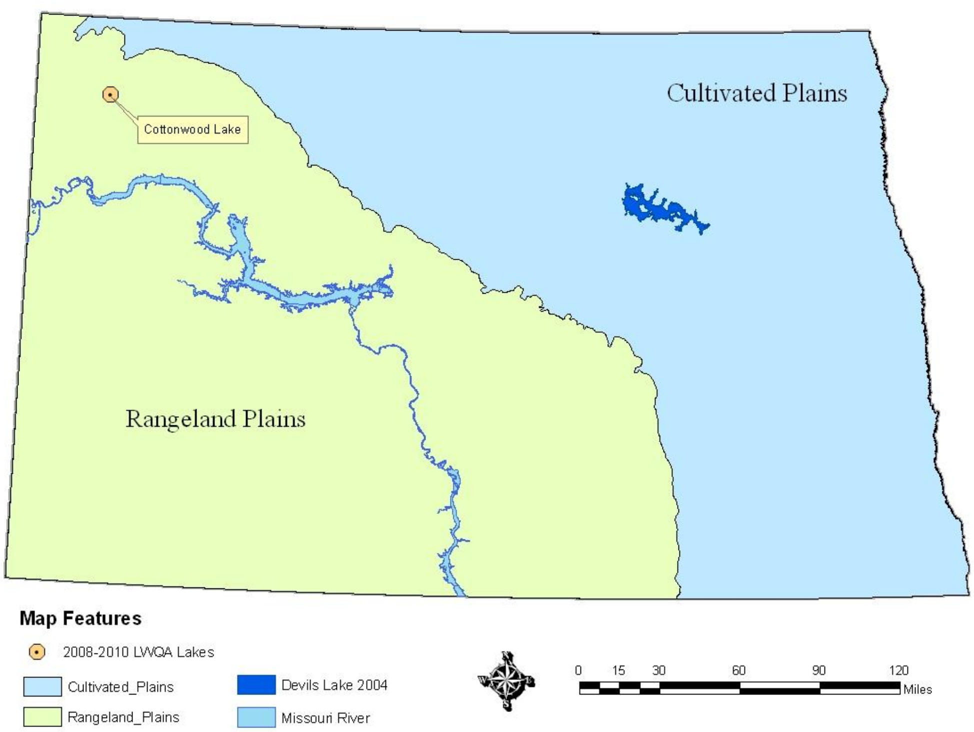

Figure 4. Cottonwood Lake Location and the Cultivated and Rangeland Plans Regions

WATER QUALITY MONITORING RESULTS

The water quality assessment for Cottonwood Lake is presented in four general categories: 1) temperature and dissolved oxygen profile results; 2) general water quality characterization; 3) nutrient limitation; and 4) trophic status. Additionally, where appropriate, results have been compared to regional data.

Temperature and Dissolved Oxygen Profile Results: There are three temperature and dissolved oxygen profiles for Cottonwood Lake collected in 2009 (Figure 5). The profile data shows that Cottonwood Lake was not thermally stratification during the open water monitoring period. Additionally during the open water period the lake remained well enough oxygenated to support aquatic Life (Figure 6).

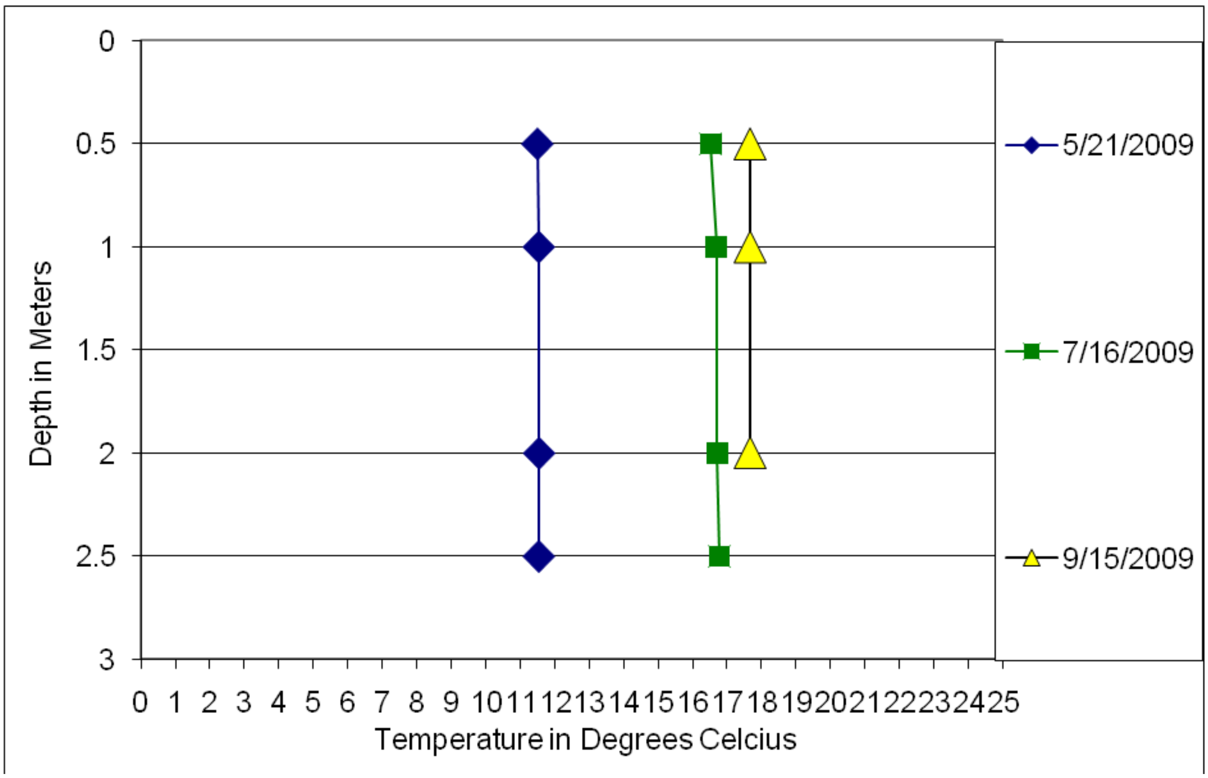

Figure 5. Temperature Profiles for Cottonwood Lake

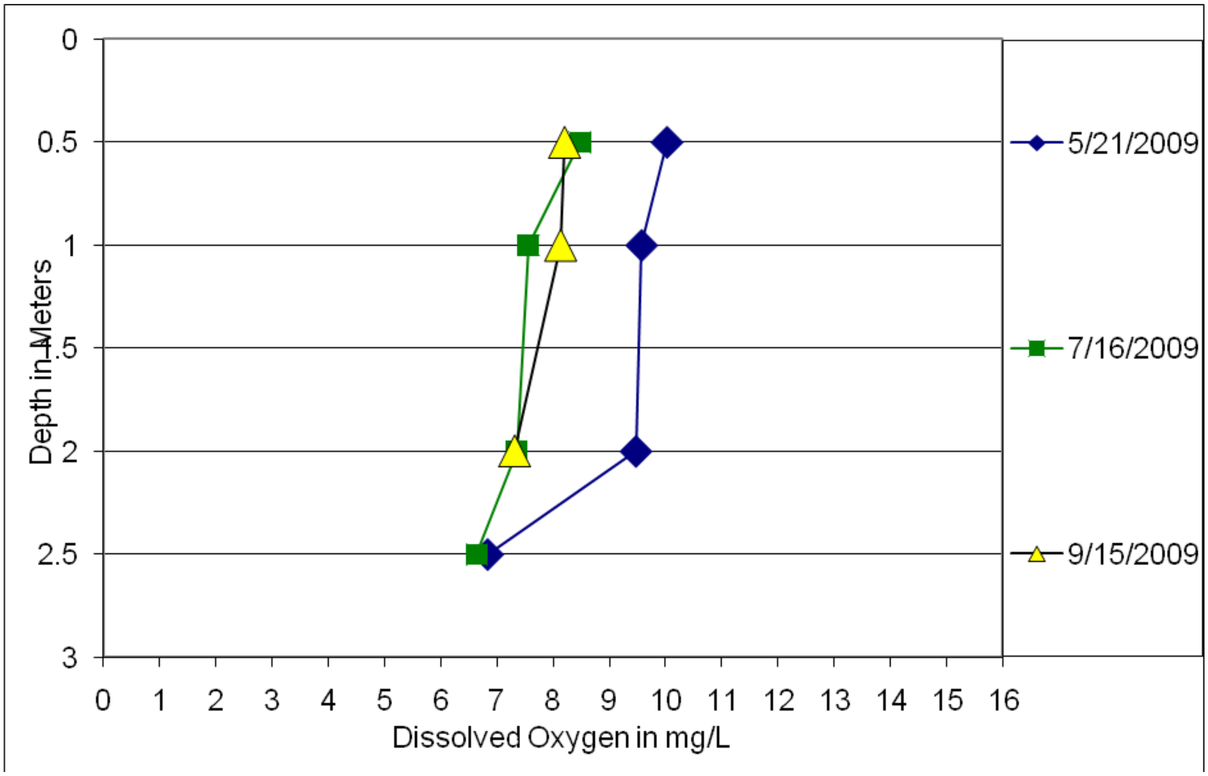

Figure 6. Dissolved Oxygen Profiles for Cottonwood Lake

General Water Quality: Data collected in 2009 indicates that Cottonwood Lake is well buffered with total alkalinity as $CaCO_3$ concentrations ranging from 245 to 324 mg/L (Table 1). The lake is sodium bicarbonate dominated with an average sodium concentration of 121 mg/L and an average bicarbonate concentration of 261 mg/L. The average total dissolved solids concentration and specific conductance measurement for 2009 sampling period were 806 mg/L and 1200 µmhos/cm respectively, and the average total nitrogen as N and total phosphorus as P concentrations were 3.557 mg/L and 0.354 mg/L respectively.

When compared to water quality for natural lakes in the Rangeland Plans region, Cottonwood Lake is fresher with fewer dissolved solids than most but substantially more eutrophic (Table 3). For example, the regional average TDS, total nitrogen and total phosphorus concentrations are 1466 mg/L, 1.794 mg/L and 0.233 mg/L respectively, compared to Cottonwood Lake's average TDS, total nitrogen, and total phosphorus concentrations of 806 mg/L, 3.557 mg/L, and 0.354 mg/L, respectively.

Table 1. Statistical Summary of Cottonwood Lake's 2009 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	3	294	245	324	43
Total Ammonia as N	mg/L	3	0.154	0.030[1]	0.403	0.215
Bicarbonate (HCO_3)	mg/L	3	261	223	310	44
Calcium (Ca)	mg/L	3	48.0	40.1	54.2	7.2
Carbonate (CO_3)	mg/L	3	48	24	85	32
Chloride (Cl)	mg/L	3	20	18	21	2
Chlorophyll-a	µg/L	2	153.0	145.0	161.0	11.3
Specific Conductance	µmhos	3	1200	1110	1280	85
Total Dissolved Solids	mg/L	3	806	719	875	80
Total Hardness as ($CaCO_3$)	mg/L	3	390	338	435	49
Hydroxide (OH)	mg/L	3	1.0[1]	1.0[1]	1.0[1]	0.0
Iron (Fe)	mg/L	3	0.248	0.229	0.263	0.017
Magnesium (Mg)	mg/L	3	65.6	57.7	72.8	7.6
Nitrate + Nitrite as N	mg/L	3	0.030[1]	0.030[1]	0.030[1]	0.000
Total Kjeldahl Nitrogen as N	mg/L	3	3.527	2.240	4.190	1.114
Total Nitrogen as N	mg/L	3	3.557	2.270	4.220	1.114
pH		3	8.93	8.73	9.25	0.28
Total Phosphorus as P	mg/L	3	0.354	0.140	0.478	0.186
Potassium (K)	mg/L	3	42.6	37.0	47.5	5.3
Sodium (Na)	mg/L	3	121.0	111.0	128.0	8.9
Sulfate (SO4)	mg/L	3	332	307	356	25

[1]Equal to the lower reporting limit

Limiting Nutrients: Water quality monitoring results for indicates that Cottonwood Lake is nitrogen limited (Figure 7). The limiting nutrient assessment is based on the assumption that either nitrogen or phosphorus is limiting algal growth with the water body, and that the ratio of total nitrogen as N to total phosphorus as P (N:P), by weight in the average algae, is approximately 15 to 1. When the N:P ratio is less than 15:1, nitrogen is assumed to be the limiting nutrient and when it exceeds 15:1, the limiting nutrient is assumed to be phosphorus.

Trophic Status Assessment: Based on the chlorophyll-a, secchi disk transparency, and total phosphorus data collected in 2009, Cottonwood Lake's trophic condition is estimated as hypereutrophic. The trophic Status Index scores ranged from a low of 65 based on secchi disk transparency to a high of 93 based on total phosphorus concentrations (Figure 8).

Table 2. Statistical Summary of Water Quality Data[2] Collected from Natural and Enhanced Lakes in the Rangeland Plains Ecological Region of North Dakota

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	383	513	111	4770	487
Total Ammonia as N	mg/L	494	0.105	0.001[1]	2.230	0.229
Bicarbonate (HCO_3)	mg/L	383	469	60	2990	320
Calcium (Ca)	mg/L	384	41.1	0.5	282.0	34.4
Carbonate (CO_3)	mg/L	377	79	1[1]	1420	148
Chloride (Cl)	mg/L	383	44	3[1]	1070	103
Chlorophyll-a	µg/L	346	22.5	1.5[1]	292.0	37.4
Specific Conductance	µmhos	383	2028	424	20100	1976
Total Dissolved Solids	mg/L	383	1466	227	18200	1717
Total Hardness as ($CaCO_3$)	mg/L	384	529	74	2370	295
Hydroxide (OH)	mg/L	322	1.0	0.0[1]	1.0	0.2
Iron (Fe)	mg/L	385	0.245	0.001[1]	7.070	0.543
Magnesium (Mg)	mg/L	384	103.6	8.5	567.0	70.9
Nitrate + Nitrite as N	mg/L	491	0.04046	0.001[1]	0.54	0.054
Total Kjeldahl Nitrogen as N	mg/L	463	1.876	0.080	8.500	1.073
Total Nitrogen as N	mg/L	401	1.794	0.240	5.520	0.897
pH		383	8.80	7.40	9.87	0.36
Total Phosphorus as P	mg/L	501	0.233	0.002[1]	1.940	0.336
Potassium (K)	mg/L	384	34.0	3.1	356.0	37.0
Sodium (Na)	mg/L	384	299.6	16.9	4680.0	514.5
Sulfate (SO4)	mg/L	383	625	34	10500	885

[1]Equal to the lower reporting limit
[2]Data collected from 64 natural and enhanced Lakes between 1991 and 2010

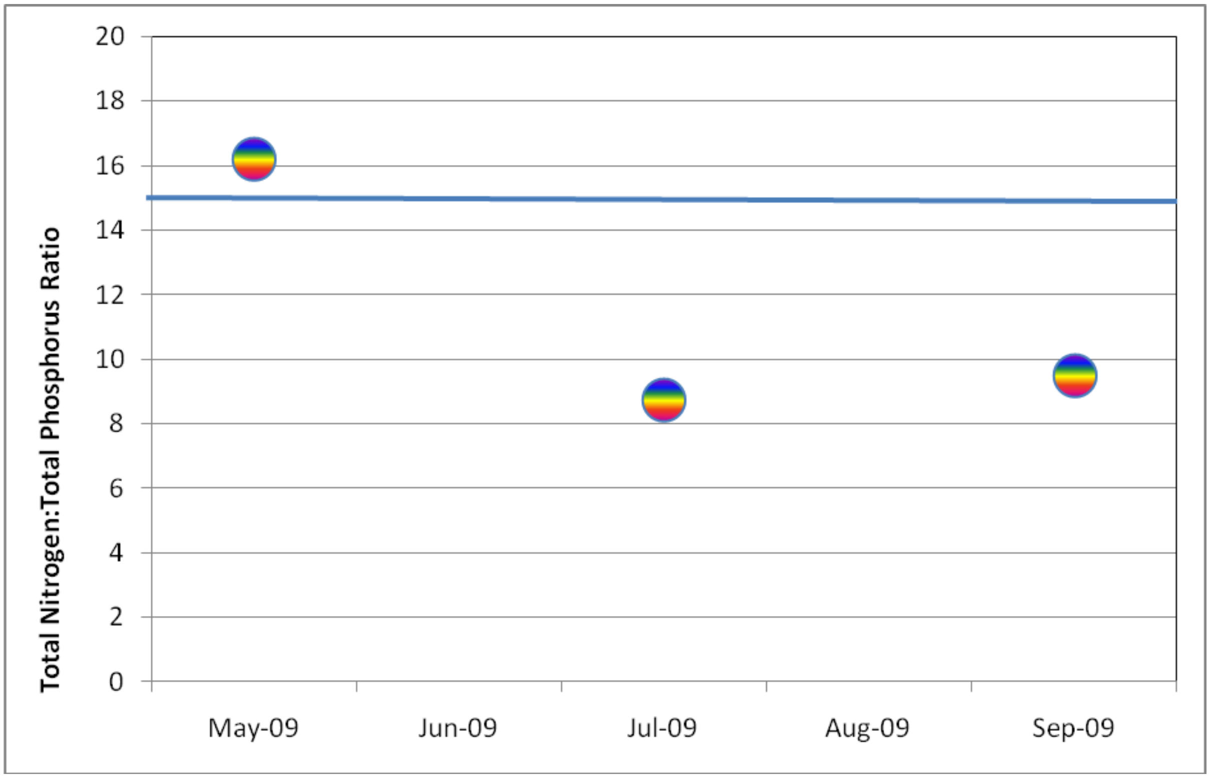

Figure 7. Cottonwood Lake's Total Nitrogen to Total Phosphorus Ratio

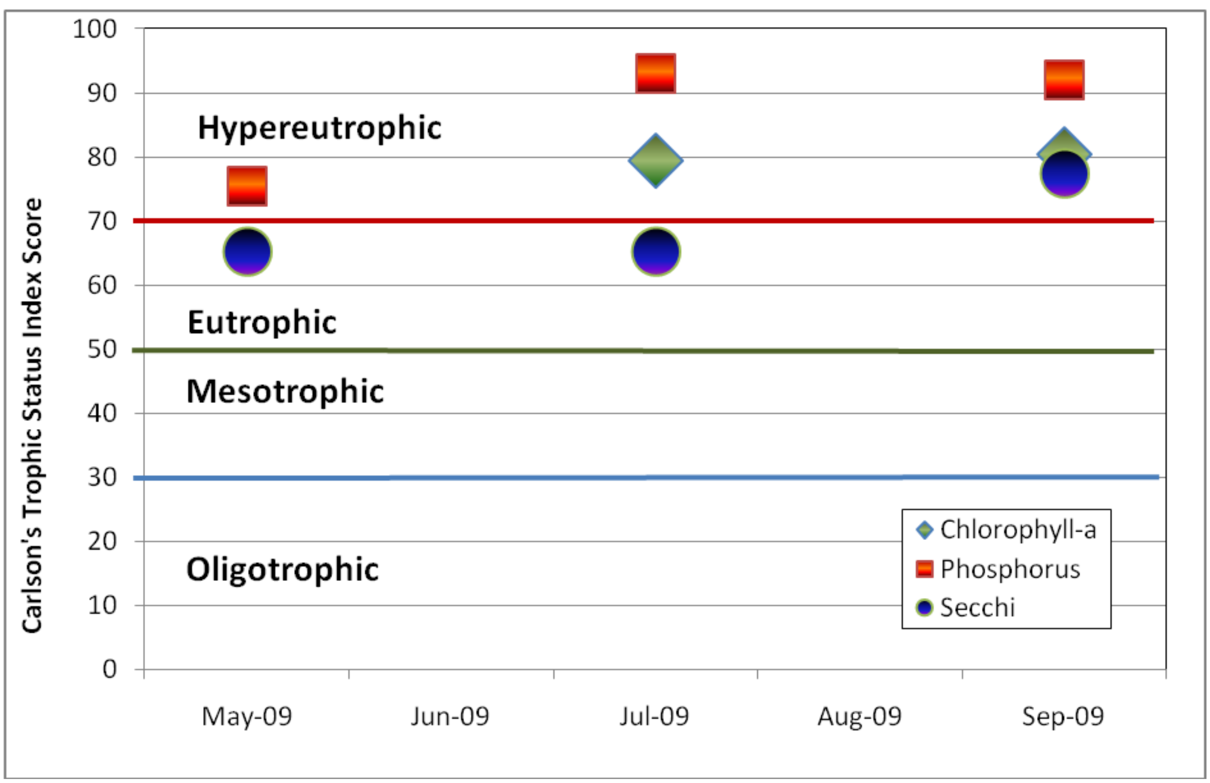

Figure 8. Cottonwood Lake's TSI Scores

Kota-Ray Dam, Williams County

BACKGROUND

Location: Kota-Ray Dam is an attractive reservoir on Nelson Creek seven miles south of Ray, North Dakota (Figure 1). It is a small cattail lined oasis of relatively deep wind protected water. The fishery is managed by the North Dakota Game and Fish Department. Fish species stocked in recent years are rainbow trout, largemouth bass and smallmouth bass.

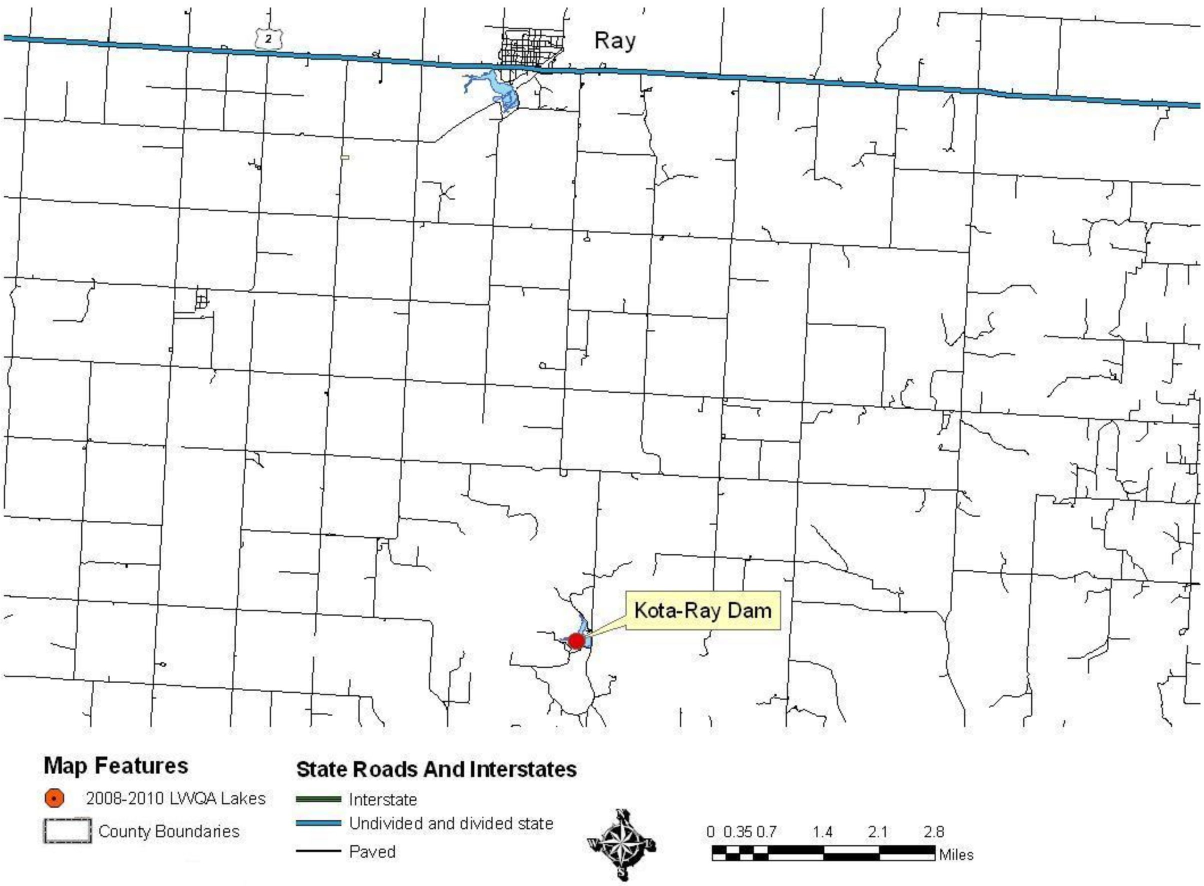

Figure 1. Location of Kota-Ray Dam

Physiographic/Ecological Setting: Kota-Ray Dam has a surface area of 26.7 acres, a maximum depth of 26.8ft, and an average depth of 12.1 ft. The reservoir provides reasonable access to for shore fishing from select areas particularly on the south and east shores (Figure 2). The reservoir is located in the Northwestern Great Plains Level III Ecoregion, which is part of the broader Rangeland Plains Region (Figures 3 and 4).

Recreational Facilities: Recreational facilities at Kota-Ray Dam include an access road, boat ramp with courtesy dock, vault toilet, and a small well maintained picnic and camping area.

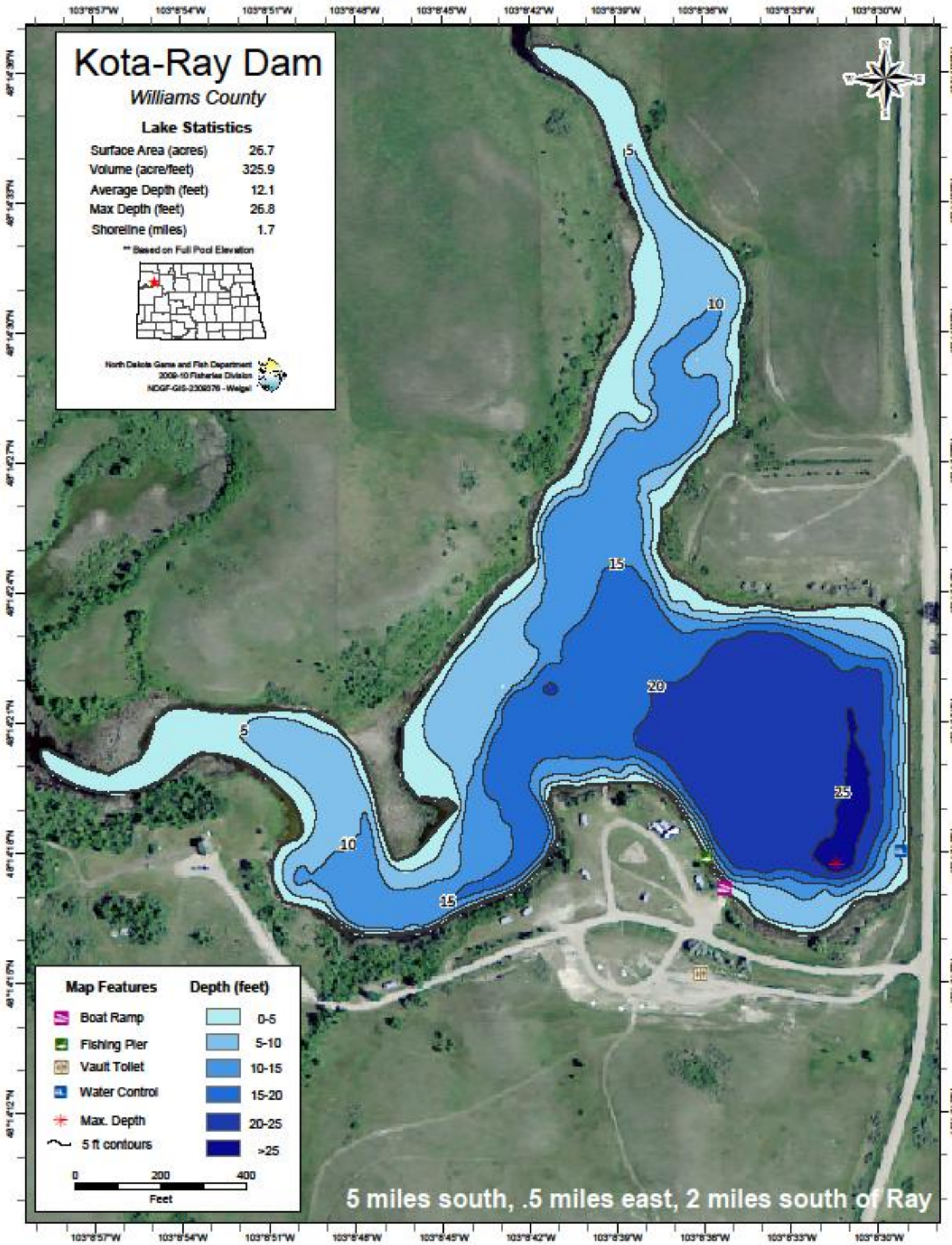

Figure 2. Contour Map of Kota-Ray Dam (Courtesy of the North Dakota Game and Fish Department)

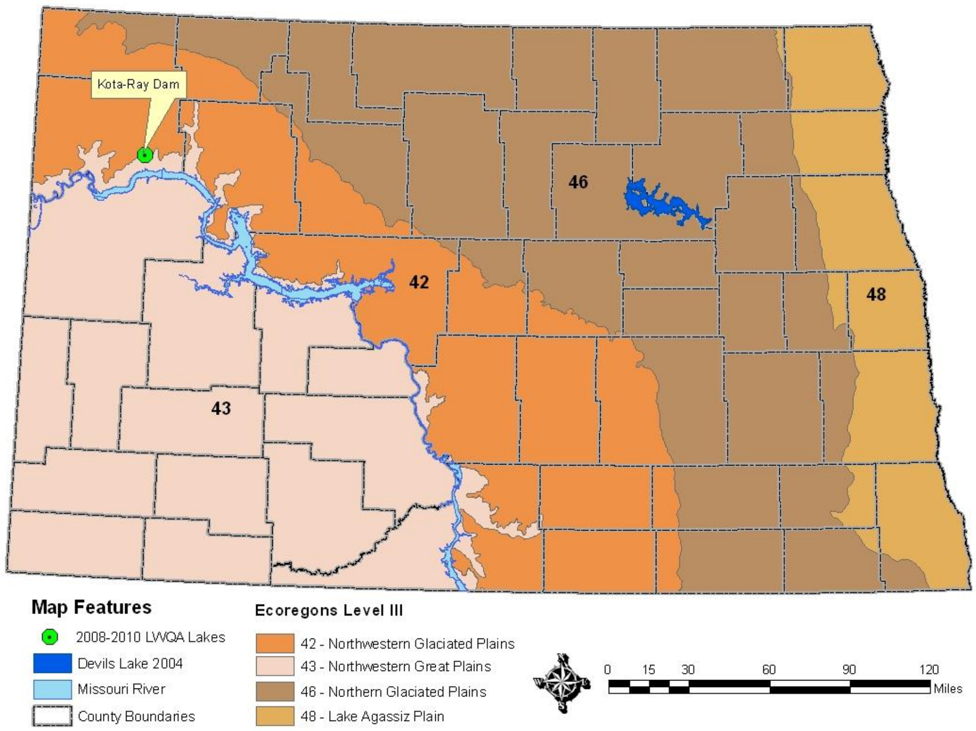

Figure 3. Kota-Ray Dam's Location and the Level III Ecoregions

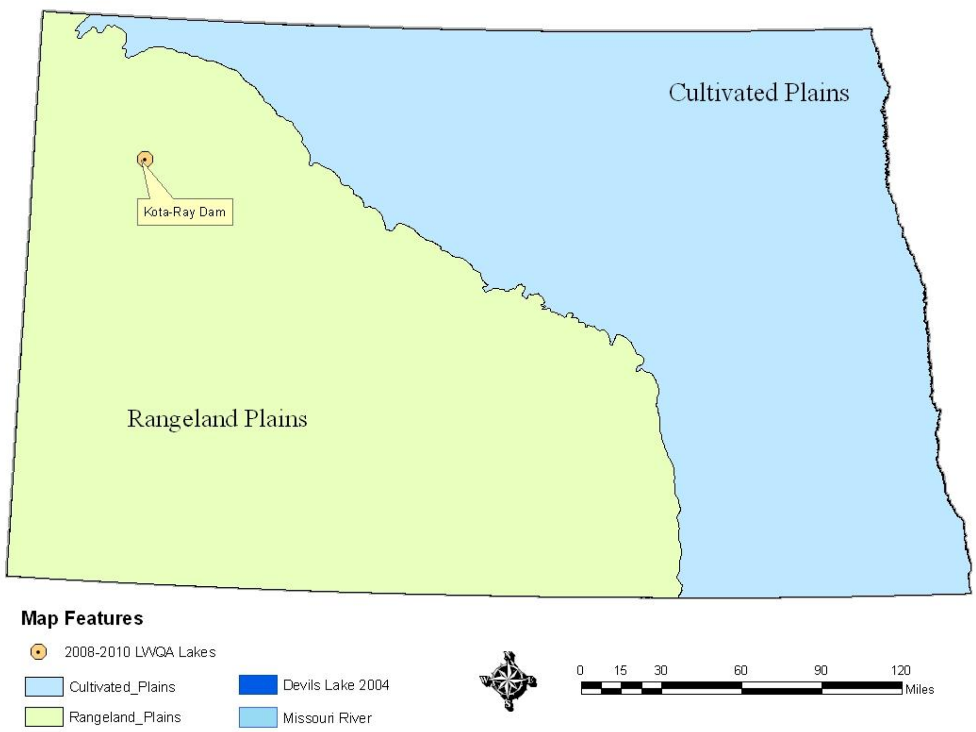

Figure 4. Kota-Ray Dams's Location and the Cultivated and Rangeland Plans Regions

Water Quality Standards Classification: Kota-Ray Dam is classified in the state "Standards of Quality for Waters of the State" (NDDoH, 2011) as a class 1 reservoir. Class 1 lakes or reservoirs are defined as a "Cold water fisheries" or "waters capable of supporting growth of cold water fish species (e.g., salmonids) and associated aquatic biota.

Historical Water Quality Sampling: Historical water quality data include 3 samples collected in 1992-1993.

WATER QUALITY MONITORING RESULTS

The water quality assessment for Kota-Ray Dam is presented in four general categories: 1) temperature and dissolved oxygen profile results; 2) general water quality characterization; 3) nutrient limitation; and 4) trophic status. Where appropriate, results have been compared to the regional data for reservoirs in the Rangeland Plains region.

Temperature and Dissolved Oxygen Profile Results: There are six temperature and dissolved oxygen profiles for Kota-Ray Dam collected in two periods 1992-93 and 2009 (Figure 5). The profile data shows that the water body does weakly thermally stratify and yet the dissolved oxygen response is minimal (Figure 6). At no time during sampling, in either the 1992-1993 or 2009 time period, did Kota-Ray Dam's dissolved oxygen concentrations dropped below the state standard designed to protect aquatic life of 5.0 mg/L.

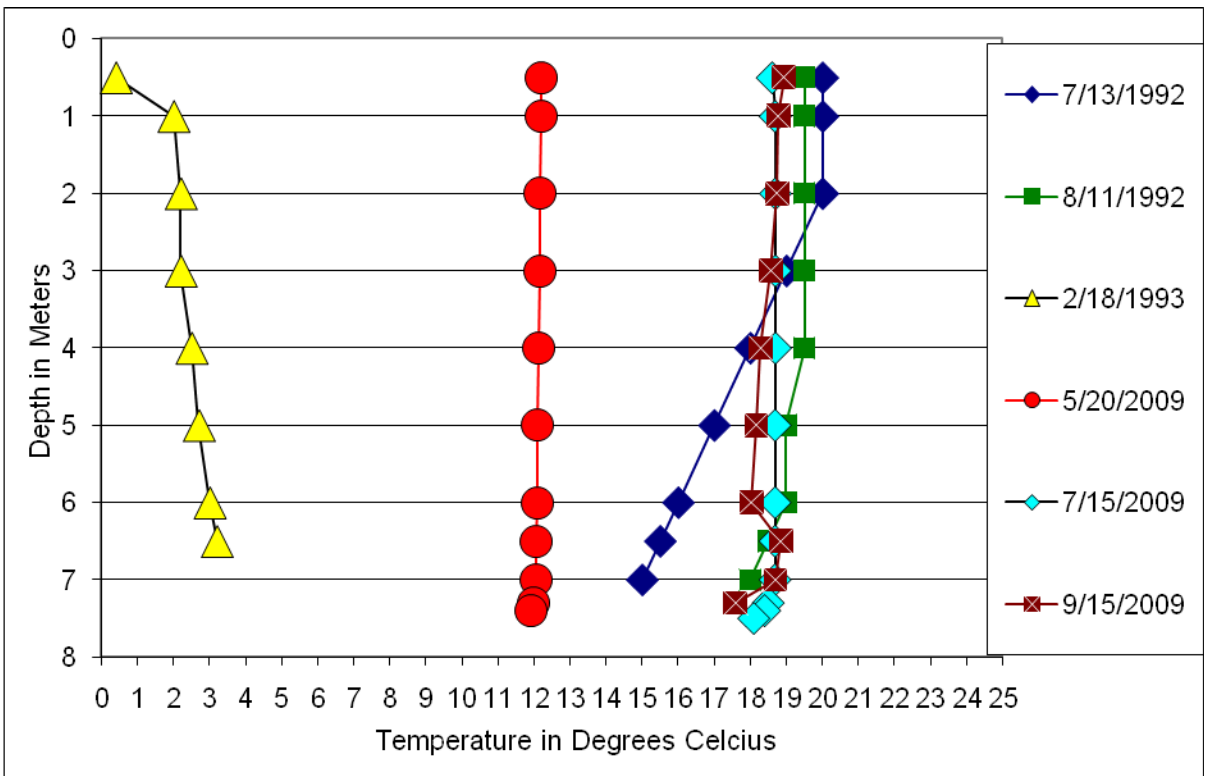

Figure 5. Temperature Profiles for Kota-Ray Dam

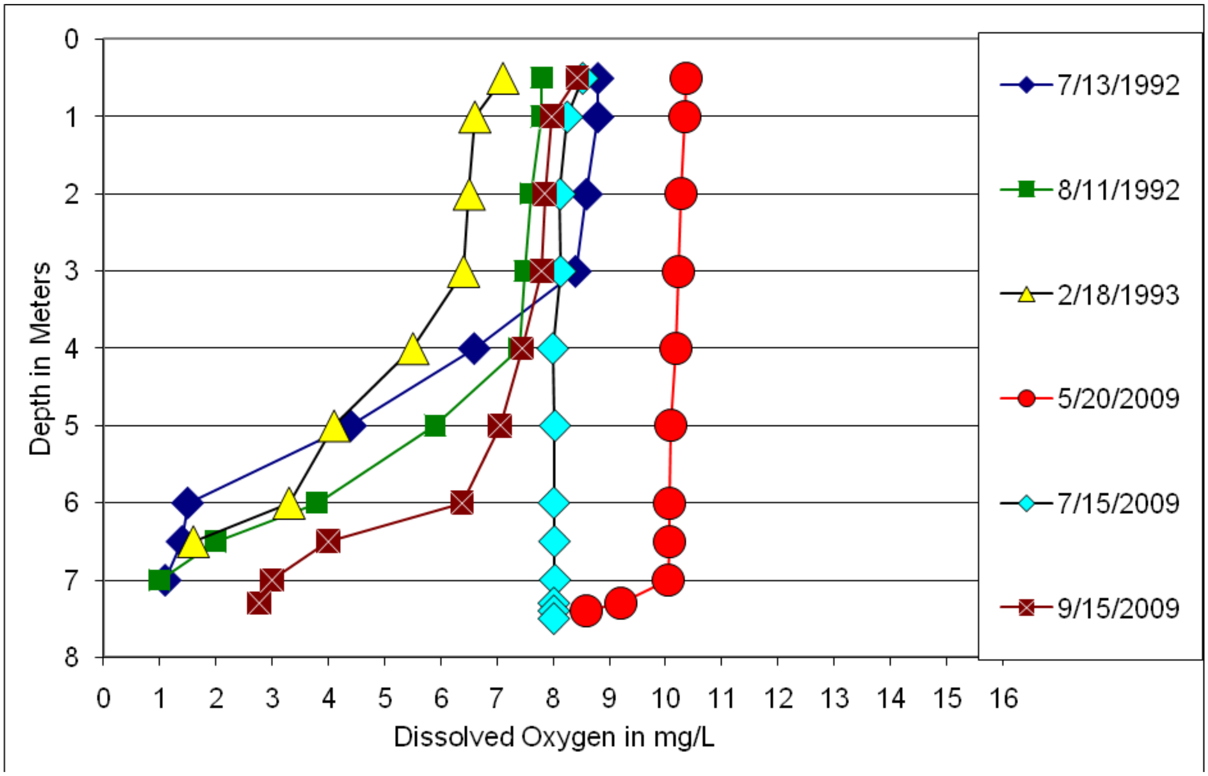

Figure 6. Dissolved Oxygen Profiles for Kota-Ray Dam

General Water Quality: Data collected in 2009 indicate that Kota-Ray Dam is well buffered with total alkalinity as $CaCO_3$ concentrations ranging from 364 to 370 mg/L (Table 1). The reservoir is sodium bicarbonate dominated with average sodium and bicarbonate concentrations of 261 mg/L and 428 mg/L, respectively. The average total dissolved solids concentration and specific conductance measurements for the 2009 sampling period were 725 mg/L and 1113 µmhos/cm, respectively, and the average total nitrogen as N and total phosphorus as P concentrations were 0.700 mg/L and 0.0.17 mg/L respectively.

When compared to the average water quality for reservoirs in the Rangeland Plans region, Kota-Ray Dam has fewer dissolved constituents, and is substantially less eutrophic than most (Table 3). For example, the average regional concentrations for TDS, total nitrogen, and total phosphorus concentrations are 1107 mg/L, 1.314 mg/L, and 0.128 mg/L respectively, compared to Kota-Ray Dam's average TDS, total nitrogen, and total phosphorus concentrations of 725 mg/L, 0.70 mg/L and 0.017 mg/L respectively.

Table 1. Statistical Summary of Kota-Ray Dam's 2009 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	3	366	364	370	3
Total Ammonia as N	mg/L	3	0.030[1]	0.030[1]	0.030[1]	0.000
Bicarbonate (HCO_3)	mg/L	3	428	424	432	4
Calcium (Ca)	mg/L	3	59.4	52.5	69.1	8.6
Carbonate (CO_3)	mg/L	3	9	8	10	1
Chloride (Cl)	mg/L	3	4	3	4	0
Chlorophyll-a	µg/L	2	4.4	3.0	5.7	1.9
Specific Conductance	µmhos	3	1113	1100	1120	12
Total Dissolved Solids	mg/L	3	725	715	737	11
Total Hardness as ($CaCO_3$)	mg/L	3	468	444	499	28
Hydroxide (OH)	mg/L	3	1.0[1]	1.0[1]	1.0[1]	0.0
Iron (Fe)	mg/L	3	0.078	0.050	0.110	0.030
Magnesium (Mg)	mg/L	3	77.5	73.5	79.9	3.5
Nitrate + Nitrite as N	mg/L	3	0.030[1]	0.030[1]	0.030[1]	0.000
Total Kjeldahl Nitrogen as N	mg/L	3	0.670	0.594	0.714	0.066
Total Nitrogen as N	mg/L	3	0.700	0.624	0.744	0.066
pH		3	8.41	8.36	8.45	0.05
Total Phosphorus as P	mg/L	3	0.017	0.013	0.024	0.006
Potassium (K)	mg/L	3	8.0	7.8	8.1	0.2
Sodium (Na)	mg/L	3	93.8	93.3	94.1	0.4
Sulfate (SO4)	mg/L	3	261	259	265	3

[1]Equal to the lower reporting limit

When comparing historical water quality data (1992-1993) to the 2009 water quality data, with the exception of sulfates, all water quality constituents have decreased. For example, the historical average bicarbonate, sulfate and sodium concentrations were 531 mg/L, 247 mg/L and 105.6 mg/L, respectively, compared to the 2009 averages of 428 mg/L, 261 mg/L and 93.8 mg/L (Tables 1 and 2). Like the dissolved solids, phosphorus concentrations also appear to be trending downward with the average total phosphorus concentrations decreasing from 0.052 mg/L, in 1992-93, to 0.017 mg/L in 2009.

Limiting Nutrients: Nutrient data collected in 2009 defined Kota-Ray Dam as phosphorus limited (Figure 7). This is a change from the 1992-1993 nutrient data that defined Kota-Ray Dam as phosphorus limited in the spring and winter but nitrogen limited in the late summer. The limiting nutrient assessment is based on the assumption that either nitrogen or phosphorus is limiting algal growth and that the ratio of total nitrogen as N to total phosphorus as P (N:P), by weight in the average algae is approximately 15 to 1. When the N:P ratio is less than 15:1, nitrogen is assumed to be the limiting nutrient and when it exceeds 15:1, the limiting nutrient is assumed to be phosphorus.

Table 2. Statistical Summary of Kota-Ray Dam's 1992-1993 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	3	464	422	547	72
Total Ammonia as N	mg/L	3	0.111	0.001[1]	0.328	0.188
Bicarbonate (HCO_3)	mg/L	3	531	470	654	106
Calcium (Ca)	mg/L	3	50.6	43.8	57.8	7.0
Carbonate (CO_3)	mg/L	3	17	7	23	9
Chloride (Cl)	mg/L	3	4	4	5	1
Chlorophyll-a	µg/L	2	5.1	5.0	5.1	0.1
Specific Conductance	µmhos	3	1193	1109	1360	144
Total Dissolved Solids	mg/L	3	775	683	941	144
Total Hardness as ($CaCO_3$)	mg/L	3	456	415	521	57
Hydroxide (OH)	mg/L	1	1.0[1]	1.0[1]	1.0[1]	0.0
Iron (Fe)	mg/L	3	0.045	0.022	0.064	0.021
Magnesium (Mg)	mg/L	3	80.1	74.3	91.6	9.9
Nitrate + Nitrite as N	mg/L	2	0.003	0.001[1]	0.006	0.004
Total Kjeldahl Nitrogen as N	mg/L	2	0.660	0.650	0.670	0.014
Total Nitrogen as N	mg/L	2	0.663	0.650	0.676	0.018
pH		3	8.46	8.27	8.59	0.17
Total Phosphorus as P	mg/L	2	0.052	0.021	0.082	0.043
Potassium (K)	mg/L	3	7.8	7.1	9.2	1.2
Sodium (Na)	mg/L	3	105.6	96.6	123.0	15.0
Sulfate (SO4)	mg/L	3	247	204	325	67

[1]Equal to the lower reporting limit

Trophic Status Assessment: Based on the chlorophyll-a, secchi disk transparency, and total phosphorus data collected in 2009, Kota-Ray Dam's trophic status is mesotrophic. The trophic status index (TSI) scores ranged from a low of 54 based on total phosphorus concentrations to a high of 77 based on secchi disk transparency (Figure 8).

Trends: A total of four total phosphorus samples and chlorophyll-a samples and five Secchi disk transparency measurements collected during the sampling periods of 1992-93 and 2009 were available to evaluate trends in the trophic status of Kota-Ray Dam. While not statistically tested, all trophic status indicators indicate an improving water quality trend. This trend is supported with a strong shift towards increasing phosphorus limitation (Figures 7 and 8).

Table 3. Statistical Summary of Water Quality Data[2] Collected from Reservoirs and Impoundments in the Rangeland Plains Ecological Region of North Dakota

Parameter	Units	N	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	522	283	54	982	131
Total Ammonia as N	mg/L	593	0.092	0.001[1]	2.440	0.183
Bicarbonate (HCO_3)	mg/L	522	295	14	1040	145
Calcium (Ca)	mg/L	522	52.3	4.7	163.0	27.3
Carbonate (CO_3)	mg/L	520	25	1[1]	197	29
Chloride (Cl)	mg/L	522	13	3[1]	75	9
Chlorophyll-a	µg/L	415	20.1	1.5[1]	218.0	27.0
Specific Conductance	µmhos	542	1621	173	5880	988
Total Dissolved Solids	mg/L	523	1107	100	5110	782
Total Hardness as ($CaCO_3$)	mg/L	522	396	45	2100	279
Hydroxide (OH)	mg/L	465	1.0	0.0[1]	1.0	0.2
Iron (Fe)	mg/L	523	0.193	0.007	4.110	0.349
Magnesium (Mg)	mg/L	522	64.5	5.6	412.0	54.0
Nitrate + Nitrite as N	mg/L	592	0.060	0.001[1]	0.790	0.102
Total Kjeldahl Nitrogen as N	mg/L	483	1.375	0.108	7.720	0.789
Total Nitrogen as N	mg/L	426	1.314	0.178	4.840	0.605
pH		542	8.55	6.73	9.87	0.55
Total Phosphorus as P	mg/L	599	0.128	0.004[1]	3.160	0.190
Potassium (K)	mg/L	522	13.8	2.6	39.2	6.5
Sodium (Na)	mg/L	522	217.2	3.0	932.0	171.6
Sulfate (SO4)	mg/L	520	573	1[1]	3210	519

[1]Equal to the lower reporting limit
[2]Data collected from 76 reservoirs between 1991 and 2010

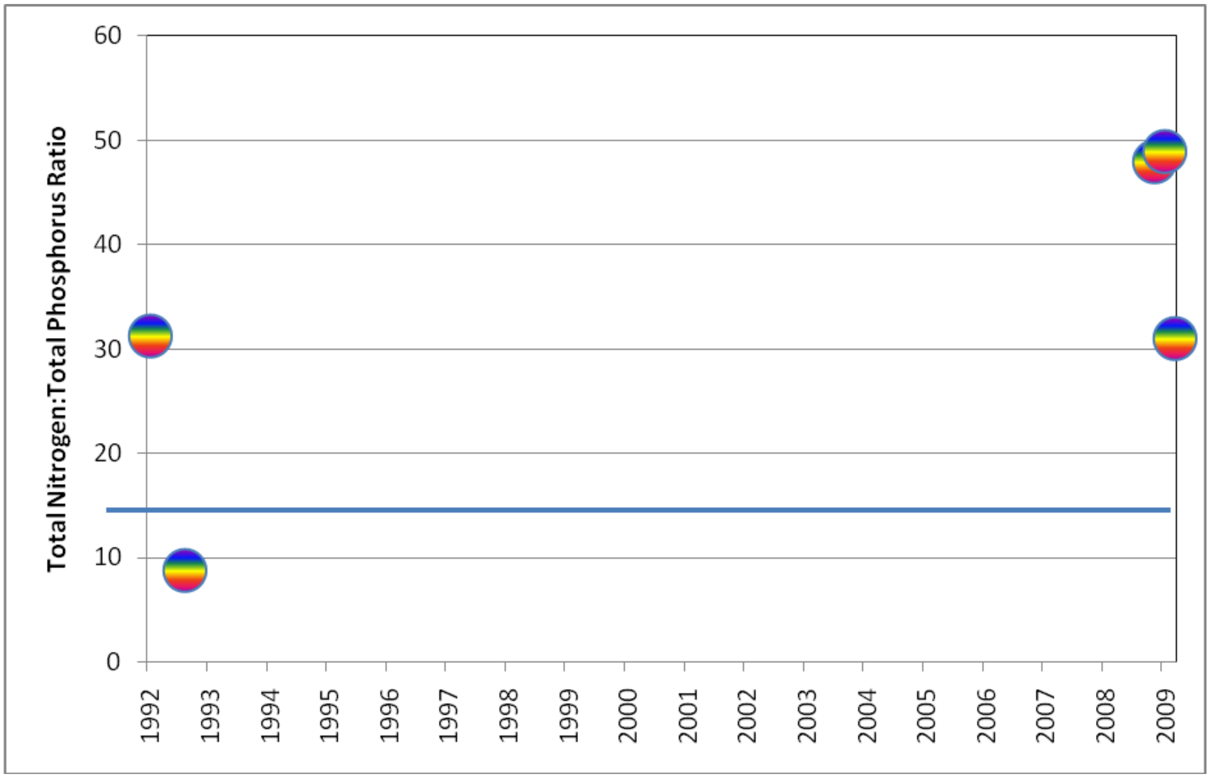

Figure 7. Kota-Ray Dam's Total Nitrogen to Total Phosphorus Ratio

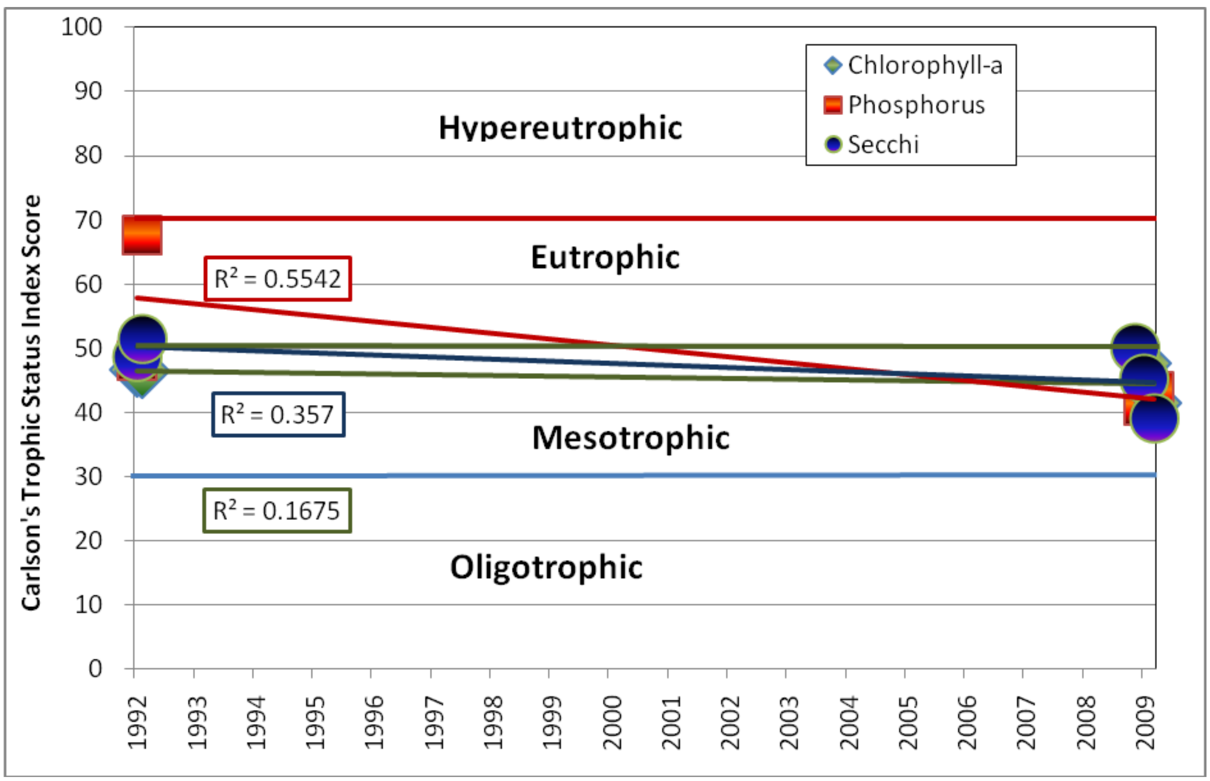

Figure 8. Kota-Ray Dam's TSI Scores

McLeod (Ray) Dam, Williams County

BACKGROUND

Location: Mcleod Dam or Ray Dam is a small reservoir on the headwaters of Beaver Creek. It lies on the south edge of the community of Ray, in Williams County, North Dakota (Figure 1). Mcleod Dam's fishery is managed by the North Dakota Game and Fish Department. Fish species stocked in recent years are northern pike, walleye and yellow perch.

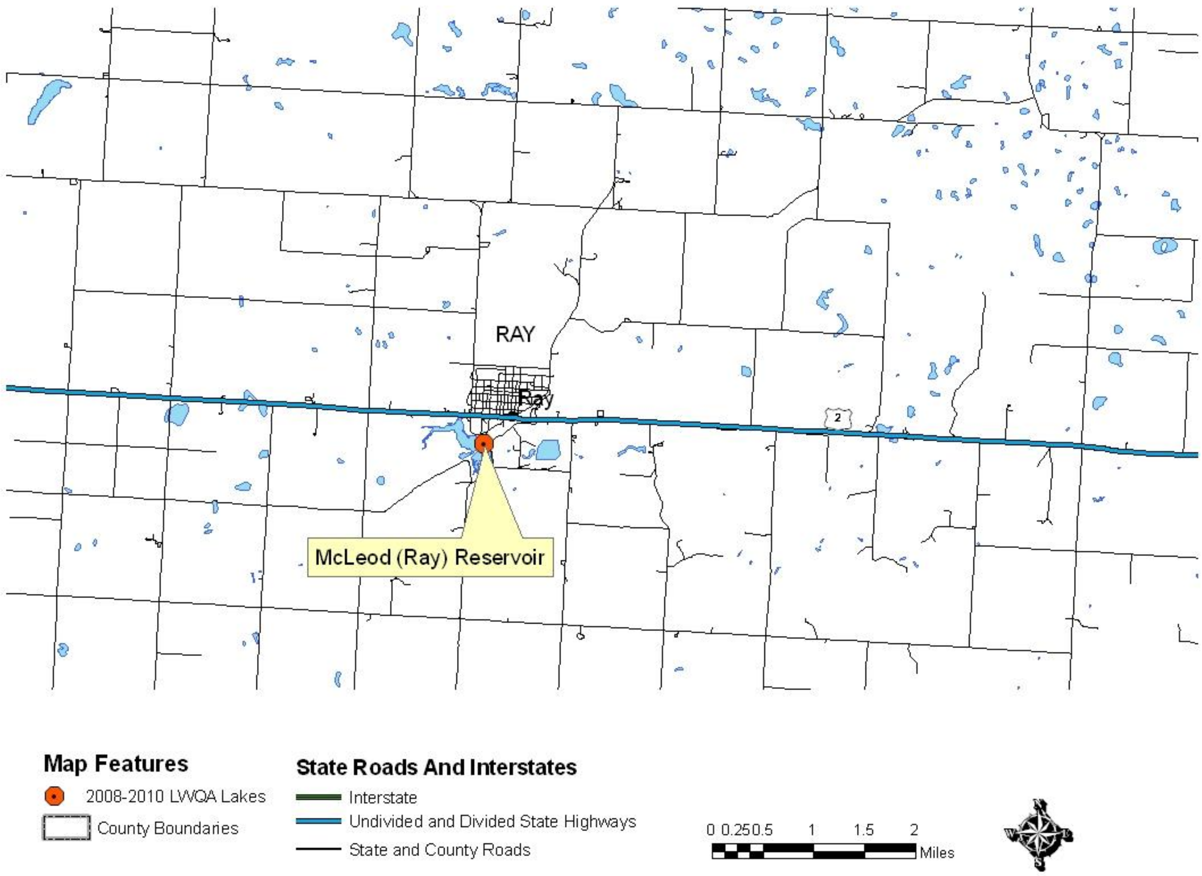

Figure 1. Location of Mcleod Dam

Physiographic/Ecological Setting: Mcleod Dam has a surface area of 428.7 acres, a maximum depth of 35.8ft and an average depth of 7.4 ft (Figure 2). The reservoir is located in the Northwestern Glaciated Plains Level III Ecoregion, which is part of the broader Rangeland Plains Region (Figures 3 and 4).

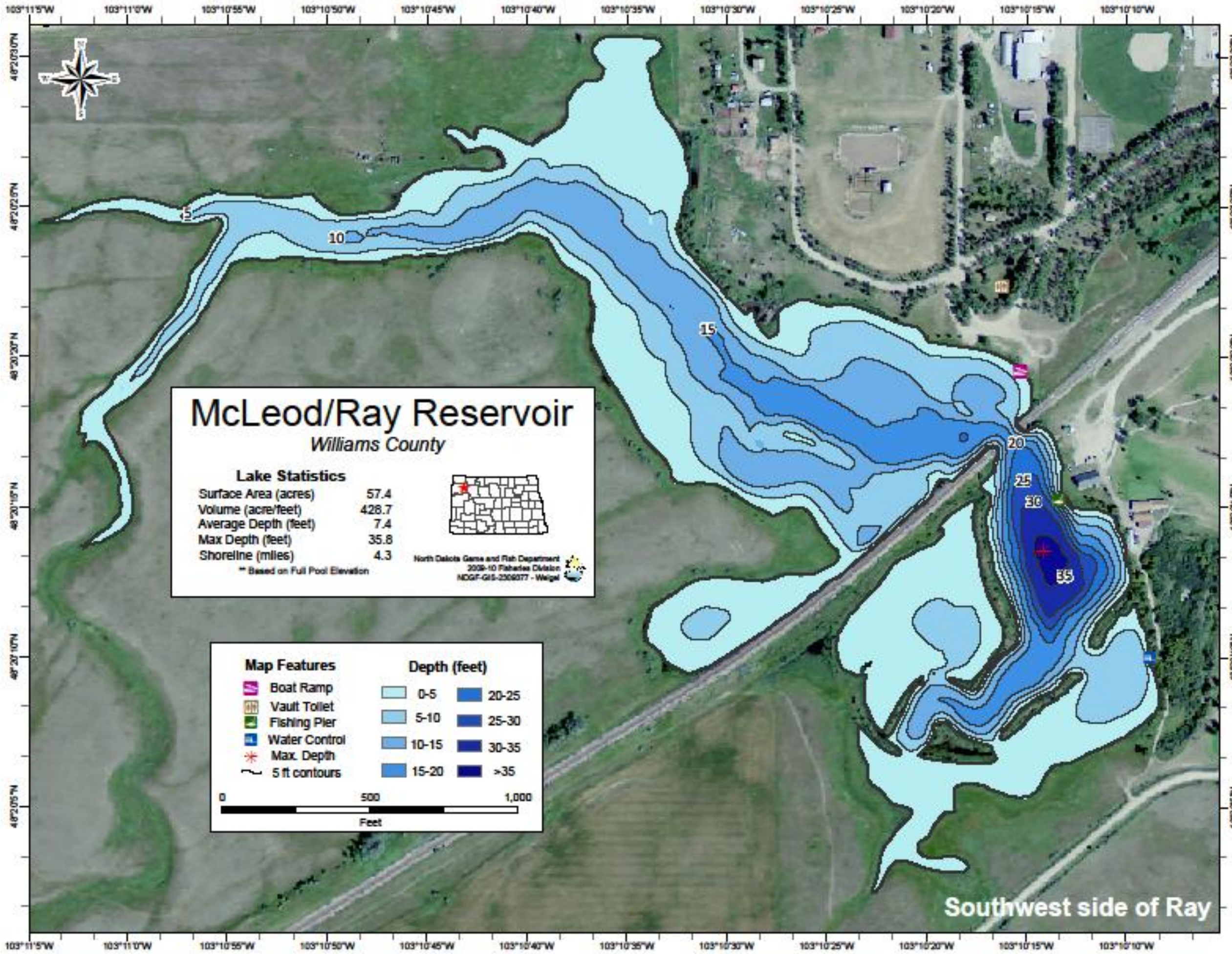

Figure 2. Contour Map of Mcleod Dam (Courtesy of the North Dakota Game and Fish Department)

Recreational Facilities: Recreational facilities at Mcleod Dam are an access road, boat ramp, courtesy dock, vault toilet, fishing pier and picnic area.

Water Quality Standards Classification: Mcleod Dam is classified in the state "Standards of Quality for Waters of the State" (NDDoH, 2011) as a class 3 lake. Class 3 lakes or reservoirs are defined as a "warm water fishery" or "waters capable of supporting natural reproduction and growth of warm water fishes (e.g., largemouth bass and bluegill) and associated aquatic biota. Some cool water species may also be present."

Historical Water Quality Sampling: There is no historical water quality data for Mcleod Dam.

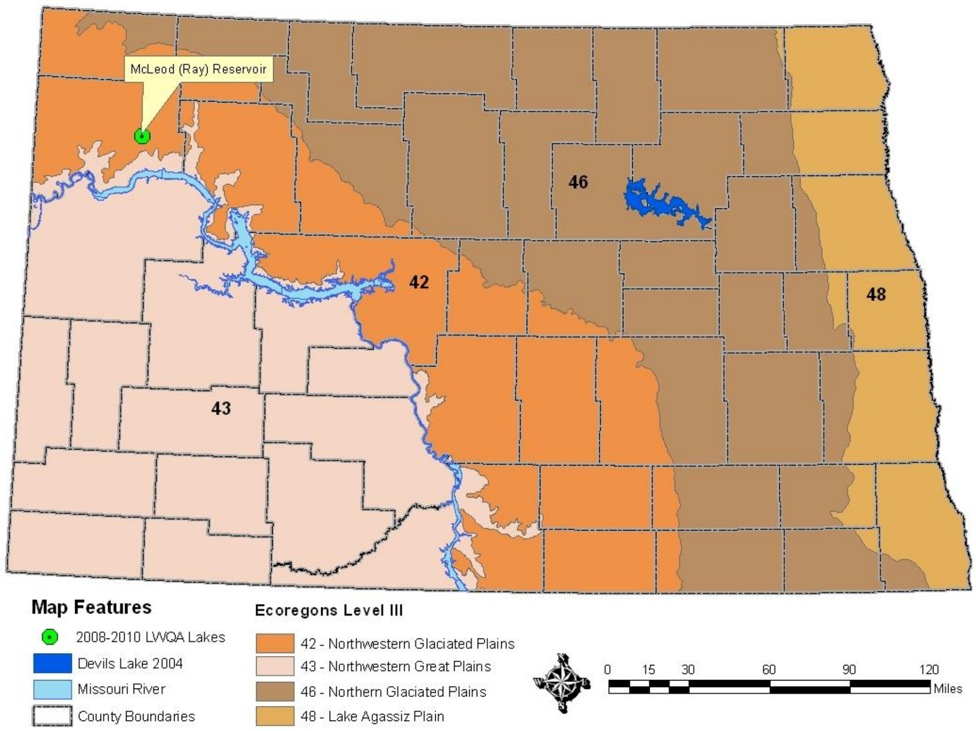

Figure 3. Mcleod Dam's Location and the Level III Ecoregions

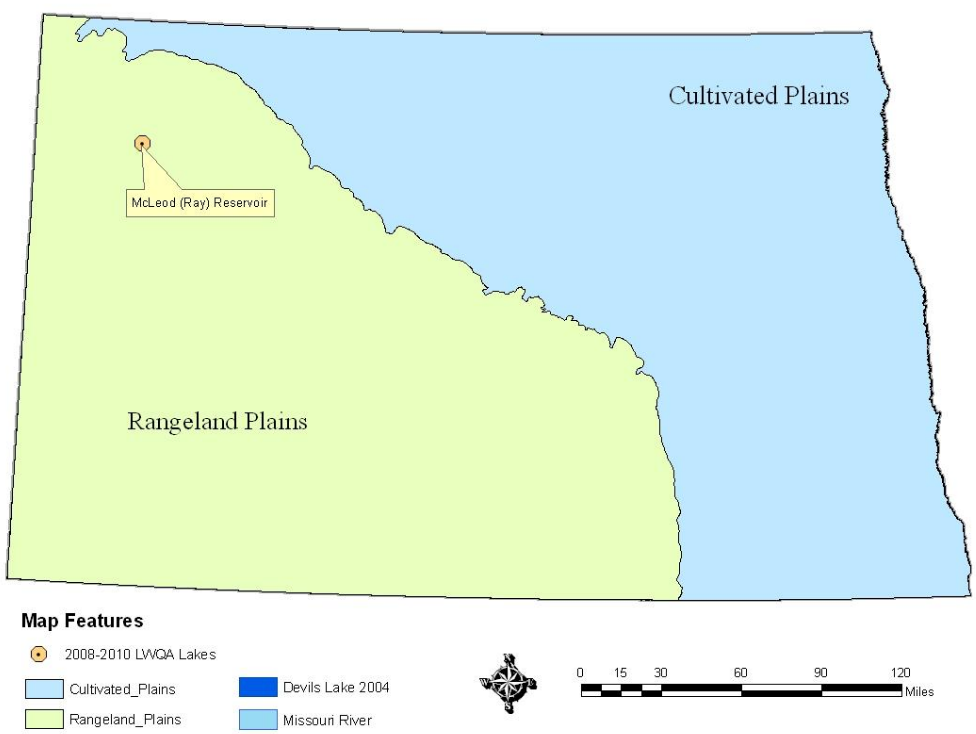

Figure 4. Mcleod Dams's Location and the Cultivated and Rangeland Plans Regions

WATER QUALITY MONITORING RESULTS

The water quality assessment for Mcleod Dam is presented in four general categories: 1) temperature and dissolved oxygen profile results; 2) general water quality characterization; 3) nutrient limitation; and 4) trophic status. Where appropriate, results have been compared to the regional data for reservoirs in the Rangeland Plains region.

Temperature and Dissolved Oxygen Profile Results: There are three temperature and dissolved oxygen profiles for Mcleod Dam collected in 2009. The profile data shows that the water body does not thermally stratify (Figure 5) and that during the sampling period of 2009 dissolved oxygen concentrations remained above the state standard designed to protect aquatic life of 5.0 mg/L (Figure 6).

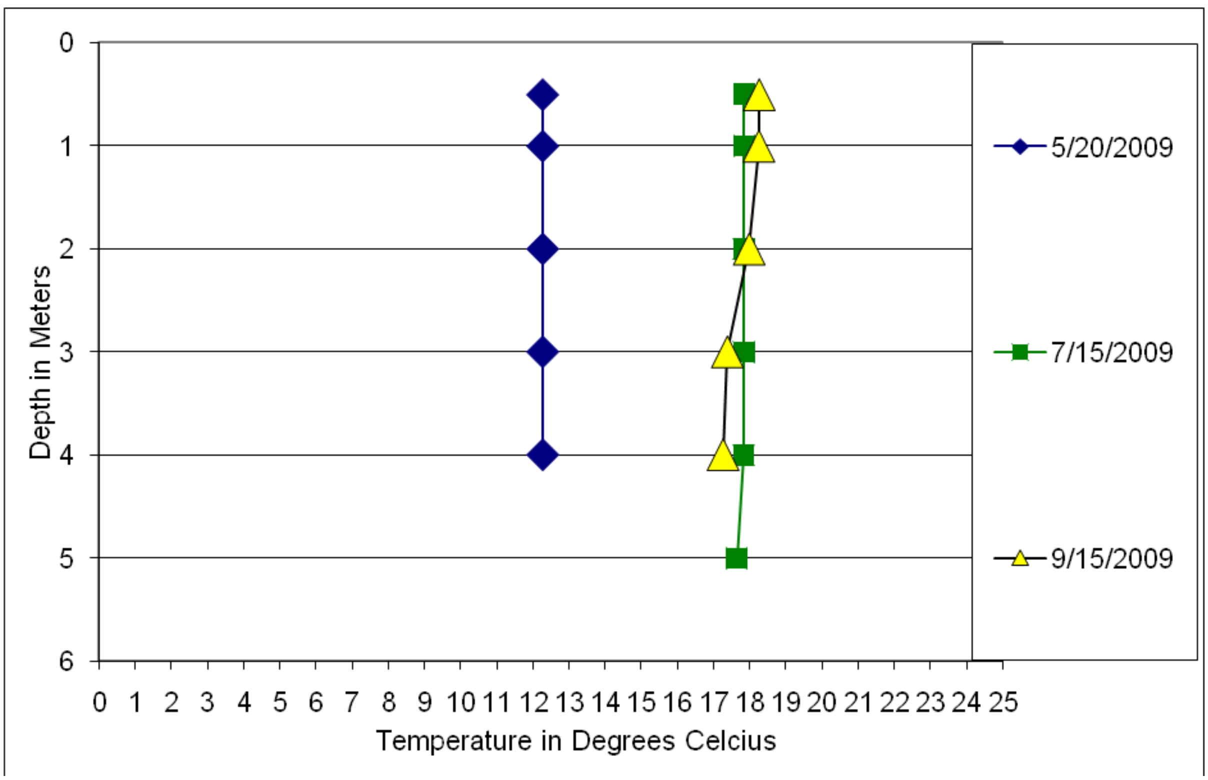

Figure 5. Temperature Profiles for Mcleod Dam

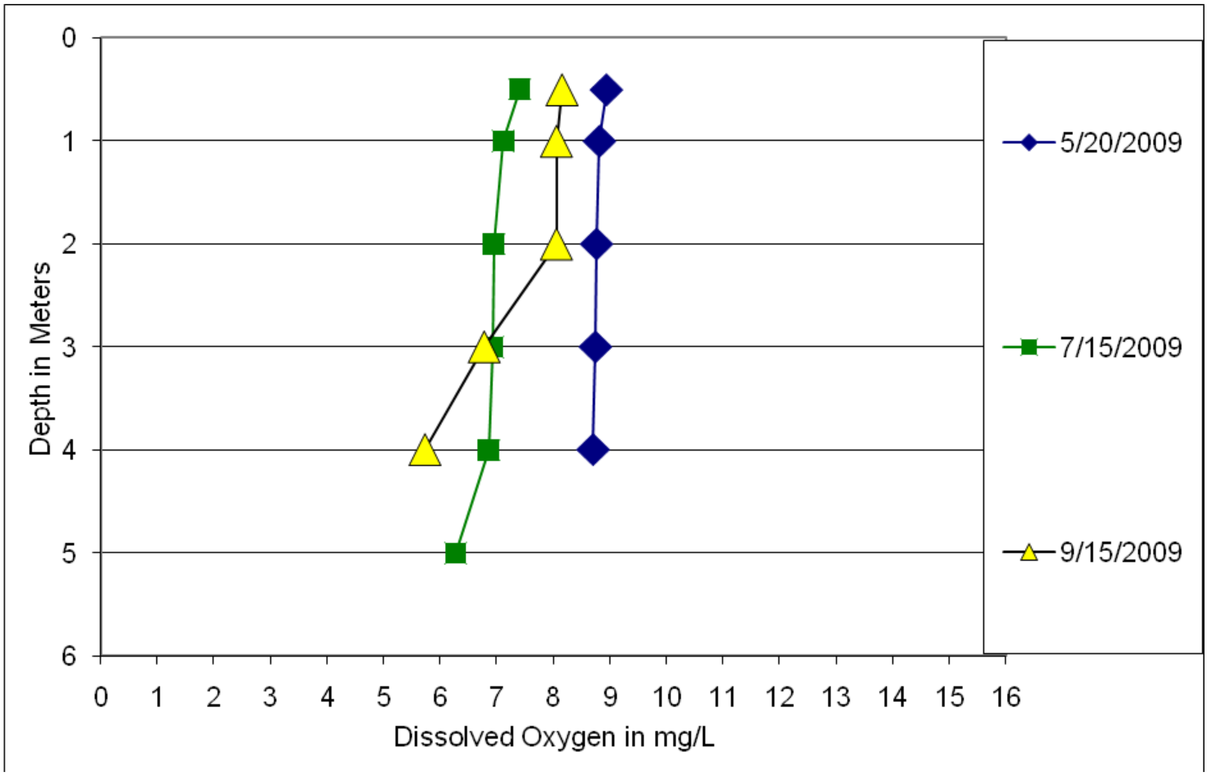

Figure 6. Dissolved Oxygen Profiles for Mcleod Dam

General Water Quality: Data collected in 2009 indicate that Mcleod Dam is moderately buffered with total alkalinity as $CaCO_3$ concentrations ranging from 66 to 101 mg/L (Table 1). The reservoir is sodium bicarbonate dominated with average sodium concentration 3 mg/L which is equal to the reporting limit and an average bicarbonate concentration of 102 mg/L. The average total dissolved solids concentration and specific conductance measurements where the lowest reported for the 2009 sampling period at 85 mg/L and 199µmhos/cm, respectively, and the average total nitrogen as N and total phosphorus as P concentrations were 1.139 mg/L and 0.289 mg/L respectively.

When compared to water quality for reservoirs in the Rangeland Plans Ecoregion, Mcleod Dam has substantially lower concentrations of dissolved constituents but is above the average for total phosphorus and resulting trophic condition (Tables 1 and 2). For example, the regional average concentrations for TDS and total phosphorus concentrations are 1107 mg/L 0.128 mg/L respectively, compared to Mcleod Dam's average TDS and total phosphorus concentrations of 85 mg/L and 0.289 mg/L.

Table 1. Statistical Summary of McLeod (Ray) Reservoir's 2009 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	3	83	66	101	18
Total Ammonia as N	mg/L	3	0.067	0.030[1]	0.142	0.065
Bicarbonate (HCO_3)	mg/L	3	102	80	123	22
Calcium (Ca)	mg/L	3	21.1	17.8	25.5	4.0
Carbonate (CO_3)	mg/L	3	1[1]	1[1]	1[1]	0
Chloride (Cl)	mg/L	3	2	1[1]	2	0
Chlorophyll-a	µg/L	2	9.0	3.0	15.0	8.5
Specific Conductance	µmhos	3	199	173	225	26
Total Dissolved Solids	mg/L	3	112	100	126	13
Total Hardness as ($CaCO_3$)	mg/L	3	85	74	100	14
Hydroxide (OH)	mg/L	3	1.0[1]	1.0[1]	1.0[1]	0.0
Iron (Fe)	mg/L	3	0.444	0.220	0.824	0.331
Magnesium (Mg)	mg/L	3	7.7	7.1	8.7	0.9
Nitrate + Nitrite as N	mg/L	3	0.037	0.030[1]	0.050	0.012
Total Kjeldahl Nitrogen as N	mg/L	3	1.103	0.928	1.300	0.187
Total Nitrogen as N	mg/L	3	1.139	0.958	1.350	0.198
pH		3	7.42	7.17	7.78	0.32
Total Phosphorus as P	mg/L	3	0.289	0.234	0.384	0.082
Potassium (K)	mg/L	3	13.9	12.8	14.9	1.1
Sodium (Na)	mg/L	3	3.0[1]	3.0[1]	3.0[1]	0.0
Sulfate (SO4)	mg/L	3	13	9	17	4

[1]Equal to the lower reporting limit

L**imiting Nutrients:** Water quality data collected in 2009 define Mcleod Dam as a nitrogen limited waterbody (Figure 7). The limiting nutrient assessment is based on the assumption that either nitrogen or phosphorus is limiting algal growth and that the ratio of total nitrogen as N to total phosphorus as P (N:P), by weight in the average algae is approximately 15 to 1. When the N:P ratio is less than 15:1, nitrogen is assumed to be the limiting nutrient and when it exceeds 15:1, the limiting nutrient is assumed to be phosphorus.

Trophic Status Assessment: Based on the chlorophyll-a, secchi disk transparency, and total phosphorus data collected in 2009, Mcleod Dam's trophic status is estimated as eutrophic. The trophic status index (TSI) scores ranged from a low of 16 based on chlorophyll-a concentrations to a high of 90 based on total phosphorus (Figure 8).

Table 2. Statistical Summary of Water Quality Data[2] Collected from Reservoirs and Impoundments in the Rangeland Plains Ecological Region of North Dakota

Parameter	Units	N	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	522	283	54	982	131
Total Ammonia as N	mg/L	593	0.092	0.001[1]	2.440	0.183
Bicarbonate (HCO_3)	mg/L	522	295	14	1040	145
Calcium (Ca)	mg/L	522	52.3	4.7	163.0	27.3
Carbonate (CO_3)	mg/L	520	25	1[1]	197	29
Chloride (Cl)	mg/L	522	13	3[1]	75	9
Chlorophyll-a	µg/L	415	20.1	1.5[1]	218.0	27.0
Specific Conductance	µmhos	542	1621	173	5880	988
Total Dissolved Solids	mg/L	523	1107	100	5110	782
Total Hardness as ($CaCO_3$)	mg/L	522	396	45	2100	279
Hydroxide (OH)	mg/L	465	1.0	0.0[1]	1.0	0.2
Iron (Fe)	mg/L	523	0.193	0.007	4.110	0.349
Magnesium (Mg)	mg/L	522	64.5	5.6	412.0	54.0
Nitrate + Nitrite as N	mg/L	592	0.060	0.001[1]	0.790	0.102
Total Kjeldahl Nitrogen as N	mg/L	483	1.375	0.108	7.720	0.789
Total Nitrogen as N	mg/L	426	1.314	0.178	4.840	0.605
pH		542	8.55	6.73	9.87	0.55
Total Phosphorus as P	mg/L	599	0.128	0.004[1]	3.160	0.190
Potassium (K)	mg/L	522	13.8	2.6	39.2	6.5
Sodium (Na)	mg/L	522	217.2	3.0	932.0	171.6
Sulfate (SO4)	mg/L	520	573	1[1]	3210	519

[1]Equal to the lower reporting limit
[2]Data collected from 76 reservoirs between 1991 and 2010

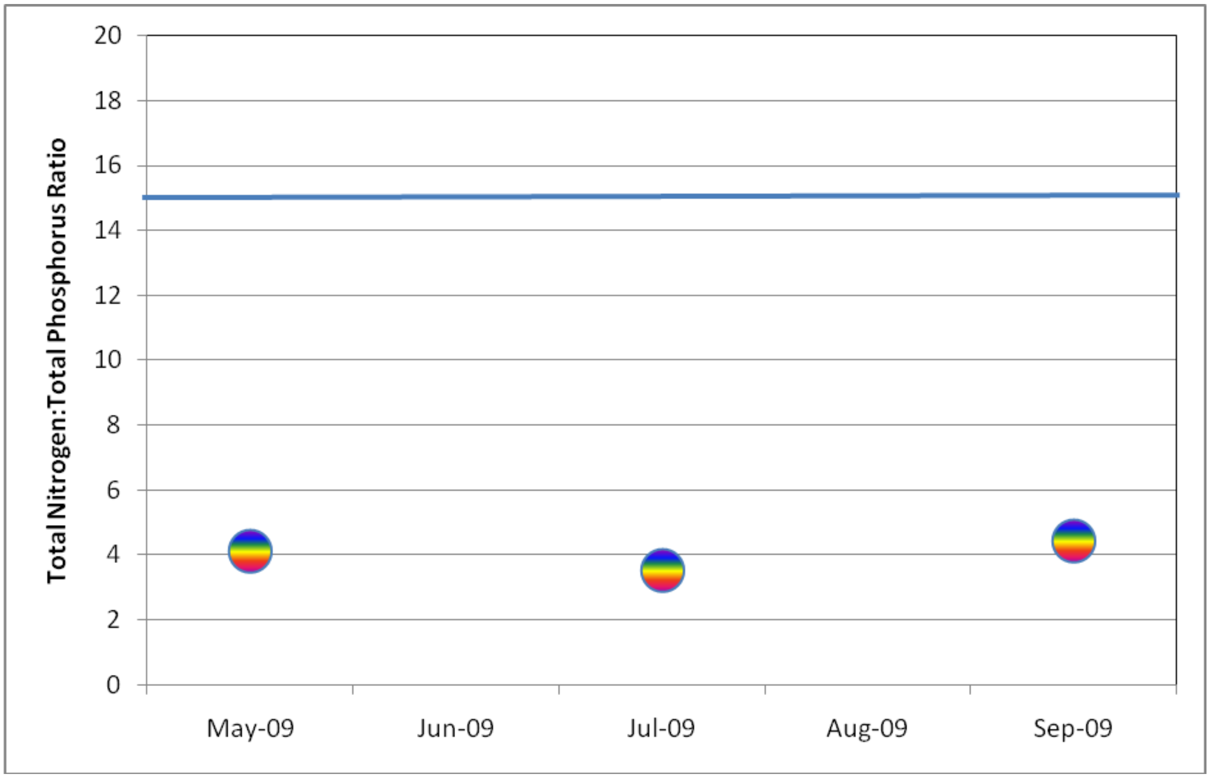

Figure 7. Mcleod Dam's Total Nitrogen to Total Phosphorus Ratio

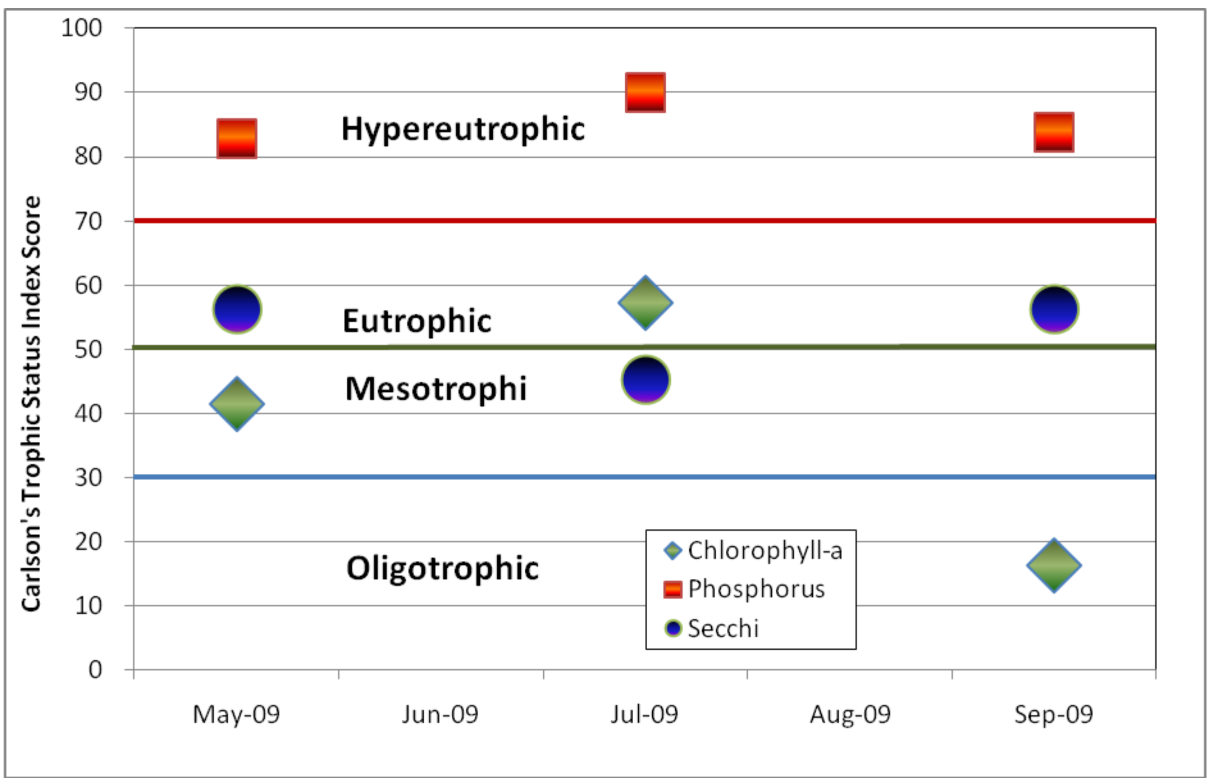

Figure 8. Mcleod Dam's TSI Scores

Tioga Dam, Williams County

BACKGROUND

Location: Tioga Dam is a small reservoir on the headwaters of Paulsen Creek. It lies on the north edge of the community of Tioga, in Williams County, North Dakota (Figure 1). Tioga Dam's fishery is managed by the North Dakota Game and Fish Department. Fish species stocked in recent years are northern pike and yellow perch.

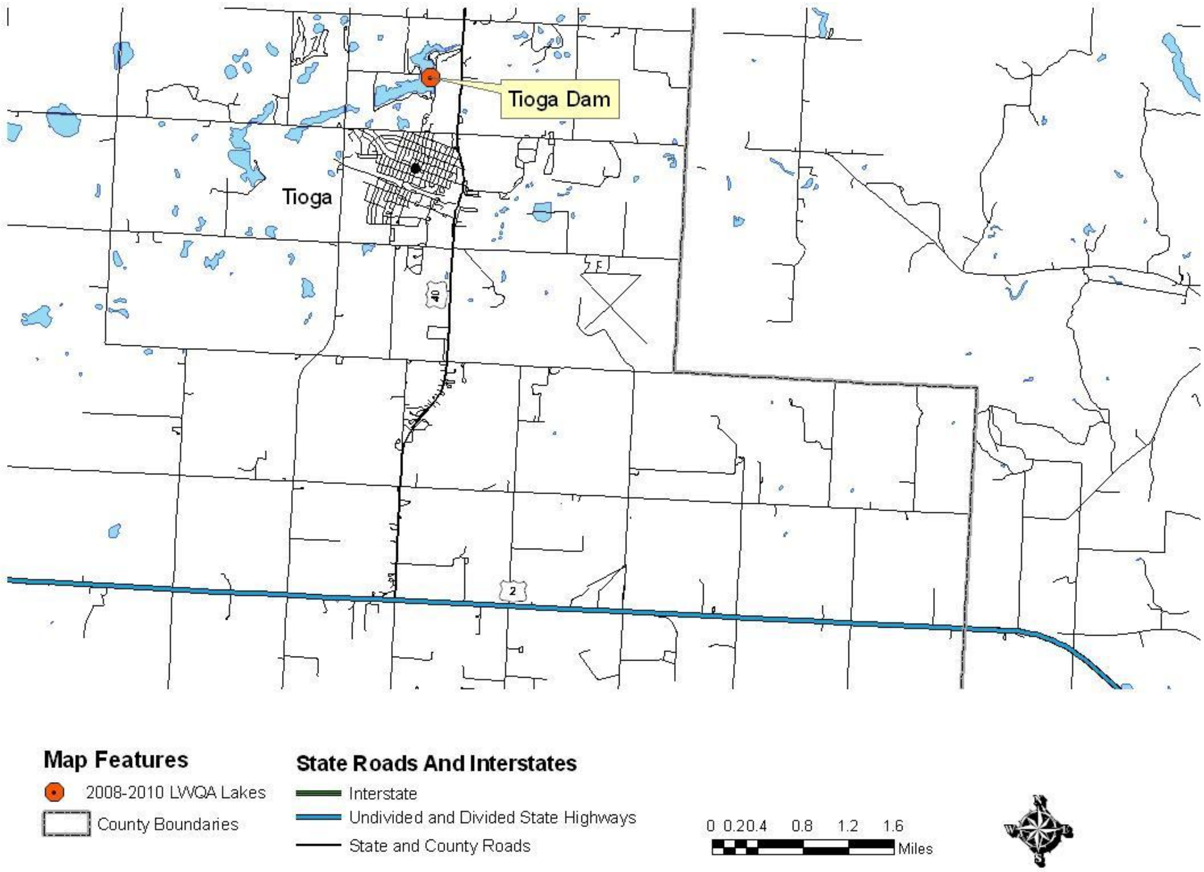

Figure 1. Location of Tioga Dam

Physiographic/Ecological Setting: Tioga Dam has a surface area of 64.6 acres, a maximum depth of 30.6ft, and an average depth of 12 ft. The reservoir provides reasonable access to for shore fishing from select areas particularly on the south and east shores (Figure 2). The reservoir is located in the Northwestern Glaciated Plains Level III Ecoregion, which is part of the broader Rangeland Plains Region (Figures 3 and 4).

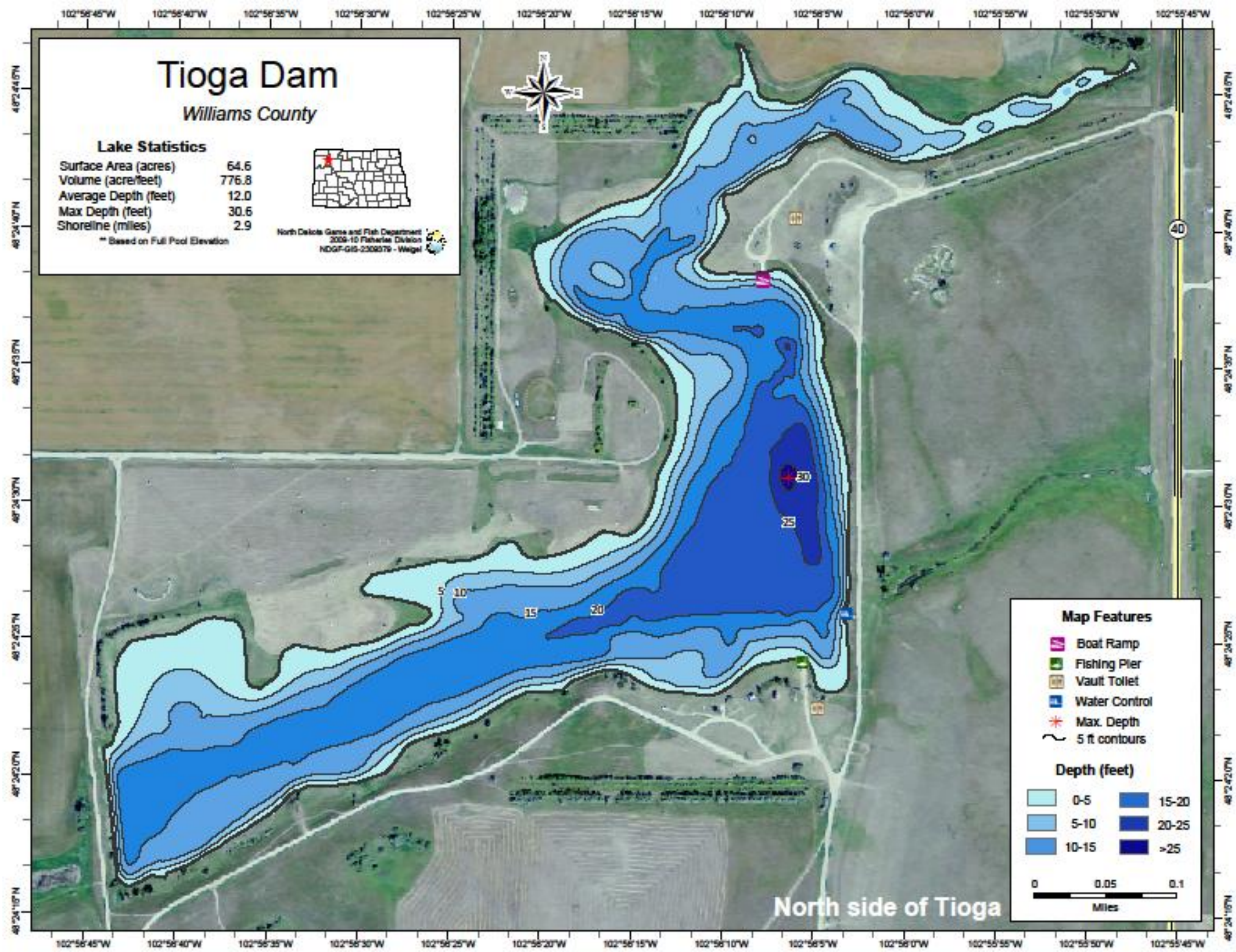

Figure 2. Contour Map of Tioga Dam (Courtesy of the North Dakota Game and Fish Department)

Recreational Facilities: Recreational facilities at Tioga Dam are an access road, boat ramp, vault toilet, and a small picnic area.

Water Quality Standards Classification: Tioga Dam is classified in the state "Standards of Quality for Waters of the State" (NDDoH, 2011) as a class 3 lake. Class 3 lakes or reservoirs are defined as a "warm water fishery" or "waters capable of supporting natural reproduction and growth of warm water fishes (e.g., largemouth bass and bluegill) and associated aquatic biota. Some cool water species may also be present."

Historical Water Quality Sampling: There is no historical water quality data for Tioga Dam.

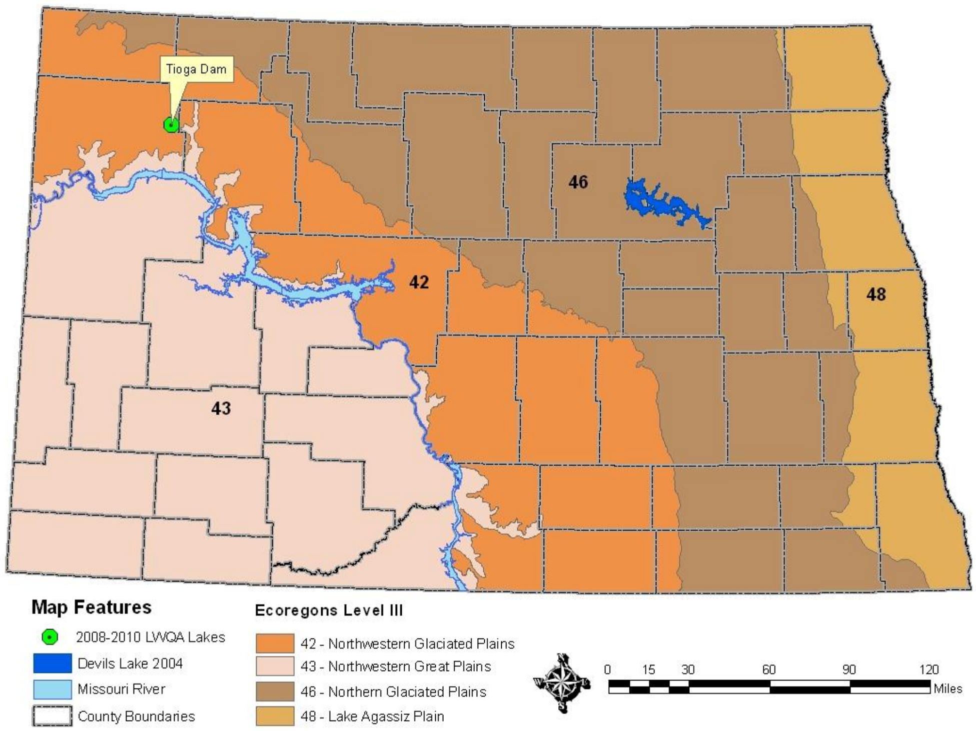

Figure 3. Tioga Dam's Location and the Level III Ecoregions

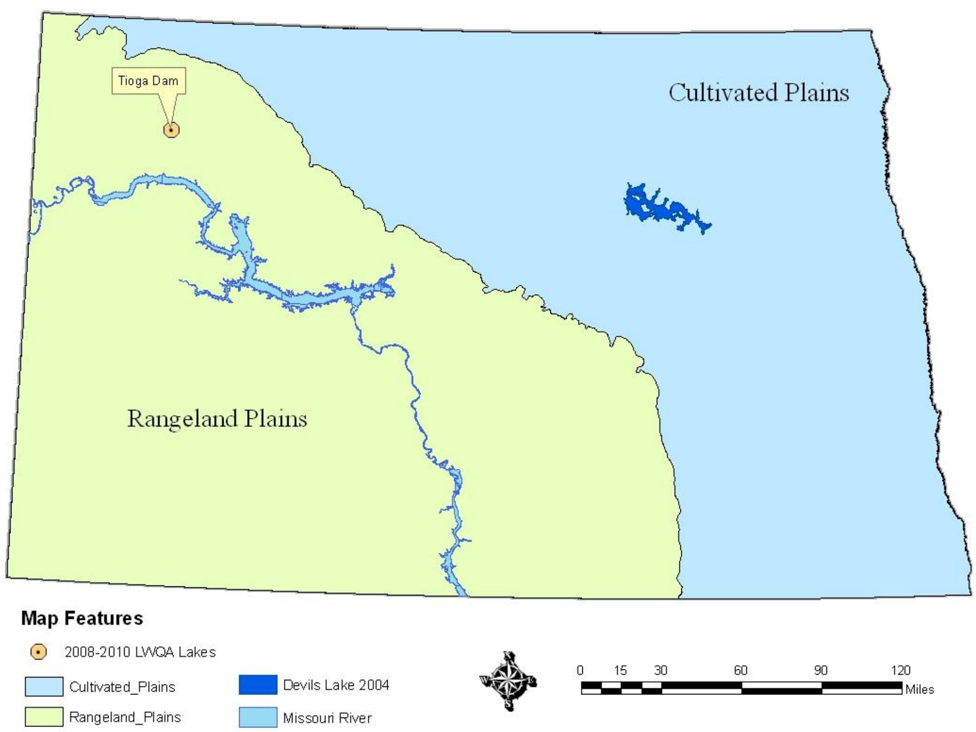

Figure 4. Tioga Dams's Location and the Cultivated and Rangeland Plans Regions

WATER QUALITY MONITORING RESULTS

The water quality assessment for Tioga Dam is presented in four general categories: 1) temperature and dissolved oxygen profile results; 2) general water quality characterization; 3) nutrient limitation; and 4) trophic status. Where appropriate, results have been compared to the regional data for reservoirs in the Rangeland Plains region.

Temperature and Dissolved Oxygen Profile Results: There are three temperature and dissolved oxygen profiles for Tioga Dam collected in 2009. The profile data shows that the water body does not thermally stratify (Figure 5) and that during the sampling period of 2009 dissolved oxygen concentrations remained above the state standard designed to protect aquatic life of 5.0 mg/L (Figure 6).

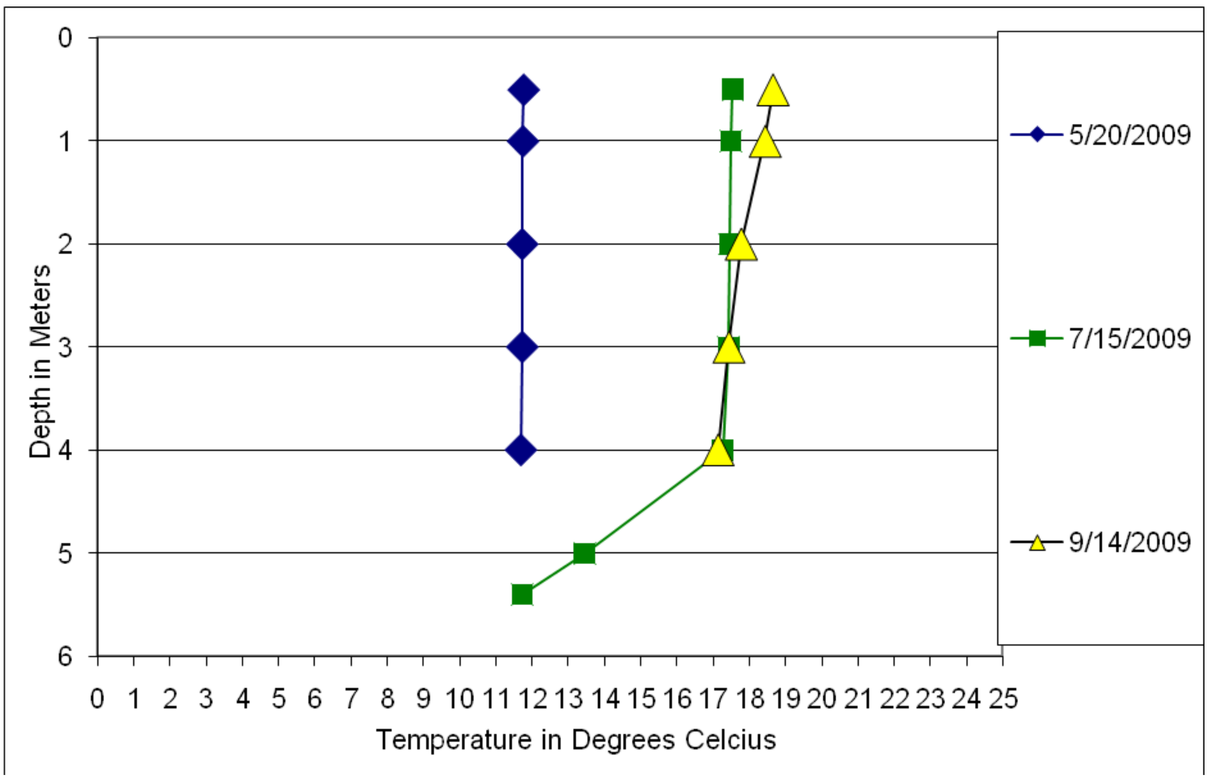

Figure 5. Temperature Profiles for Tioga Dam

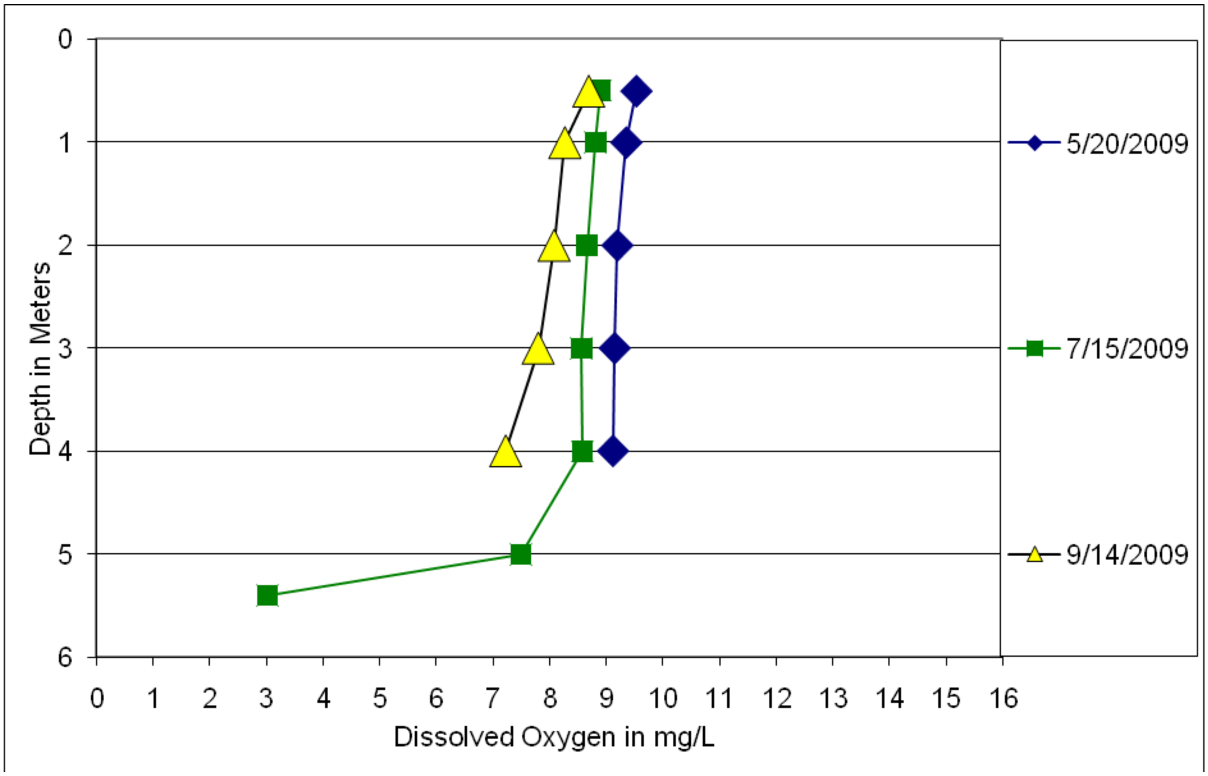

Figure 6. Dissolved Oxygen Profiles for Tioga Dam

General Water Quality: Data collected in 2009 indicate that Tioga Dam is well buffered with total alkalinity as $CaCO_3$ concentrations ranging from 106 and 153 mg/L (Table 1). The reservoir is sodium bicarbonate dominated with average sodium and bicarbonate concentrations of 10.6 mg/L and 158 mg/L, respectively. The average total dissolved solids concentration and specific conductance measurements for the 2009 sampling period were 290 mg/L and 501µmhos/cm, respectively, and the average total nitrogen as N and total phosphorus as P concentrations were 1.178 mg/L and 0.208 mg/L respectively.

When compared to the average water quality for reservoirs in the Rangeland Plans region, Tioga Dam has fewer dissolved constituents and is less eutrophic than most (Table 2). For example, the average regional concentrations for TDS, total nitrogen, and total phosphorus concentrations are 1107 mg/L, 1.314 mg/L, and 0.128 mg/L respectively, compared to Tioga Dam’s average TDS, total nitrogen, and total phosphorus concentrations of 290 mg/L, 1.178 mg/L and 0.208 mg/L respectively.

Table 1. Statistical Summary of Tioga Dam's 2009 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	3	133	106	153	24
Total Ammonia as N	mg/L	3	0.064	0.030[1]	0.128	0.056
Bicarbonate (HCO_3)	mg/L	3	158	130	174	24
Calcium (Ca)	mg/L	3	50.4	45.1	55.9	5.4
Carbonate (CO_3)	mg/L	3	3	1[1]	6	3
Chloride (Cl)	mg/L	3	25	23	26	2
Chlorophyll-a	µg/L	2	12.0	7.7	16.3	6.1
Specific Conductance	µmhos	3	501	455	539	43
Total Dissolved Solids	mg/L	3	290	258	318	30
Total Hardness as ($CaCO_3$)	mg/L	3	225	203	253	25
Hydroxide (OH)	mg/L	3	1.0[1]	1.0[1]	1.0[1]	0.0
Iron (Fe)	mg/L	3	0.082	0.070	0.101	0.016
Magnesium (Mg)	mg/L	3	24.2	22.0	27.6	3.0
Nitrate + Nitrite as N	mg/L	3	0.030[1]	0.030[1]	0.030[1]	0.000
Total Kjeldahl Nitrogen as N	mg/L	3	1.148	0.883	1.450	0.285
Total Nitrogen as N	mg/L	3	1.178	0.913	1.480	0.285
pH		3	8.13	7.64	8.47	0.43
Total Phosphorus as P	mg/L	3	0.208	0.140	0.255	0.060
Potassium (K)	mg/L	3	16.4	14.4	18.4	2.0
Sodium (Na)	mg/L	3	10.6	9.7	11.3	0.8
Sulfate (SO4)	mg/L	3	82	78	86	4

[1]Equal to the lower reporting limit

Limiting Nutrients: Water quality data collected in 2009 define Tioga Dam as a nitrogen limited waterbody (Figure 7). The limiting nutrient assessment is based on the assumption that either nitrogen or phosphorus is limiting algal growth and that the ratio of total nitrogen as N to total phosphorus as P (N:P), by weight in the average algae is approximately 15 to 1. When the N:P ratio is less than 15:1, nitrogen is assumed to be the limiting nutrient and when it exceeds 15:1, the limiting nutrient is assumed to be phosphorus.

Trophic Status Assessment: Based on the chlorophyll-a, secchi disk transparency, and total phosphorus data collected in 2009, Tioga Dam's trophic status is estimated as eutrophic. The trophic status index (TSI) scores ranged from a low of 50 based on secchi disk transparency to a high of 84 based on total phosphorus concentrations (Figure 8).

Table 2. Statistical Summary of Water Quality Data[2] Collected from Reservoirs and Impoundments in the Rangeland Plains Ecological Region of North Dakota

Parameter	Units	N	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	522	283	54	982	131
Total Ammonia as N	mg/L	593	0.092	0.001[1]	2.440	0.183
Bicarbonate (HCO_3)	mg/L	522	295	14	1040	145
Calcium (Ca)	mg/L	522	52.3	4.7	163.0	27.3
Carbonate (CO_3)	mg/L	520	25	1[1]	197	29
Chloride (Cl)	mg/L	522	13	3[1]	75	9
Chlorophyll-a	µg/L	415	20.1	1.5[1]	218.0	27.0
Specific Conductance	µmhos	542	1621	173	5880	988
Total Dissolved Solids	mg/L	523	1107	100	5110	782
Total Hardness as ($CaCO_3$)	mg/L	522	396	45	2100	279
Hydroxide (OH)	mg/L	465	1.0	0.0[1]	1.0	0.2
Iron (Fe)	mg/L	523	0.193	0.007	4.110	0.349
Magnesium (Mg)	mg/L	522	64.5	5.6	412.0	54.0
Nitrate + Nitrite as N	mg/L	592	0.060	0.001[1]	0.790	0.102
Total Kjeldahl Nitrogen as N	mg/L	483	1.375	0.108	7.720	0.789
Total Nitrogen as N	mg/L	426	1.314	0.178	4.840	0.605
pH		542	8.55	6.73	9.87	0.55
Total Phosphorus as P	mg/L	599	0.128	0.004[1]	3.160	0.190
Potassium (K)	mg/L	522	13.8	2.6	39.2	6.5
Sodium (Na)	mg/L	522	217.2	3.0	932.0	171.6
Sulfate (SO4)	mg/L	520	573	1[1]	3210	519

[1]Equal to the lower reporting limit
[2]Data collected from 76 reservoirs between 1991 and 2010

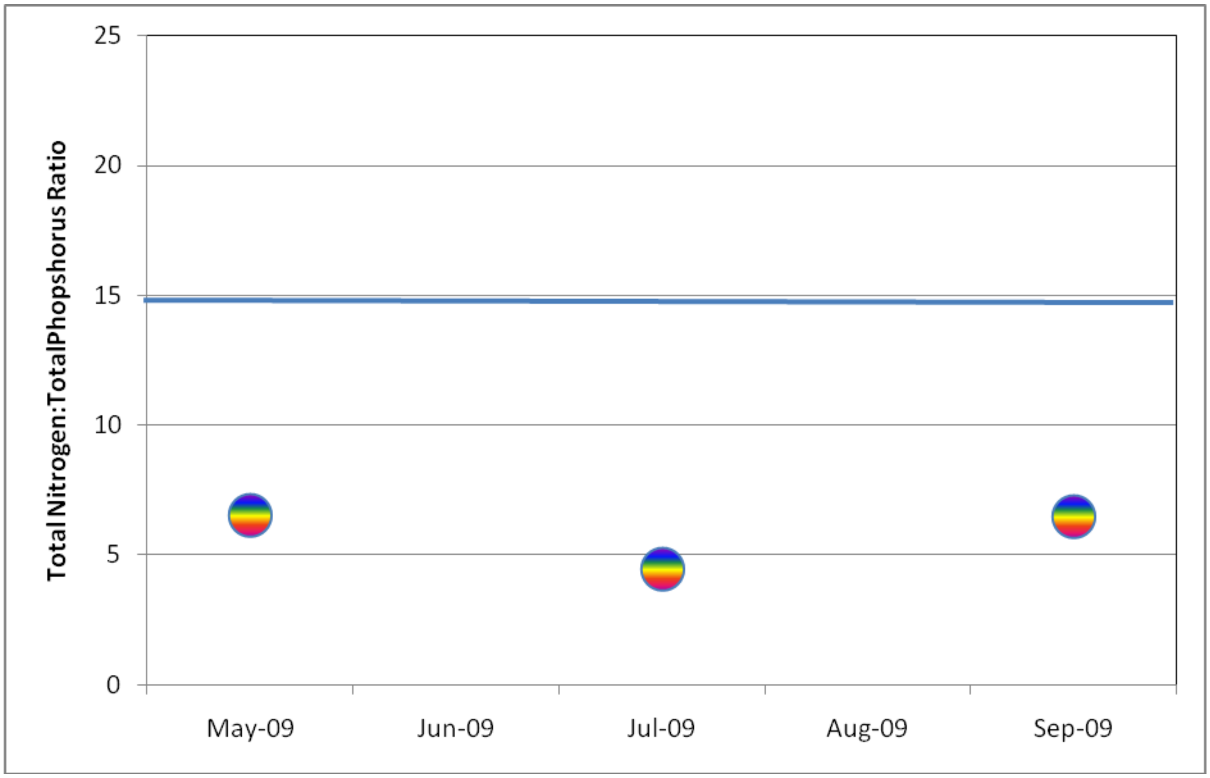

Figure 7. Tioga Dam's Total Nitrogen to Total Phosphorus Ratio

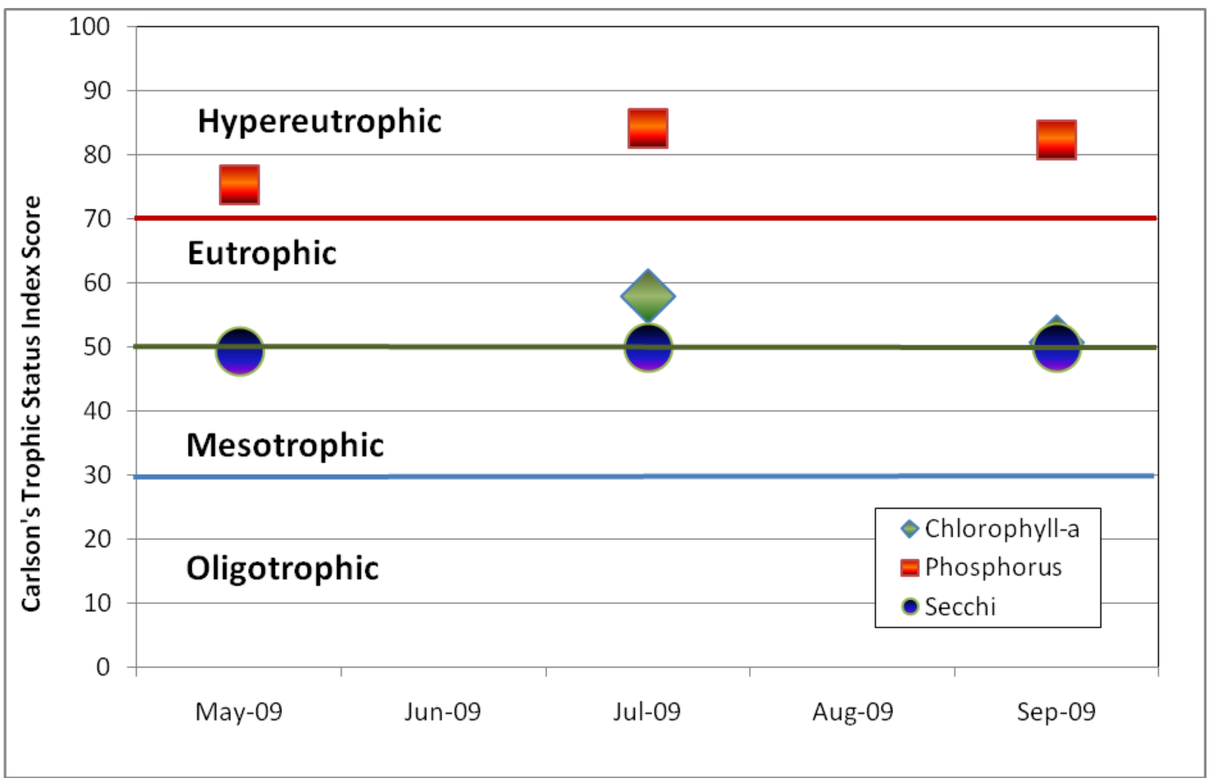

Figure 8. Tioga Dam's TSI Scores

Trenton Lake, Williams County

BACKGROUND

Location: Trenton Lake is a shallow oxbow lake on the south edge of the community of Trenton in Williams County North Dakota (Figure 1). The fishery is composed of a myriad of species associated with the Missouri River system. Currently the sport fishery is known for its excellent northern pike and crappie.

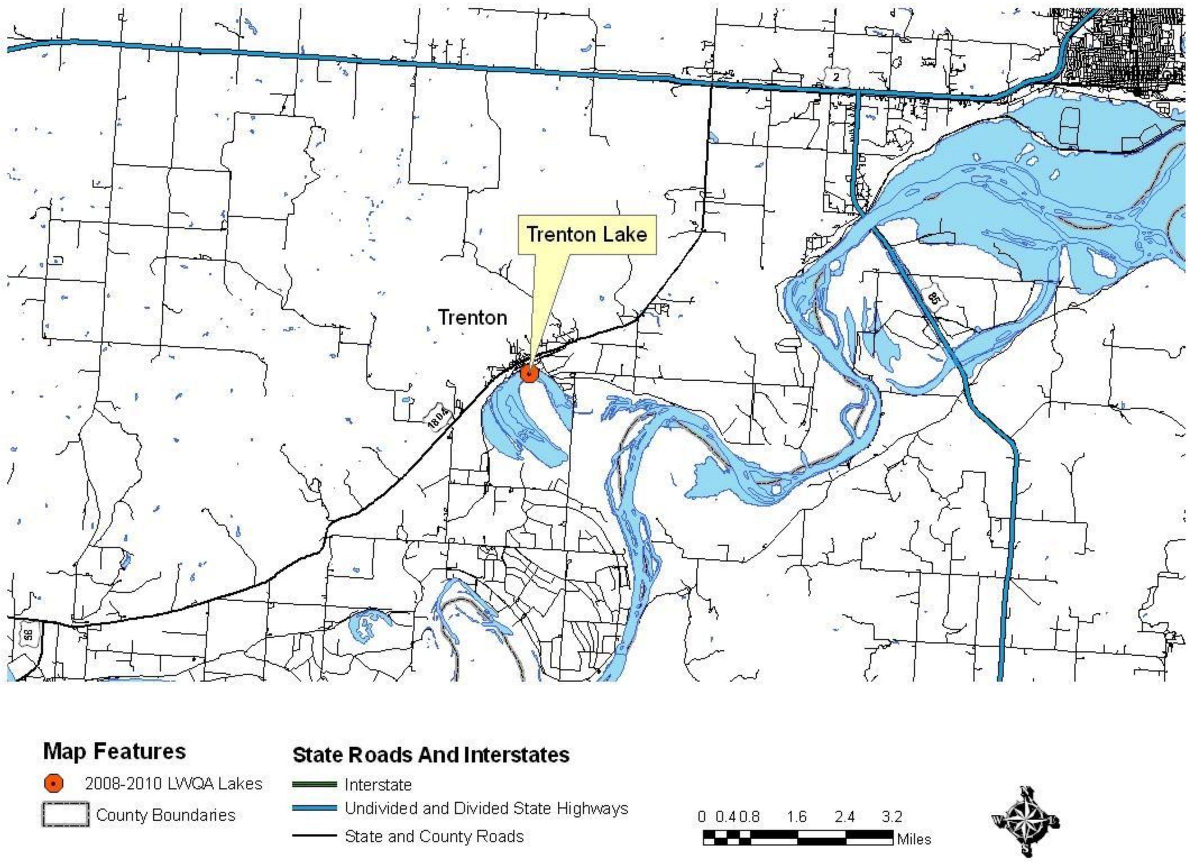

Figure 1. Location of Trenton Lake

Physiographic/Ecological Setting: Trenton Lake has a surface area of 662 acres with a maximum depth of 9 ft and an average depth of 4.3 ft (Figure 2). The lake's depth varies annual and seasonally with the ebb and flow of the Missouri River. The lake is located within the Northwestern Great Plains Level III Ecoregion, which is part of the broader Rangeland Plains region (Figures 3 and 4).

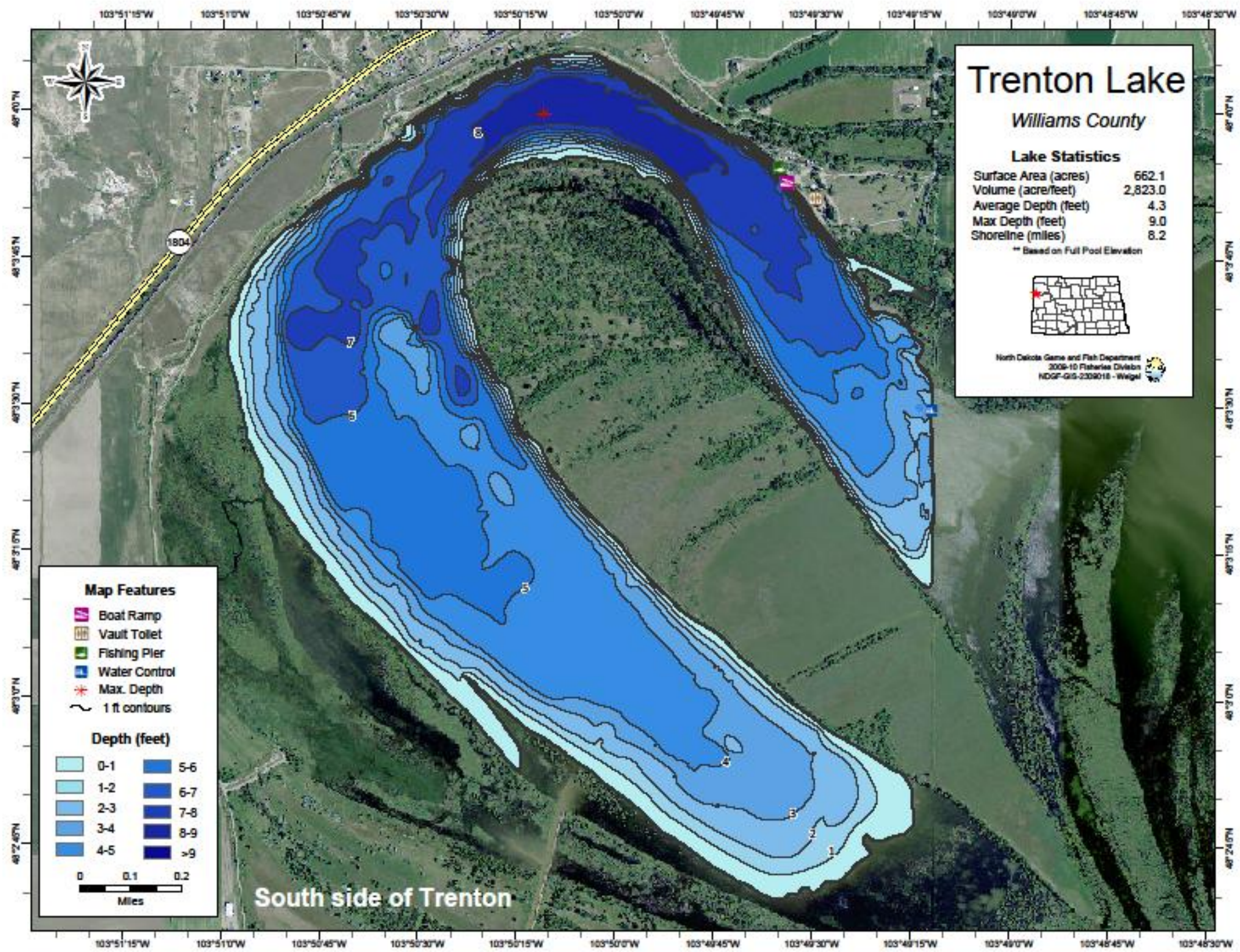

Figure 2. Contour Map of Trenton Lake (Courtesy of the North Dakota Game and Fish Department)

Recreational Facilities: Recreational facilities at Trenton Lake are extensive and well maintained. Facilities include a cement boat ramp, courtesy dock, parking, vault toilet, swimming beach, small picnic, and overnight camping. The lake facilities are situated in the scenic Missouri River bottoms, an excellent destination for water based recreation. Access is good from well marked paved roads.

Water Quality Standards Classification: Trenton Lake is classified in the state "Standards of Quality for Waters of the State" (NDDoH, 2011) as a class 3 lake. Class 3 lakes or reservoirs are defined as a "warm water fishery" or "waters capable of supporting natural reproduction and growth of warm water fishes (e.g., largemouth bass and bluegill) and associated aquatic biota. Some cool water species may also be present."

Historical Water Quality Sampling: No historical water quality data.

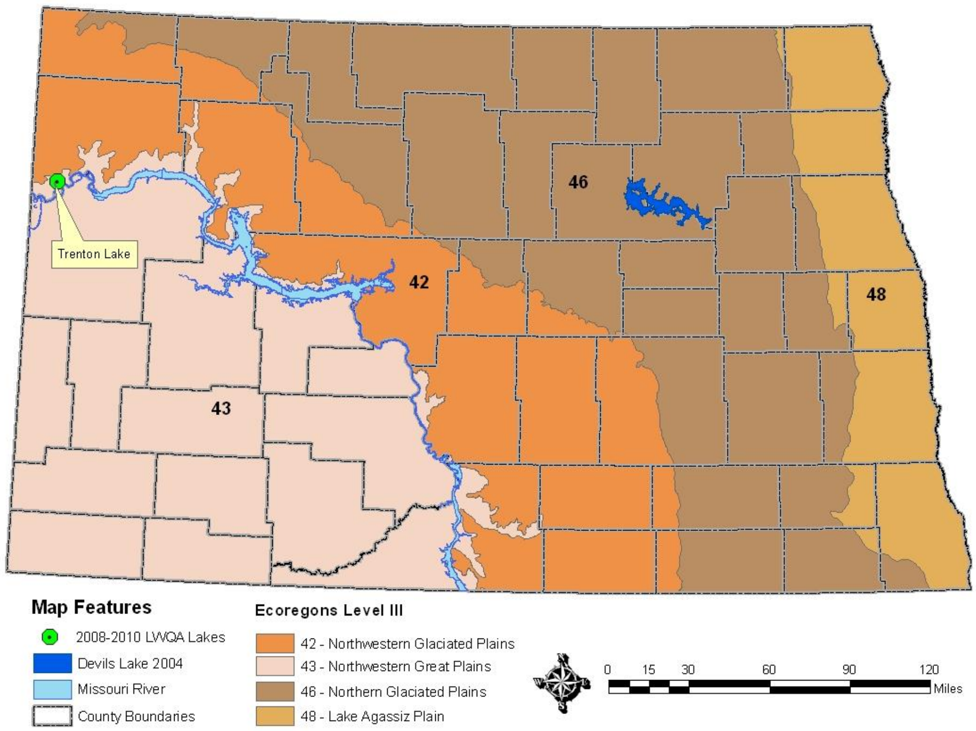

Figure 3. Trenton Lake's Location and the Level III Ecoregions

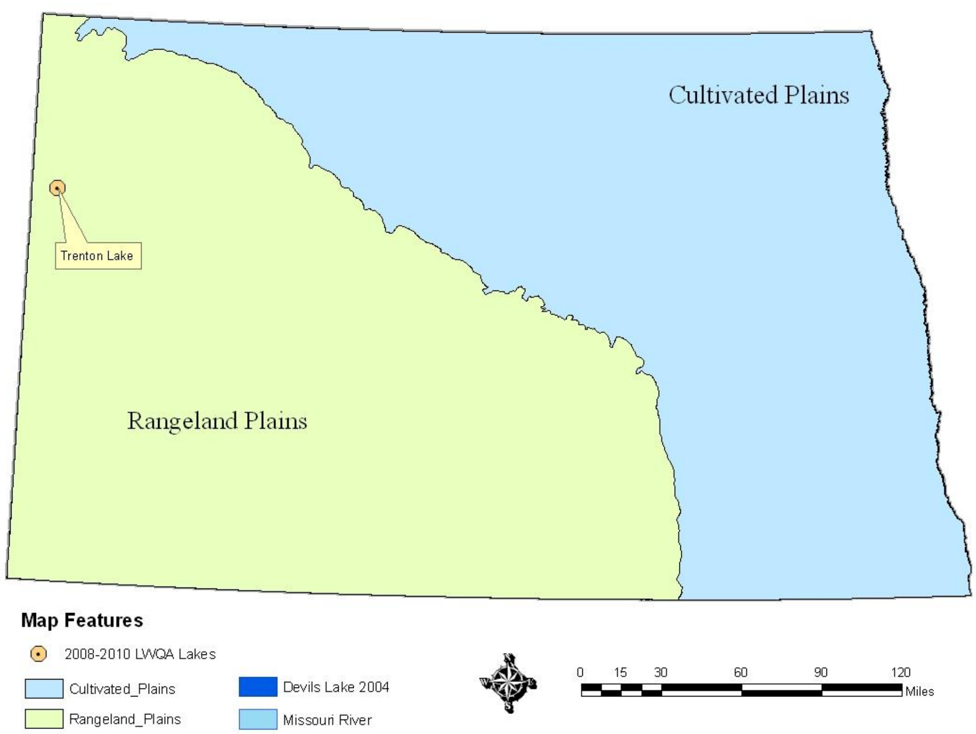

Figure 4. Trenton Lake Location and the Cultivated and Rangeland Plans Regions

WATER QUALITY MONITORING RESULTS

The water quality assessment for Trenton Lake is presented in four general categories: 1) temperature and dissolved oxygen profile results; 2) general water quality characterization; 3) nutrient limitation; and 4) trophic status. Additionally, where appropriate, results have been compared to regional data.

Temperature and Dissolved Oxygen Profile Results: There are three temperature and dissolved oxygen profiles for Trenton Lake collected in 2009 (Figure 5). The profile data shows that Trenton Lake was not thermally stratification during the open monitoring water period. Additionally during the open water period the lake remained well enough oxygenated to support aquatic Life (Figure 6).

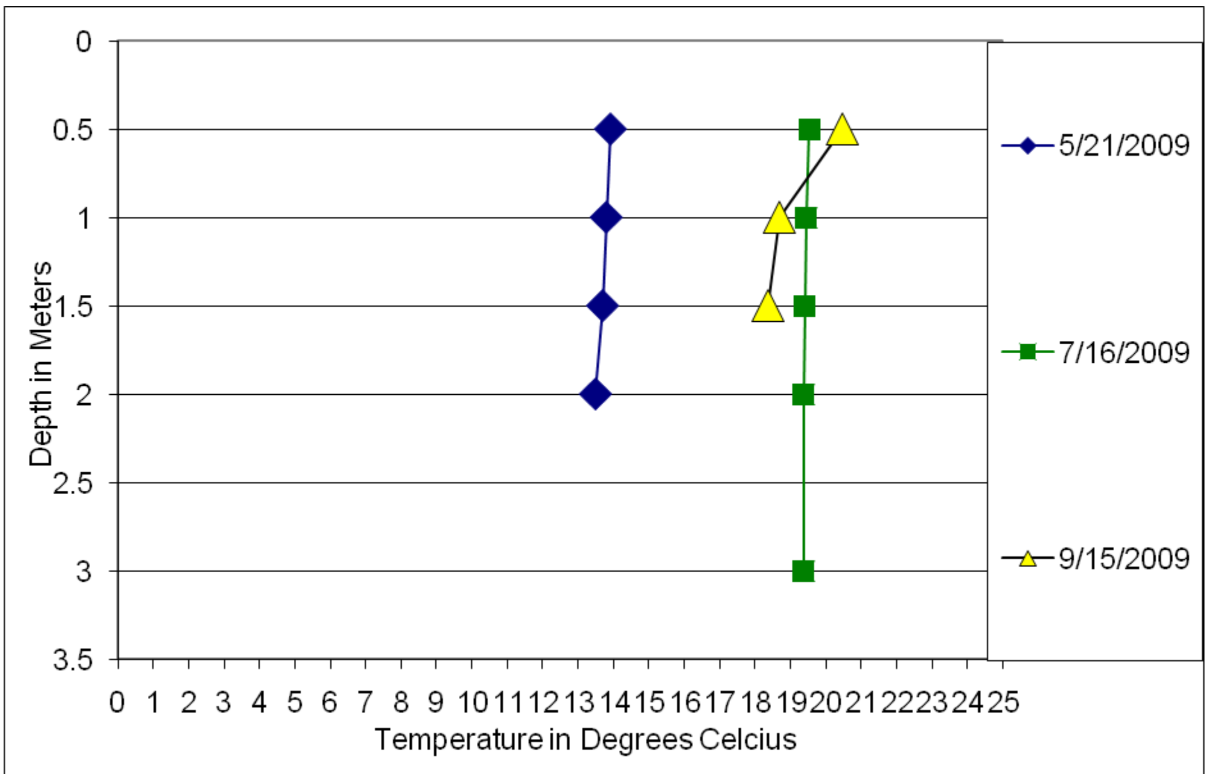

Figure 5. Temperature Profiles for Trenton Lake

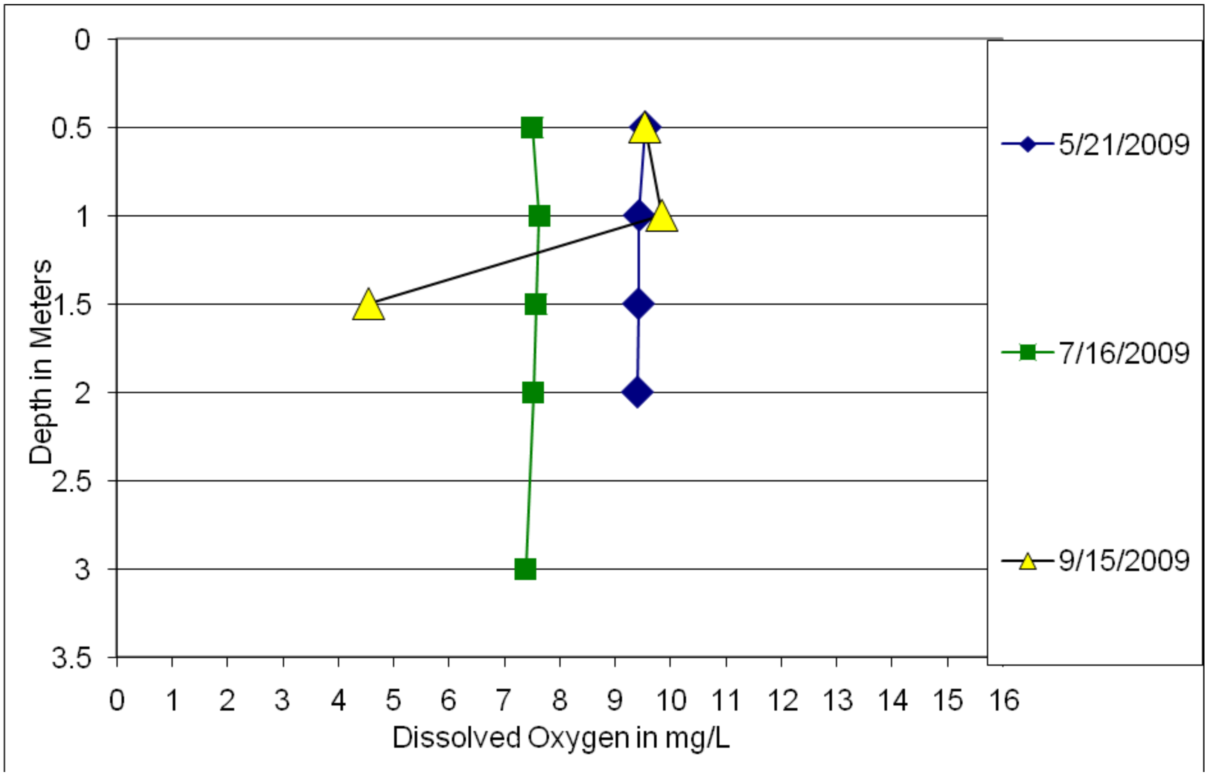

Figure 6. Dissolved Oxygen Profiles for Trenton Lake

General Water Quality: Data collected in 2009 indicates that Trenton Lake is well buffered with total alkalinity as $CaCO_3$ concentrations ranging from 175 to 212 mg/L (Table 1). The lake is sodium bicarbonate dominated with an average sodium concentration of 80.4 mg/L and an average bicarbonate concentration of 220 mg/L. The average total dissolved solids concentration and specific conductance measurement for 2009 sampling period were 475 mg/L and 755 µmhos/cm respectively, and the average total nitrogen as N and total phosphorus as P concentrations were 0.334 mg/L and 0.028 mg/L respectively.

When compared to water quality for natural lakes in the Rangeland Plans region, Trenton Lake is substantially fresher less eutrophic than most (Table 3). For example, the regional average TDS, total nitrogen and total phosphorus concentrations are 1466 mg/L, 1.794 mg/L and 0.233 mg/L respectively, compared to Trenton Lake's average TDS, total nitrogen, and total phosphorus concentrations of 475 mg/L, 0.334 mg/L, and 0.028 mg/L, respectively.

Table 1. Statistical Summary of Trenton Lake's 2009 Water Quality Data

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	3	188	175	212	21
Total Ammonia as N	mg/L	3	0.030[1]	0.030[1]	0.030[1]	0.000
Bicarbonate (HCO_3)	mg/L	3	220	204	246	23
Calcium (Ca)	mg/L	3	56.3	50.0	62.7	6.4
Carbonate (CO_3)	mg/L	3	5	2	6	2
Chloride (Cl)	mg/L	3	10	9	10	1
Chlorophyll-a	µg/L	2	23.3	13.5	33.1	13.9
Specific Conductance	µmhos	3	755	626	860	119
Total Dissolved Solids	mg/L	3	475	385	544	82
Total Hardness as ($CaCO_3$)	mg/L	3	234	206	261	28
Hydroxide (OH)	mg/L	3	1.0[1]	1.0[1]	1.0[1]	0.0
Iron (Fe)	mg/L	3	1.089	0.746	1.340	0.307
Magnesium (Mg)	mg/L	3	22.8	19.8	25.4	2.8
Nitrate + Nitrite as N	mg/L	3	0.030[1]	0.030[1]	0.030[1]	0.000
Total Kjeldahl Nitrogen as N	mg/L	3	0.304	0.210	0.404	0.097
Total Nitrogen as N	mg/L	3	0.334	0.240	0.434	0.097
pH		3	8.41	8.34	8.49	0.08
Total Phosphorus as P	mg/L	3	0.028	0.020	0.035	0.008
Potassium (K)	mg/L	3	5.4	5.0	5.8	0.4
Sodium (Na)	mg/L	3	80.4	56.2	94.6	21.0
Sulfate (SO4)	mg/L	3	186	137	217	43

[1]Equal to the lower reporting limit

Limiting Nutrients: Water quality monitoring results for Trenton Lake indicate it is phosphorus limited (Figure 7). The limiting nutrient assessment is based on the assumption that either nitrogen or phosphorus is limiting algal growth with the water body, and that the ratio of total nitrogen as N to total phosphorus as P (N:P), by weight in the average algae, is approximately 15 to 1. When the N:P ratio is less than 15:1, nitrogen is assumed to be the limiting nutrient and when it exceeds 15:1, the limiting nutrient is assumed to be phosphorus.

Trophic Status Assessment: Based on the chlorophyll-a, secchi disk transparency, and total phosphorus data collected in 2009, Trenton Lake's trophic condition is estimated as eutrophic. The trophic Status Index scores ranged from a low of 53 based on total phosphorus concentrations to a high of 77 based on secchi disk transparency (Figure 8).

Table 2. Statistical Summary of Water Quality Data[2] Collected from Natural and Enhanced Lakes in the Rangeland Plains Ecological Region of North Dakota

Parameter	Units	n	Average	Minimum	Maximum	Standard Deviation
Total Alkalinity ($CaCO_3$)	mg/L	383	513	111	4770	487
Total Ammonia as N	mg/L	494	0.105	0.001[1]	2.230	0.229
Bicarbonate (HCO_3)	mg/L	383	469	60	2990	320
Calcium (Ca)	mg/L	384	41.1	0.5	282.0	34.4
Carbonate (CO_3)	mg/L	377	79	1[1]	1420	148
Chloride (Cl)	mg/L	383	44	3[1]	1070	103
Chlorophyll-a	µg/L	346	22.5	1.5[1]	292.0	37.4
Specific Conductance	µmhos	383	2028	424	20100	1976
Total Dissolved Solids	mg/L	383	1466	227	18200	1717
Total Hardness as ($CaCO_3$)	mg/L	384	529	74	2370	295
Hydroxide (OH)	mg/L	322	1.0	0.0[1]	1.0	0.2
Iron (Fe)	mg/L	385	0.245	0.001[1]	7.070	0.543
Magnesium (Mg)	mg/L	384	103.6	8.5	567.0	70.9
Nitrate + Nitrite as N	mg/L	491	0.04046	0.001[1]	0.54	0.054
Total Kjeldahl Nitrogen as N	mg/L	463	1.876	0.080	8.500	1.073
Total Nitrogen as N	mg/L	401	1.794	0.240	5.520	0.897
pH		383	8.80	7.40	9.87	0.36
Total Phosphorus as P	mg/L	501	0.233	0.002[1]	1.940	0.336
Potassium (K)	mg/L	384	34.0	3.1	356.0	37.0
Sodium (Na)	mg/L	384	299.6	16.9	4680.0	514.5
Sulfate (SO4)	mg/L	383	625	34	10500	885

[1]Equal to the lower reporting limit
[2]Data collected from 64 natural and enhanced Lakes between 1991 and 2010

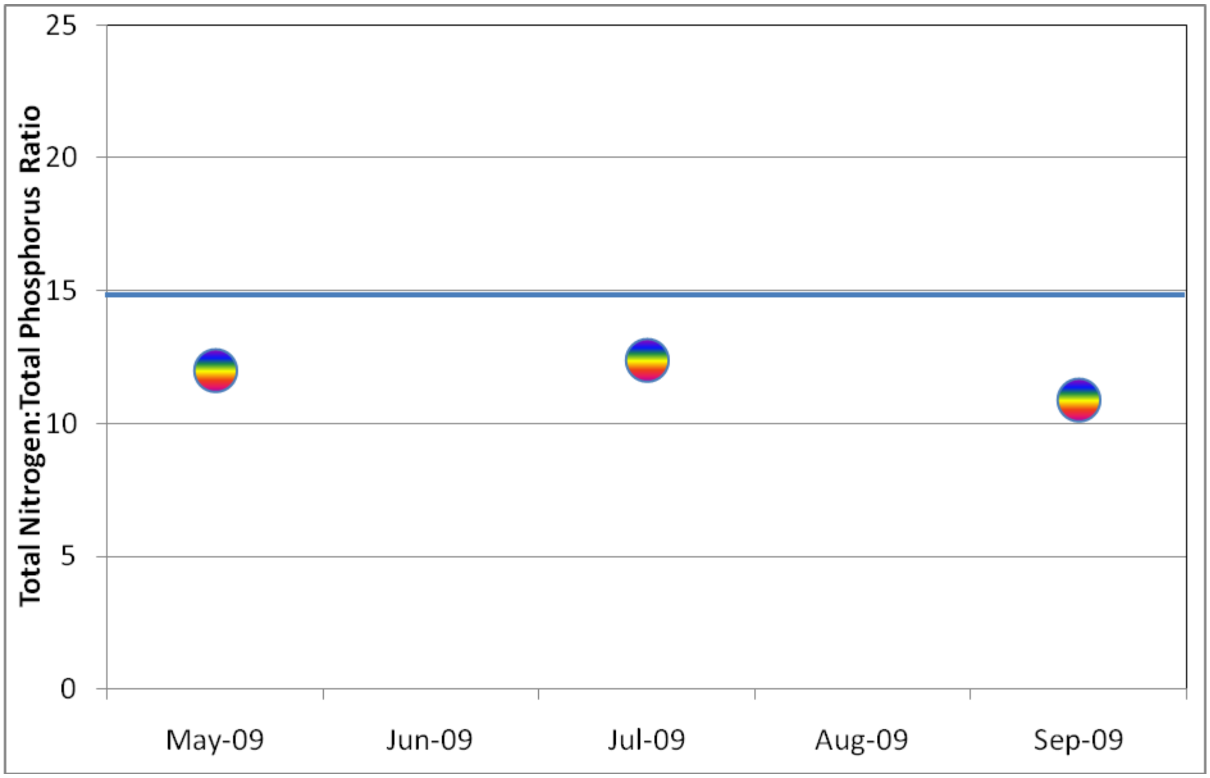

Figure 7. Trenton Lake's Total Nitrogen to Total Phosphorus Ratio

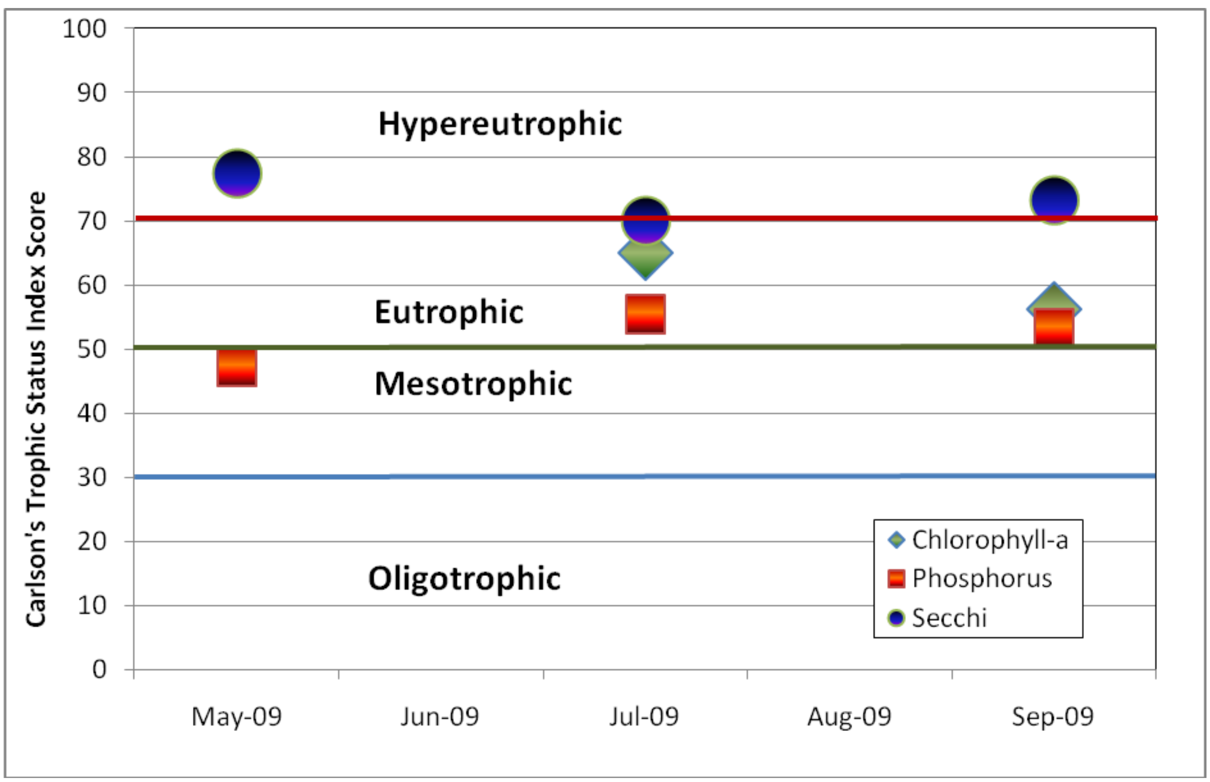

Figure 8. Trenton Lake's TSI Scores

Literature Cited

Carlson, R.E., 1997, *A Trophic Status Index for Lakes, Limnology and Oceanography*, Vol. 22 (Issue 2), pp. 361-364.

2007, *Standards of Quality for Waters of the State* (revised), North Dakota Century Code 33-16-02.1., North Dakota Department of Health, Bismarck, ND.

Omernik, J. M. 1987. Ecoregions of the conterminous United States. Annals of the Association of American Geographers 77, 118-125.

Stoddard, J.L., Peck, D.V., Olsen, A.R., Larsen, D.P., Van Sickle, J., Hawkins, C.P., Hughes, R.M., Whittier, T.R., Lomnicky, G.A., Herlihy, A.T., Kaufman, P.R., Peterson, S.A., Ringold, P.L., Paulsen, S.G., and Blair, R. 2005a. Environmental Monitoring and Assessment Program (EMAP) western streams and rivers statistical summary: U.S. Environmental Protection Agency Report 620/R-05/006, 1,762 p.

North Dakota Department of Health, August 2009, *Quality Assurance Project Plan for the 2008-2010 Lake Water Assessment Project.*