Nutrient and Dissolved Oxygen TMDLs for Brewer Lake in Cass County, North Dakota

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1.0 INTRODUCTION AND DESCRIPTION OF THE WATERSHED

Brewer Lake is a small deep reservoir on the Rush River and is located in Cass County approximately one mile south and one mile west of Erie, North Dakota. Built in 1970, Brewer Lake was constructed for the purpose of water recreation.

The Brewer Lake watershed consists of 6,107 acres of the most fertile land in the Red River Valley and is located in Cass County. The Brewer Lake watershed lies within two ecoregions the Northern Glaciated Plains ecoregion (46i); which is characterized by a flat to gently rolling landscape composed of glacial drift and (48a) the Glacial Lake Agassiz Basin which is extremely flat with thick lacustrine sediments underlain by glacial till. The subhumid climate fosters a grassland, transitional between the tall and shortgrass prairie. The historic tall grass prairie has been replaced by intensive agriculture. Though the soil is very fertile, agricultural success is subject to annual climatic fluctuations. Table 1 summarizes some of the geographical, hydrological, and physical characteristics of Brewer Lake and its watershed.

Table 1. General Characteristics of Brewer Lake and its Watershed.

Legal Name	Brewer Lake
Major Drainage Basin	Rush River Basin
Nearest Municipality	Erie, North Dakota
Assessment Unit ID	ND-09020204-003-L_00
County Location	Cass County, North Dakota
Physiographic Region	Glacial Lake Agassiz Basin and Northern Glaciated Plains
Latitude	47.09641
Longitude	-97.40907
Surface Area	124 acres
Watershed Area	6,107 acres
Average Depth	12.6 feet
Maximum Depth	31.2 feet
Volume	1,583.4 acre-feet
Tributaries	Rush River
Type of Waterbody	Recreational Impoundment
Dam Type	Earthen Dam
Fishery Type	Bluegill, Crappie, Largemouth Bass, Smallmouth Bass, and Walleye

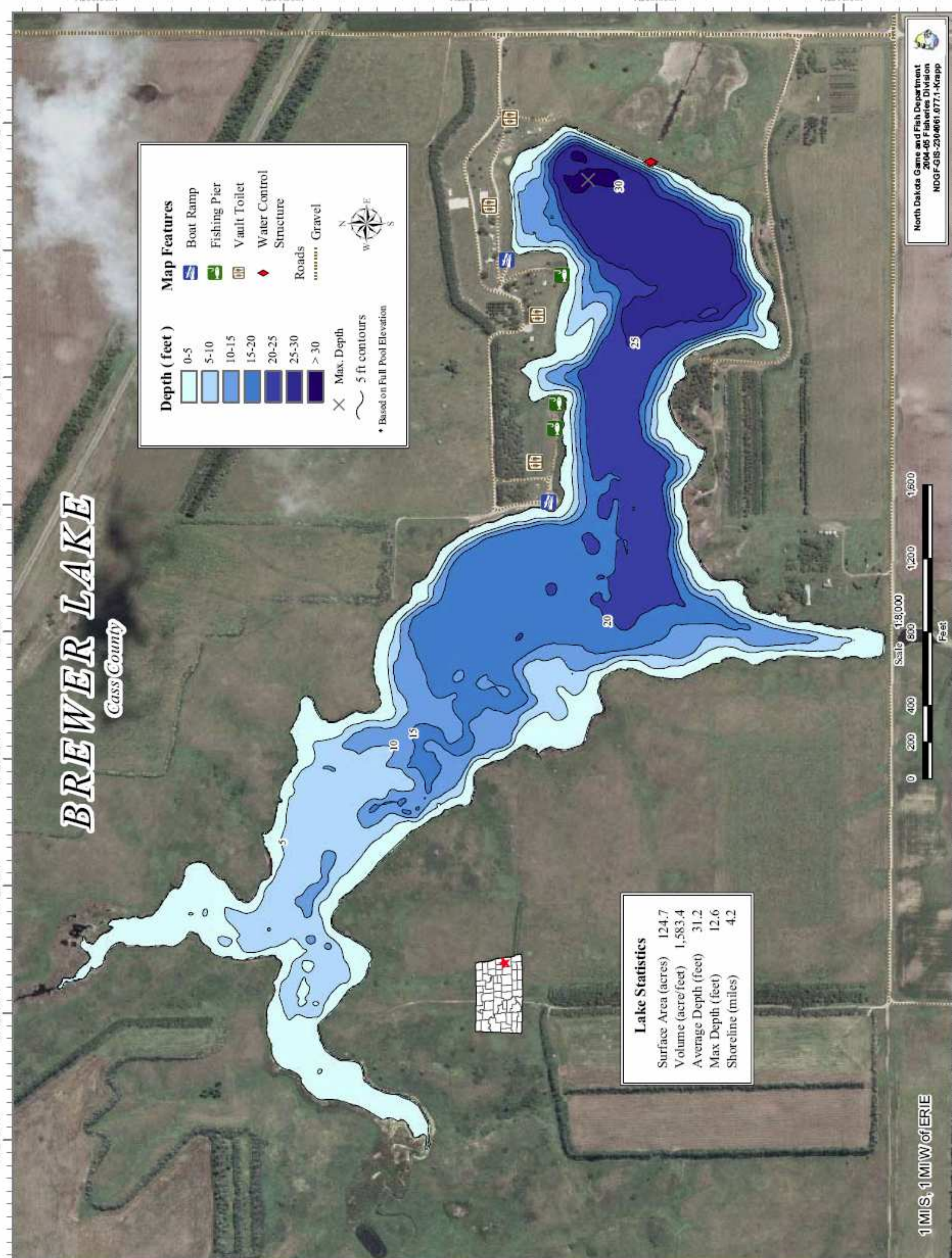

Figure 1. North Dakota Game and Fish Contour Map of Brewer Lake.

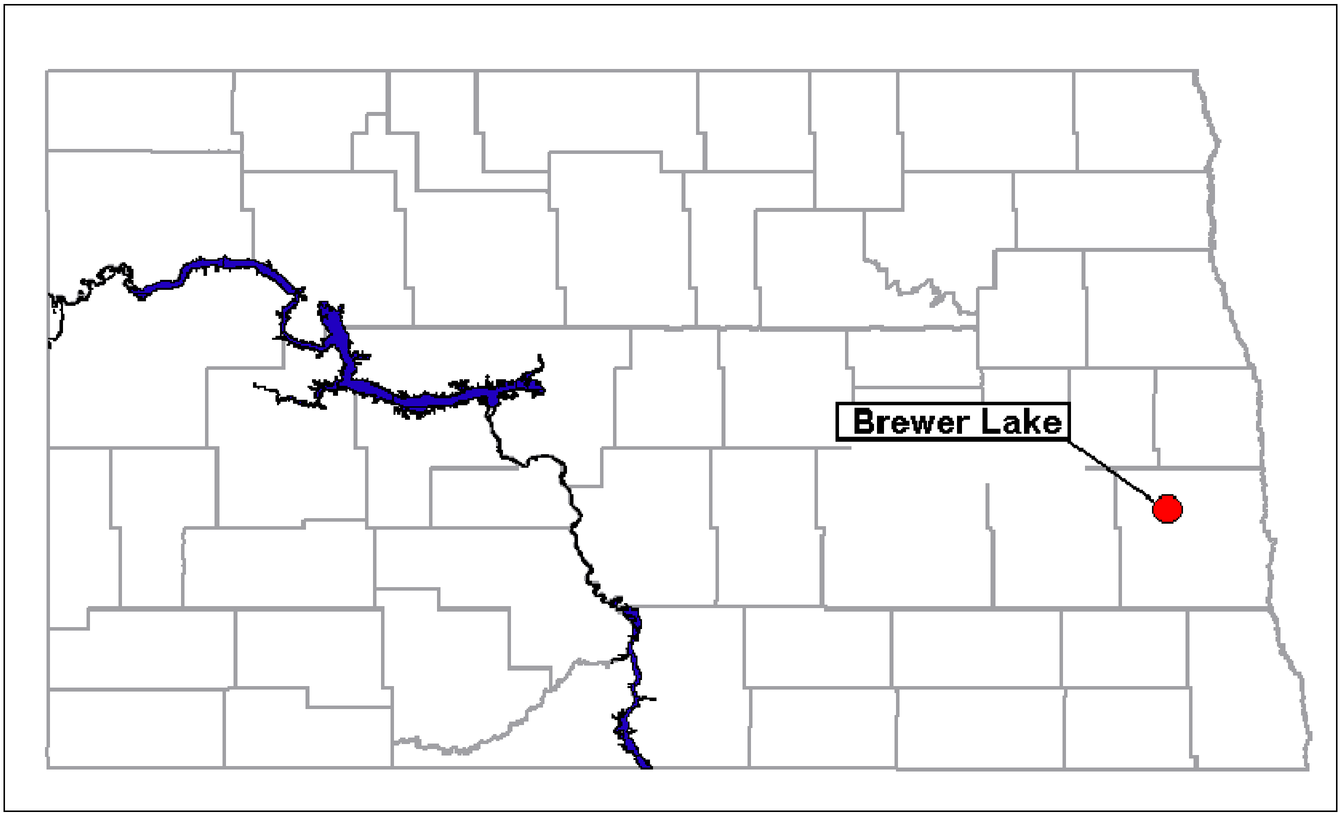

Figure 2. General Location of Brewer Lake and the Brewer Lake Watershed.

1.1 Clean Water Act Section 303(d) Listing Information

As part of the Clean Water Act section 303(d) listing process, the North Dakota Department of Health has identified Brewer Lake as an impaired waterbody (Table 2). Based on a Trophic State Index (TSI) score, aquatic life and recreation uses of Brewer Lake are impaired. Aquatic life is listed as impaired due to nutrients, sedimentation, and low dissolved oxygen. Recreational use is impaired due to nutrients. North Dakota's Section 303(d) list did not provide any potential sources of these impairments. As reflected in its title, this TMDL report only addresses the nutrient impairments for aquatic life and recreation use and the low dissolved oxygen impairment for aquatic life use. Sediment remains as a Section 303(d) TMDL listed pollutant threatening aquatic life use. Currently, there are not adequate data available to address the sediment TMDL listing. As additional monitoring data become available (e.g., through a Section 319 Watershed Implementation and Lake Restoration Project) a TMDL (or de-listing justification) will be prepared to address this pollutant.

Brewer Lake has been classified as a Class 2 cool-water fishery, "capable of supporting natural reproduction and growth of cool water fishes (i.e. walleye and northern pike) and associated aquatic biota and marginal growth and survival of cold water species and associated biota" (NDDoH, 2006).

The fishery that was initially established within the reservoir in 1970 consisted of rainbow trout with plans of developing a secondary walleye fishery. The walleye fishery improved each year while the trout fishery declined due to fish kills and potential inferior stock.

Subsequent stockings have included rainbow trout, walleye, and largemouth bass. In 1991, test netting results showed the fish community of bluegills, smallmouth bass, and walleye.

Table 2. Brewer Lake Section 303(d) Listing Information (NDDH, 2004).

Assessment Unit ID	ND-09020204-003-L_00
Waterbody Name	Brewer Lake
Class	2-Cool-water fishery
Impaired Uses	Fish and Other Aquatic Biota (fully supporting but threatened), Recreation (fully supporting but threatened)
Causes	Nutrients, Dissolved Oxygen, Sedimentation
Priority	High
First Appeared on 303(d) list	1998

1.2 Topography

The topography of Cass County is characterized by its association with two physiographic regions. The eastern seventy five percent of the county is contained in the Lake Agassiz Plain while the remaining one fourth falls within the Drift Prairie. The Lake Agassiz Plain is comprised of the Sheyenne Delta and beach ridge of glacial Lake Agassiz. Local relief in Cass County ranges from 5-20 feet. Western Cass County lies within the glaciated plain which is interrupted only by minor glacial landforms and stream valleys. Land surfaces vary from rolling to nearly flat. Relief ranges from 10-20 feet per mile but can rise to as much as 40 feet in some areas. Soils in Cass County range from silty to clayey in texture. Most have high water tables and are very productive. Common soil series are Bearden, Hegne, Glyndon, Ulen, Fargo, Gardena, Embden, Ryan. These soils are deep, well to poorly drained with moderately slow permeability. Figure 3 shows the hydrological soil classification map of Cass County.

1.3 Land Use/Land Cover

Land use in the Brewer Lake watershed is primarily agricultural (86%). Approximately 81% of the land is active cropland with the other 19% in low density urban development, haylands, pasture, water, or in the conservation reserve program (CRP). The majority of the crops grown consist of wheat, soybean, dry beans, corn and sunflowers (Figure 4).

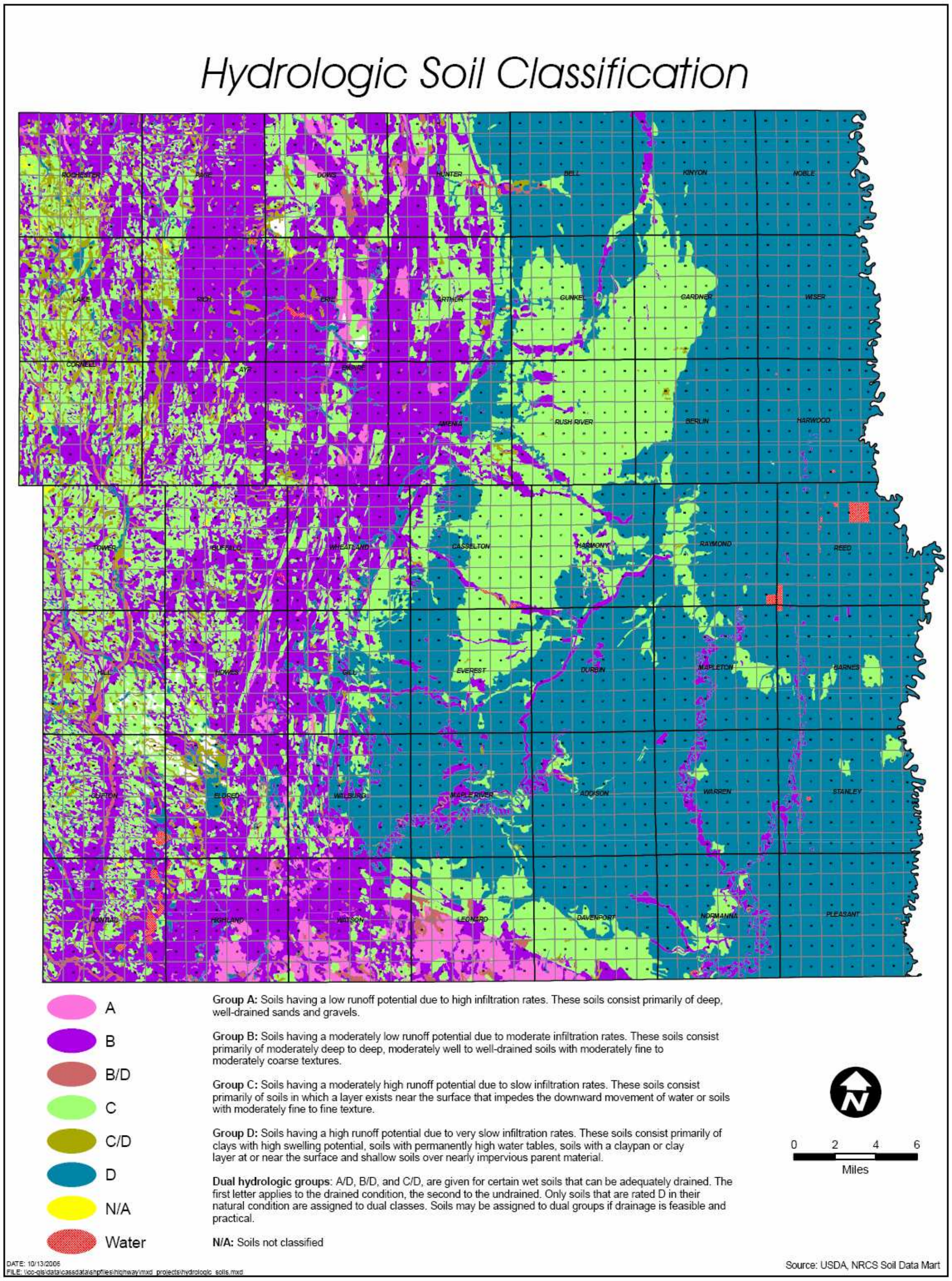

Figure 3. Hydrologic Soil Classification for Cass County. Courtesy of the Natural Resource Conservation Service (NRCS) 2006.

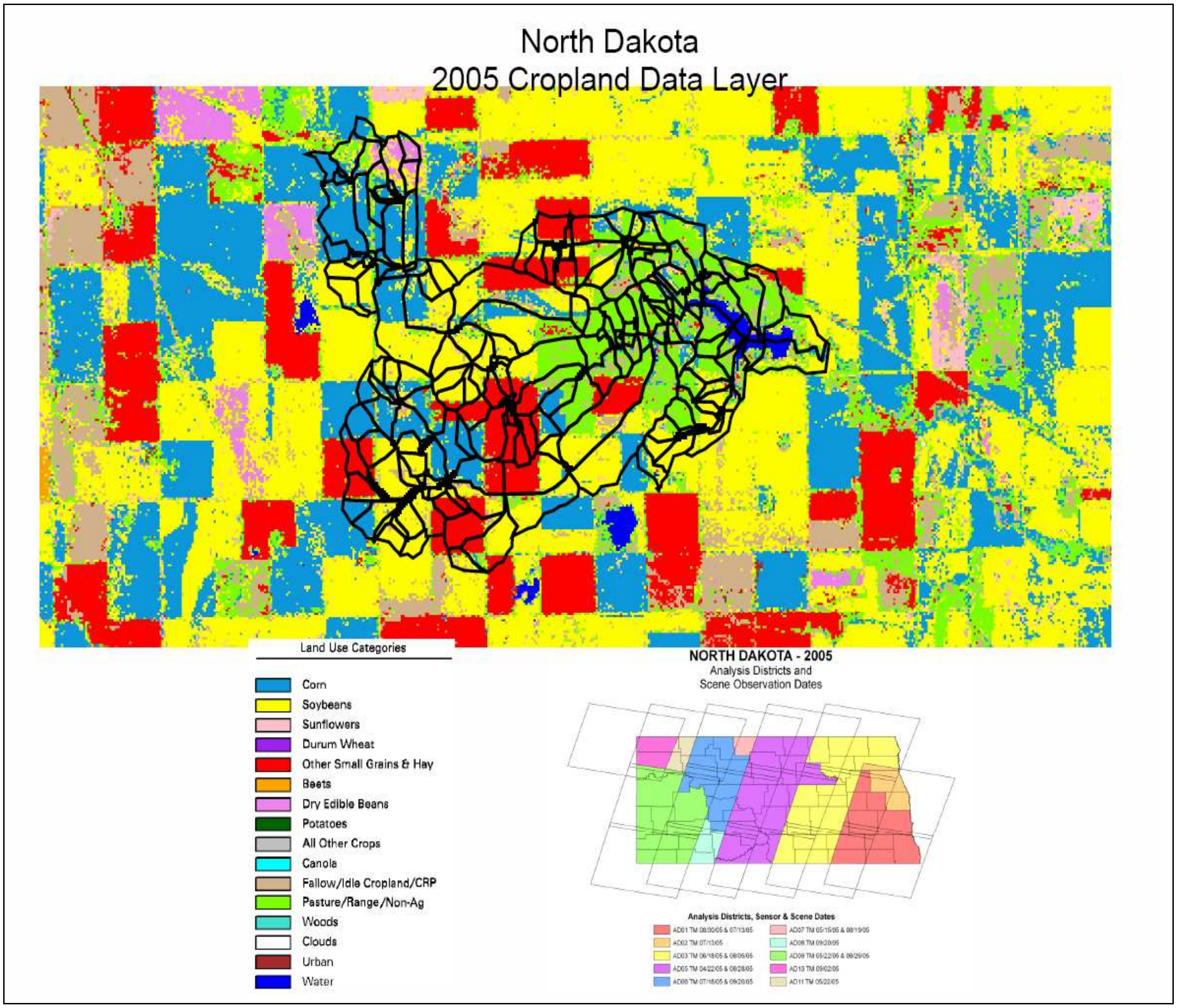

Figure 4. Cropland and Landuse of the Brewer Lake Watershed National Agricultural Statistics Service (NASS) 2005.

1.4 Climate and Precipitation

Cass County has a subhumid climate characterized by quite warm summers with frequent hot days and occasional cool days. Winters are very cold influenced by blasts of arctic air surging over the area. Average temperatures range from 20º F in winter to 68º F in summer. Precipitation occurs primarily during the warm period and is normally heavy in later spring and early summer. Total average annual precipitation for Cass County is about 16 inches. About 12 inches or 80 percent of rain falls between April and September. Average seasonal snowfall is approximately 31 inches. Winds prevail generally from the north at an annual average wind speed of 14 mph. Figure 5 and 6 shows the annual precipitation and temperature for Cass County from 1996-2006.

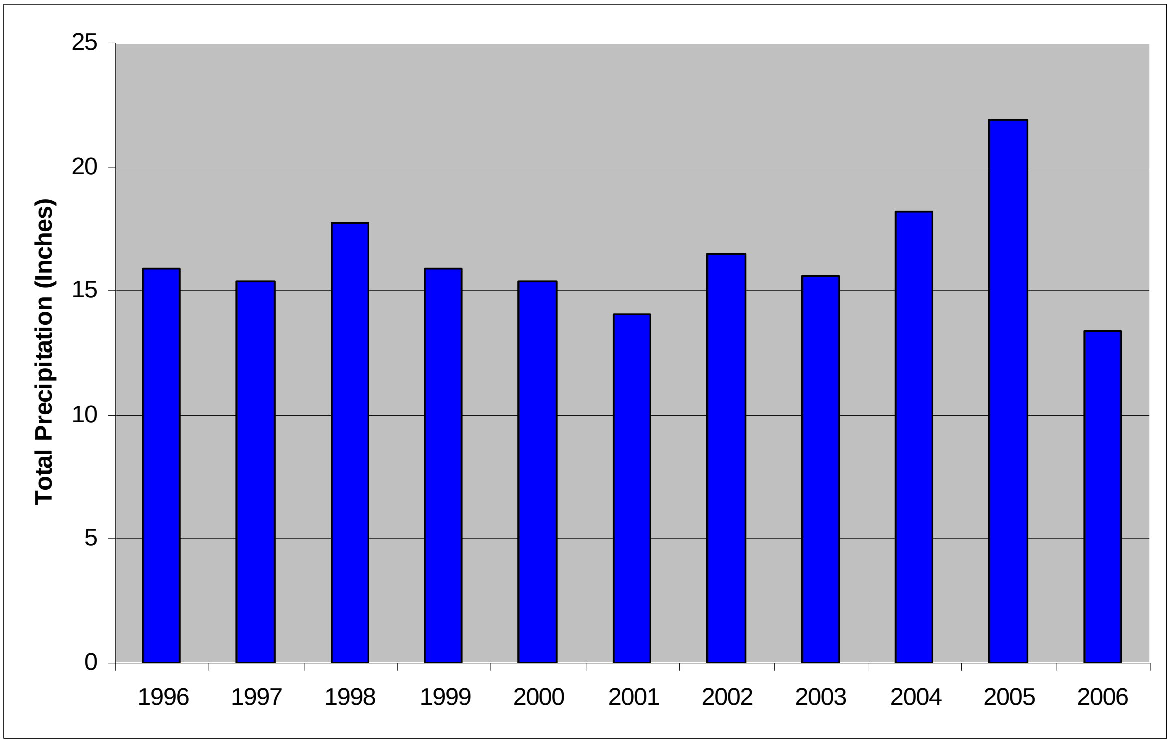

Figure 5. Total Annual Precipitation at Galesburg, North Dakota from 1996-2006. North Dakota Agricultural Weather Network (NDAWN).

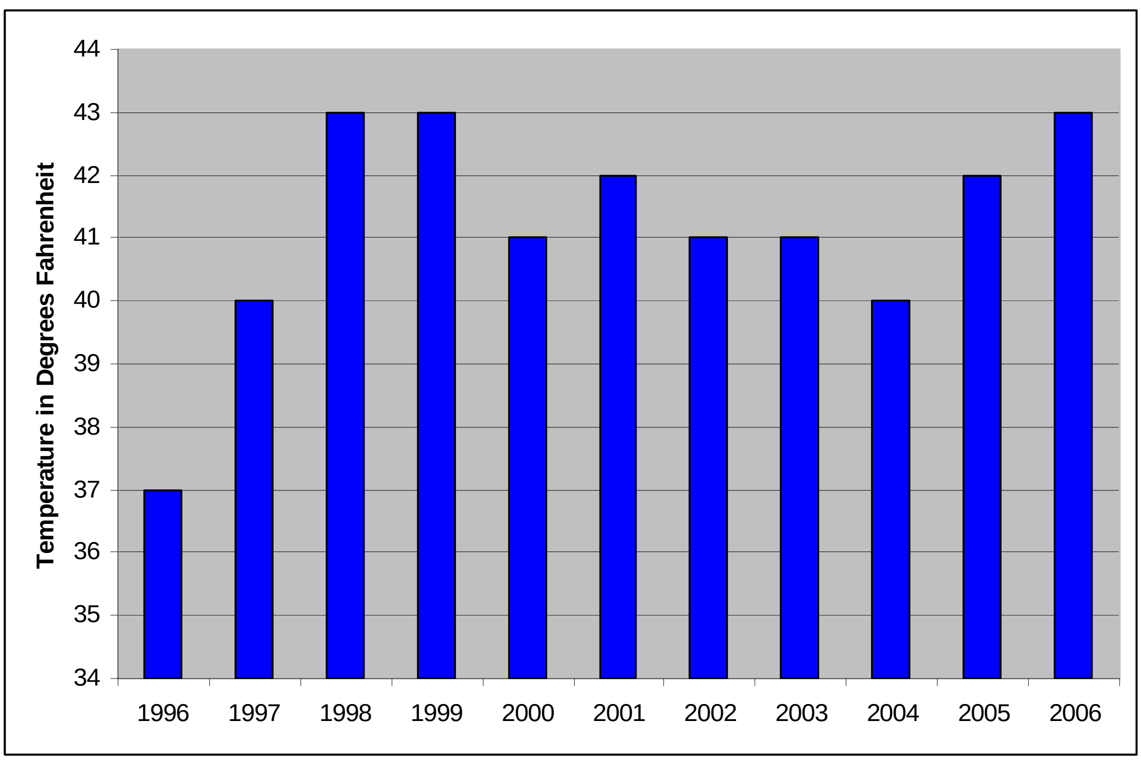

Figure 6. Average Annual Temperature at Galesburg, North Dakota from 1996-2006. North Dakota Agricultural Weather Network (NDAWN).

1.5 Available Water Quality Data

1.5.1 1991-1992 Lake Water Quality Assessment Project

A Lake Water Quality Assessment Project (LWQA) was conducted on Brewer Lake in 1991-1992. Two samples were collected in the summer of 1991 and once during the winter of 1992. Samples were collected at one site located in the deepest area of the lake (381010). During summer sampling in July and August of 1991 Brewer Lake was thermally stratified at 7 and 1 meters respectively. Dissolved oxygen concentration during this time period indicated saturation at a depth of 1 meter and falling to 1.0 mg L^{-1} or less at the bottom of the lake. Winter sampling in February of 1992 showed no thermal stratification and dissolved oxygen concentrations ranging from 9.2 mg L^{-1} at the surface to 1mg L^{-1} near the bottom.

The 1991-1992 LWQA Project characterized Brewer Lake as having a volume weighted mean concentration of total phosphate as phosphorus of 0.188 mg L^{-1}, which exceeded the State's target concentration of 0.02 mg L^{-1} during all sampling occasions. Nitrate + Nitrite as nitrogen exhibited a volume weighted mean concentration of 0.100 mg L^{-1}. According to State standards, this is below the target concentration of 0.25 mg L^{-1}. Other sample parameters and average volume weighted mean concentrations are provided in Table 3. A volume-weighted mean was calculated using a stratified sampling technique to describe the general chemical characteristics of the reservoir. The volume-weighted mean was calculated by weighting the parameter analyzed by the percentage of water volume represented at each depth interval.

Trophic status was also determined using the water quality data collected during the LWQA project. Brewer Lake was identified as being hypereutrophic. This was determined based on summer total phosphate as phosphorus concentrations and secchi disk transparency. Total phosphate concentrations averaged 0.199 mg L^{-1} and secchi disk transparency averaged 1.0 meter.

Table 3. Data Summary for Brewer Lake's Lake Water Quality Assessment (1991-1992).

Parameter	Units	Lake Water Quality Assessment (1991-1992)			
		Max	Median	Avg	Min
Total Phosphorus	mg L^{-1}	1.23	0.185	0.340	0.106
Dissolved Phosphorus	mg L^{-1}	1.23	0.127	0.312	0.093
Total Nitrogen	mg L^{-1}	4.89	0.192	0.953	0.011
Total Kjeldahl Nitrogen	mg L^{-1}	5.94	2.24	2.75	1.41
Nitrate/Nitrite	mg L^{-1}	0.377	0.011	0.082	0

1.5.2 2004-2005 Brewer Lake TMDL Project

The Cass County Soil Conservation District (SCD) conducted a water quality assessment of Brewer Lake and its watershed from April 2004 to October 2005. Sampling was done on three inlet sites (385305, 385306, and 385307), one outlet site (385304), and one reservoir sites (381010) on Brewer Lake and accompanying watershed. Sites are identified in Table 4, and Figures 7 and 8.

Stream Monitoring

Sampling frequency for the stream sampling sites was stratified to coincide with the typical hydrograph for the region. This sampling design resulted in more frequent samples during spring and early summer, typically when stream discharge is greatest and less frequent samples during the summer and fall. Sampling was discontinued during the winter during ice cover. Sampling was also terminated if the stream stopped flowing. If the stream should begin flow again, water quality sampling was reinitiated.

Lake Monitoring

In order to accurately account for temporal variation in lake water quality, the lake was sampled twice per month during the open water season and monthly under ice cover conditions.

Table 4. General Information for Water Sampling Sites for Brewer Lake.

Sample Site	Site ID	Dates Sampled		Latitude	Longitude
		Start	End		
Stream Sites					
Outlet	385304	05/06/2004	10/31/2005	47.09641	-97.40907
South West Inlet	385305	06/03/2004	07/07/2005	47.09671	-97.43854
West Inlet	385306	06/03/2004	10/31/2005	47.09486	-97.47245
North West Inlet	385307	05/25/2004	10/31/2005	47.10917	-97.45071
Lake Sites					
Deepest	381010	04/28/2004	09/22/2005	47.09778	-97.41286

The Cass County SCD followed the methodology for water quality sampling found in the QAPP Quality Assurance Project Plan for the Brewer Lake TMDL Project. (NDDoH, 2004) Sampling and analysis variables are shown in Table 5.

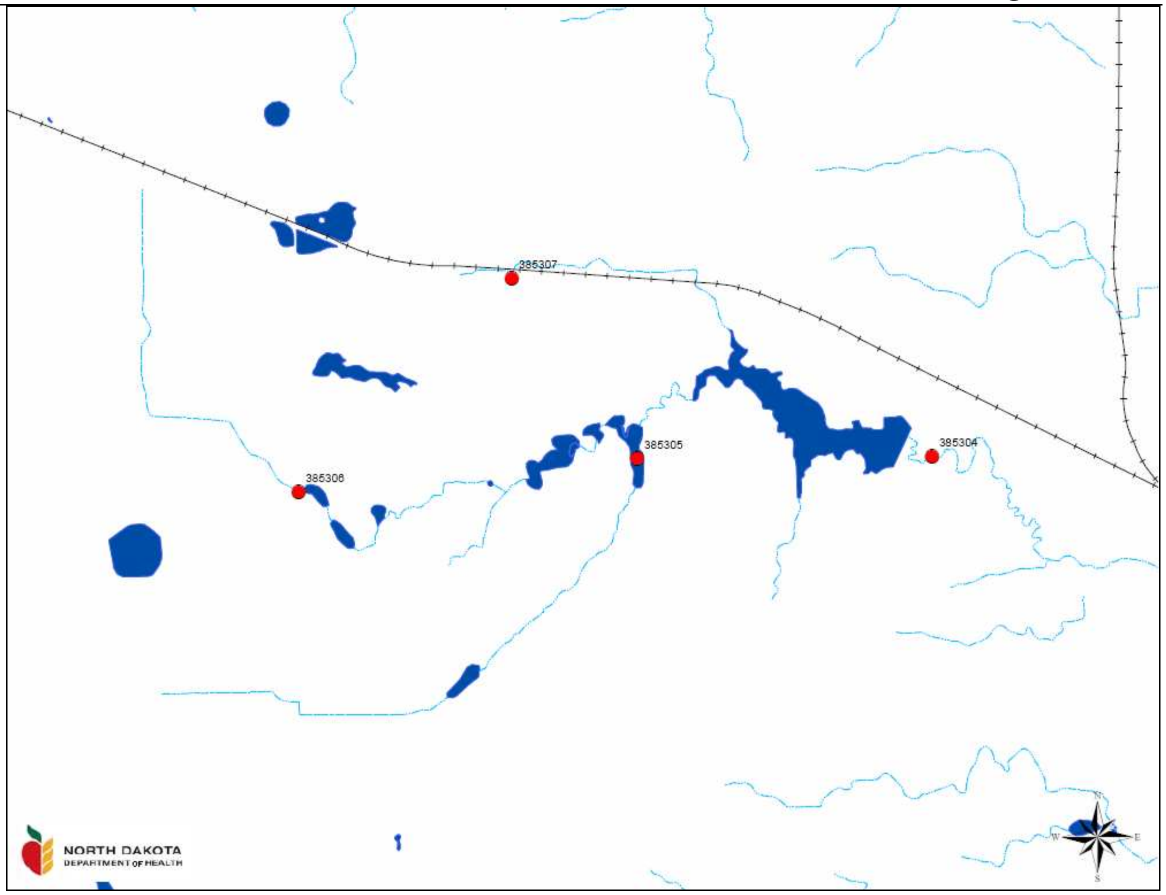

Figure 7. Stream Sampling Sites for Brewer Lake.

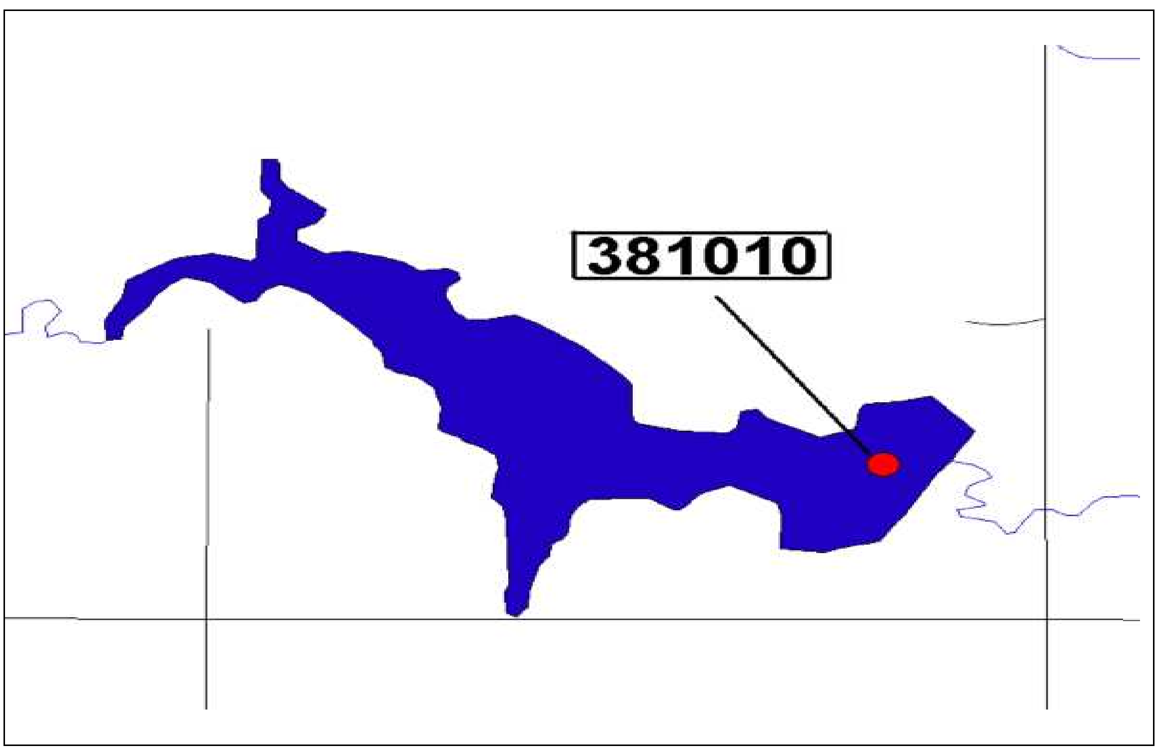

Figure 8. Lake Sampling Sites for Brewer Lake.

Table 5. Brewer Lake Sampling and Analysis Parameters.

Field Measurements	General Chemical Variables	Nutrient Variables	Biological Variables
Secchi Disk Transparency	Lab pH	Total Phosphorus	Chlorophyll-a
Temperature	Lab Specific Conductance	Dissolved Phosphorus	Phytoplankton
Dissolved Oxygen	Major Anions & Cations	Total Nitrogen	
	Total Suspended Solids	Total Kjeldahl Nitrogen	
		Nitrate plus Nitrite Nitrogen	
		Ammonia Nitrogen	

1.5.3 pH and Nutrient Data

Surface water quality parameters were monitored in Brewer Lake at one site between April 2004 and October 2005. A data summary table for this site is summarized in Table 6. Laboratory pH measurements ranged from 7.46 to 8.86 with a geometric mean of 8.54. All pH measurements were within the state water quality standard of 6 to 9. The data shows average total phosphorus and dissolved phosphorus concentration values for this site are at 0.162 mg L^{-1} and 0.100 mg L^{-1}. Total Kjeldahl nitrogen and nitrate/nitrite values are 0.930 mg L^{-1} and 0.090 mg L^{-1}. Total nitrogen had a value of 1.018 mg L^{-1}.

Table 6. Data Summary for Brewer Lake TMDL Project 2004-2005.

Parameter	Deepest Site (381010)				
	N	Max	Median	Avg	Min
Total Phosphorus (mg L^{-1})	25	1.24	0.116	0.162	0.013
Dissolved Phosphorus (mg L^{-1})	26	0.504	0.071	0.100	0.004
Total Nitrogen (mg L^{-1})	25	1.96	0.923	1.018	0.653
Total Kjeldahl Nitrogen (mg L^{-1})	25	1.94	0.87	0.930	0.55
Nitrate/Nitrite (mg L^{-1})	25	0.94	0.04	0.090	0.02
Lab pH	26	8.86	8.49	8.54*	7.46
Chlorophyll-a (µg/L)	25	43.1	5.7	11.67	1.5

*Expressed as the geometric mean

Nutrient concentrations from Brewer Lake in 2004-2005 can be compared to data collected from the 1991-1992 Lake Water Quality Assessment. Nutrient concentrations reported for the 2004-2005 TMDL Project were lower for total phosphorus, dissolved phosphorus, total nitrogen and total Kjeldahl nitrogen but higher for nitrate/nitrite (Tables 3 and 6).

1.5.4 Dissolved Oxygen and Temperature

Dissolved oxygen and temperature were monitored in Brewer Lake from April 2004 thru October 2005 at the deepest site (381010). Brewer Lake demonstrated strong stratification on July 21, 2004. Stratification occurred at 3, 4 and 8 meters respectively. Dissolved oxygen levels at that time ranged from 8.8 mg L^{-1} at 1-meter and falling to 0.05 mg L^{-1} at the bottom. Brewer Lake also experiences periodic weak thermal stratification during the hottest times of the summer (June-August) and once in the winter (February) (Figures 9 and 11).

Dissolved oxygen concentrations dropped below the State's minimum standard concentration of 5.0 mg L^{-1} at varying depths throughout the year. The midwinter and the hot summer months appear to be the most critical time period for maintaining dissolved oxygen concentrations. Concentrations dropped below the State standard of 5.0 mg L^{-1} at a depth of approximately 6 meters at the deepest site and continued to a depth of 8 meters during January and February 2005. During the summer months of July thru August dissolved oxygen concentrations began to fall below the 5.0 mg L^{-1} standard at a depth of 5 meters to the bottom 8 meters during 2004 and 2005. (Figure 10 and 12).

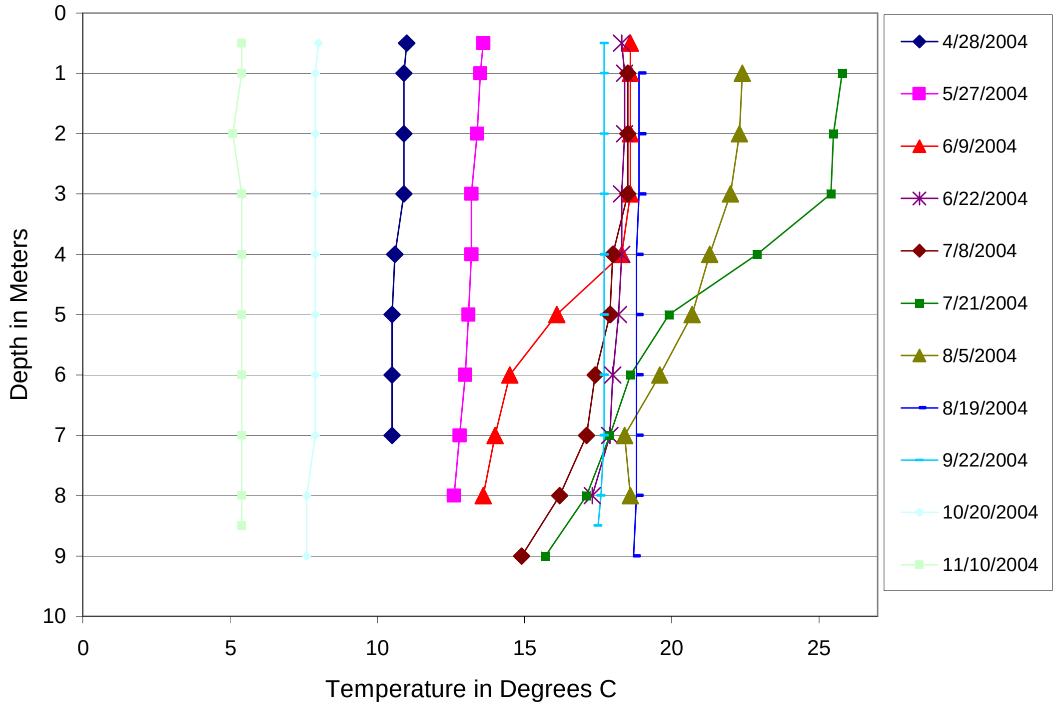

Figure 9. Summary of Temperature Data for the Brewer Lake Deepest Site (381010) for 2004.

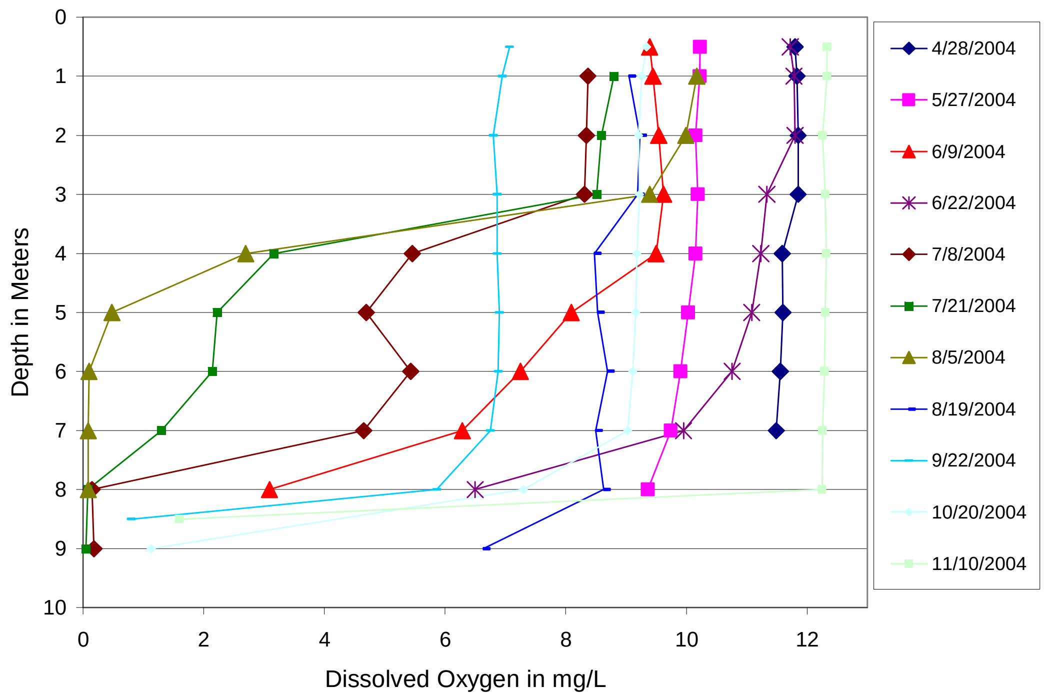

Figure 10. Summary of Dissolved Oxygen Concentration for the Brewer Lake Deepest Site (381010) for 2004.

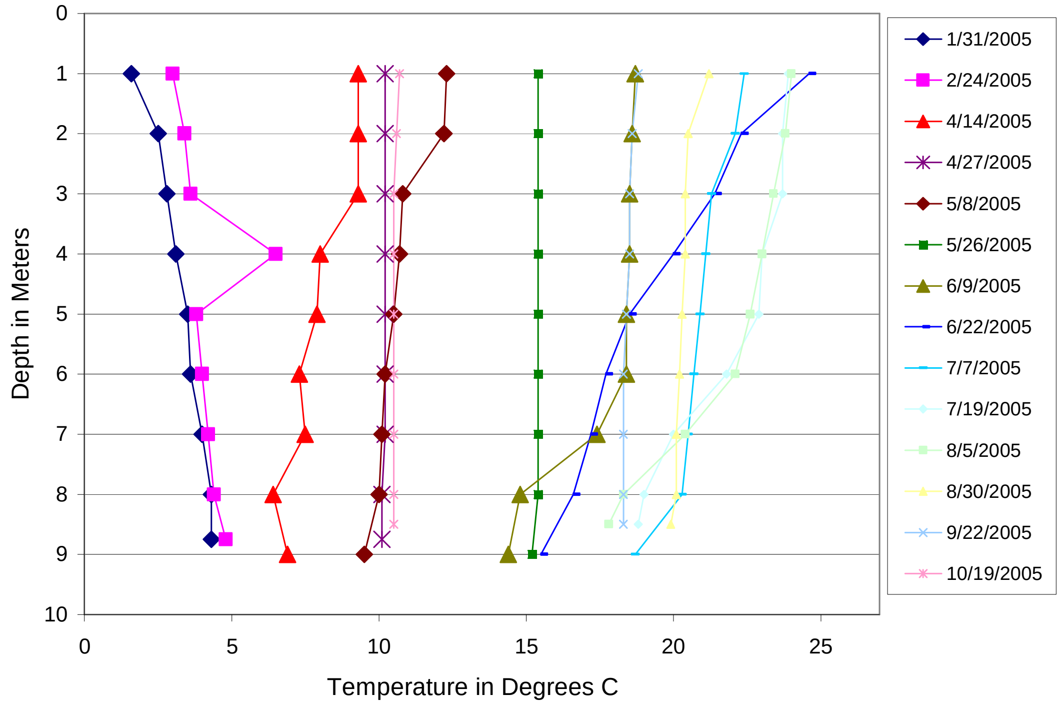

Figure 11. Summary of Temperature Data for the Brewer Lake Deepest Site (381010) for 2005.

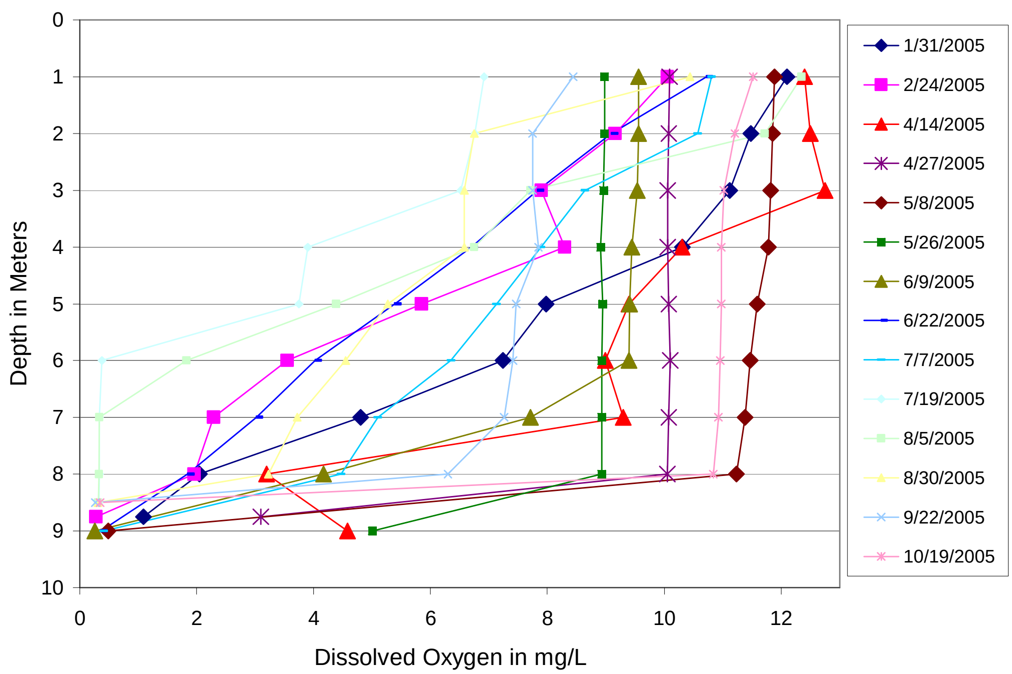

Figure 12. Summary of Dissolved Oxygen Concentration for the Brewer Lake Deepest Site (381010) for 2005.

1.5.5 Secchi Disk In-Lake and Total Suspended Solids

Secchi disk depth data was collected by the Cass County SCD staff between April 2004 and October 2005. As shown in Table 7 secchi depths appear to be greatest in May with values ranging from 2.25-4.00 meters. As summer continues secchi depth appears to decrease to its lowest depths in August with values ranging 1.00-1.75 meters, and then rebounding in October and November. Available data indicates a rise in trophic condition during the warmest and most productive period of the year.

Table 7. Summary of Secchi Depths in Brewer Lake (2004-2005).

Deepest Site (381010)									
Date	Average Secchi	Date	Average Secchi	Date	Average Secchi	Date	Average Secchi	Date	Average Secchi
4/28/2004	2.70	8/5/2004	1.75	12/28/2004	no sample	5/8/2005	2.75	7/19/2005	1.50
5/27/2004	4.00	8/19/2004	1.25	1/31/2005	no sample	5/26/2005	2.25	8/5/2005	1.25
6/22/2004	1.75	9/22/2004	1.75	2/24/2005	no sample	6/9/2005	3.50	8/30/2005	1.00
7/8/2004	2.75	#########	3.75	4/14/2005	1.75	6/22/2005	2.75	9/22/2005	1.25
7/21/2004	3.00	#########	3.50	4/27/2005	3.25	7/7/2005	1.75	10/19/2005	1.75

1.5.6 Tributary Total Suspended Solids

Total suspended solids (TSS) samples were collected by the Cass County SCD staff between May 2004 and October 2005. TSS samples were collected from the northwest, west, and southwest inlets and from the outlet to the reservoir. Average TSS concentrations at the northwest inlet were 15.5 mg L^{-1}, 18.6 mg L^{-1} at the west inlet site, 6.9 mg L^{-1} for the southwest intlet, and 9.8 mg L^{-1} from the outlet (Table 8).

Table 8. Average Total Suspended Solids Concentrations for the Brewer Lake Tributary and Outlet Sites (2004-2005).

Site ID	# Samples	Site Description	Average TSS (mg L-1)
385304	52	Outlet	9.81
385305	22	Southwest Tributary	6.86
385306	38	West Tributary	18.65
385307	50	Northwest Tributary	15.50
Storage			31.20

2.0 WATER QUALITY STANDARDS

The Clean Water Act requires that Total Maximum Daily Loads (TMDLs) be developed for waters on a state's Section 303(d) list. A TMDL is defined as “the sum of the individual wasteload allocations for point sources and load allocations for nonpoint sources and natural background” such that the capacity of the waterbody to assimilate pollutant loadings is not exceeded. The purpose of a TMDL is to identify the pollutant load reductions or other actions that should be taken so that impaired waters will be able to attain water quality standards. TMDLs are required to be developed with seasonal variations and must include a margin of safety that addresses the uncertainty in the analysis. Separate TMDLs are required to address each pollutant or cause of impairment (i.e., nutrients, sediment).

2.1 Narrative Water Quality Standards

The North Dakota Department of Health has set narrative water quality standards, which apply to all surface waters in the state. The narrative standards pertaining to nutrient impairments are listed below (NDDH, 2006).

- All waters of the state shall be free from substances attributable to municipal, industrial, or other discharges or agricultural practices in concentrations or combinations which are toxic or harmful to humans, animals, plants, or resident aquatic biota.

- No discharge of pollutants, which alone or in combination with other substances shall:
  1) Cause a public health hazard or injury to environmental resources;
  2) Impair existing or reasonable beneficial uses of the receiving waters; or
  3) Directly or indirectly cause concentrations of pollutants to exceed applicable standards of the receiving waters.

In addition to the narrative standards, the NDDoH has set a biological goal for all surface waters in the state. The goal states that "the biological condition of surface waters shall be similar to that of sites or waterbodies determined by the department to be regional reference sites," (NDDoH, 2006)

2.2 Numeric Water Quality Standards

Brewer Lake is classified as a Class 2 cool water fishery. Class 2 fisheries are defined as waterbodies "capable of supporting natural reproduction and growth of cool water fishes (i.e. walleye and northern pike) and associated aquatic biota and marginal growth and survival of cold water species and associated biota" (NDDoH, 2006). All classified lakes in North Dakota are assigned aquatic life, recreation, irrigation, livestock watering, and wildlife beneficial uses. The North Dakota State Water Quality Standards state that lakes shall use the same numeric criteria as Class 1 streams. This includes the state standard for dissolved oxygen of 5 mg L^{-1} as a daily minimum (up to 10% of representative samples collected during any three year period may be less than this value provided that lethal conditions are avoided). State standards for lakes and reservoirs also specify guidelines for nitrogen 1.0 mg L^{-1} as nitrate (up to 10% of samples may exceed) (Table 9).

Table 9. Numeric Standards Applicable for North Dakota Lakes and Reservoirs (NDDoH , 2006).

Parameter		Guidelines	Limit
Guidelines for Classified Lakes			
	Nitrates (dissolved)	1.0 mg L^{-1}	Maximum allowed[1]
	Dissolved Oxygen	5 mg L^{-1}	Daily minimum[2]
Guidelines for goals in a lake improvement or maintenance program			
	NO_3 as N	0.25 mg L^{-1}	Goal
	PO_4 as P	0.02 mg L^{-1}	Goal

[1] "Up to 10% of samples may exceed"

[2] "Up to 10% of representative samples collected during any three year period may be less than this value provided that lethal conditions are avoided."

3.0 TMDL TARGETS

A TMDL target is the value that is measured to judge the success of the TMDL effort. TMDL targets should be based on state water quality standards, but can also include site-specific values when no numeric criteria are specified in the standard. The following sections summarize water quality targets for Brewer Lake based on its beneficial uses. If the specific target is met, it is assumed the reservoir will meet the applicable water quality standards, including its designated beneficial uses.

3.1 Nutrient Target

North Dakota's 2004 Integrated Section 305(b) Water Quality Assessment Report indicates that Carlson's Trophic State Index (TSI) is the primary indicator used to assess beneficial uses of the State's lakes and reservoirs (NDDoH, 2008). Trophic State is the measure of productivity of a lake or reservoir and is directly related to the level of nutrients (phosphorus and nitrogen) entering the lake or reservoir from its watershed. Lakes tend to become eutrophic (more productive) with higher nitrogen and phosphorus inputs. Eutrophic lakes often have nuisance algal blooms, limited water clarity, and low dissolved oxygen concentrations that can result in impaired aquatic life and recreational uses. Carlson's TSI attempts to measure the trophic state of a lake using nitrogen, phosphorus, chlorophyll-a, and Secchi disk depth measurements (Carlson, 1977).

Based on Carlson's TSI and water quality data collected between April 2004 and October 2005, Brewer Lake was generally assessed as a eutrophic to hypereutrophic lake (Table 10). Hypereutrophic lakes are characterized by large growths of weeds, bluegreen algal blooms, and low dissolved oxygen concentrations. These lakes experience frequent fish kills and are generally characterized as having excessive rough fish populations (carp, bullhead, sucker) and poor sport fisheries. Because of the frequent algal blooms and excessive weed growth, these lakes are also undesirable for recreational uses such as swimming and boating.

Table 10. Carlson's Trophic State Indices for Brewer Lake.

Parameter	Relationship	Units	TSI Value	Trophic Status
Chlorophyll-a	TSI (Chl-a) = 30.6 + 9.81[ln(Chl-a)]	µg/L	55.69	Eutrophic
Total Phosphorus (TP)	TSI (TP) = 4.15 + 14.42[(ln(TP)]	µg/L	75.00	Hypereutrophic
Secchi Depth (SD)	TSI (SD) = 60 - 14.41[ln(SD)]	meters	48.00	Mesotrophic
Total Nitrogen (TN)	TSI (TN) = 54.45 + 14.43[ln(TN)]	mg/L	64.33	Eutrophic

TSI < 25 - Oligotrophic (least productive) TSI 25-50 Mesotrophic
TSI 50-75 Eutrophic TSI > 75 - Hypereutrophic (most productive)

The reasons for the different TSI values estimated for Brewer Lake are varied. According to the phosphorus TSI value, Brewer Lake is an extremely productive lake (hypereutrophic) (Figure 13). Carlson and Simpson (1996) suggest that if the phosphorus and secchi depth TSI values are relatively similar and higher than the chlorophyll-a TSI value, then dissolved color or nonalgal particulates dominate light attenuation. It follows that, as is the case with Brewer Lake, if the secchi depth and chlorophyll-a TSI values are similar, then chlorophyll-a is dominating light attenuation (Table 11). Carlson and Simpson (1996) also state that a nitrogen index value might be a more universally applicable nutrient index than a phosphorus index, but it also means that a correspondence of the nitrogen index with the chlorophyll-a index cannot be used to indicate nitrogen limitation.

Table 11. Relationships Between TSI Variables and Conditions.

Relationship Between TSI Variables	Conditions
TSI(Chl) = TSI(TP) = TSI(SD)	Algae dominate light attenuation; TN/TP ~ 33:1
TSI(Chl) > TSI(SD)	Large particulates, such as *Aphanizomenon* flakes, dominate
TSI(TP) = TSI(SD) > TSI(CHL)	Non-algal particulates or color dominate light attenuation
TSI(SD) = TSI(CHL) > TSI(TP)	Phosphorus limits algal biomass (TN/TP >33:1)
TSI(TP) >TSI(CHL) = TSI(SD)	Algae dominate light attenuation but some factor such as nitrogen limitation, zooplankton grazing or toxics limit algal biomass.

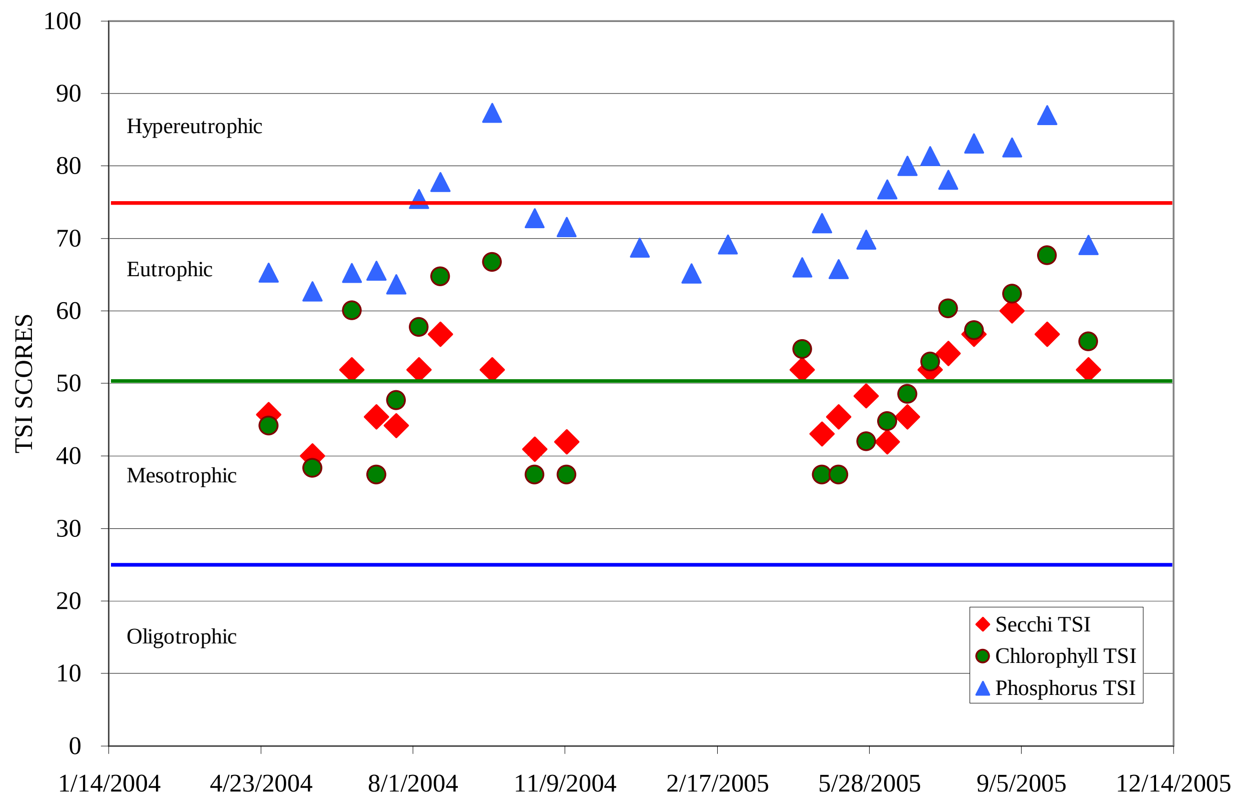

Figure 13. Temporal Distribution of Carlson's Trophic Status Index Scores for Brewer Lake.

A Carlson's TSI target of 65 based on total phosphorus was chosen for the Brewer Lake endpoint. While this will not bring concentrations of total phosphorus to the NDDoH State Water Quality Standard guideline for lakes (0.02 mg L^{-1}), it should result in a change of trophic status for the lake from hypereutrophic down to eutrophic during all times of the year. Given the size of the lake, the probable amount of phosphorus in bottom sediments, nearly constant wind in North Dakota causing a mixing effect, and few cost efficient ways to reduce in-lake nutrient cycling, this was determined to be the best possible outcome for the reservoir. If the specified TMDL TSI target of 65 based on total phosphorus is met, the reservoir can be expected to meet the applicable water quality standards for aquatic life and recreational beneficial uses.

3.2 Dissolved Oxygen Target

The North Dakota State Water Quality Standard for dissolved oxygen is "5.0 mg L^{-1} as a daily minimum (up to 10% of representative samples collected during any three year period may be less than this value provided that lethal conditions are avoided)" and will be the dissolved oxygen target for Brewer Lake.

4.0 SIGNIFICANT SOURCES

There are no known point sources upstream of Brewer Lake. The pollutants of concern originated from non-point sources.

5.0 TECHNICAL ANALYSIS

Establishing a relationship between in-stream water quality targets and pollutant source loading is a critical component of TMDL development. Identifying the cause-and-effect relationship between pollutant loads and the water quality response is necessary to evaluate the loading capacity of the receiving waterbodies. The loading capacity is the amount of a pollutant that can be assimilated by the waterbody while still attaining and maintaining water quality standards. This section discusses the technical analysis used to estimate existing loads to Brewer Lake and the predicted trophic response of the reservoir to reductions in loading capacity.

5.1 Tributary Load Analysis

To facilitate the analysis and reduction of tributary inflow and outflow water quality and flow data the FLUX program was employed. The FLUX program, also developed by the US Corps of Engineers Waterways Experiment Station (Walker, 1996), uses six calculation techniques to estimate the average mass discharge or loading that passes through a given river or stream site. FLUX estimates loadings based on grab sample chemical concentrations and the continuous daily flow record. Load is therefore defined as the mass of a pollutant during a given time period (e.g., hour, day, month, season, year). The FLUX program allows the user, through various iterations, to select the most appropriate load calculation technique and data stratification scheme, either by flow or date, which will give a load estimate with the smallest statistical error, as represented by the coefficient of variation. Output from the FLUX program is then provided as an input file to calibrate the BATHTUB eutrophication response model. For a complete description of the FLUX program the reader is referred to Walker (1996).

5.2 BATHTUB Trophic Response Model

The BATHTUB model (Walker, 1996) was used to predict and evaluate the effects of various nutrient load reduction scenarios on Brewer Lake. BATHTUB performs steady-state water and nutrient balance calculations in a spatially segmented hydraulic network. The model accounts for advective and diffusive transport and nutrient sedimentation. Eutrophication related water quality conditions are predicted using empirical relationships previously developed and tested for reservoir applications.

The BATHTUB model is developed in three phases. The first two phases involve the analysis and reduction of the tributary and in-lake water quality data. The third phase involves model calibration. In the data reduction phase, the in-lake and tributary monitoring data collected as part of the project were summarized in a format which can serve as inputs to the model.

The tributary data were analyzed and reduced by the FLUX program. FLUX uses tributary inflow and outflow water quality and flow data to estimate average mass discharge or loading that passes a river or stream site using six calculation techniques. Load is therefore defined as the mass of a pollutant during a given unit of time. In the case of Brewer Lake, the FLUX program came up with an annual phosphorus load of 203.3 kg/yr. The FLUX model then allows the user to pick the most appropriate load calculation technique with the smallest statistical error. Output for the FLUX program is then used to calibrate the BATHTUB model.

The reservoir data were reduced in Excel using three computational functions. These include: 1) the ability to display concentrations as a function of depth, location, or date; 2) summary statistics (mean, median, etc.); and 3) an evaluation of trophic status. The output data from the Excel program were then used to calibrate the BATHTUB model.

When the input data from FLUX and Excel programs are entered into the BATHTUB model the user has the ability to compare predicted conditions (model output) to actual conditions using general rates and factors. The BATHTUB model is then calibrated by combining tributary load estimates for the project period with in-lake water quality estimates. The model is termed calibrated when the predicted estimates for the trophic response variables are similar to observed estimates from the project monitoring data. BATHTUB then has the ability to predict total phosphorus concentration, chlorophyll-a concentration, and secchi disk transparency along with and the associated TSI scores as a means of expressing trophic response.

As stated above, BATHTUB can compare predicted vs. actual conditions. After calibration, the model was run based on observed concentrations of phosphorus and nitrogen, to derive an estimated annual average total phosphorus load of 500.9 kg and annual average nitrogen load of 3,428.9 kg. The model was then run to evaluate the effectiveness of a number of nutrient reduction alternatives including; (1) reducing externally derived nutrient loads; (2) reducing internally available nutrients; and (3) reducing both external and internal nutrient loads.

BATHTUB modeled the trophic response of Brewer Lake by reducing externally derived nutrient loads. Phosphorus was used in the initial set of simulation models based on its known relationship to eutrophication and that it is controllable with the implementation of watershed Best Management Practices (BMPs) or lake restoration methods. Simulated reductions were achieved by reducing concentrations of phosphorus and nitrogen in the contributing tributaries by 25, 50, and 75 percent while keeping the hydraulic discharge constant (Table 12).

Table 12. Observed and Predicted Values for Selected Trophic Response Variables Assuming a 25, 50, and 75 Percent Reduction in External Phosphorus and Nitrogen Loading.

		Predicted Value		
Variable	**Observed Value**	**25%**	**50%**	**75%**
Total Phosphorus (mg/L)	0.136	0.103	0.070	0.037
Total Dissolved Phosphorus (mg/L)	0.091	0.060	0.030	0.003
Total Nitrogen (mg/L)	1.98	1.55	1.11	0.688
Chlorophyll-a (µg/L)	12.90	11.66	10.07	6.87
Secchi Disk Transparency (meters)	2.30	2.35	2.42	2.57
Carlson's TSI for Phosphorus	74.99	70.98	65.44	56.23
Carlson's TSI for Chlorophyll-a	55.69	54.69	53.26	49.51
Carlson's TSI for Secchi Disk	48.00	47.66	47.25	46.37

To acquire a noticeable change in the tropic status the BATHTUB model predicted that a 50 percent reduction in external total phosphorus and nitrogen loads would achieve the target of 0.070 mg L^{-1} and 1.11 mg L^{-1}. This reduction in phosphorus is predicted to result in a reservoir in the eutrophic range (Figure 14).

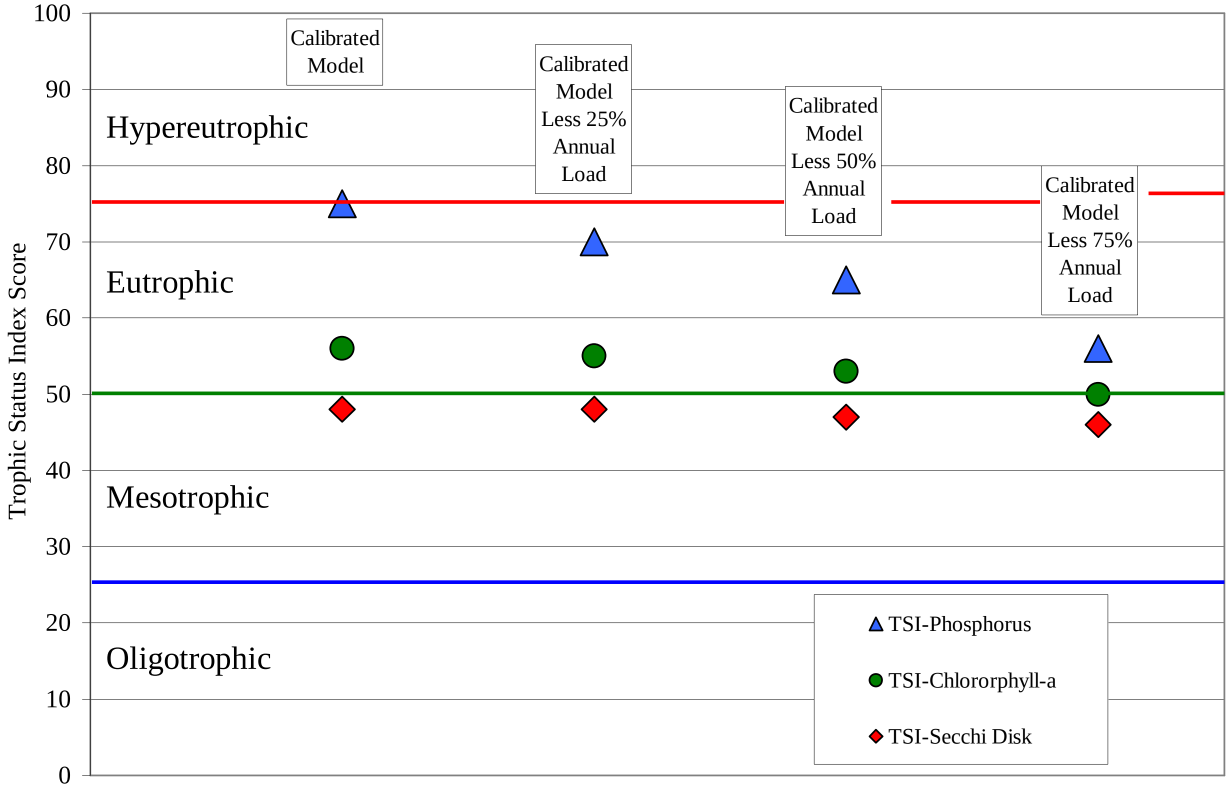

Figure 14. Predicted trophic response measured by Carlson's TSI scores to phosphorus and nitrogen load reductions to Brewer Lake of 25, 50, and 75 percent.

5.3 AnnAGNPS Watershed Model

The AnnAGNPS (Annualized Agricultural NonPoint Source Pollution) model was developed by the USDA Agricultural Research Service and Natural Resource Conservation Service (NRCS) to expand the earlier AGNPS single event model. The AnnAGNPS model consists of a system of computer models used to predict nonpoint source pollution (NPS) loadings within agricultural watersheds. The continuous simulation surface runoff model contains programs for 1) input generation and editing; 2) "annualized" pollutant loading model; and 3) output reformatting and analysis.

The AnnAGNPS model uses batch processing, continual-simulation, and surface runoff pollutant loading to generate amounts of water, sediment, and chemicals (nutrients and pesticides) moving from land areas (cells) and flowing into the watershed stream network at user specified locations (reaches) on a daily basis. The water, sediment, and chemicals travel throughout the watershed reaches to the watershed outlets. Feedlots, gullies, point sources, and impoundments are special components that can be included in the cells and reaches. Each component adds water, sediment, or chemicals to the reaches.

The AnnAGNPS model is able to partition soluble nutrients and pesticides up between surface runoff and infiltration. Sediment-attached nutrients and pesticides are also calculated in the stream system. Sediment is divided into five particle size classes (clay, silt, sand, small aggregate, and large aggregate) and are moved separately through the stream reaches.

AnnAGNPS uses various models to develop an annualized load in the watershed. These models account for surface runoff, soil moisture, erosion, nutrients, pesticides, and reach routing. Each model serves a particular purpose and function in simulating the NPS processes occurring in the watershed.

To generate surface runoff and soil moisture, the soil profile is divided into two layers. The top layer is used as the tillage layer and has properties that change (bulk density etc.). While the remaining soil profile makes up the second layer with properties that remain static. A daily soil moisture budget is calculated based on (rainfall, irrigation, and snow melt), runoff, evapotranspiration, and percolation. Runoff is calculated using the NRCS Runoff Curve Number equation. These curve numbers can be modified based on tillage operations, soil moisture, and crop stage.

Overland sediment erosion was determined using a modified watershed-scale version of (Revised Universal Soil Loss Equation) RUSLE. (Geter and Theurer, 1998).

A daily mass balance for nitrogen (N), phosphorus (P), and organic carbon (OC) are calculated for each cell. Major components considered include plant uptake N and P, fertilization, residue decomposition, and N and P transport. Soluble and sediment absorbed N and P are also calculated. Nitrogen and phosphorus are then separated into organic and mineral phases. Plant uptake N and P are modeled through a crop growth stage index. (Theurer et. al. 1998)

Each pesticide is expressed in a daily mass balance. The AnnAGNPS model allows for numerous pesticides, each exhibiting their own chemical properties. Major components of the pesticide model include foliage wash-off, vertical transport in the soil profile, and degradation. Soluble and sediment absorbed fractions are calculated for each cell on a daily basis.

The reach routing model moves sediment, nutrients, and pesticides through the watershed. Sediment routing is calculated based upon transport capacity relationships using the Bagnold stream power equation (Bagnold, 1966). Routing of nutrients and pesticides through the watershed is accomplished by subdividing them into soluble and sediment attached components and are based on reach travel time, water temperature, and decay constant. Infiltration is also used to further reduce soluble nutrients. Both the upstream and downstream points of the reach are calculated for equilibrium concentrations by using a first order equilibrium model.

AnnAGNPS uses 34 different categories of input data and over 400 separate input parameters to execute the model. The input data categories can be split into five major classifications: climatic data, land characterization, field operations, chemical characteristics, and feedlot operations. Climatic data includes precipitation, maximum and minimum air temperature, relative humidity, sky cover, and wind speed. Land characterization consists of soil characterization, curve number, RUSLE parameters, and watershed drainage characterization. Field operations contain tillage, planting, harvest, rotation, chemical operations, and irrigation schedules. Finally, feedlot operations require daily manure rates, times of manure removal, and residue amount from previous operations.

Input parameters are used to verify the model. Some input parameters may be repeated for each cell, soil type, landuse, feedlot, and channel reach. Default values are available for some input parameters, others can be simplified because of duplication. Daily climatic input data can be obtained through weather generators, local data, and/or both. Geographical input data including cell boundaries, land slope, slope direction, and landuse can be generated by GIS or DEM (digital elevation models).

Output data is expressed through an event based report for stream reaches and a source accounting report for land or reach components. Output parameters are selected by the user for the desired watershed source locations (specific cells, reaches, feedlots, point sources, or gullies) for any simulation period. Source accounting for land or reach components are calculated as a fraction of a pollutant load passing through any reach in the stream network that came from the user identified watershed source locations. Event based output data is defined as event quantities for user selected parameters at desired stream reach locations.

AnnAGNPS was utilized for the Brewer Lake TMDL project. The Brewer Lake watershed delineation began with downloading a 30-meter digital elevation model (DEM) of Cass County from the Natural Resource Conservation Service (NRCS) database. Delineation is defined as drawing a boundary and dividing the land within the boundary into subwatersheds in such a matter that each subwatershed has uniformed hydrological parameters (land slope, elevation, etc.).

Landuse and soil digital images were then used to extract the dominate identification of landuse and soil for each subwatershed. This process is achieved by overlaying Landsat and soil images over the subwatershed file. Each dominate soil is then further identified by its physical and chemical soil properties found in a database called National Soils Information System (NASIS) developed by the NRCS. Dominate landuse identification input parameters were obtained using Revised Universal Soil Loss Equation (RUSLE).

Several management simulations were completed for the Brewer Lake watershed including: 1) “Current Condition”, 2) Presettlement Condition, and 3) Implementation Condition. A 3-year simulation period was used to calculated loading and climate data was obtained from the North Dakota Agricultural Weather Network (NDAWN) website. Actual climatic data was retrieved from the NDAWN station located in Galesburg, ND for the years of 2003-2005. Nutrient and sediment loads at the outlet were calculated then compared against each management simulation. These comparisons were completed to identify critical cells within the watershed and to obtain an estimate of the nutrient load reductions possible for the watershed.

The first simulation completed of the Brewer Lake watershed at its “Current Condition” which is the best estimation of the current land use practices applied to the soils and slopes of the watershed to obtain nutrient and sediment loads from the individual cells as well as the watershed as a whole. Major land use in the Brewer Lake watershed was identified as small grains, corn, soybeans, dry beans, sunflowers, and pasture. Disking or chisel plowing and a conventional drill were used in the cropland field operations. Default values were used for crop rotations and consisted of wheat-corn-soybean and dry bean-wheat-sunflower. Disking of the field was done in early April with planting following in mid April and harvest in early August. Fertilizer application defaults varied between the two crop rotations when using a wheat-corn-soybean rotation nitrogen and phosphorus was applied at a low rate during planting in mid April, this stayed consistent throughout the rotation. With the dry bean-wheat-sunflower rotation, fertilizer application was done using anhydrous ammonia applied a week before planting. This also continued throughout the rotation schedule. Pasture land was defaulted as fair throughout the entire watershed when used in the simulation. Actual pasture and cropland conditions may vary and would require analysis on a tract by tract basis during implementation. The estimated sediment load was calculated at 578 tons. Attached phosphorus and soluble phosphorus loads were 4.40 tons and 21.07 tons respectively, while attached and soluble nitrogen loads were 0.29 tons and 0.55 tons (Table 13).

The second simulation completed involved simulating the watershed as it may have been prior to settlement. Grass conditions similar to tall grass prairie or CRP were applied to all of the cells within the watershed. Loading was significantly reduced in this simulation, the sediment load was calculated to be approximately 1.01 tons per year. Attached phosphorus 0.39 tons and soluble phosphorus 2.27 tons, as well as attach nitrogen at 0.00029 tons and soluble nitrogen 0.0079 tons annually. This simulation is **NOT** intended to be used as a TMDL goal but only to show a correlation between current land uses and loading within the Brewer Lake watershed.

Table 13. AnnAGNPS Management Simulation Nutrient and Sediment Loads for the Brewer Lake Watershed.

Management Simulations	Untis	Total Sediment	Attach Nitrogen	Soluble Nitrogen	Attached Phosphorus	Soluble Phosphorus
Current Condition	tons/yr	578.79	0.29	0.55	4.40	21.07
Presettlement Condition	tons/yr	1.01	0.00029	0.0079	0.39	2.27
Implementation Condition	tons/yr	69.26	0.06	0.26	2.14	11.73

The third simulation involved implementing BMPs on critical cells within the Brewer Lake watershed. Critical cells were identified from the “Current Condition” simulation and were determined by the model as producing excessive sediment loads greater than 0.5 tons or in close proximity to Brewer Lake. These critical areas account for approximately 3,480 acres of the watershed. A breakdown of this acreage shows that 31 percent or 1,892 acres are composed of pastureland with the remaining 26 percent or 1,588 acres are cropland. When BMP’s were placed on these cells, total sediment was reduced to 69.26 tons per year, while attached and soluble phosphorus to 2.14 tons and 11.73 tons respectively. Attached and soluble nitrogen accounted for a reduction of 0.06 tons and 0.26 tons annually. (Table 13).

5.4 Dissolved Oxygen

Brewer Lake is listed as fully supporting but threatened for fish and aquatic biota uses because dissolved oxygen levels were observed below the North Dakota water quality standard of 5.0 mg L^{-1} as a daily minimum (up to 10% of representative samples collected during any three year period may be less than this value provided that lethal conditions are avoided). For Brewer Lake, low dissolved oxygen levels appear to be related to excessive nutrient loadings.

The cycling of nutrients in aquatic ecosystems is largely determined by oxidation-reduction (redox) potential and the distribution of dissolved oxygen and oxygen-demanding particles (Dodds, 2002). Dissolved oxygen gas has a strong affinity for electrons, and thus influences biogeochemical cycling and the biological availability of nutrients to primary producers such as algae. High levels of nutrients can lead to eutrophication, which is defined as the undesirable growth of algae and other aquatic plants. In turn, eutrophication can lead to increased biological oxygen demand and oxygen depletion due to the respiration of microbes that decompose the dead algae and other organic material.

AnnAGNPS and BATHTUB models indicate that excessive nutrient loading is responsible for the low dissolved oxygen levels in Brewer Lake. Wetzel (1983) summarized, “The loading of organic matter to the hypolimnion and sediments of productive eutrophic lakes increases the consumption of dissolved oxygen. As a result, the oxygen content of the hypolimnion is reduced progressively during the period of summer stratification.”

Carpenter et al. (1998), has shown that nonpoint sources of phosphorous has lead to eutrophic conditions for many lakes/reservoirs across the U.S. One consequence of eutrophication is oxygen depletions caused by decomposition of algae and aquatic plants. They also document that a reduction in nutrients will eventually lead to the reversal of eutrophication and attainment of designated beneficial uses. However, the rates of recovery are variable among lakes/reservoirs. This supports the North Dakota Department of Health’s (NDDoH) viewpoint that decreased nutrient loads at the watershed level will result in improved oxygen levels. The concern is that this process takes a significant amount of time (5-15 years).

In Lake Erie, heavy loadings of phosphorous have impacted the lake severely. Monitoring and research from the 1960’s has shown that depressed hypolimnetic dissolved oxygen levels were responsible for large fish kills and large mats of decaying algae. Binational programs to reduce nutrients into the lake have resulted in a downward trend of the oxygen depletion rate since monitoring began in the 1970’s. The trend of oxygen depletion has lagged behind that of phosphorous reduction, but this was expected (See: http://www.epa.gov/glnpo/lakeerie/dostory.html).

Nürnberg (1995, 1995a, 1996, 1997), developed a model that quantified duration (days) and extent of lake oxygen depletion, referred to as an anoxic factor (AF). This model showed that AF is positively correlated with average annual total phosphorous (TP) concentrations. The AF may also be used to quantify responses to watershed restoration measures which make it very useful for TMDL development. Nürnberg (1996), developed several regression models that show nutrients control all trophic state indicators related to oxygen and phytoplankton in lakes/reservoirs. These models were developed from water quality characteristics using a suite of North American lakes. NDDoH has calculated the morphometric parameters such as surface area (A_o = 124.7

acres; 0.504 km^2), mean depth (z = 12.6 feet; 3.84 meters), and the ratio of mean depth to the surface area ($z/A_o^{0.5}$ = 1.07) for Brewer Lake which show that these parameters are within the range of lakes used by Nürnberg. Based on this information, NDDoH is confident that Nürnberg's empirical nutrient-oxygen relationship holds true for North Dakota lakes and reservoirs. NDDoH is also confident that prescribed BMPs will reduce external loading of nutrients to Brewer Lake which will reduce algae blooms and therefore increase oxygen levels to above State standards.

6.0 MARGIN OF SAFETY AND SEASONALITY

6.1 Margin of Safety

Section 303(d) of the Clean Water Act and EPA's regulations require that "TMDLs should be established at levels necessary to attain and maintain the applicable narrative and numerical water quality standards with seasonal variations and a margin of safety that takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality." The margin of safety (MOS) can either be incorporated into conservative assumptions used to develop the TMDL (implicit) or added as a separate component of the TMDL (explicit). For the purposes of this nutrient TMDL, a MOS of 10% of the loading capacity will be used as an explicit MOS.

Assuming the existing annual phosphorus load to Brewer Lake from tributary sources and internal cycling is 500.9 kg and the TMDL reduction goal is a 50% reduction in total annual phosphorus loading, then this would result in a TMDL target total phosphorus loading capacity of 250.45 kg of total phosphorus per year. Based on a 10 % explicit margin of safety, the MOS for the Brewer Lake TMDL would be 25.04 kg of phosphorus per year.

Post-implementation monitoring related to the effectiveness of the TMDL controls can also be used to assure attainment of the targets, using adaptive management during the implementation phase.

6.2 Seasonality

Section 303(d)(1)(C) of the Clean Water Act and the EPA's regulations require that a TMDL be established with seasonal variations. Brewer Lake's TMDL addresses seasonality because the BATHTUB and AnnAGNPS models incorporate seasonal differences in their prediction of annual total phosphorus and nitrogen loadings.

7.0 TMDL

The table below summarizes the nutrient and dissolved oxygen TMDLs for Brewer Lake in terms of loading capacity, wasteload allocations, load allocations, and a margin of safety. The TMDL can be generically described by the following equation.

TMDL = LC = WLA + LA + MOS

where

LC loading capacity, or the greatest loading a waterbody can receive without violating water quality standards;

WLA wasteload allocation, or the portion of the TMDL allocated to existing or future point sources;

LA load allocation, or the portion of the TMDL allocated to existing or future non-point sources;

MOS margin of safety, or an accounting of the uncertainty about the relationship between pollutant loads and receiving water quality. The margin of safety can be provided implicitly through analytical assumptions or explicitly by reserving a portion of the loading capacity.

7.1 Nutrient TMDL

Table 14. Summary of the Phosphorus TMDL for Brewer Lake.

Category	Total Phosphorus (kg/yr)	Explanation
Existing Load	500.9	From observed data
Loading Capacity	250.45	50 percent total reduction based on BATHTUB modeling
Wasteload Allocation	0.0	No point sources
Load Allocation	225.41	Entire loading capacity minus MOS is allocated to non-point sources
MOS	25.04	10% of the loading capacity (kg/yr) is reserved as an explicit margin of safety

Based on data collected in 2003 thru 2005, the existing annual total phosphorus load to Brewer Lake is estimated at 500.9 kg. Assuming a 50% reduction in phosphorus loading will result in Brewer Lake reaching a TMDL target total phosphorus concentration of 0.070 mg L^{-1}, the TMDL or Loading Capacity is 250.45 kg per year. Assuming 10% of the loading capacity (25.04 kg/yr) is explicitly assigned to the MOS and there are no point sources in the watershed all of the remaining loading capacity (225.41 kg/yr) is assigned to the load allocation.

In November 2006 EPA issued a memorandum “Establishing TMDL “Daily” Loads in Light of the Decision by the U.S. Court of Appeals for the D.C. Circuit in Friends of the Earth, Inc. v. EPA et. al., No. 05-5015 (April 25, 2006) and Implications for NPDES Permits,” which recommends that all TMDLs and associated load allocations and wasteload allocations include a daily time increment in conjunction with other appropriate temporal expressions that may be necessary to implement the relevant water quality standard. While the Department believes that the appropriate temporal expression for phosphorus loading to lakes and reservoirs is as an annual load, the phosphorus TMDL has also been expressed as a daily load. In order to express this phosphorus

TMDL as a daily load the annual loading capacity of 250.45 kg/yr was divided by 365 days. Based on this analysis, the phosphorus TMDL, expressed as an average daily load, is 0.6862 kg/day with the load allocation equal to 0.6176 kg/day and the MOS equal to 0.0686 kg/day.

7.2 Dissolved Oxygen TMDL

It is expected that by attaining the nutrient load reduction target established for Brewer Lake, the dissolved oxygen impairment will be addressed. A reduction in nutrient load to Brewer Lake would be expected to lower algal biomass levels in the water column thereby reducing the biological oxygen demand exerted by the decomposition of these primary producers. The reduction in biological oxygen demand is therefore assumed to result in attainment of the dissolved oxygen standard.

8.0 ALLOCATION

A 50 percent nutrient load reduction target was established for the entire Brewer Lake watershed. This reduction was set based on the BATHTUB model, which predicted that under similar hydraulic conditions, an external nutrient load reduction of 50 percent would lower Carlson's phosphorus TSI from 75 to 65 (Figure 14).

Using the AnnAGNPS model, it was determined there are two distinct groups, or critical areas, in the watershed. These priority areas account for approximately 3,480 acres of the watershed. A breakdown of this acreage shows that 31 percent or 1,892 acres are composed of pastureland with the remaining 26 percent or 1,588 acres as cropland. The first group of cells is located around Brewer Lake. These cells were identified as largely pastureland and are in close proximity to the lake. The second group of cells was identified as cropland within the Brewer Lake watershed. These areas are cropped and located primarily along the main stem and tributary inlets to Brewer Lake. These cells should be the critical cells examined to determine the necessity and types of BMP's to be implemented (Figure 16). According to the AnnAGNPS, model if BMP's are implemented on these critical areas the phosphorus load would be reduced 51 percent meeting the TMDL goal.

The TMDLs in this report are a plan to improve water quality by implementing BMPs through a volunteer, incentive-based approach. This TMDL plan is put forth as a recommendation to what needs to be accomplished for Brewer Lake and its watershed to meet and protect its beneficial uses. Water quality monitoring should continue to assess the effects of recommendations made in this TMDL. Monitoring may indicate that loading capacity recommendations be adjusted.

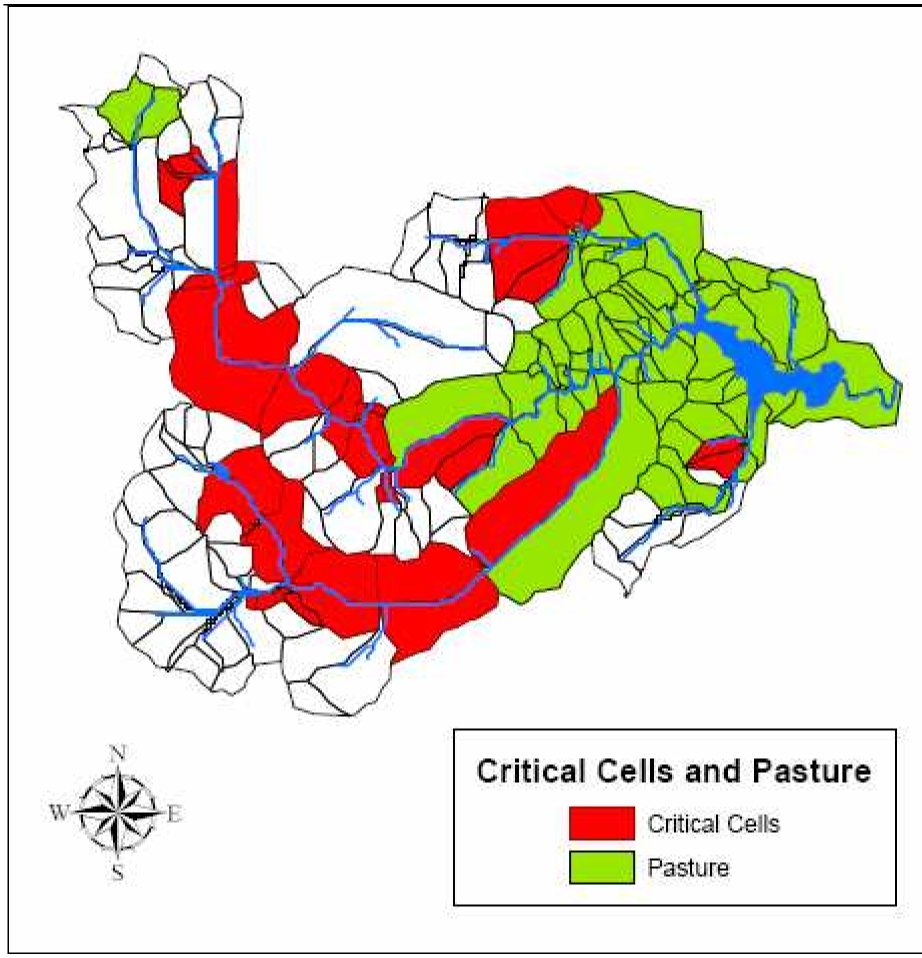

Figure 15. AnnAGNPS Model Identification of Critical Areas for BMP Implementation.

9.0 PUBLIC PARTICIPATION

To satisfy the public participation requirement of this TMDL, a hard copy of the TMDL for Brewer Lake Dam and a request for comment was mailed to participating agencies, partners, and to those who requested a copy. Those included in the mailing of a hard copy were as follows:

- Cass County Soil Conservation District
- Cass County Water Resource Board
- North Dakota Game and Fish Department
- Natural Resource Conservation Service (State and Cass County Field Offices)
- U.S. Environmental Protection Agency, Region VIII
- U.S. Fish & Wildlife Service

In addition to mailing copies of this TMDL for Brewer Lake to interested parties, the TMDL was been posted on the North Dakota Department of Health, Division of Water Quality web site at http://www.health.state.nd.us/wq/. A 30 day public notice soliciting comment and participation was also published in the following newspapers:

- Fargo Forum
- Bismarck Tribune

In response to the Department’s public notice, comments were received from the US Fish and Wildlife Service’s North Dakota Field Office, the US EPA Region 8 and a hand written note from Scott Elstad with the North Dakota Game and Fish Department. Stating they had no comment on the draft report. A copy of the US EPA’s and US Fish and Wildlife Service’s comments is provided in Appendices E and F, respectively. The Department’s response to comments is provided in Appendix G.

10.0 MONITORING

To insure that the implementation of BMPs will reduce phosphorus levels and result in a corresponding increase in dissolved oxygen, water quality monitoring will be conducted in accordance with an approved Quality Assurance Project Plan (QAPP).

Specifically, monitoring will be conducted for all variables that are currently causing impairments to the beneficial uses of the waterbody. These include, but are not limited to nutrients (i.e., nitrogen and phosphorus) and dissolved oxygen. Once a watershed restoration plan (e.g. 319 PIP) is implemented, monitoring will be conducted in the lake/reservoir beginning two years after implementation and extending five years after the implementation project is complete.

11.0 TMDL IMPLEMENTATION STRATEGY

Implementation of TMDLs is dependent upon the availability of Section 319 NPS funds or other watershed restoration programs (e.g. USDA EQIP), as well as securing a local project sponsor and the required matching funds. Provided these three requirements are in place, a project implementation plan (PIP) is developed in accordance with the TMDL and submitted to the ND Nonpoint Source Pollution Task Force and US EPA for approval. The implementation of the best management practices contained in the NPS pollution management project is voluntary. Therefore, success of any TMDL implementation project is ultimately dependent on the ability of the local project sponsor to find cooperating producers.

Monitoring is an important and required component of any PIP. As a part of the PIP, data are collected to monitor and track the effects of BMP implementation as well as to judge overall project success. Quality Assurance Project Plans (QAPPs) detail the strategy of how, when and where monitoring will be conducted to gather the data needed to document the TMDL implementation goal(s). As data are gathered and analyzed, watershed restoration tasks are adapted to place BMPs where they will have the greatest benefit to water quality.

12.0 ENDANGERED SPECIES

The North Dakota Department of Health has reviewed the list of Threatened and Endangered Species in Cass County as provided by the US Fish and Wildlife Service (Appendix A). Although there are listed species present in the county they do not utilize the waterbody that is targeted by this TMDL. It is, therefore, the Department’s best professional judgment that the Brewer Lake TMDL poses “No Adverse Effect” to those Threatened and Endangered species listed for Cass County.

In a letter dated September 4, 2008 (Appendix F) which was sent in response to the Department's request for public comments on the Brewer Lake TMDL report, the US Fish and Wildlife Service concurred with the Department's conclusion.

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Appendix A

County Occurrence of Endangered, Threatened and Candidate Species and Designated Critical Habitat in North Dakota (March 2006)

Species	Adams	Barnes	Benson	Billings	Bottineau	Bowman	Burke	Burleigh	Cass	Cavalier	Dickey	Divide	Dunn	Eddy	Emmons	Foster	Go. Valley	Gr. Forks	Grant	Griggs	Hettinger	Kidder	Lamoure	Logan	McHenry	McIntosh	McKenzie
Interior Least Tern - E								X					X		X												X
Whooping Crane - E	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X
Black-footed Ferret - E	X			X		X							X				X		X		X						X
Pallid Sturgeon - E								X					X		X												X
Gray Wolf - E					X		X		X	X	X	X	X					X							X	X	X
Bald Eagle - T	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Piping Plover - T			X				X	X				X	X	X	X	X						X		X	X	X	X
Western Prairie Fringed Orchid - T																											
Dakota Skipper - C							X							X											X		X
Designated Critical Habitat																											
Piping Plover			X				X	X				X	X	X	X							X		X	X	X	X

E - Endangered **T - Threatened** **C - Candidate**

Species	McLean	Mercer	Morton	Mountrail	Nelson	Oliver	Pembina	Pierce	Ramsey	Ransom	Renville	Richland	Rolette	Sargent	Sheridan	Sioux	Slope	Stark	Steele	Stutsman	Towner	Traill	Walsh	Ward	Wells	Williams
Interior Least Tern - E	X	X	X	X		X										X										X
Whooping Crane - E	X	X	X	X		X		X			X		X		X	X	X	X		X	X			X	X	X
Black-footed Ferret - E		X	X			X										X	X	X								
Pallid Sturgeon - E	X	X	X	X		X										X										X
Gray Wolf - E	X		X	X	X		X	X	X		X	X	X	X	X						X		X	X		X
Bald Eagle - T	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Piping Plover - T	X	X	X	X		X		X			X				X	X				X				X	X	X
W. P. Fringed Orchid - T										X		X														
Dakota Skipper - C										X		X	X	X						X				X	X	
Designated Critical Habitat																										
Piping Plover	X	X	X	X		X		X			X				X	X				X				X		X

E - Endangered **T - Threatened** **C – Candidate**

Appendix B

A Calibrated Trophic Response Model (Bathtub) for Brewer Lake

A Calibrated Trophic Response Model (Bathtub) for Brewer Lake
As a Tool to Evaluate Various Nutrient Reduction Alternatives
Based on Data Collected by the Cass County Soil Conservation District from
April 28, 2004 through October 31, 2005
Prepared by
Peter Wax
June 28, 2006

Introduction

In order to meet the project goals, as set forth by the project sponsors of improving the trophic condition of Brewer Lake to levels capable of maintaining the reservoirs beneficial uses (e.g., fishing and recreation), and the objectives of this project, which are to: (1) develop a nutrient and sediment budget for the reservoir; (2) identify the primary sources and causes of nutrients and sediments to the reservoir; and (3) examine and make recommendations for reservoir restoration measures which will reduce documented nutrient and sediment loadings to the reservoir, a calibrated trophic response model was developed for Brewer Lake. The model enables investigations into various nutrient reduction alternatives relative to the project goal of improving Brewer Lake's trophic status. The model will allow resource managers and the public to relate changes in nutrient loadings to the trophic condition of the reservoir and to set realistic lake restoration goals that are scientifically defensible, physically achievable and socially acceptable.

Methods

For purposes of this project, the BATHTUB program was use to predict changes in trophic status based on changes in nutrient loading. The BATHTUB program, developed by the US Army Corps of Engineers Waterways Experiment Station (Walker 1996), applies an empirically derived eutrophication model to reservoirs. The model is developed in three phases. The first two phases involve the analysis and reduction of the tributary and in-lake water quality data. The third phase involves model calibration. In the data reduction phase, the in-lake and tributary monitoring data collected as part of the project are summarized, or reduced, in a format which can serve as inputs to the model. The following is a brief explanation of the computer software, methods, and procedures used to complete each of these phases.

Tributary Data

To facilitate the analysis and reduction of tributary inflow and outflow water quality and flow data the FLUX program was employed. The FLUX program, also developed by the US Corps of Engineers Waterways Experiment Station (Walker 1996), uses six calculation techniques to estimate the average mass discharge or loading that passes a given river or stream site. FLUX estimates loadings based on grab sample chemical concentrations and continuous daily flow record. Load is therefore defined as the mass of a pollutant during a given time period (e.g., hour, day, month, season, year). The FLUX program allows the user, through various iterations, to select the most appropriate load calculation technique and data stratification scheme, either by flow or date, which will give a load estimate with the smallest statistical error, as represented by the coefficient of variation. Output from the FLUX program is then provided as an input file to calibrate the BATHTUB eutrophication response model. For a complete description of the FLUX program the reader is referred to Walker (1996).

Lake Data

Brewer Lake's in-lake water quality data was reduced using Microsoft Excel. The data was reduced in excel to provide three computational functions, including: (1) the ability to display constitutes as a function of depth, location, and/or date; (2) calculate summary statistics (e.g., mean, median and standard error in the mixed layer of the lake or reservoir); and (3) track the temporal trophic status. As is the case with FLUX, output from the Excel program is used as input to calibrate the BATHTUB model.

Bathtub Model Calibration

As stated previously, the BATHTUB eutrophication model was selected for this project as a means evaluating the effects of various nutrient reduction alternatives on the predicted trophic status of Brewer Lake. BATHTUB performs water and nutrient balance calculations in a steady-state. The BATHTUB model also allows the user to spatially segment the reservoir. Eutrophication related water quality variables (e.g., total phosphorus, total nitrogen, chlorophyll-*a*, secchi depth, organic nitrogen, orthophosphorous, and hypolimnetic oxygen depletion rate) are predicted using empirical relationships previously developed and tested for reservoir systems (Walker 1985).

Within the BATHTUB program the user can select from six schemes based on reservoir morphometry and the needs of the resource manager. Using BATHTUB the user can view the reservoir as a single spatially averaged reservoir or as single segmented reservoir. The user can also model parts of the reservoir, such as an embayment, or model a collection of reservoirs. For purposes of this project, Brewer Lake was modeled as a single, spatially averaged, reservoir. Once input is provided to the model from FLUX and Excel the user can compare predicted conditions (i.e., model output) to actual conditions. Since BATHTUB uses a set of generalized rates and factors, predicted vs. actual conditions may differ by a factor of 2 or more using the initial, un-calibrated, model. These differences reflect a combination of measurement errors in the inflow and outflow data, as well as unique features of the reservoir being modeled.

In order to closely match an actual in-lake condition with the predicted condition, BATHTUB allows the user to modify a set of calibration factors (Table 1). For a complete description of the BATHTUB model the reader is referred to Walker (1996).

Table 1. Selected model parameters, number and name of model, and where appropriate the calibration factor used for Brewer Lake Bathtub Model.

Model Option	Model Selection	Calibration Factor
Conservative Substance	1 Computed	1.000
Phosphorus Balance	6 First Order	0.935
Phosphorus – Ortho P	6	1.00
Nitrogen Balance	7 Settling Velocity	1.01
Organic Nitrogen	7	3.50
Chlorophyll-a	2 P, Light, T	1.00
Secchi Depth	1 Vs. Chla & Turbidity	3.30
Phosphorus Calibration	1 Concentrations	NA
Nitrogen Calibration	1 Concentrations	NA
Availability Factors	0 Ignore	NA
Mass-Balance Tables	0 Use Observed Concentrations	NA

Results

The trophic response model, BATHTUB, has been calibrated to match Brewer Lake's trophic response for the project period of April 28, 2004 through October 31, 2005. This is accomplished by combining tributary loading estimates for the project period with in-lake water quality estimates. Tributary flow and concentration data for the project period are reduced by the FLUX program and the corresponding in-lake water quality data are reduced utilizing Excel. The output from these two programs is then provided as input to the BATHTUB model. The model is calibrated through several iterations, first by selecting appropriate empirical relationships for model coefficients (e.g., nitrogen and phosphorus sedimentation, nitrogen and phosphorus decay, oxygen depletion, and algal/chlorophyll growth), and second by adjusting model calibration factors for those coefficients (Table 1). The model is termed calibrated when the predicted estimates for the trophic response variables are similar to observed estimates made from project monitoring data.

The two most important nutrients controlling trophic response in Brewer Lake are nitrogen and phosphorus. After calibration the observed average annual concentration of total nitrogen and total phosphorus compare well with those of the BATHTUB model. The trophic response model predicts and that the reservoir has a bi-annual volume weighted average total phosphorus concentration of 0.1358 mg L^{-1} and an annual average volume weighted total nitrogen concentration of 1.987 mg L^{-1} compared to observed values for total phosphorus and total nitrogen of 0.136 mg L^{-1} and 1.984 mg L^{-1}, respectively (Table 2).

Other measures of trophic response predicted by the model are average annual chlorophyll-a concentration and average secchi disk transparency. The calibrated model did just as good a job of predicting average chlorophyll-a concentration and secchi disk transparency within the reservoir as total phosphorus and total nitrogen (Table 2).

Once predictions of total phosphorus, chlorophyll-a, and secchi disk transparency are made, the model calculates Carlson's Trophic Status Index (TSI) as a means of expressing predicted trophic response (Table 2). Carlson's TSI is an index that can be used to measure the relative trophic state of a lake or reservoir. Simply stated, trophic state is how much production (i.e., algal and weed growth) occurs in the waterbody. The lower the nutrient concentrations are within the waterbody the lower the production and the lower the trophic state or level. In contrast, increased nutrient concentrations in a lake or reservoir increase the production of algae and weeds which make the lake or reservoir more eutrophic or of a higher trophic state. Oligotrophic is the term which describes the least productive lakes and hypereutrophic is the term used to describe lakes and reservoirs with excessive nutrients and primary production.

Table 2. Observed and Predicted Values for Selected Trophic Response Variables for the Calibrated "BATHTUB" Model.

	Value	
Variable	Observed	Predicted
Total Phosphorus as P (mg/L)	0.136	0.136
Total Nitrogen as N (mg/L)	1.984	1.987
Organic Nitrogen as N (mg/L)	1.886	1.844
Chlorophyll-a (μg/L)	12.90	12.56
Secchi Disk Transparency (meters)	2.30	2.32
Carlson's TSI for Phosphorus	74.99	74.97
Carlson's TSI for Chlorophyll-a	55.69	55.42
Carlson's TSI for Secchi Disk	48.00	48.89

Figure 1 provides a graphic summary of the TSI range for each trophic level compared to values for each of the trophic response variables. The calibrated model provided predictions of trophic status which are similar to the observed TSI values for the project period (Table 2). Predicted and observed TSI values for phosphorus and secchi disk suggest Brewer Lake is hypereutrophic, while the TSI value chlorophyll-a indicated the reservoir is eutrophic. Figure 2 is a graphic that shows the annual temporal distribution of Brewer Lake's trophic state based on the three parameters total phosphorus as phosphate, and chlorophyll-a concentrations and secchi disk depth transparency.

Model Predictions

Once the model is calibrated to existing conditions, the model can be used to evaluate the effectiveness of any number of nutrient reduction or lake restoration alternatives. This evaluation is accomplished by comparing the predicted trophic state, as reflected by Carlson's TSI, with currently observed TSI values. Modeled nutrient reduction alternatives are presented in three basic categories: (1) reducing externally derived nutrient loads; (2) reducing internally available nutrients; and (3) reducing both external and internal nutrient loads. For Brewer Lake only external nutrient loads were addressed. External nutrient loads were addressed because they are known to cause eutrophication and because they are controllable through the implementation of watershed Best Management Practices (BMPs).

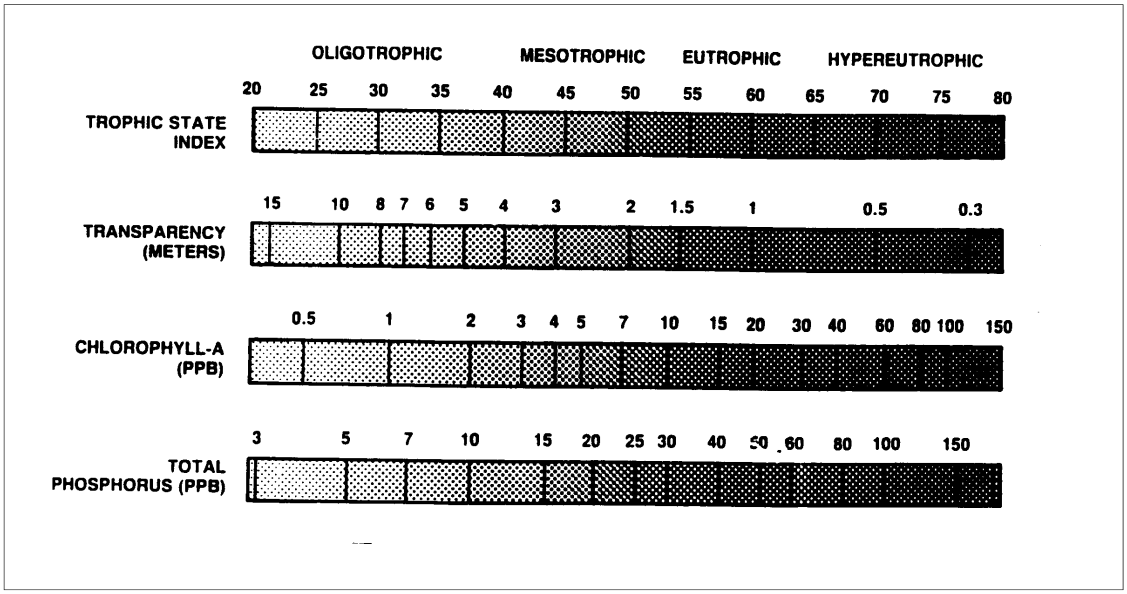

Figure 1. Graphic depiction of Carlson's Trophic Status Index

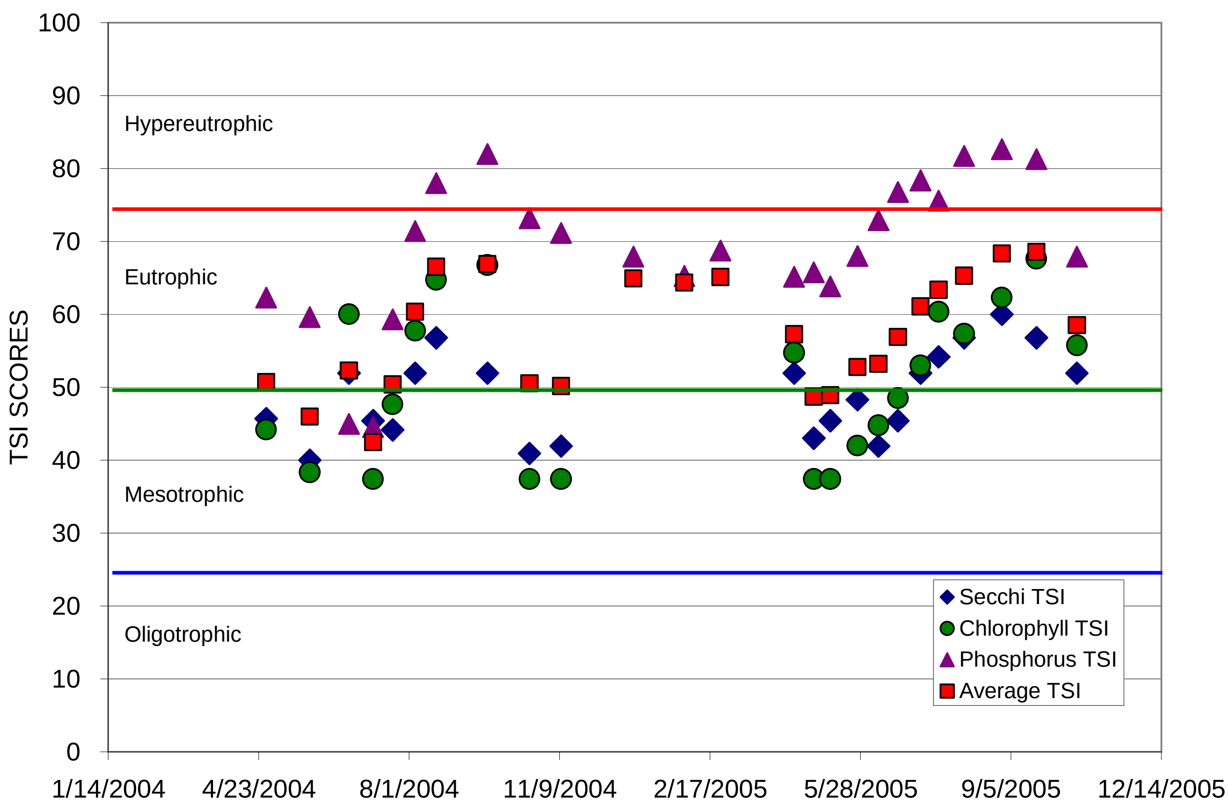

Figure 2. Distribution of Carlosn's Trophic Status Index scores for Brewer Lake (4-28-04 through 10-31-05)

Predicted changes in trophic response to Brewer Lake were evaluated by reducing externally derived phosphorus loads by 25, 50, and 75 percent. These reductions were simulated in the model by reducing the phosphorus and nitrogen concentrations in the contributing tributaries by 25, 50, and 75 percent. Since there is no reliable means of estimating how much hydraulic

discharge would be reduced through the implementation of BMPs, flow was held constant. Additionally the portion of the watershed not monitored was left constant.
The model results indicate that if it were possible to reduce external nutrient loading to Brewer Lake by 50 percent or greater the average annual total phosphorus concentrations in the lake would decrease a measurable amount (Table 3, Figure 3). It is also likely, that a 50 plus percent reduction in nutrient load would result in an improvement to the trophic status of Brewer Lake that would be noticeable to the average lake user through reduced intensity and length of algal blooms as represented by in-lake phosphorus concentrations declining to the eutrophic range.

With a 75 percent reduction in external phosphorus and nitrogen load, the model predicts a reduction in Carlson's TSI score from 75 to 63 based on inlake phosphorus corresponding to a trophic state of eutrophic.

Table 3. Observed and Predicted Values for Selected Trophic Response Variables Assuming a 25, 50, and 75 Percent Reduction in External Phosphorus and Nitrogen Loading.

Variable	Observed	Predicted 25 %	Predicted 50 %	Predicted 75 %
Total Phosphorus as P (mg/L)	0.136	0.103	0.070	0.037
Total Diss. Phosphorus as P (mg/L)	0.091	0.060	0.030	0.003
Total Nitrogen as N (mg/L)	1.984	1.553	1.1121	0.688
Chlorophyll-a (μg/L)	12.90	11.66	10.07	6.87
Secchi Disk Transparency (meters)	2.30	2.35	2.42	2.57
Carlson's TSI for Phosphorus	74.99	70.98	65.44	56.23
Carlson's TSI for Chlorophyll-a	55.69	54.69	53.26	49.51
Carlson's TSI for Secchi Disk	48.00	47.66	47.25	46.37

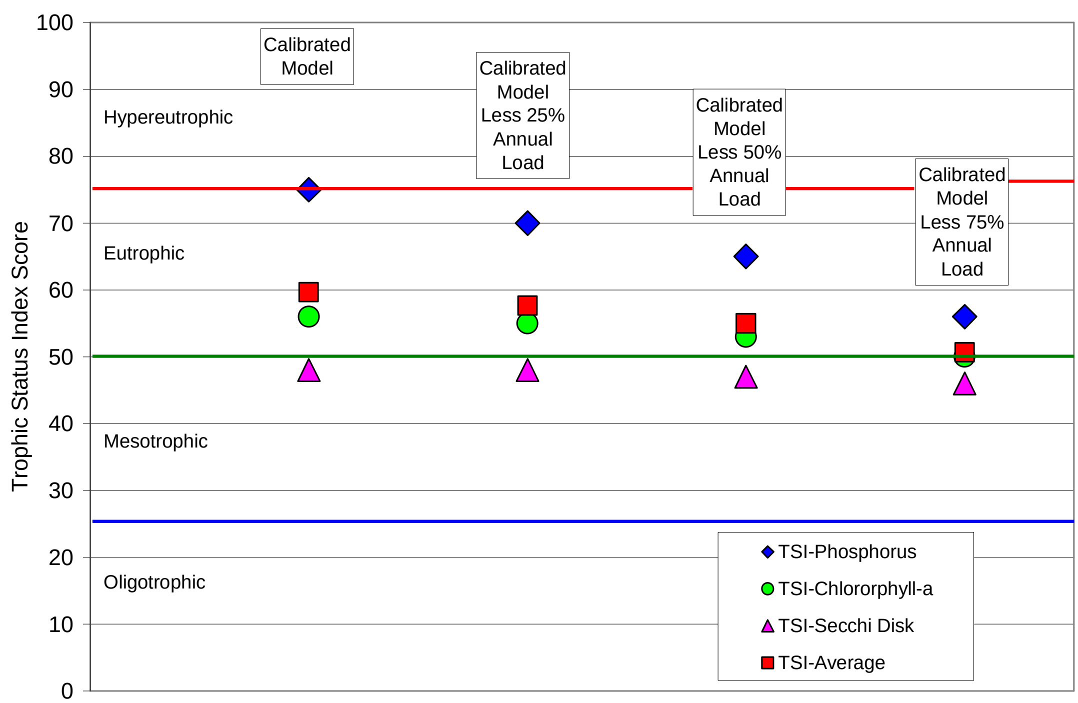

Figure 3. Predicted trophic response measured by Carlson's TSI scores to phosphorus and nitrogen load reductions to Brewer Lake of 25, 50, and 75 percent

Appendix C

Flux Analysis

585304 Brewer Outlet 04 and 05

Average Sample Interval = 10.4 Days, Date Range = 20040506 to 20051031
Maximum Sample Interval =   93 Days, Date Range = 20041029 to 20050131
Percent of Total Flow Volume Occuring In This Interval =   9.3%

Total Flow Volume on Sampled Days =   98.2 hm3
Total Flow Volume on All Days   =   1050.2 hm3
Percent of Total Flow Volume Sampled =   9.4%

Maximum Sampled Flow Rate =   12.15 hm3/yr
Maximum Total Flow Rate   =   17.96 hm3/yr
Number of Days when Flow Exceeded Maximum Sampled Flow = 8 out of 731
Percent of Total Flow Volume Occurring at Flow Rates Exceeding the
Maximum Sampled Flow Rate =   12.2%

585304 Brewer Outlet 04 and 05   VAR=nh3-4   METHOD= 3 IJC

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	438	24	24	12.7	.305	.243	-.753	.004
2	184	18	18	30.5	1.741	1.755	-.309	.771
3	109	10	10	56.8	5.469	6.078	-.776	.402
***	731	52	52	100.0	1.437	1.889		

FLOW STATISTICS
FLOW DURATION =   731.0 DAYS = 2.001 YEARS
MEAN FLOW RATE =   1.437 HM3/YR
TOTAL FLOW VOLUME =   2.88 HM3
FLOW DATE RANGE   = 20040101 TO 20051231
SAMPLE DATE RANGE = 20040506 TO 20051031

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	294.0	146.9	.7711E+03	102.26	.189
2 Q WTD C	291.4	145.6	.8231E+03	101.35	.197
3 IJC	286.7	143.3	.7438E+03	99.73	.190
4 REG-1	293.1	146.4	.1239E+04	101.92	.240
5 REG-2	292.1	146.0	.1333E+04	101.61	.250
6 REG-3	376.2	188.0	.3188E+04	130.86	.300

585304 Brewer Outlet 04 and 05   VAR=nh3-4   METHOD= 3 IJC
Load Time Series

				------Model------		----Interpolated----	
		Sample	Volume	Mass	Conc	Mass	Conc
Date	Days	Count	(hm3)	(kg)	(ppb)	(kg)	(ppb)
2004	366.00	19	1.001	112.6	112.44	117.1	116.93
2005	365.00	33	1.874	174.2	92.94	170.2	90.83
ALL	731.01	52	2.875	286.7	99.73	287.3	99.92

585304 Brewer Outlet 04 and 05   VAR=no2+no3   METHOD= 6 REG-3

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	438	24	24	12.7	.305	.243	.346	.027
2	184	18	18	30.5	1.741	1.755	-1.478	.087
3	109	10	10	56.8	5.469	6.078	.727	.344
***	731	52	52	100.0	1.437	1.889		

FLOW STATISTICS
FLOW DURATION = 731.0 DAYS = 2.001 YEARS
MEAN FLOW RATE = 1.437 HM3/YR
TOTAL FLOW VOLUME = 2.88 HM3
FLOW DATE RANGE = 20040101 TO 20051231
SAMPLE DATE RANGE = 20040506 TO 20051031

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	498.5	249.1	.1211E+05	173.37	.442
2 Q WTD C	481.9	240.8	.9845E+04	167.61	.412
3 IJC	484.9	242.3	.1027E+05	168.66	.418
4 REG-1	469.2	234.4	.8948E+04	163.19	.403
5 REG-2	488.3	244.0	.1307E+05	169.84	.468
6 REG-3	405.6	202.6	.5093E+04	141.06	.352

585304 Brewer Outlet 04 and 05 VAR=no2+no3 METHOD= 6 REG-3
Load Time Series

		Sample	Volume	------Model------		----Interpolated----	
Date	Days	Count	(hm3)	Mass (kg)	Conc (ppb)	Mass (kg)	Conc (ppb)
2004	366.00	19	1.001	168.8	168.65	187.4	187.18
2005	365.00	33	1.874	236.7	126.32	224.6	119.85
ALL	731.01	52	2.875	405.6	141.06	412.0	143.29

585304 Brewer Outlet 04 and 05 VAR=inorg-n METHOD= 2 Q WTD C

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	438	24	24	12.7	.305	.243	-.410	.019
2	184	18	18	30.5	1.741	1.755	-1.188	.162
3	109	10	10	56.8	5.469	6.078	-.083	.911
***	731	52	52	100.0	1.437	1.889		

FLOW STATISTICS
FLOW DURATION = 731.0 DAYS = 2.001 YEARS
MEAN FLOW RATE = 1.437 HM3/YR
TOTAL FLOW VOLUME = 2.88 HM3
FLOW DATE RANGE = 20040101 TO 20051231
SAMPLE DATE RANGE = 20040506 TO 20051031

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	792.5	396.0	.1230E+05	275.63	.280
2 Q WTD C	773.3	386.4	.9948E+04	268.96	.258
3 IJC	771.7	385.6	.1035E+05	268.39	.264
4 REG-1	765.9	382.7	.1060E+05	266.37	.269
5 REG-2	769.1	384.3	.1018E+05	267.49	.263
6 REG-3	837.0	418.2	.1291E+05	291.12	.272

585304 Brewer Outlet 04 and 05 VAR=inorg-n METHOD= 2 Q WTD C
Load Time Series

		Sample	Volume	------Model------		----Interpolated----	
Date	Days	Count	(hm3)	Mass (kg)	Conc (ppb)	Mass (kg)	Conc (ppb)
2004	366.00	19	1.001	286.0	285.71	307.3	306.95
2005	365.00	33	1.874	487.3	260.01	466.3	248.81
ALL	731.01	52	2.875	773.3	268.96	773.6	269.05

585304 Brewer Outlet 04 and 05   VAR=tn   METHOD= 2 Q WTD C

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	438	24	24	12.7	.305	.243	-.172	.009
2	184	18	18	30.5	1.741	1.755	-.360	.095
3	109	10	10	56.8	5.469	6.078	-.105	.704
***	731	52	52	100.0	1.437	1.889		

FLOW STATISTICS
FLOW DURATION =   731.0 DAYS = 2.001 YEARS
MEAN FLOW RATE =   1.437 HM3/YR
TOTAL FLOW VOLUME =   2.88 HM3
FLOW DATE RANGE   = 20040101 TO 20051231
SAMPLE DATE RANGE = 20040506 TO 20051031

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	3199.5	1598.7	.3678E+05	1112.81	.120
2 Q WTD C	3094.8	1546.3	.1546E+05	1076.38	.080
3 IJC	3089.4	1543.7	.1577E+05	1074.52	.081
4 REG-1	3098.8	1548.3	.1683E+05	1077.76	.084
5 REG-2	3090.8	1544.3	.1595E+05	1074.98	.082
6 REG-3	3123.4	1560.6	.1743E+05	1086.32	.085

585304 Brewer Outlet 04 and 05   VAR=tn   METHOD= 2 Q WTD C
Load Time Series

				------Model------		----Interpolated----	
		Sample	Volume	Mass	Conc	Mass	Conc
Date	Days	Count	(hm3)	(kg)	(ppb)	(kg)	(ppb)
2004	366.00	19	1.001	1103.3	1102.03	1135.1	1133.80
2005	365.00	33	1.874	1991.5	1062.68	1960.0	1045.87
ALL	731.01	52	2.875	3094.8	1076.38	3095.1	1076.49

585304 Brewer Outlet 04 and 05   VAR=tdp   METHOD= 2 Q WTD C

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	438	24	24	12.7	.305	.243	-.497	.005
2	184	17	17	30.5	1.741	1.766	1.062	.078
3	109	10	10	56.8	5.469	6.078	-.698	.256
***	731	51	51	100.0	1.437	1.895		

FLOW STATISTICS
FLOW DURATION =   731.0 DAYS = 2.001 YEARS
MEAN FLOW RATE =   1.437 HM3/YR
TOTAL FLOW VOLUME =   2.88 HM3
FLOW DATE RANGE   = 20040101 TO 20051231
SAMPLE DATE RANGE = 20040506 TO 20051031

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	317.5	158.6	.6993E+03	110.43	.167
2 Q WTD C	308.7	154.2	.5626E+03	107.36	.154
3 IJC	306.6	153.2	.5501E+03	106.63	.153
4 REG-1	314.3	157.1	.8786E+03	109.32	.189
5 REG-2	316.4	158.1	.7844E+03	110.06	.177
6 REG-3	342.4	171.1	.1300E+04	119.07	.211

585304 Brewer Outlet 04 and 05 VAR=tdp METHOD= 2 Q WTD C

Load Time Series

Date	Sample Days	Count	Volume (hm3)	Model Mass (kg)	Model Conc (ppb)	Interpolated Mass (kg)	Interpolated Conc (ppb)
2004	366.00	19	1.001	113.0	112.91	114.1	113.98
2005	365.00	32	1.874	195.6	104.39	194.7	103.87
ALL	731.01	51	2.875	308.7	107.36	308.8	107.39

585304 Brewer Outlet 04 and 05 VAR=tp METHOD= 3 IJC

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	438	24	24	12.7	.305	.243	-.413	.003
2	184	18	18	30.5	1.741	1.755	.559	.255
3	109	10	10	56.8	5.469	6.078	-.607	.228
***	731	52	52	100.0	1.437	1.889		

FLOW STATISTICS
FLOW DURATION = 731.0 DAYS = 2.001 YEARS
MEAN FLOW RATE = 1.437 HM3/YR
TOTAL FLOW VOLUME = 2.88 HM3
FLOW DATE RANGE = 20040101 TO 20051231
SAMPLE DATE RANGE = 20040506 TO 20051031

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	422.2	210.9	.8434E+03	146.84	.138
2 Q WTD C	412.6	206.2	.6302E+03	143.50	.122
3 IJC	410.3	205.0	.6196E+03	142.71	.121
4 REG-1	419.3	209.5	.9391E+03	145.85	.146
5 REG-2	419.7	209.7	.8568E+03	145.97	.140
6 REG-3	442.7	221.2	.1209E+04	153.98	.157

585304 Brewer Outlet 04 and 05 VAR=tp METHOD= 3 IJC

Load Time Series

Date	Sample Days	Count	Volume (hm3)	Model Mass (kg)	Model Conc (ppb)	Interpolated Mass (kg)	Interpolated Conc (ppb)
2004	366.00	19	1.001	151.7	151.54	152.8	152.64
2005	365.00	33	1.874	258.6	138.00	257.8	137.57
ALL	731.01	52	2.875	410.3	142.71	410.6	142.82

585304 Brewer Outlet 04 and 05 VAR=tss METHOD= 3 IJC

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	438	24	24	12.7	.305	.243	.185	.028
2	184	18	18	30.5	1.741	1.755	-.670	.271
3	109	10	10	56.8	5.469	6.078	.241	.499
***	731	52	52	100.0	1.437	1.889		

FLOW STATISTICS
FLOW DURATION = 731.0 DAYS = 2.001 YEARS
MEAN FLOW RATE = 1.437 HM3/YR
TOTAL FLOW VOLUME = 2.88 HM3
FLOW DATE RANGE = 20040101 TO 20051231
SAMPLE DATE RANGE = 20040506 TO 20051031

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	26329.8	13155.9	.1016E+08	9157.60	.242
2 Q WTD C	25660.1	12821.3	.8695E+07	8924.68	.230
3 IJC	25588.2	12785.3	.8609E+07	8899.66	.229
4 REG-1	25569.6	12776.1	.8622E+07	8893.22	.230
5 REG-2	25680.1	12831.2	.9587E+07	8931.62	.241
6 REG-3	22783.5	11384.0	.4327E+07	7924.19	.183

585304 Brewer Outlet 04 and 05   VAR=tss   METHOD= 3 IJC

Load Time Series

				------Model------		----Interpolated----	
Date	Days	Sample Count	Volume (hm3)	Mass (kg)	Conc (ppb)	Mass (kg)	Conc (ppb)
2004	366.00	19	1.001	9299.2	9288.72	9535.0	9524.23
2005	365.00	33	1.874	16288.9	8691.83	16058.4	8568.80
ALL	731.01	52	2.875	25588.2	8899.67	25593.4	8901.47

585305 Brewer SW TRIB 04 & 05

Average Sample Interval = 18.1 Days, Date Range = 20040603 to 20050707
Maximum Sample Interval =   254 Days, Date Range = 20040723 to 20050404
Percent of Total Flow Volume Occuring In This Interval =   1.0%

Total Flow Volume on Sampled Days =   34.7 hm3
Total Flow Volume on All Days   =   750.3 hm3
Percent of Total Flow Volume Sampled =   4.6%

Maximum Sampled Flow Rate =   15.59 hm3/yr
Maximum Total Flow Rate   =   161.13 hm3/yr
Number of Days when Flow Exceeded Maximum Sampled Flow = 10 out of 731
Percent of Total Flow Volume Occurring at Flow Rates Exceeding the
Maximum Sampled Flow Rate =   75.9%

585305 Brewer SW TRIB 04 & 05   VAR=nh3-4   METHOD= 1 AV LOAD
COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	689	16	16	5.5	.060	.297	.164	.516
2	42	6	6	94.5	16.880	4.990	.418	.523
***	731	22	22	100.0	1.026	1.577		

FLOW STATISTICS
FLOW DURATION =   731.0 DAYS = 2.001 YEARS
MEAN FLOW RATE =   1.026 HM3/YR
TOTAL FLOW VOLUME =   2.05 HM3
FLOW DATE RANGE   = 20040101 TO 20051231
SAMPLE DATE RANGE = 20040603 TO 20050707

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	123.9	61.9	.5213E+03	60.32	.369
2 Q WTD C	121.3	60.6	.7762E+03	59.04	.460
3 IJC	114.3	57.1	.1030E+04	55.65	.562
4 REG-1	179.4	89.6	.9172E+06	87.33	10.685
5 REG-2	299.4	149.6	.3995E+08	145.73	42.255
6 REG-3	246.6	123.2	.5173E+06	120.05	5.837

585305 Brewer SW TRIB 04 & 05   VAR=nh3-4   METHOD= 1 AV LOAD

Load Time Series

Date	Days	Sample Count	Volume (hm3)	Model Mass (kg)	Model Conc (ppb)	Interpolated Mass (kg)	Interpolated Conc (ppb)
2004	366.00	5	1.358	59.1	43.53	58.4	43.01
2005	365.00	24	.696	64.8	93.05	65.6	94.26
ALL	731.01	29	2.054	123.9	60.32	124.0	60.38

585305 Brewer SW TRIB 04 & 05   VAR=no2+no3   METHOD= 2 Q WTD C

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	689	16	16	5.5	.060	.297	.763	.001
2	42	6	6	94.5	16.880	4.990	.087	.941
***	731	22	22	100.0	1.026	1.577		

FLOW STATISTICS
FLOW DURATION =   731.0 DAYS = 2.001 YEARS
MEAN FLOW RATE =   1.026 HM3/YR
TOTAL FLOW VOLUME =   2.05 HM3
FLOW DATE RANGE   = 20040101 TO 20051231
SAMPLE DATE RANGE = 20040603 TO 20050707

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	1665.5	832.2	.3428E+05	810.80	.222
2 Q WTD C	2766.3	1382.2	.6343E+06	1346.69	.576
3 IJC	2443.4	1220.9	.8395E+06	1189.49	.750
4 REG-1	2907.4	1452.7	.8395E+08	1415.40	6.307
5 REG-2	3427.7	1712.7	.1734E+10	1668.66	24.317
6 REG-3	22335.8	11160.2	.6898E+10	10873.47	7.442

585305 Brewer SW TRIB 04 & 05   VAR=no2+no3   METHOD= 2 Q WTD C

Load Time Series

Date	Days	Sample Count	Volume (hm3)	Model Mass (kg)	Model Conc (ppb)	Interpolated Mass (kg)	Interpolated Conc (ppb)
2004	366.00	5	1.358	1817.2	1338.43	1796.3	1323.05
2005	365.00	24	.696	949.1	1362.80	970.0	1392.83
ALL	731.01	29	2.054	2766.3	1346.69	2766.3	1346.71

585305 Brewer SW TRIB 04 & 05   VAR=inorg-n   METHOD= 2 Q WTD C

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	689	16	16	5.5	.060	.297	.587	.004
2	42	6	6	94.5	16.880	4.990	.049	.964
***	731	22	22	100.0	1.026	1.577		

FLOW STATISTICS
FLOW DURATION =   731.0 DAYS = 2.001 YEARS
MEAN FLOW RATE =   1.026 HM3/YR
TOTAL FLOW VOLUME =   2.05 HM3
FLOW DATE RANGE   = 20040101 TO 20051231
SAMPLE DATE RANGE = 20040603 TO 20050707

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	1789.4	894.1	.4178E+05	871.12	.229
2 Q WTD C	2887.6	1442.8	.6702E+06	1405.72	.567
3 IJC	2557.7	1278.0	.8943E+06	1245.13	.740
4 REG-1	2920.1	1459.0	.7262E+08	1421.54	5.841
5 REG-2	3286.9	1642.3	.1368E+10	1600.13	22.522
6 REG-3	16631.7	8310.2	.2769E+10	8096.65	6.332

585305 Brewer SW TRIB 04 & 05 VAR=inorg-n METHOD= 2 Q WTD C

Load Time Series

				------Model------		----Interpolated----	
		Sample	Volume	Mass	Conc	Mass	Conc
Date	Days	Count	(hm3)	(kg)	(ppb)	(kg)	(ppb)
2004	366.00	5	1.358	1892.7	1394.05	1870.7	1377.84
2005	365.00	24	.696	994.9	1428.48	1016.9	1460.15
ALL	731.01	29	2.054	2887.6	1405.72	2887.6	1405.74

585305 Brewer SW TRIB 04 & 05 VAR=tn METHOD= 2 Q WTD C

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	689	16	16	5.5	.060	.297	.220	.006
2	42	6	6	94.5	16.880	4.990	-.280	.485
***	731	22	22	100.0	1.026	1.577		

FLOW STATISTICS
FLOW DURATION = 731.0 DAYS = 2.001 YEARS
MEAN FLOW RATE = 1.026 HM3/YR
TOTAL FLOW VOLUME = 2.05 HM3
FLOW DATE RANGE = 20040101 TO 20051231
SAMPLE DATE RANGE = 20040603 TO 20050707

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	2632.4	1315.3	.7164E+05	1281.51	.203
2 Q WTD C	4353.0	2175.0	.8387E+06	2119.11	.421
3 IJC	3976.9	1987.1	.1112E+07	1936.05	.531
4 REG-1	3155.6	1576.7	.3706E+07	1536.21	1.221
5 REG-2	2262.7	1130.6	.1005E+08	1101.52	2.804
6 REG-3	4368.9	2182.9	.3771E+07	2126.85	.890

585305 Brewer SW TRIB 04 & 05 VAR=tn METHOD= 2 Q WTD C

Load Time Series

				------Model------		----Interpolated----	
		Sample	Volume	Mass	Conc	Mass	Conc
Date	Days	Count	(hm3)	(kg)	(ppb)	(kg)	(ppb)
2004	366.00	5	1.358	2858.5	2105.42	2834.7	2087.91
2005	365.00	24	.696	1494.5	2145.81	1518.3	2179.99
ALL	731.01	29	2.054	4353.0	2119.11	4353.0	2119.13

585305 Brewer SW TRIB 04 & 05 VAR=tdp METHOD= 3 IJC

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	661	13	13	2.7	.030	.159	.091	.624
2	41	6	6	5.5	1.014	1.328	.091	.766
3	29	3	3	91.8	23.751	8.221	-.088	.891
***	731	22	22	100.0	1.026	1.577		

FLOW STATISTICS
FLOW DURATION = 731.0 DAYS = 2.001 YEARS
MEAN FLOW RATE = 1.026 HM3/YR
TOTAL FLOW VOLUME = 2.05 HM3
FLOW DATE RANGE = 20040101 TO 20051231
SAMPLE DATE RANGE = 20040603 TO 20050707

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	253.8	126.8	.1196E+04	123.53	.273
2 Q WTD C	498.6	249.1	.7999E+03	242.73	.114
3 IJC	490.4	245.0	.3421E+03	238.72	.075
4 REG-1	471.3	235.5	.2117E+05	229.44	.618
5 REG-2	385.0	192.4	.5796E+05	187.44	1.251
6 REG-3	537.5	268.6	.1348E+06	261.67	1.367

585305 Brewer SW TRIB 04 & 05 VAR=tdp METHOD= 3 IJC
Load Time Series

	Sample		Volume	------Model------		----Interpolated----	
				Mass	Conc	Mass	Conc
Date	Days	Count	(hm3)	(kg)	(ppb)	(kg)	(ppb)
2004	366.00	5	1.358	322.4	237.49	322.5	237.55
2005	365.00	24	.696	167.9	241.13	168.1	241.39
ALL	731.01	29	2.054	490.4	238.72	490.6	238.85

585305 Brewer SW TRIB 04 & 05 VAR=tp METHOD= 3 IJC
COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	661	13	13	2.7	.030	.159	-.071	.620
2	41	6	6	5.5	1.014	1.328	-.013	.964
3	29	3	3	91.8	23.751	8.221	-.126	.854
***	731	22	22	100.0	1.026	1.577		

FLOW STATISTICS
FLOW DURATION = 731.0 DAYS = 2.001 YEARS
MEAN FLOW RATE = 1.026 HM3/YR
TOTAL FLOW VOLUME = 2.05 HM3
FLOW DATE RANGE = 20040101 TO 20051231
SAMPLE DATE RANGE = 20040603 TO 20050707

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	314.7	157.2	.1557E+04	153.21	.251
2 Q WTD C	581.9	290.8	.1550E+04	283.30	.135
3 IJC	568.3	284.0	.8841E+03	276.66	.105
4 REG-1	543.2	271.4	.2711E+05	264.44	.607
5 REG-2	403.0	201.3	.7126E+05	196.17	1.326
6 REG-3	629.3	314.4	.5503E+06	306.35	2.359

585305 Brewer SW TRIB 04 & 05 VAR=tp METHOD= 3 IJC
Load Time Series

	Sample		Volume	------Model------		----Interpolated----	
				Mass	Conc	Mass	Conc
Date	Days	Count	(hm3)	(kg)	(ppb)	(kg)	(ppb)
2004	366.00	5	1.358	372.8	274.56	372.6	274.42
2005	365.00	24	.696	195.5	280.75	196.2	281.69
ALL	731.01	29	2.054	568.3	276.66	568.8	276.89

585305 Brewer SW TRIB 04 & 05 VAR=tss METHOD= 2 Q WTD C
COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	689	16	16	5.5	.060	.297	.099	.187
2	42	6	6	94.5	16.880	4.990	.069	.691
***	731	22	22	100.0	1.026	1.577		

FLOW STATISTICS
FLOW DURATION = 731.0 DAYS = 2.001 YEARS
MEAN FLOW RATE = 1.026 HM3/YR
TOTAL FLOW VOLUME = 2.05 HM3
FLOW DATE RANGE = 20040101 TO 20051231
SAMPLE DATE RANGE = 20040603 TO 20050707

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	8832.2	4413.1	.1947E+07	4299.69	.316
2 Q WTD C	12811.7	6401.5	.1402E+07	6236.98	.185
3 IJC	12476.2	6233.8	.1994E+07	6073.64	.227
4 REG-1	13607.7	6799.2	.7745E+08	6624.51	1.294
5 REG-2	15281.0	7635.3	.7508E+09	7439.11	3.589
6 REG-3	14122.6	7056.5	.4319E+08	6875.15	.931

585305 Brewer SW TRIB 04 & 05   VAR=tss   METHOD= 2 Q WTD C
Load Time Series

Date	Days	Sample Count	Volume (hm3)	------Model------ Mass (kg)	Conc (ppb)	----Interpolated---- Mass (kg)	Conc (ppb)
2004	366.00	5	1.358	8325.0	6131.72	8268.5	6090.09
2005	365.00	24	.696	4486.7	6442.19	4543.3	6523.51
ALL	731.01	29	2.054	12811.7	6236.99	12811.8	6237.04

585306 Brewer W TRIB 04 & 05

Average Sample Interval = 13.6 Days, Date Range = 20040603 to 20051031
Maximum Sample Interval = 156 Days, Date Range = 20041029 to 20050404
Percent of Total Flow Volume Occuring In This Interval = 3.2%

Total Flow Volume on Sampled Days = 14.6 hm3
Total Flow Volume on All Days = 239.4 hm3
Percent of Total Flow Volume Sampled = 6.1%

Maximum Sampled Flow Rate = 3.14 hm3/yr
Maximum Total Flow Rate = 16.59 hm3/yr
Number of Days when Flow Exceeded Maximum Sampled Flow = 14 out of 731
Percent of Total Flow Volume Occurring at Flow Rates Exceeding the
Maximum Sampled Flow Rate = 51.1%

585306 Brewer W TRIB 04 & 05   VAR=nh3-4   METHOD= 2 Q WTD C
COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	731	38	38	100.0	.327	.383	.092	.442
***	731	38	38	100.0	.327	.383		

FLOW STATISTICS
FLOW DURATION = 731.0 DAYS = 2.001 YEARS
MEAN FLOW RATE = .327 HM3/YR
TOTAL FLOW VOLUME = .66 HM3
FLOW DATE RANGE = 20040101 TO 20051231
SAMPLE DATE RANGE = 20040603 TO 20051031

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	22.2	11.1	.1797E+02	33.86	.382
2 Q WTD C	19.0	9.5	.8758E+01	28.95	.312
3 IJC	18.9	9.4	.9889E+01	28.79	.334
4 REG-1	18.7	9.3	.9009E+01	28.54	.321
5 REG-2	30.7	15.3	.1537E+03	46.86	.808
6 REG-3	20.0	10.0	.1182E+02	30.52	.344

585306 Brewer W TRIB 04 & 05 VAR=nh3-4 METHOD= 2 Q WTD C
Load Time Series

Date	Sample Days	Count	Volume (hm3)	Model Mass (kg)	Model Conc (ppb)	Interpolated Mass (kg)	Interpolated Conc (ppb)
2004	366.00	10	.323	9.3	28.95	9.0	27.99
2005	365.00	28	.333	9.6	28.95	9.9	29.89
ALL	731.01	38	.655	19.0	28.95	19.0	28.96

585306 Brewer W TRIB 04 & 05 VAR=no2+no3 METHOD= 3 IJC
COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	569	21	21	11.7	.049	.080	-.167	.718
2	109	12	12	14.0	.308	.283	.181	.562
3	53	5	5	74.2	3.352	1.894	-.558	.409
***	731	38	38	100.0	.327	.383		

FLOW STATISTICS
FLOW DURATION = 731.0 DAYS = 2.001 YEARS
MEAN FLOW RATE = .327 HM3/YR
TOTAL FLOW VOLUME = .66 HM3
FLOW DATE RANGE = 20040101 TO 20051231
SAMPLE DATE RANGE = 20040603 TO 20051031

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	870.6	435.0	.3369E+04	1328.40	.133
2 Q WTD C	1111.4	555.3	.6475E+04	1695.80	.145
3 IJC	1100.6	549.9	.6090E+04	1679.43	.142
4 REG-1	944.2	471.8	.2277E+05	1440.66	.320
5 REG-2	830.2	414.8	.7965E+05	1266.74	.680
6 REG-3	1108.9	554.1	.1712E+05	1692.07	.236

585306 Brewer W TRIB 04 & 05 VAR=no2+no3 METHOD= 3 IJC
Load Time Series

Date	Sample Days	Count	Volume (hm3)	Model Mass (kg)	Model Conc (ppb)	Interpolated Mass (kg)	Interpolated Conc (ppb)
2004	366.00	10	.323	537.3	1665.75	536.8	1664.01
2005	365.00	28	.333	563.3	1692.69	564.2	1695.27
ALL	731.01	38	.655	1100.6	1679.43	1100.9	1679.88

585306 Brewer W TRIB 04 & 05 VAR=inorg-n METHOD= 3 IJC
COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	569	21	21	11.7	.049	.080	-.160	.724
2	109	12	12	14.0	.308	.283	.166	.598
3	53	5	5	74.2	3.352	1.894	-.546	.414
***	731	38	38	100.0	.327	.383		

FLOW STATISTICS
FLOW DURATION = 731.0 DAYS = 2.001 YEARS
MEAN FLOW RATE = .327 HM3/YR
TOTAL FLOW VOLUME = .66 HM3
FLOW DATE RANGE = 20040101 TO 20051231
SAMPLE DATE RANGE = 20040603 TO 20051031

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	884.1	441.7	.3373E+04	1349.00	.131
2 Q WTD C	1130.4	564.8	.6387E+04	1724.80	.142
3 IJC	1119.3	559.2	.5916E+04	1707.85	.138
4 REG-1	962.4	480.9	.2265E+05	1468.49	.313
5 REG-2	845.4	422.4	.8297E+05	1289.94	.682
6 REG-3	1128.5	563.9	.1636E+05	1721.99	.227

585306 Brewer W TRIB 04 & 05 VAR=inorg-n METHOD= 3 IJC
Load Time Series

				------Model------		----Interpolated----	
		Sample	Volume	Mass	Conc	Mass	Conc
Date	Days	Count	(hm3)	(kg)	(ppb)	(kg)	(ppb)
2004	366.00	10	.323	546.6	1694.58	545.8	1691.89
2005	365.00	28	.333	572.6	1720.71	573.8	1724.28
ALL	731.01	38	.655	1119.3	1707.84	1119.6	1708.33

585307 Brewer NW TRIB 04-05

Average Sample Interval = 10.5 Days, Date Range = 20040525 to 20051031
Maximum Sample Interval = 156 Days, Date Range = 20041029 to 20050404
Percent of Total Flow Volume Occuring In This Interval = .3%

Total Flow Volume on Sampled Days = 4.7 hm3
Total Flow Volume on All Days = 82.7 hm3
Percent of Total Flow Volume Sampled = 5.6%

Maximum Sampled Flow Rate = .79 hm3/yr
Maximum Total Flow Rate = 17.96 hm3/yr
Number of Days when Flow Exceeded Maximum Sampled Flow = 9 out of 731
Percent of Total Flow Volume Occurring at Flow Rates Exceeding the
Maximum Sampled Flow Rate = 70.0%

585307 Brewer NW TRIB 04-05 VAR=nh3-4 METHOD= 2 Q WTD C
COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	731	50	50	100.0	.113	.093	-.057	.409
***	731	50	50	100.0	.113	.093		

FLOW STATISTICS
FLOW DURATION = 731.0 DAYS = 2.001 YEARS
MEAN FLOW RATE = .113 HM3/YR
TOTAL FLOW VOLUME = .23 HM3
FLOW DATE RANGE = 20040101 TO 20051231
SAMPLE DATE RANGE = 20040525 TO 20051031

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	5.9	2.9	.8467E+00	25.89	.314
2 Q WTD C	7.1	3.6	.7374E+00	31.46	.241
3 IJC	7.1	3.6	.7387E+00	31.44	.242
4 REG-1	7.0	3.5	.7659E+00	31.11	.249
6 REG-3	6.0	3.0	.8326E+00	26.52	.304

585307 Brewer NW TRIB 04-05 VAR=nh3-4 METHOD= 2 Q WTD C
Load Time Series

				------Model------		----Interpolated----	
		Sample	Volume	Mass	Conc	Mass	Conc
Date	Days	Count	(hm3)	(kg)	(ppb)	(kg)	(ppb)
2004	366.00	18	.142	4.5	31.46	4.4	31.15
2005	365.00	32	.085	2.7	31.46	2.7	31.97
ALL	731.01	50	.226	7.1	31.46	7.1	31.46

585307 Brewer NW TRIB 04-05 VAR=no2+no3 METHOD= 2 Q WTD C

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	731	50	50	100.0	.113	.093	-.025	.545
***	731	50	50	100.0	.113	.093		

FLOW STATISTICS
FLOW DURATION = 731.0 DAYS = 2.001 YEARS
MEAN FLOW RATE = .113 HM3/YR
TOTAL FLOW VOLUME = .23 HM3
FLOW DATE RANGE = 20040101 TO 20051231
SAMPLE DATE RANGE = 20040525 TO 20051031

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	288.3	144.1	.6481E+03	1273.47	.177
2 Q WTD C	350.3	175.0	.7354E+03	1547.21	.155
3 IJC	344.5	172.2	.7889E+03	1521.80	.163
4 REG-1	348.6	174.2	.7569E+03	1539.72	.158
5 REG-2	62.2	31.1	.3053E+05	274.81	5.621
6 REG-3	387.0	193.4	.5755E+03	1709.20	.124

585307 Brewer NW TRIB 04-05 VAR=no2+no3 METHOD= 2 Q WTD C
Load Time Series

		Sample	Volume	------Model------		----Interpolated----	
				Mass	Conc	Mass	Conc
Date	Days	Count	(hm3)	(kg)	(ppb)	(kg)	(ppb)
2004	366.00	18	.142	219.1	1547.21	220.7	1558.17
2005	365.00	32	.085	131.1	1547.21	129.6	1528.88
ALL	731.01	50	.226	350.3	1547.20	350.3	1547.20

585307 Brewer NW TRIB 04-05 VAR=inorg-n METHOD= 2 Q WTD C
COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	731	50	50	100.0	.113	.093	-.025	.436
***	731	50	50	100.0	.113	.093		

FLOW STATISTICS
FLOW DURATION = 731.0 DAYS = 2.001 YEARS
MEAN FLOW RATE = .113 HM3/YR
TOTAL FLOW VOLUME = .23 HM3
FLOW DATE RANGE = 20040101 TO 20051231
SAMPLE DATE RANGE = 20040525 TO 20051031

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	294.2	147.0	.6720E+03	1299.36	.176
2 Q WTD C	357.4	178.6	.7337E+03	1578.66	.152
3 IJC	351.7	175.7	.7851E+03	1553.24	.159
4 REG-1	355.7	177.7	.7553E+03	1570.93	.155
5 REG-2	59.7	29.8	.3150E+05	263.86	5.946
6 REG-3	383.3	191.5	.5442E+03	1693.17	.122

585307 Brewer NW TRIB 04-05 VAR=inorg-n METHOD= 2 Q WTD C
Load Time Series

		Sample	Volume	------Model------		----Interpolated----	
				Mass	Conc	Mass	Conc
Date	Days	Count	(hm3)	(kg)	(ppb)	(kg)	(ppb)
2004	366.00	18	.142	223.6	1578.66	225.1	1589.32
2005	365.00	32	.085	133.8	1578.67	132.3	1560.85
ALL	731.01	50	.226	357.4	1578.66	357.4	1578.66

585307 Brewer NW TRIB 04-05 VAR=tn METHOD= 2 Q WTD C

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	731	50	50	100.0	.113	.093	.010	.671
***	731	50	50	100.0	.113	.093		

FLOW STATISTICS
FLOW DURATION = 731.0 DAYS = 2.001 YEARS
MEAN FLOW RATE = .113 HM3/YR
TOTAL FLOW VOLUME = .23 HM3
FLOW DATE RANGE = 20040101 TO 20051231
SAMPLE DATE RANGE = 20040525 TO 20051031

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	421.3	210.5	.1830E+04	1860.90	.203
2 Q WTD C	511.9	255.8	.2821E+03	2260.91	.066
3 IJC	509.8	254.7	.2845E+03	2251.72	.066
4 REG-1	512.9	256.2	.3177E+03	2265.21	.070
5 REG-2	676.8	338.2	.2954E+05	2989.46	.508
6 REG-3	529.3	264.5	.4316E+03	2337.99	.079

585307 Brewer NW TRIB 04-05 VAR=tn METHOD= 2 Q WTD C

Load Time Series

	Sample		Volume	------Model------		----Interpolated----	
				Mass	Conc	Mass	Conc
Date	Days	Count	(hm3)	(kg)	(ppb)	(kg)	(ppb)
2004	366.00	18	.142	320.2	2260.91	320.8	2265.00
2005	365.00	32	.085	191.6	2260.91	191.1	2254.09
ALL	731.01	50	.226	511.9	2260.92	511.9	2260.92

585307 Brewer NW TRIB 04-05 VAR=tdp METHOD= 3 IJC

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	587	23	23	3.9	.006	.011	.058	.382
2	115	21	21	17.2	.123	.107	-.189	.392
3	29	5	5	78.9	2.251	.420	1.593	.038
***	731	49	49	100.0	.113	.094		

FLOW STATISTICS
FLOW DURATION = 731.0 DAYS = 2.001 YEARS
MEAN FLOW RATE = .113 HM3/YR
TOTAL FLOW VOLUME = .23 HM3
FLOW DATE RANGE = 20040101 TO 20051231
SAMPLE DATE RANGE = 20040525 TO 20051031

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	12.6	6.3	.4512E+01	55.58	.338
2 Q WTD C	47.0	23.5	.3614E+02	207.42	.256
3 IJC	49.5	24.7	.2751E+02	218.42	.212
4 REG-1	121.5	60.7	.2146E+04	536.57	.763
5 REG-2	4175.4	2086.2	.1175E+08	18442.07	1.643
6 REG-3	83.9	41.9	.7023E+03	370.67	.632

585307 Brewer NW TRIB 04-05 VAR=tdp METHOD= 3 IJC

Load Time Series

				------Model------		----Interpolated----	
	Sample		Volume	Mass	Conc	Mass	Conc
Date	Days	Count	(hm3)	(kg)	(ppb)	(kg)	(ppb)
2004	366.00	18	.142	30.6	216.18	30.2	213.41
2005	365.00	31	.085	18.8	222.16	19.1	225.86
ALL	731.01	49	.226	49.5	218.42	49.4	218.07

585307 Brewer NW TRIB 04-05 VAR=tp METHOD= 3 IJC

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	587	24	24	3.9	.006	.013	-.035	.502
2	115	21	21	17.2	.123	.107	.255	.044
3	29	5	5	78.9	2.251	.420	.776	.019
***	731	50	50	100.0	.113	.093		

FLOW STATISTICS

FLOW DURATION = 731.0 DAYS = 2.001 YEARS

MEAN FLOW RATE = .113 HM3/YR

TOTAL FLOW VOLUME = .23 HM3

FLOW DATE RANGE = 20040101 TO 20051231

SAMPLE DATE RANGE = 20040525 TO 20051031

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	20.6	10.3	.5645E+01	90.81	.231
2 Q WTD C	66.6	33.3	.2677E+02	294.32	.155
3 IJC	68.7	34.3	.2012E+02	303.63	.131
4 REG-1	103.8	51.9	.2483E+03	458.46	.304
5 REG-2	1616.3	807.6	.5576E+06	7139.21	.925
6 REG-3	87.2	43.6	.1390E+03	385.14	.271

585307 Brewer NW TRIB 04-05 VAR=tp METHOD= 3 IJC

Load Time Series

				------Model------		----Interpolated----	
	Sample		Volume	Mass	Conc	Mass	Conc
Date	Days	Count	(hm3)	(kg)	(ppb)	(kg)	(ppb)
2004	366.00	18	.142	42.7	301.47	42.4	299.47
2005	365.00	32	.085	26.0	307.24	26.3	309.79
ALL	731.01	50	.226	68.7	303.63	68.7	303.33

585307 Brewer NW TRIB 04-05 VAR=tss METHOD= 2 Q WTD C

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	731	50	50	100.0	.113	.093	-.171	.005
***	731	50	50	100.0	.113	.093		

FLOW STATISTICS

FLOW DURATION = 731.0 DAYS = 2.001 YEARS

MEAN FLOW RATE = .113 HM3/YR

TOTAL FLOW VOLUME = .23 HM3

FLOW DATE RANGE = 20040101 TO 20051231

SAMPLE DATE RANGE = 20040525 TO 20051031

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	2466.1	1232.2	.1400E+06	10892.42	.304
2 Q WTD C	2996.2	1497.1	.1438E+06	13233.84	.253
3 IJC	2981.4	1489.7	.1516E+06	13168.54	.261
4 REG-1	2898.0	1448.0	.1373E+06	12800.37	.256
6 REG-3	1949.7	974.2	.6339E+05	8611.48	.258

585307 Brewer NW TRIB 04-05 VAR=tss METHOD= 2 Q WTD C

Load Time Series

				------Model------		----Interpolated----	
		Sample	Volume	Mass	Conc	Mass	Conc
Date	Days	Count	(hm3)	(kg)	(ppb)	(kg)	(ppb)
2004	366.00	18	.142	1874.4	13233.84	1911.4	13494.91
2005	365.00	32	.085	1121.8	13233.86	1084.7	12797.00
ALL	731.01	50	.226	2996.2	13233.81	2996.1	13233.58

Appendix D

AnnAGNPS Watershed Model Results

“Current State” Simulation

```
AnnAGNPS: v3.51.a.16         Accumulation File            04/02/2007  15:49:42
Brewerlake watershed
Simulation Period     1  12003 12 312005

Simulation Accumulation:                        1
Totals at Outlet:
          Simulation Days           1096
          Drainage Area         6107.500

Outlet              Y Y Y Y Y N         Y            6107.50   6107.50
          Water                                     295.3633
          Bed & Bank        0.0       0.0       0.0       0.0       0.0
          Gully             0.0       0.0       0.0       0.0       0.0
          Sheet&Rill    521.561    50.017     7.212       0.0       0.0
          Size Total    521.561    50.017     7.212       0.0       0.0
          Source Tot        0.0       0.0   578.791   578.791
          Nutrients        0.29      0.55     42.75       0.0      4.40     21.07
```

“Presettlement” Simulation

```
AnnAGNPS: v3.51.a.16         Accumulation File            10/16/2007   9:39:35
Brewerlake watershed
Simulation Period     1  12003 12 312005

Simulation Accumulation:                        1
Totals at Outlet:
          Simulation Days           1096
          Drainage Area         6107.500

Outlet              Y Y Y Y Y N         Y            6107.50   6107.50
          Water                                       9.4008
          Bed & Bank        0.0       0.0       0.0       0.0       0.0
          Gully             0.0       0.0       0.0       0.0       0.0
          Sheet&Rill      0.757     0.149     0.099       0.0       0.0
          Size Total      0.757     0.149     0.099       0.0       0.0
          Source Tot        0.0       0.0     1.006     1.006
          Nutrients   0.29E-03  0.79E-02      0.05       0.0      0.39      2.27
```

“BMP Implementation” Simulation

```
AnnAGNPS: v3.51.a.16         Accumulation File            10/15/2007  14:30:06
Brewerlake watershed
Simulation Period     1  12003 12 312005

Simulation Accumulation:                        1
Totals at Outlet:
          Simulation Days           1096
          Drainage Area         6107.500

Outlet              Y Y Y Y Y N         Y            6107.50   6107.50
          Water                                     161.7097
          Bed & Bank        0.0       0.0       0.0       0.0       0.0
          Gully             0.0       0.0       0.0       0.0       0.0
          Sheet&Rill     62.810     4.726     1.720       0.0       0.0
          Size Total     62.810     4.726     1.720       0.0       0.0
          Source Tot        0.0       0.0    69.255    69.255
          Nutrients        0.06      0.26      5.96       0.0      2.14     11.73
```

Appendix E
Review Comments Provided by the US EPA Region 8

EPA REGION VIII TMDL REVIEW FORM

Document Name:	**Brewer Lake Nutrient and Dissolved Oxygen TMDLs**
Submitted by:	**Mike Ell, NDDoH**
Date Received:	**August 19, 2008**
Review Date:	**August 27, 2008**
Reviewer:	**Vern Berry, EPA**
Formal or Informal Review?	**Informal – Public Notice**

This document provides a standard format for EPA Region 8 to provide comments to the North Dakota Department of Health (NDDoH) on TMDL documents provided to the EPA for either official formal or informal review. All TMDL documents are measured against the following 11 review criteria:

1. Water Quality Impairment Status
2. Water Quality Standards
3. Water Quality Targets
4. Significant Sources
5. Technical Analysis
6. Margin of Safety and Seasonality
7. Total Maximum Daily Load
8. Allocation
9. Public Participation
10. Monitoring Strategy
11. Restoration Strategy

Each of the 11 review criteria are described below to provide the rational for the review, followed by EPA's comments. This review is intended to ensure compliance with the Clean Water Act and also to ensure that the reviewed documents are technically sound and the conclusions are technically defensible.

1. Water Quality Impairment Status

Criterion Description – Water Quality Impairment Status

TMDL documents must include a description of the listed water quality impairments. While the 303(d) list identifies probable causes and sources of water quality impairments, the information contained in the 303(d) list is generally not sufficiently detailed to provide the reader with an adequate understanding of the impairments. TMDL documents should include a thorough description/summary of all available water quality data such that the water quality impairments are clearly defined and linked to the impaired beneficial uses and/or appropriate water quality standards.

- [x] Satisfies Criterion
- [ ] Satisfies Criterion. Questions or comments provided below should be considered.
- [ ] Partially satisfies criterion. Questions or comments provided below need to be addressed.
- [ ] Criterion not satisfied. Questions or comments provided below need to be addressed.
- [ ] Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – Brewer Lake is located approximately 42 miles northwest of Fargo near the small town of Erie in Cass County, North Dakota. It is a 124 acre man-made impoundment in the Lower Sheyenne sub-basin (HUC 09020204) of the Red River basin of North Dakota. Rush River is the main tributary that drains into the reservoir. Brewer Lake is listed on the State's 2008 303(d) list as fully supporting but threatened for fish and other aquatic biota uses by nutrient/eutrophication biological indicators, dissolved oxygen and sedimentation/siltation, and as fully supported but threatened for recreational uses by nutrient/eutrophication biological indicators. Approximately 6,107 acres of land drain to the lake from the watershed. Brewer Lake is classified as a Class 2 cool water fishery, and is listed as a high priority for TMDL development. The majority of the land use in this watershed is agricultural (approximately 86 percent). Cropland acreage is approximately 81%, and the remaining 19% is haylands, pasture, low density development, conservation reserve program acres and water.

2. Water Quality Standards

Criterion Description – Water Quality Standards

The TMDL document must include a description of all applicable water quality standards for all affected jurisdictions. TMDLs result in maintaining and attaining water quality standards. Water quality standards are the basis from which TMDLs are established and the TMDL targets are derived, including the numeric, narrative, use classification, and antidegradation components of the standards.

- [x] Satisfies Criterion
- [ ] Satisfies Criterion. Questions or comments provided below should be considered.
- [ ] Partially satisfies criterion. Questions or comments provided below need to be addressed.
- [ ] Criterion not satisfied. Questions or comments provided below need to be addressed.
- [ ] Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – Brewer Lake is listed as impaired for nutrients/eutrophication, dissolved oxygen and sedimentation/siltation. The North Dakota Department of Health has set narrative water quality standards that apply to all surface waters of the state. The NDDoH narrative standards that apply to nutrients and sedimentation include:

"All waters of the state shall be free from substances attributable to municipal, industrial, or other discharges or agricultural practices in concentrations or combinations which are toxic or harmful to humans, animals, plants, or resident aquatic biota." (See NDAC 33-16-02-08.1.a.(4))

"No discharge of pollutants, which alone or in combination with other substances, shall:
1. Cause a public health hazard or injury to environmental resources;
2. Impair existing or reasonable beneficial uses of the receiving waters; or
3. Directly or indirectly cause concentrations of pollutants to exceed applicable standards of the receiving waters." (See NDAC 33-16-02-08.1.e.)

In addition to the narrative standards, the NDDH has set a biological goal for all surface waters of the state:

"The biological condition of surface waters shall be similar to that of sites or waterbodies determined by the department to be regional reference sites." (See NDAC 33-16-02-08.2.a.)

Currently, North Dakota does not have a numeric standard for nutrients, however nutrient guidelines for lakes have been established. The nutrient guidelines for lakes are: NO_3 as N = 0.25 mg/L; PO_4 as P = 0.02 mg/L; and total phosphorus = 0.1 mg/L.

The numeric standard for dissolved oxygen is $\geq$ 5.0 mg/L (single sample minimum).

Other applicable water quality standards are included on pages 14 - 16 of the TMDL report.

3. Water Quality Targets

Criterion Description – Water Quality Targets

Quantified targets or endpoints must be provided to address each listed pollutant/water body combination. Target values must represent achievement of applicable water quality standards and support of associated beneficial uses. For pollutants with numeric water quality standards, the numeric criteria are generally used as the TMDL target. For pollutants with narrative standards, the narrative standard must be translated into a measurable value. At a minimum, one target is required for each pollutant/water body combination. It is generally desirable, however, to include several targets that represent achievement of the standard and support of beneficial uses (e.g., for a sediment impairment issue it may be appropriate to include targets representing water column sediment such as TSS, embeddeness, stream morphology, up-slope conditions and a measure of biota).

☐ Satisfies Criterion
☐ Satisfies Criterion. Questions or comments provided below should be considered.
☒ Partially satisfies criterion. Questions or comments provided below need to be addressed.
☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
☐ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – The main water quality target for this TMDL is based on interpretation of narrative provisions found in State water quality standards. In North Dakota, algal blooms can limit contact and immersion recreation beneficial uses. Also algal blooms can deplete oxygen levels which can affect aquatic life uses. Several algal species are considered to be nuisance aquatic species. TSI measurements can be used to estimate how much algal production may occur in lakes.   Therefore, TSI is used as a measure of the narrative standard in order to determine whether beneficial uses are being met.

The mean total phosphorus TSI for Brewer Lake during the period of the assessment was 75.0. Nutrient reduction response modeling was conducted with BATHTUB, an Army Corps of Engineers eutrophication response model. The results of the modeling show that a 50% reduction in phosphorus loading to the reservoir will achieve a total phosphorus TSI of 65, which corresponds to a phosphorus concentration of 0.070 mg/L. This target is based on reducing the TSI values for the reservoir to within the eutrophic range as defined by Carlson, and decreasing the productivity of the reservoir and increasing dissolved oxygen concentrations. This target is based on best professional judgement and will fully support its beneficial uses.

The water quality targets used in this TMDL are: **maintain a mean annual total phosphorus TSI at or below 65; maintain a dissolved oxygen level of not less than 5 mg/L.**

COMMENTS – Brewer Lake is listed as impaired for sedimentation/siltation in addition to nutrients and dissolved oxygen. However, the TMDL does not contain a target for sediment, nor a justification that the lake is not impaired by sediment nor a statement that the sediment impairment will be addressed in a separate, future document. The TMDL needs to include an explanation of how the sedimentation/siltation impairment will be addressed.

The TMDL shows that pH data was collected in Brewer Lake, but it does not summarize or mention the pH results or whether its meeting the applicable pH WQS. A few sentences need to be added to the TMDL to summarize the pH readings in the lake and compare them with the pH WQS.

4. Significant Sources

Criterion Description – Significant Sources

TMDLs must consider all significant sources of the stressor of concern. All sources or causes of the stressor must be identified or accounted for in some manner. The detail provided in the source assessment step drives the rigor of the allocation step. In other words, it is only possible to specifically allocate quantifiable loads or load reductions to each significant source when the relative load contribution from each source has been estimated. Ideally, therefore, the pollutant load from each significant source should be quantified. This can be accomplished using site-specific monitoring data, modeling, or application of other assessment techniques. If insufficient time or resources are available to accomplish this step, a phased/adaptive management approach can be employed so long as the approach is clearly defined in the document.

- ☒ Satisfies Criterion
- ☐ Satisfies Criterion. Questions or comments provided below should be considered.
- ☐ Partially satisfies criterion. Questions or comments provided below need to be addressed.
- ☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
- ☐ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – The TMDL identifies the major sources of phosphorus as coming from nonpoint source agricultural landuses within the watershed. There are no known point source contributions in this watershed. A loading analysis was done for nutrients and sediment considering various agricultural land use and land management factors. Cropland and pastureland are the primary sources identified. Cropland acreage is approximately 81%, and the remaining 19% is haylands, pasture, low density development, conservation reserve program acres and water.

5. Technical Analysis

Criterion Description – Technical Analysis

*TMDLs must be supported by an appropriate level of technical analysis. It applies to **all** of the components of a TMDL document. It is vitally important that the technical basis for **all** conclusions be articulated in a manner that is easily understandable and readily apparent to the reader. Of particular importance, the cause and effect relationship between the pollutant and impairment and between the selected targets, sources, TMDLs, and allocations needs to be supported by an appropriate level of*

☐ Satisfies Criterion
☐ Satisfies Criterion. Questions or comments provided below should be considered.
☒ Partially satisfies criterion. Questions or comments provided below need to be addressed.
☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
☐ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – The technical analysis addresses linkage between the water quality target and the identified sources of nutrients, and describes the models or methods used to derive the TMDL loads that will ensure that the water quality standards are met. To determine the cause and effect relationship between the water quality target and the identified sources various models and loading analysis were utilized.

The FLUX model was used to facilitate the analysis and reduction of tributary inflow and outflow nutrient and sediment loadings for the Brewer Lake. Output from the FLUX program is then provided as an input file to calibrate the BATHTUB eutrophication response model. The BATHTUB model was used to predict and evaluate the effects of various nutrient load reduction scenarios on Brewer Lake.

The Annualized Agricultural Non-Point Source Model (AnnAGNPS) model was used to simulate alterations in land use practices and the resulting nutrient reduction response. The nutrient loading source analysis, that was used to identify necessary controls in the watershed, was based on the identification of critical cells.

Improvements in the dissolved oxygen concentration of the reservoir can be achieved through reduction of organic loading to the lake as a result of proposed BMP implementation. The TMDL contains a linkage analysis between phosphorus loading and low dissolved oxygen in lakes and reservoirs. It is anticipated that meeting the phosphorus load reduction target in Brewer Lake will address the dissolved oxygen impairment.

COMMENTS – Similar to the comment above in the Water Quality Targets section, the TMDL fails include a discussion of the sedimentation/siltation impairment in the Technical Analysis section. The Technical Analysis section should include a sub-section addressing the sediment impairment. This may include, as appropriate, a justification that the lake is not impaired by sediment, or a statement that the sediment impairment will be addressed in a separate, future document.

6. Margin of Safety and Seasonality

Criterion Description – Margin of Safety and Seasonality

A margin of safety (MOS) is a required component of the TMDL that accounts for the uncertainty about the relationship between the pollutant loads and the quality of the receiving water body (303(d)(1)(c)). The MOS can be implicitly expressed by incorporating a margin of safety into conservative assumptions used to develop the TMDL. In other cases, the MOS can be built in as a separate component of the TMDL (in this case, quantitatively, a TMDL = WLA + LA + MOS). In all cases, specific documentation describing the rational for the MOS is required.

Seasonal considerations, such as critical flow periods (high flow, low flow), also need to be considered

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☐ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – To account for the uncertainty associated with known sources and the load reductions necessary to reach the water quality target of TP TSI = 65, a 10% (25.04 kg/yr) explicit margin of safety is included in the nutrient TMDL. It is anticipated that the load reductions from the BMPs applied to the critical cells in the watershed, along improvements to riparian health through working with landowners to exclude cattle from riparian areas in the watershed, will meet the phosphorus loading target.

Seasonality was adequately considered by evaluating the cumulative impacts of the various seasons on water quality and by proposing BMPs that can be tailored to seasonal needs.

COMMENTS – Section 6.1, Margin of Safety (MOS), defines MOS, but does not say what the MOS is for this TMDL. The MOS section within the TMDL document needs to include an explanation of how the uncertainty in the TMDL loading calculations, and between the pollutant loads and the water quality of receiving waterbody. For an explicit MOS this could simply include the numeric value, and perhaps include a brief sentence of why an explicit MOS was chosen. For future TMDLs, EPA plans to work with all of the Region 8 states to strengthen the margin of safety in TMDLs, to be able to more accurately account for the uncertainty in the derivation of the TMDL loads.

7. TMDL

Criterion Description – Total Maximum Daily Load
TMDLs include a quantified pollutant reduction target. According to EPA regulations (see 40 CFR 130.2(i)). TMDLs can be expressed as mass per unit of time, toxicity, % load reduction, or other measure. TMDLs must address, either singly or in combination, each listed pollutant/water body combination.

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SUMMARY – The TMDL established for Brewer Lake is a 250.45 kg/yr (0.69 kg/day) total phosphorus load to the lake (50% reduction in external annual total phosphorus load). This is the modeled load which derived from the BATHTUB model using the flow and concentration data collected during the period of the assessment. The annual loading will vary from year-to-year; therefore, this TMDL is considered a long term average percent reduction in phosphorus loading. The TMDL contains a linkage analysis between phosphorus loading and low dissolved oxygen in lakes and reservoirs. It is anticipated that meeting the phosphorus load reduction target in Brewer Lake will address the dissolved oxygen impairment.

The NDDoH believes that describing the load as an annual load is more realistic and protective of the waterbody. Most phosphorus based eutrophication models use annual phosphorus loads, and seasonality and unpredictable precipitation patterns make a daily load unrealistic. EPA recognizes that, under the specific circumstances, the state may deem the annual load the most appropriate timeframe (i.e., the TSI water quality target is based on an interpretation of narrative water quality standards which naturally does not include an averaging period). EPA notes that the Brewer Lake TMDL calculations for phosphorus include an approximated daily load derived through simple division of the annual load by the number of days in a year**.** This should be considered an "average" daily load that typically will not match the actual phosphorus load reaching the lake on a given day.

8. Allocation

Criterion Description – Allocation *TMDLs apportion responsibility for taking actions or allocate the available assimilative capacity among the various point, nonpoint, and natural pollutant sources. Allocations may be expressed in a variety of ways such as by individual discharger, by tributary watershed, by source or land use category, by land parcel, or other appropriate scale or dividing of responsibility. A performance based allocation approach, where a detailed strategy is articulated for the application of BMPs, may also be appropriate for nonpoint sources. Every effort should be made to be as detailed as possible and also, to base all conclusions on the best available scientific principles.* *In cases where there is substantial uncertainty regarding the linkage between the proposed allocations and achievement of water quality standards, it may be necessary to employ a phased or adaptive management approach (e.g., establish a monitoring plan to determine if the proposed allocations are, in fact, leading to the desired water quality improvements).*

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SUMMARY – This TMDL addresses the need to achieve reductions in nutrients to attain water quality goals in Brewer Lake. The allocations in the TMDL include a "load allocation" attributed agricultural to nonpoint sources, and an explicit margin of safety. There are no known point source contributions in this watershed. The source allocations for phosphorus are assigned to the critical loading cells in the watershed. Critical cells are those with pasturelands in close proximity to the lake, and croplands located along along the Rush River and tributary inlets flowing to Brewer Lake. See the critical cells in Figure 16 of the TMDL for targeted areas for BMP implementation.

9. Public Participation

Criterion Description – Public Participation *The fundamental requirement for public participation is that all stakeholders have an opportunity to be part of the process. Notifications or solicitations for comments regarding the TMDL should clearly identify the product as a TMDL and the fact that it will be submitted to EPA for review. When the final TMDL is submitted to EPA for review, a copy of the comments received by the state should be also submitted to EPA..*

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☐ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – The TMDL includes a summary of the public participation process that has occurred. It describes the opportunities the public had to be involved in the TMDL development process. Copies of the draft TMDL were mailed to stakeholders in the watershed during public comment. Also, the draft

TMDL was posted on NDoDH's Water Quality Division website, and a public notice for comment was published in three newspapers.

10. Monitoring Strategy

Criterion Description – Monitoring Strategy
TMDLs may have significant uncertainty associated with selection of appropriate numeric targets and estimates of source loadings and assimilative capacity. In these cases, a phased TMDL approach may be necessary. For Phased TMDLs, it is EPA's expectation that a monitoring plan will be included as a component of the TMDL documents to articulate the means by which the TMDL will be evaluated in the field, and to provide supplemental data in the future to address any uncertainties that may exist when the document is prepared.

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☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
☒ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – Future monitoring is recommended in Section 10.0 of the TMDL to address margin of safety and seasonality needs, as well as provide additional data to ensure that the goals of the TMDL are met.

11. Restoration Strategy

Criterion Description – Restoration Strategy
At a minimum, sufficient information should be provided in the TMDL document to demonstrate that if the TMDL were implemented, water quality standards would be attained or maintained. Adding additional detail regarding the proposed approach for the restoration of water quality <u>*is not*</u> *currently a regulatory requirement, but is considered a value added component of a TMDL document.*

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☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
☒ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – The North Dakota Department of Health will work with the local soil conservation district, local volunteer groups and landowners to initiate restoration projects in the watershed.

Appendix F
Review Comments Provided by the US Fish and Wildlife Service

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Ecological Services
3425 Miriam Avenue
Bismarck, North Dakota 58501

SEP - 4 2008

Mr. Mike Ell
Environmental Administrator
Division of Water Quality
North Dakota Department of Health
918 East Divide Avenue
Bismarck, North Dakota 58501-1947

Dear Mr. Ell:

The U.S. Fish and Wildlife Service (Service) has reviewed the draft Brewer Lake and the draft Powers Lake Nutrient and Dissolved Oxygen Total Maximum Daily Load reports, and offers the following comments.

The North Dakota Department of Health (Department) has identified Brewer Lake, Cass County, and Powers Lake, in Burke and Mountrail Counties, as being water quality limited and needing total maximum daily loads (TMDL). Brewer Lake, a man-made reservoir, and Powers Lake, a natural lake, are on the Department's Section 303(d) List of Impaired Waters. Aquatic life in the two waterbodies is listed as impaired due to nutrients, sedimentation, and low dissolved oxygen. The draft TMDL reports indicate there are no waste allocations from point sources in the watersheds. Pollutant loads are attributed to nonpoint sources.

The draft documents provide discussion on identifying the pollutant reductions needed and actions that should be taken to achieve water quality standards for Brewer and Powers Lakes. The Service supports the Department's efforts to restore water quality to fully support aquatic life within the two lakes.

The Service concurs with the Department's assessment that the Brewer Lake TMDL and the Powers Lake TMDL will have no adverse effect to federally listed threatened or endangered species.

Thank you for the opportunity to comment on the draft documents. If you have any questions or need further assistance, please do not hesitate to contact Kevin Johnson of my staff at 701-250-4481, or at the letterhead address.

Sincerely,

Jeffrey K. Towner

Jeffrey K. Towner
Field Supervisor
North Dakota Field Office

Appendix G

Department Response to Comments

Department Response to Comments

During the 30 day public notice soliciting comment and participation for the Brewer Lake Nutrient and Dissolved Oxygen TMDL, the North Dakota Department of Health received comments from the US EPA (see Appendix E) and from Scott Elstad with the North Dakota Game and Fish Department in the form of a hand written note stating he had "no comment.". Below are the comments provided by EPA and the departments' response.

Comment from US EPA: "Brewer Lake is listed as impaired for sedimentation/siltation in addition to nutrients and dissolved oxygen. However, the TMDL does not contain a target for sediment, nor a justification that the lake is not impaired by sediment nor a statement that the sediment impairment will be addressed in a separate, future document. The TMDL needs to include an explanation of how the sedimentation/siltation impairment will be addressed."

NDDoH Response: Additional language has been added to Section 1.1, Clean Water Act Section 303(d) Listing Information, stating that the purpose of this TMDL report is for the pollutants, nutrients and low dissolved oxygen and that the sediment listing will be addressed as additional data become available.

Comment from US EPA: "The TMDL shows that pH data was collected in Brewer Lake, but it does not summarize or mention the pH results or whether its meeting the applicable pH WQS. A few sentences need to be added to the TMDL to summarize the pH readings in the lake and compare them with the pH WQS."

NDDoH Response: The references to pH and Specific Conductance in Table 5 have been changed to reflect that these data are laboratory measurements and not in situ readings in the field. Table 6 has been changed to include a statistical summary of the laboratory pH data and narrative language added to Section 1.5.3, pH and Nutrient Data, describing these results. It should be noted that the laboratory pH measurements ranged from 7.46 to 8.86 with a geometric mean of 8.54 and that all pH measurements were within the state water quality standard of 6 to 9.

Comment from US EPA: "Section 6.1, Margin of Safety (MOS), defines MOS, but does not say what the MOS is for this TMDL. The MOS section within the TMDL document needs to include an explanation of how the uncertainty in the TMDL loading calculations, and between the pollutant loads and the water quality of receiving waterbody. For an explicit MOS this could simply include the numeric value, and perhaps include a brief sentence of why an explicit MOS was chosen. For future TMDLs, EPA plans to work with all of the Region 8 states to strengthen the margin of safety in TMDLs, to be able to more accurately account for the uncertainty in the derivation of the TMDL loads."

NDDoH Response: Additional language has been added to Section 6.1 describing how the 10 percent explicit margin of safety that has been used for this TMDL was calculated and the values used.