Nutrient and Dissolved Oxygen TMDLs for Mirror Lake in Adams County, North Dakota

Final: August 2008

Prepared for:
USEPA Region 8
1595 Wynkoop Street
Denver, CO 80202-1129

Prepared by:
Michael J. Ell
Environmental Scientist
North Dakota Department of Health
Division of Water Quality
Gold Seal Center, 4th Floor
918 East Divide Avenue
Bismarck, ND 58501-1947

North Dakota Department of Health
Division of Water Quality

Nutrient and Dissolved Oxygen TMDLs for Mirror Lake in Adams County, North Dakota

John Hoeven, Governor
Terry Dwelle, M.D., State Health Officer

North Dakota Department of Health
Division of Water Quality
Gold Seal Center, 4th Floor
918 East Divide Avenue
Bismarck, ND 58501-1947

701.328.5210

TABLE OF CONTENTS

List of Tables

List of Figures

<u>Appendices</u>

1.0 INTRODUCTION AND DESCRIPTION OF THE LAKE AND WATERSHED

Mirror Lake is a small 63 acre impoundment on Flat Creek, located in south-central Adams County at the southern edge of the city of Hettinger, North Dakota (Figure 1). This shallow reservoir was constructed in 1907 with the purpose of providing steam locomotive water for the Chicago, Milwaukee, St. Paul, and Pacific Railroad Companies. At that time, the town of Hettinger resembled little of what it is today, but the city's residents were already adopting Mirror Lake as an excellent source of recreation. However, excessive sediment and nutrient loads entered the lake in the 1920's and 1930's as a result of collective efforts to break the prairie sod near the growing town. These actions, combined with years of severe drought conditions, ultimately threatened the future of the lake. Normal precipitation returned to the area in the early 1940's and triggered heavy recreational use once more. This prompted the development of a city park on the north shore of the lake that was completed in 1946.

The contributing watershed of Mirror Lake consists of 41,960 acres. Table 1 summarizes some of the geographical, hydrological, and physical characteristics of Mirror Lake and its watershed.

Table 1. General Characteristics of Mirror Lake and Its Watershed.

Legal Name	Mirror Lake
Major Drainage Basin	Lower Missouri River Basin
Nearest Municipality	Hettinger, North Dakota
Assessment Unit ID	ND-10130303-001-L_00
County Location	Adams County, North Dakota
Physiographic Region	Missouri Plateau
Latitude	45.995078 N
Longitude	102.636633 W
Surface Area	63.0 acres
Watershed Area	41,960 acres
Average Depth	5.5 feet
Maximum Depth	14.3 feet
Volume	350.1 acre-feet
Tributaries	Flat Creek
Type of Waterbody	Constructed Reservoir
Dam Type	Constructed Earthen Dam
Fishery Type	The 1997-2006 stocking list included Largemouth Bass, Walleye, and Northern Pike

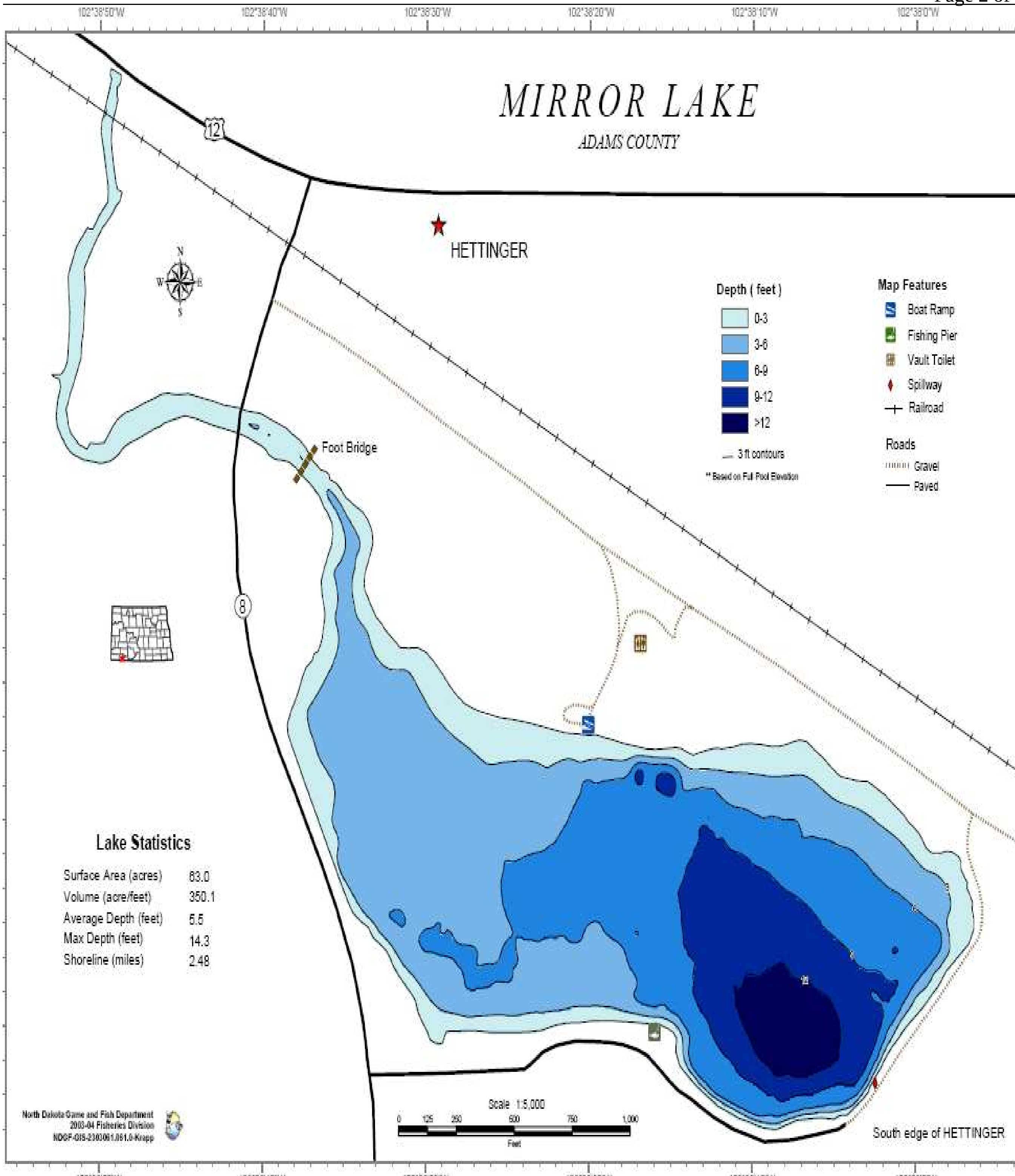


Figure 1. North Dakota Game and Fish Department Contour Map of Mirror Lake.

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 (NDDoH) has identified Mirror Lake as an impaired waterbody. Based on a Trophic State Index (TSI) score, the designated beneficial use of fish and other aquatic biota in Mirror Lake is assessed as fully supporting, but threatened (Table 2). While this impairment is due to nutrient enrichment (Table 2), North Dakota's Section 303(d) list did not provide any information on potential sources of nutrient loading to Mirror Lake. Mirror Lake is classified as a Class 3 warm-water fishery. Class 3 lakes or reservoirs are "waters capable of supporting natural reproduction and growth of warm water fishes (e.g., largemouth bass and bluegill) and associated aquatic biota" (NDDoH, 2006). Some cool water species may also be present in Class 3 lakes.

In response to deteriorating water quality and excessive sedimentation during Mirror Lake's early history, the lake was drained and bottom sediments were excavated in the early 1980's. The fishery in Mirror Lake is managed by the North Dakota Game and Fish Department (NDGF) through test netting and fish stocking. The stocking regiment of the late 1980's and early 1990's consisted mainly of rainbow trout and walleye, although test nets captured (in order of abundance) black bullhead, bluegill, white sucker, rainbow trout, walleye, northern pike, largemouth bass, black crappie, yellow perch, green sunfish, and channel catfish. Proven to be a diverse and successful sport fishery, recent fish stockings have been reduced to largemouth bass, walleye, and northern pike.

Table 2. Mirror Lake Section 303(d) Listing Information (NDDoH, 2006).

Waterbody Name	Mirror Lake
Assessment Unit ID	ND-10130303-001-L_00
Class	3 – Warm water fishery
Impaired Uses	Fish and other aquatic biota assessed as fully supporting, but threatened
Causes	Nutrients/Eutrophication, Dissolved Oxygen, Sedimentation/Siltation
Priority	High (1A)

1.2 Topography

Mirror Lake and its watershed lie within the Missouri Plateau level IV ecogregion (43a), which is part of the larger Northwestern Great Plains level III ecoregion. The topography of the ecoregion, including the Mirror Lake watershed, is characterized by short grass prairie, rolling upland plains, and occasional sandstone buttes. Slopes in the watershed are gentle, with relief ranging from 50-150 feet. Elevation at Hettinger is 2,670-feet (msl). The highest point in the county is 3,150-feet (msl) at Whetstone Butte, while the lowest point is at 2,350-feet (msl) in the bed of Cedar Creek at the eastern border of Adams County (Ulmer et al, 1987). Some areas in the ecoregion have either never been glaciated, or were glaciated so long ago as to have no glacial evidence remaining. The watershed, unlike the Glaciated Plains or the Missouri Coteau physiographic regions of North Dakota, has well defined drainages in the form of intermittent streams (NDDoH, 1993). Figure 2 shows the general shape and size of the Mirror Lake watershed in Adams County, North Dakota.

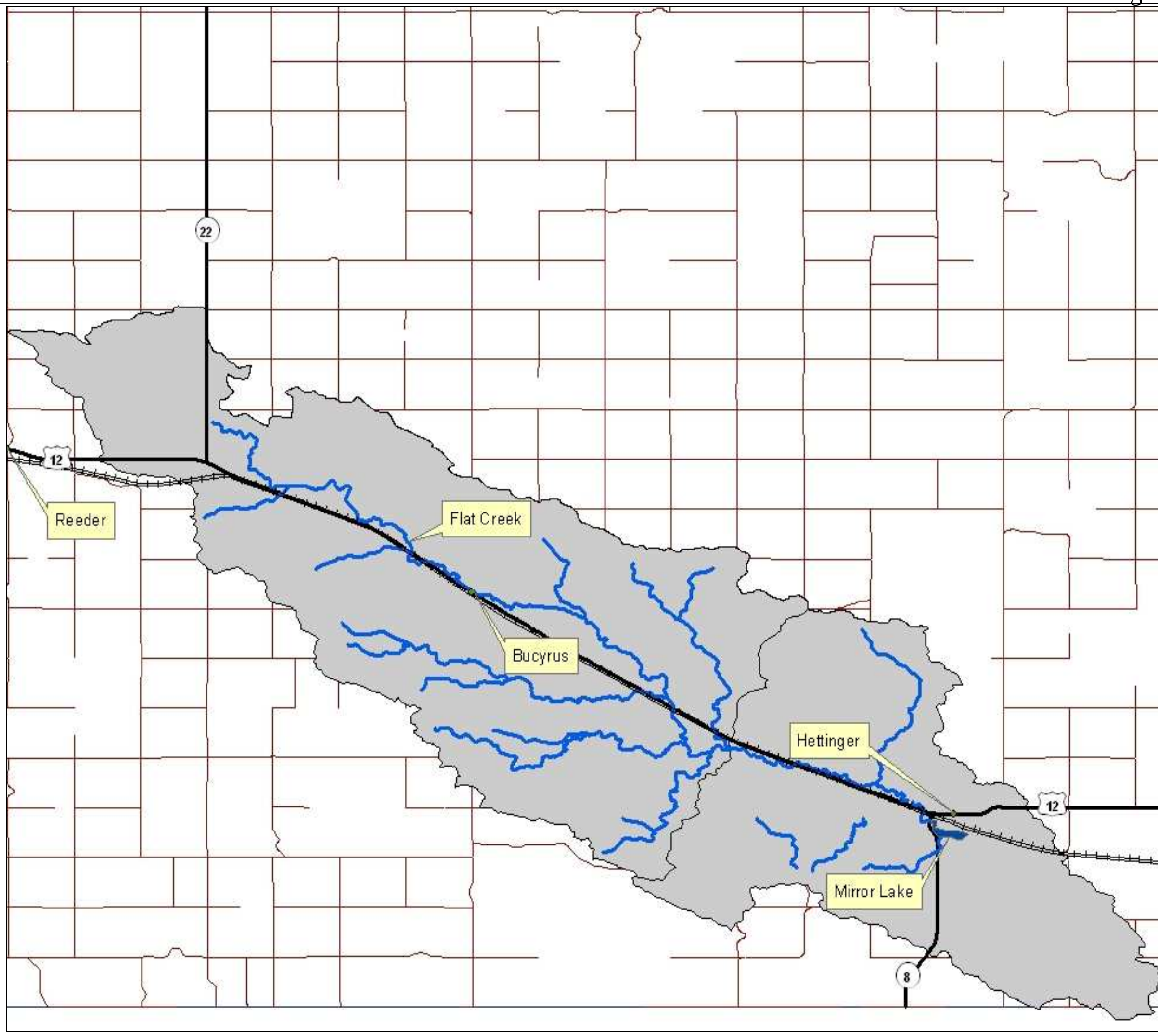


Figure 2. Mirror Lake Watershed in Adams County, North Dakota.

1.3 Land Use/Land Cover

Land use within the Mirror Lake watershed is primarily agricultural (95 percent), with an estimated 43 percent of land in the watershed being actively cultivated, 25 percent in rangeland, 18 percent in hay production, and 9 percent in the Conservation Reserve Program (CRP) (Table 3). Spring wheat is the predominant crop grown in the area, with acreage of barley, oats, and sunflowers common as well. Potential native vegetation in the Mirror Lake watershed consist of mixed grasses like blue grama, little bluestem, wheatgrass/needlegrass associations, and prairie sandreed in undisturbed or minimally disturbed areas. Farmsteads, low density urban development (including the city of Hettinger), roads, and wildlife management area habitat comprise the remaining 5 percent of the watershed (Table 3). As a result, dryland farming and cattle production are the dominant land use practices in the ecoregion and watershed and are the primary source of external nutrient loading to Mirror Lake.

Table 3. Land Use Within the Mirror Lake Watershed.

Land Use Type	Acres	Percent of Total Acreage
Actively Cultivated Land	19,594	43
Rangeland	11,392	25
Hayland	8,202	18
Conservation Reserve Program (CRP)	4,102	9
Farmsteads, development, wet/wild management	2,278	5

The town of Hettinger had a 2000 census population of 1,306 people, and is very close to Mirror Lake. Due to its proximity, nearly 100 percent of Mirror Lake's shoreline is publicly owned. There are no other large towns or urban areas in the watershed, but numerous farmsteads dot the landscape. Portions of state highways 8, 12, and 22 also traverse the watershed, as well as a railroad track from the western edge to eastern edge of the watershed.

1.4 Climate and Precipitation

The climate of southwestern North Dakota and the area encompassing Mirror Lake is semiarid to sub-humid and continental. Southwestern North Dakota has a typical continental climate characterized by large annual, daily, and day-to-day temperature changes, light to moderate precipitation, and nearly continuous air movement (Figure 3). Extreme seasonal variations in temperature are typical of the climate in this region of the northern plains. North Dakota Agricultural Weather Network (NDAWN) calculates average air temperature and precipitation data through interpolation of measurements from nearby National Weather Service (NWS) Cooperative Station data (1971-2000) in Hettinger, ND. Based on NDAWN (2006) the annual average temperature is 42° F and mean annual precipitation is 15.51 inches.

Mean monthly temperature in Hettinger, ND for the period 1971 through 2006 is shown in Figure 3, while mean monthly precipitation for the same time period is shown in Figure 4 (NDAWN, 2006). January is typically the coldest month of the year with a mean monthly temperature of 16° F (Figure 3). July and August are the warmest months of the year with mean monthly temperatures of 69° F and 68° F, respectively (Figure 3). Precipitation events tend to be brief and intense and occur mainly during the months of May through August, with little precipitation from November through March. June is the wettest month of the year with average precipitation of 2.95 inches (Figure 4).

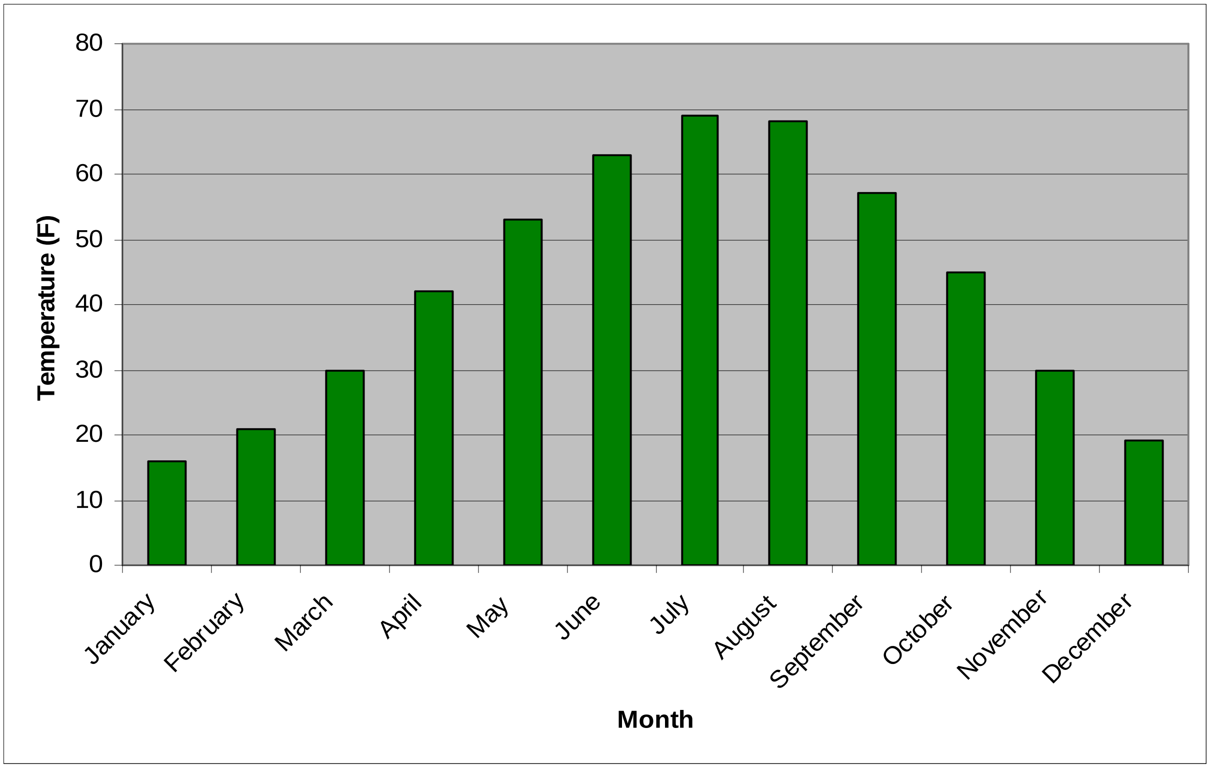


Figure 3. Mean Monthly Air Temperature from 1971-2006 at the North Dakota Agricultural Weather Network (NDAWN) Station in Hettinger, ND.

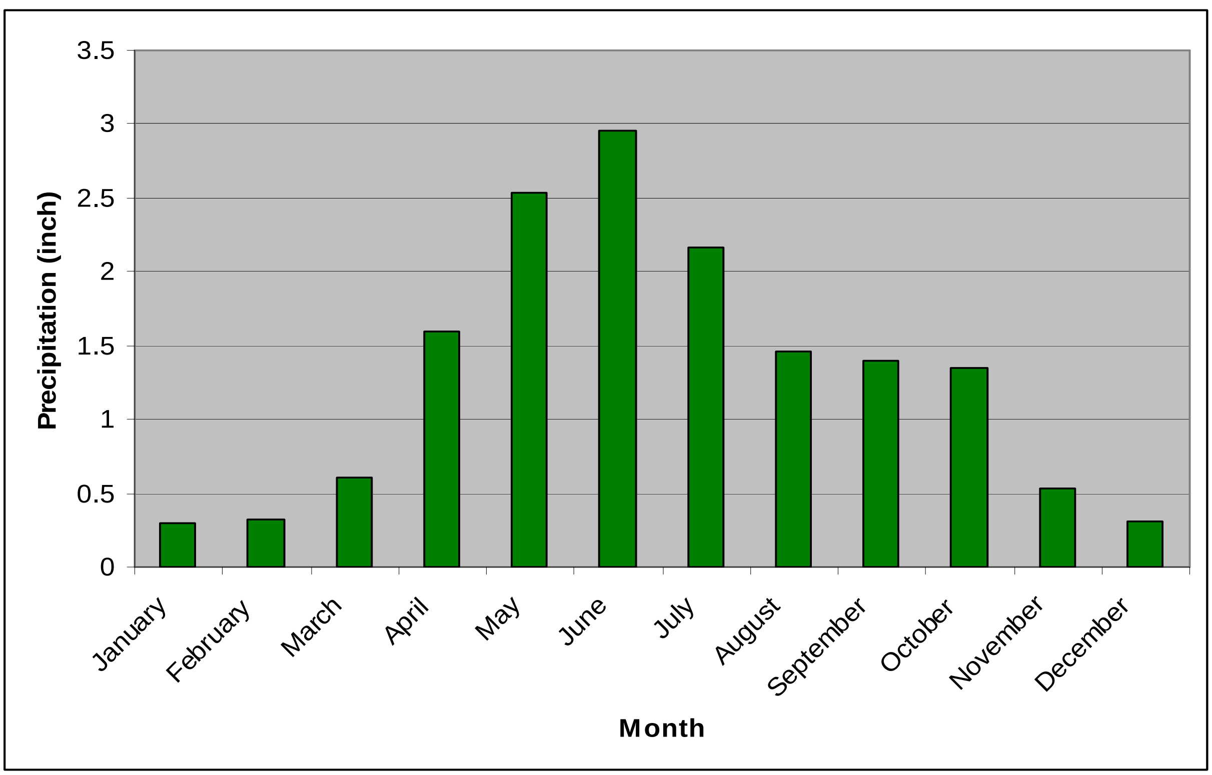


Figure 4. Mean Monthly Precipitation from 1971-2006 at the North Dakota Agricultural Weather Network (NDAWN) Station in Hettinger, ND.

1.5 Available Water Quality Data

1.5.1 1992-1993 Lake Water Quality Assessment Project

A Lake Water Quality Assessment (LWQA) was conducted on Mirror Lake in 1992-1993. Water quality samples were collected from Mirror Lake twice during the summer of 1992 and once during the winter of 1993. All lake samples were taken from one sample site (380630) located in the deepest portion of Mirror Lake near the dam. Water column samples were collected from three separate depths during summer sampling and two separate depths during the winter sampling of 1993.

LWQA data collected from Mirror Lake showed no thermal stratification during summer sampling in 1992. Dissolved oxygen concentrations ranged from 6.0-8.6 mg/L in 1992. However, the winter sampling of January 17, 1993 showed evidence of thermal stratification in the water column of Mirror Lake between two and three meters of depth. The January sample also revealed dissolved oxygen concentrations above 7.0 mg/L below three meters of depth, and concentrations near saturation above the depth of thermal stratification. The volume-weighted mean concentrations in Mirror Lake of total dissolved solids (755 mg/L), hardness as calcium (314 mg/L), and conductivity (1,168 mg/L) were all high during the LWQA, yet below the state's long-term average for all lakes measured. The volume-weighted mean concentration of bicarbonates and sulfates, the dominant anions in the water column, were 277 and 352 mg/L, respectively. Volume-weighted mean concentrations were calculated by weighing the parameter analyzed by the percentage of water volume represented at each depth interval sampled.

Parameters sampled between July 1992 and January 1993 revealed volume-weighted mean concentrations of total phosphate as P and nitrate plus nitrite as N of 0.094 mg/L and 0.008 mg/L, respectively, and a P:N ratio of 11.8:1 indicating nitrogen limitation in Mirror Lake. Under such conditions, nitrogen fixing bacteria like species of blue-green algae are favored in the water column. Based on LWQA data collected in 1992-1993, Mirror Lake is assessed as a eutrophic lake. Supporting water quality data included total phosphate as P concentrations between 0.046 and 0.062 mg/L, and chlorophyll-a concentrations between 4 and 9 µg/L for summer surface water. In addition, Secchi Disk Transparency measurements averaged 1.0 meter. A large macrophyte biomass and additional ancillary information helped support the eutrophic determination.

1.5.2 1995-2003 Mirror Lake Water Quality Assessment and Restoration Project

Recognizing the need to improve water quality conditions in Mirror Lake, the Adams County Soil Conservation District (SCD) conducted monitoring as part of a water quality assessment project in 1995-1996 and as part of a water quality watershed restoration project from 1998 to 2002 with the goal of sustaining or improving the trophic condition of Mirror Lake. The assessment project was designed to identify the nonpoint source pollution (NPS) impacts to Mirror Lake and the potential pollutant sources in the watershed. The information obtained from the water quality assessment project in 1995-1996, was used to develop the restoration project and abate NPS pollution entering Mirror Lake to sustainable levels. In-lake data were collected from 1998-2002 to track the effects of the Mirror Lake restoration project. Samples were collected from the tributary entering Mirror Lake (i.e., Flat Creek) from 1998-2003. The SCD followed the methodology for water quality sampling found in the Sampling and Analysis Plan (SAP) for the Mirror Lake Water Quality Restoration Project (NDDoH, 1997). Sampling and analysis variables are shown in Table 4.

Table 4. Mirror Lake Water Quality Restoration Project (1998-2002) Sampling and Analysis Variables.

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

Stream Monitoring

Stream sampling was conducted at one inlet site on Flat Creek, one storm water outfall site, and one outlet site on Flat Creek below Mirror Lake (Figure 5). The 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 collected during spring and early summer when stream discharge is typically greatest. Less frequent sampling was conducted during the summer and fall. Sampling efforts were discontinued during periods of no flow and during winter ice cover conditions. If the stream began to flow again, water quality sampling was reinitiated at the sampling locations.

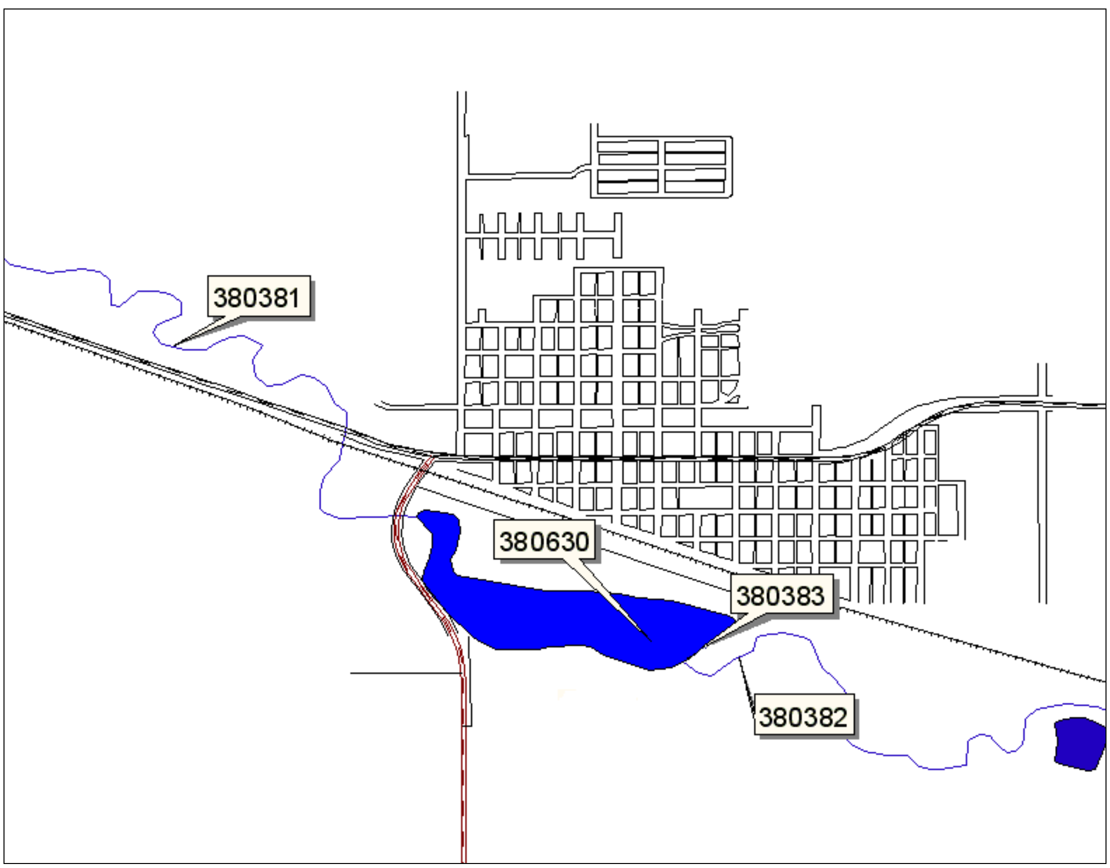


Figure 5. Mirror Lake Sampling Locations.

Lake Monitoring

Lake sampling was conducted three to four times per year, usually between March and September, to monitor lake improvements with the addition of watershed Best Management Practices (BMPs). Toward the end of project sampling in 2001, lake monitoring was conducted two times per month during the open water period to better account for temporal variation in lake water quality and overall improvements in the trophic condition resulting from project efforts.

Nutrient Data

Surface water quality parameters were monitored at four sample stations (three stream sites and one in-lake site) between February 1995 and June 2002, excluding 1997. The stream sites included an inlet sampling site, a storm water outfall sampling site, and an outlet stream site. Both the outlet and stormwater sites were downstream of the lake. Sample parameters and volume-weighted mean concentrations are provided in Table 5. The average total Kjeldahl nitrogen concentration at the inlet was the only nutrient sampled with a lower average concentration than at the in-lake sampling site. The assessment project showed that the greatest amounts of nutrients were delivered via Flat Creek into Mirror Lake during the spring planting season. This coincides well with periods of significant precipitation in the watershed. In addition, far more samples were also collected during the project period at the inlet site, which may have provided a more accurate data set. Mirror Lake displayed an average total nitrogen to total phosphorus ratio of 10.7:1 at the in-lake site 380910 (Table 5). This ratio indicates nitrogen limitation. Under such conditions, nitrogen fixing organisms like species of blue-green algae are typically favored.

Table 5. Data Summary for the Mirror Lake Assessment and Restoration Projects 1995-1996 and 1998-2002.

Parameter	Inlet Stream Site #380381					Deepest Site #380630					Volume-weighted Mean
	N	Max	Med	Avg	Min	N	Max	Med	Avg	Min	
Total Phosphorus as P (mg/L)	107	0.639	0.090	0.137	0.018	34	0.375	0.108	0.133	0.036	0.128
Dissolved Phosphorus as P (mg/L)	N/A	N/A	N/A	N/A	N/A	34	0.203	0.047	0.068	0.010	0.058
Total Nitrogen as N (mg/L)	107	3.690	1.460	1.586	0.359	33	2.120	1.363	1.417	0.900	1.349
Total Kjeldahl Nitrogen as N (mg/L)	107	3.660	1.430	1.521	0.338	32	2.087	1.324	1.390	0.880	1.328
Nitrate/Nitrite as N (mg/L)	107	1.010	0.020	0.065	0.005	33	0.187	0.020	0.026	0.005	0.020
Chlorophyll-*a* (µg/L)	N/A	N/A	N/A	N/A	N/A	24	54.00	14.50	21.79	4.00	20.70
Secchi Disk Transparency (meters)	N/A	N/A	N/A	N/A	N/A	29	2.30	0.90	1.19	0.50	N/A

Mirror Lake nutrient concentrations during the periods of 1995-1996 and 1998-2002 were pooled and compared to data collected from Mirror Lake in 1992-1993. Volume-weighted mean nutrient concentrations reported for the 1992-1993 LWQA were lower when compared to data from the Mirror Lake Water Quality Assessment and Restoration Projects. The 1995-1996 and 1998-2002 Watershed Assessment and Restoration Project data showed small increases in nutrient concentrations such as nitrate/nitrite, total Kjeldahl nitrogen, and total phosphorus (Table 6) suggesting a possible declining trend in water quality.

Table 6. Volume-Weighted Mean Nutrient Concentration Comparisons for Mirror Lake.

Parameter	Mirror Lake 1992-1993	Mirror Lake 1995-1996, 1998-2002
Nitrate/Nitrite (mg/L)	0.008	0.020
Total Kjeldahl Nitrogen (mg/L)	1.150	1.328
Total Phosphorus (mg/L)	0.094	0.128

Dissolved Oxygen and Temperature

Dissolved oxygen and temperature were monitored at the in-lake site and inlet site of Mirror Lake from March 1995 through October 2001, excluding the open water year of 1997. Raw data for the entire project is provided in Appendix A. Figures 6-9 illustrate the results of the temperature and dissolved oxygen data for the in-lake monitoring site for the final two years (2000-2001) of the project. Samples were collected at 1-meter intervals during ice cover and open water periods. Although there were no signs of thermal stratification during sampling in 2000, dissolved oxygen levels were consistently below the 5 mg/L state standard between 3 and 4-meters of depth in June 2000 and July 2000. In addition, dissolved oxygen levels were no greater than 3.7 mg/L throughout the water column on December 19, 2000.

In 2001, dissolved oxygen levels were found to be above the state standard of 5 mg/L throughout the year. Mirror Lake was thermally stratified in 2001 between 0.5 and 1.0-meter on March 6, 2001, May 11, 2001 and October 21, 2001. The June 12, 2001 sampling date also revealed thermal stratification between 3 and 4-meters of depth.

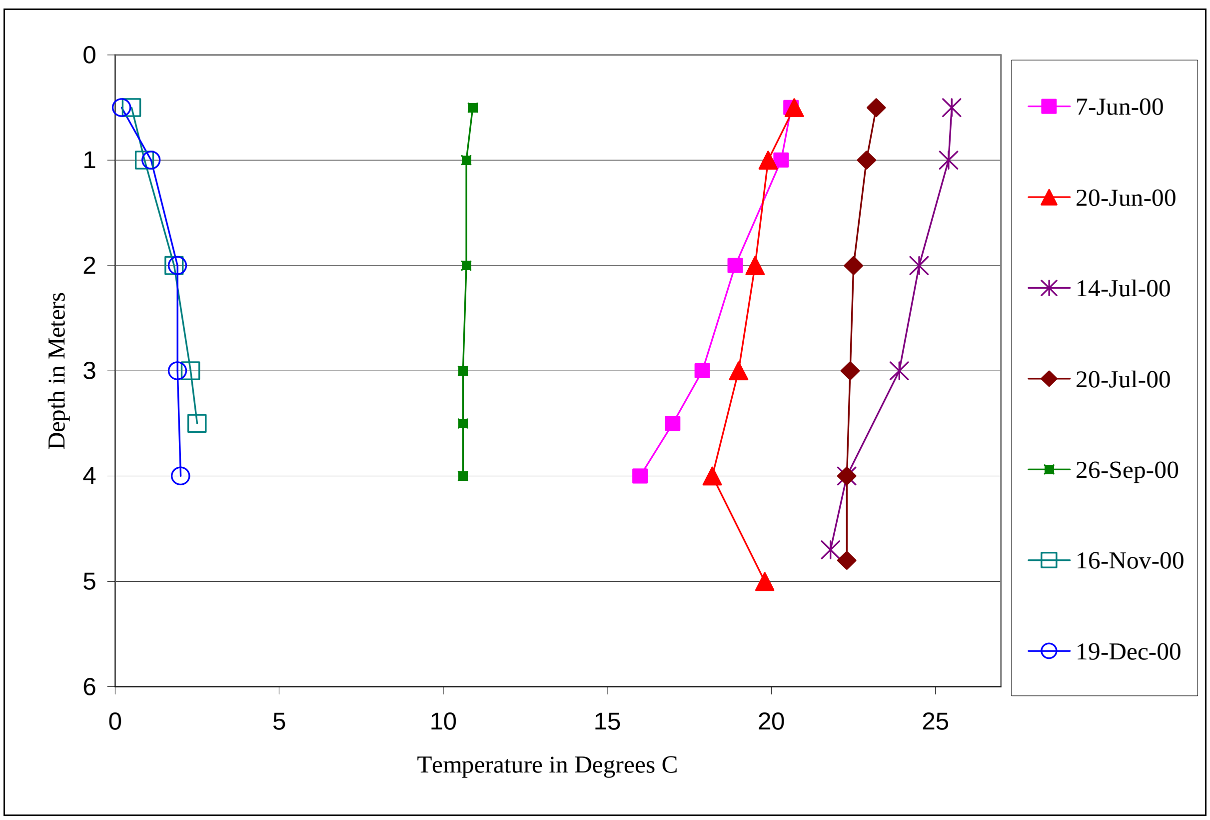


Figure 6. Summary of Temperature Data for the Mirror Lake Deepest Area Site in 2000.

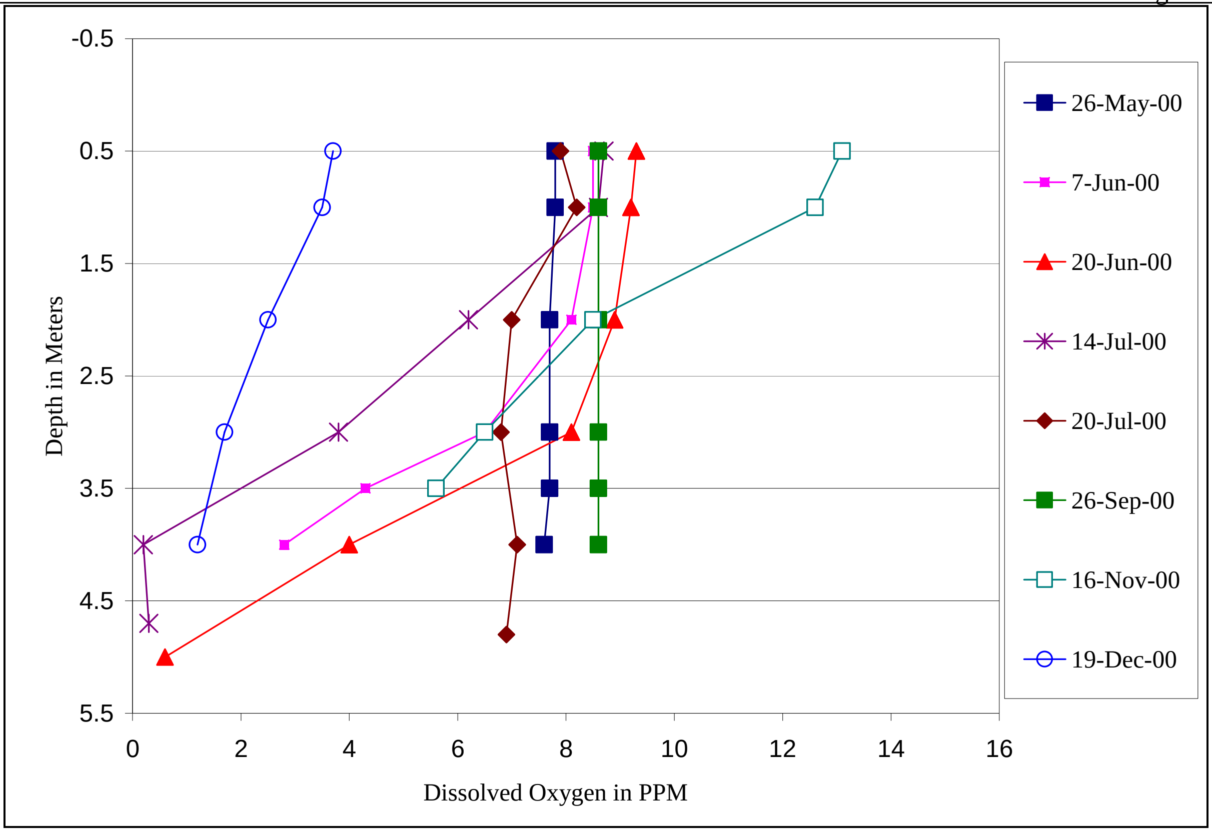


Figure 7. Summary of Dissolved Oxygen Data for the Mirror Lake Deepest Area Site in 2000.

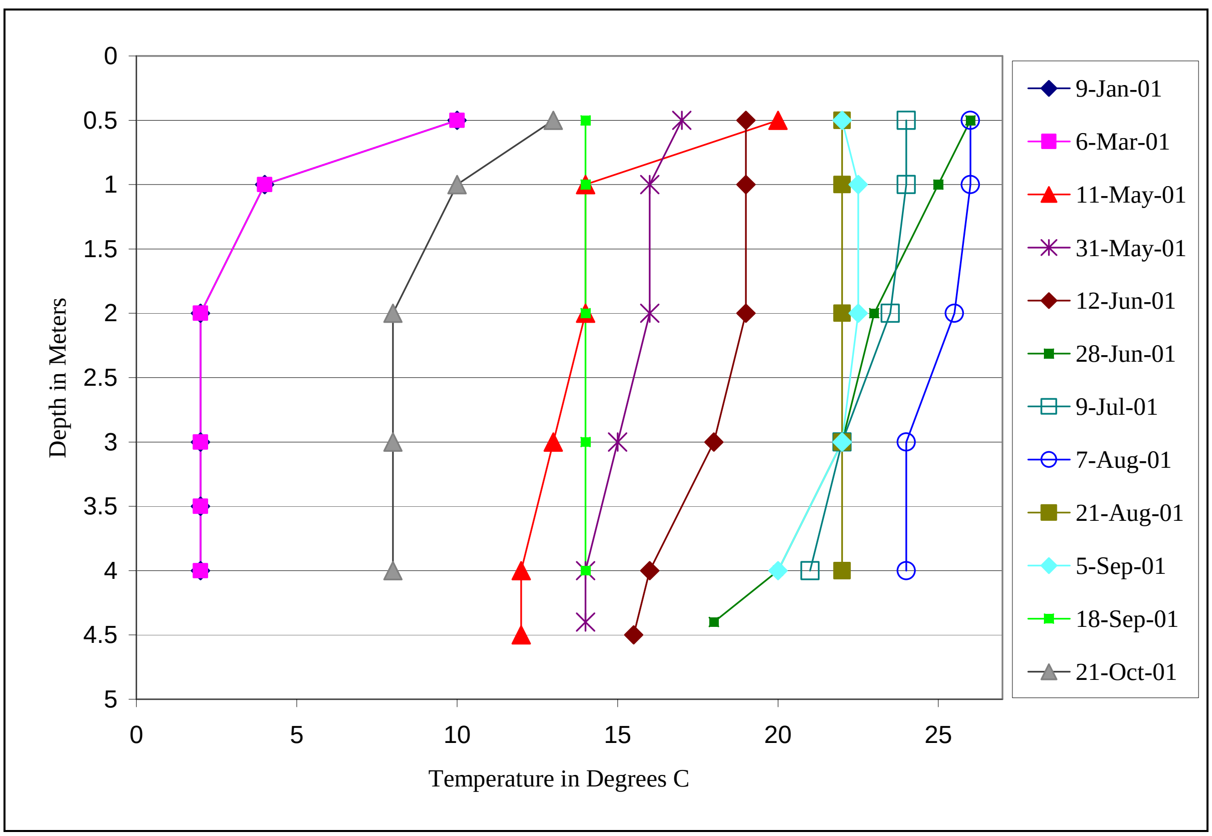


Figure 8. Summary of Temperature Data for the Mirror Lake Deepest Area Site in 2001.

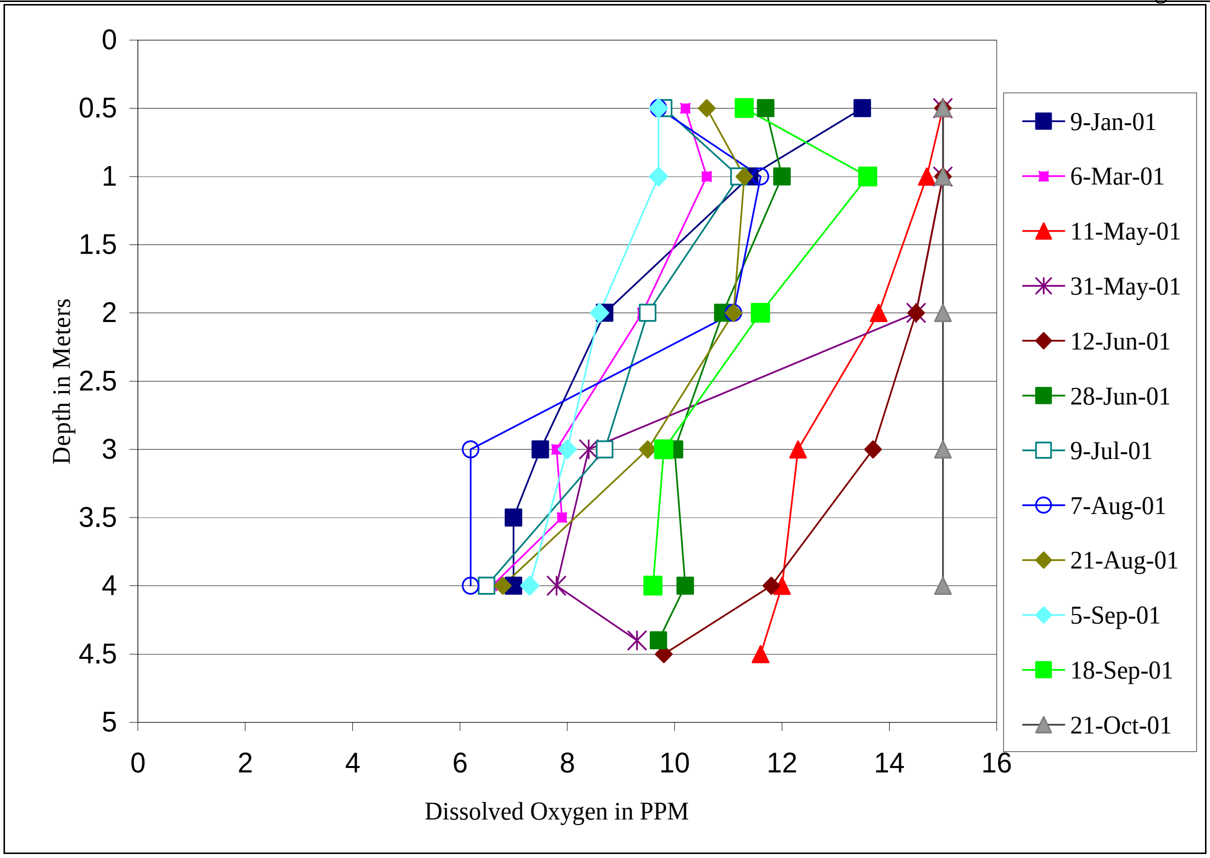


Figure 9. Summary of Dissolved Oxygen Data for the Mirror Lake Deepest Area Site in 2001.

Secchi Disk Transparency and In-Lake Total Suspended Solids Results

Water clarity in a reservoir can be affected by many factors. Algal biomass, suspended sediment, depth of the reservoir, and turbidity all affect Secchi Disk Transparency measurements in a waterbody. Secchi Disk Transparency data were collected by Adams County Soil Conservation District (SCD) staff between May 1995 and October 2001, excluding the 1997 and 2000 open water years during the eight open water months of April-November (Table 7). There were 29 measurements taken throughout the sampling period. As shown in Table 7, the average Secchi Disk Transparency measurement for the in-lake sampling site was 1.19 meters. Based on average Secchi Disk Transparency, the TSI score for this reservoir was 58.6.

The data showed that visibility throughout the water column was consistently low during the late summer and early fall months, which may be attributable to algal blooms and biomass production. Visibility throughout the water column was greatest during late fall just prior to ice up (November) when typically little if any runoff enters the lake (Table 7).

Table 7. Average Monthly Secchi Disk Transparency Depths in Mirror Lake for the Period 1995-1996 and 1998-2001.

Month	Average Secchi Disk Depth (M)	Month	Average Secchi Disk Depth (M)
January	N/A	July	1.30
February	N/A	August	0.77
March	N/A	September	0.84
April	1.10	October	0.80
May	0.83	November	2.20
June	1.70	December	N/A
	All Months Combined		1.19

Tributary Total Suspended Solids Results

Two hundred forty-four (244) tributary total suspended solid (TSS) samples were collected by the Adams County Soil Conservation District staff from 1995-2003. TSS samples were collected from the inlet site (380381) and the outlet site (380382) of Mirror Lake. Average TSS concentrations at the inlet and outlet sites were 8.5 and 16.3 mg/L, respectively (Table 8). As evidenced by Table 8, nearly twice the concentration of suspended solids passed through the outlet site when compared to the inlet site. This was most likely due to large algal blooms that repeatedly took place in the lake, resulting in algal particulates and other suspended solids passing through the outlet site that were not present at the inlet site in Flat Creek.

Table 8. Total Suspended Solid Concentrations at the Mirror Lake Inlet and Outlet Sites, 1995-2003.

Site ID	Site Description	Average TSS (mg/L)
380381	Inlet	8.5
380382	Outlet	16.3

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 waste load allocations for point sources and load allocations for nonpoint sources and natural background" such that the capacity of the waterbody to assimilate pollutant loading 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, dissolved oxygen).

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 as follows (NDDoH, 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

Mirror Lake is classified as a Class 3 warm water fishery. Class 3 fisheries are defined as waterbodies "capable of supporting natural reproduction and growth of warm water fishes (e.g., largemouth bass and bluegill) and associated aquatic biota" (NDDoH, 2006). All classified lakes in North Dakota are assigned aquatic life, recreation, irrigation, livestock watering, and wildlife beneficial uses. The beneficial use threatened in Mirror Lake is fish and other aquatic biota. State Water Quality Standards provide that lakes shall use the same numeric criteria as Class 1 streams. This includes the state standard for dissolved oxygen set at no less than 5 mg/L and nitrate as N as 1.0 mg/L. The state water quality standards also specify guidelines for lake or reservoir improvement programs as well (Table 9).

Table 9. Numeric Guidelines for Classified Lakes and Reservoirs (NDDoH, 2006).

Parameter	Guidelines	Limit
Guidelines or Standards for Classified Lakes		
Nitrates (dissolved)	1.0 mg/L	Maximum allowed[1]
Dissolved Oxygen	5 mg/L	Not less than
Guidelines for goals in a lake improvement or maintenance program		
NO_3 as N	0.25 mg/L	Goal
PO_4 as P	0.02 mg/L	Goal

[1] "The water quality standard for nitrates dissolved (N) is intended as an interim guideline limit. Since each stream or lake has unique characteristics which determine the levels of these constituents that will cause excessive plant growth (eutrophication), the department reserves the right to review this standard after additional study and to set specific limitations on any waters of the state. However, in no case shall the concentration for nitrate plus nitrite N exceed 10 mg/l for any waters used as municipal or drinking water supply".

3.0 TMDL TARGETS

A TMDL target is the value that is measured to judge the success of the TMDL effort. TMDL targets must 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 section summarizes water quality targets for Mirror Lake based on its' impaired beneficial uses due to nutrient enrichment and dissolved oxygen. While sedimentation/siltation is also listed as a cause of aquatic life impairment to the reservoir it will not be addressed as a TMDL in this report. Based on an analysis of available suspended sediment data for Mirror Lake (NDDoH, draft March 2008), it appears that sediment is not threatening aquatic life use. Therefore it can be assumed that if the specific targets for nutrients, expressed as phosphorus, and dissolved oxygen are met, the reservoir will meet the applicable water quality standards, including its designated beneficial uses.

3.1 Nutrient Target

A Carlson’s Trophic State Index (TSI) target of 66 based on total phosphorus was chosen for the Mirror Lake endpoint. North Dakota’s 2006 Integrated Section 305(b) and Section 303(d) Water Quality Assessment Report indicates that Carlson’s TSI is the primary indicator used to assess beneficial uses of the state’s lakes and reservoirs (NDDoH, 2006). Trophic state is the measure of the 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 Transparency measurements (Carlson, 1977).

TSI values for Mirror Lake were calculated for total phosphorus, chlorophyll-*a*, and Secchi Disk Transparency. The highest TSI value was for total phosphorus at 76, while chlorophyll-*a* and Secchi Disk Transparency values were 60 and 59, respectively (Table 10). Based on Carlson’s TSI and water quality data collected between February 1995 and June 2003, Mirror Lake was generally assessed as a highly eutrophic to hypereutrophic lake (Table 10). Hypereutrophic lakes are characterized by excessive weed growth, blue-green algal blooms, and low dissolved oxygen concentrations. These lakes may experience periodic fish kills and are generally characterized as having excessive rough fish populations (carp, bullhead, and sucker) that reflect negatively on the sport fishery. Due to frequent algal blooms and excessive weed growth, these lakes often become undesirable for recreational uses such as swimming and boating.

Table 10. Carlson’s Trophic State Indices for Mirror Lake.

Parameter	Relationship	Units	TSI Value	Trophic Status
Chlorophyll-*a*	TSI (Chl-a) = 30.6 + 9.81[ln(Chl-a)]	µg/L	60	eutrophic
Total Phosphorus (TP)	TSI (TP) = 4.15 + 14.42[ln(TP)]	µg/L	76	hypereutrophic
Secchi Disk (SD)	TSI (SD) = 60 - 14.41[ln(SD)]	meters	59	eutrophic

TSI < 28 - Oligotrophic (least productive) TSI 28-51 Mesotrophic
TSI 52-73 Eutrophic TSI > 73 - Hypereutrophic (most productive)

The reasons for the different estimated TSI values for Mirror Lake are varied. According to the phosphorus TSI value, Mirror Lake is a very productive lake (hypereutrophic) (Table 10). Carlson and Simpson (1996) suggest that if the phosphorus and Secchi Disk Transparency TSI values are relatively similar and higher than the chlorophyll-*a* TSI value, then dissolved color or non-algal particulates dominate light attenuation. It follows that, as is the case with Mirror Lake, if the Secchi Disk Transparency and chlorophyll-*a* TSI values are similar, then chlorophyll-*a* is dominating light attenuation. 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.

The three variables measured in Carlson's TSI, chlorophyll pigments, Secchi depth, and total phosphorus, independently estimate algal biomass (production as a result of excess nutrients). The three index variables are interrelated by linear regression models, and should produce the same index value for a given combination of variable values. As a result, any of the three variables can therefore theoretically be used to classify a given waterbody. For the purpose of classification, priority is given to chlorophyll, because this variable is the most accurate of the three at predicting algal biomass (Carlson 1980). Although transparency and phosphorus may co-vary with trophic state, the changes in transparency are caused by changes in algal biomass and total phosphorus may or may not be strongly related to algal biomass. Therefore, neither transparency nor phosphorus is an independent estimator of trophic state (Carlson 1996).

A major strength of TSI is that the interrelationships between variables can be used to identify certain conditions in the reservoir that are related to the factors that limit algal biomass or affect the measured variables. When more than one of the three variables is measured, it is possible that different index values will be obtained. Because the relationships between the variables were originally derived from regression relationships and the correlations were not perfect, some variability between the index values is to be expected (Carlson 1996). These deviations of the total phosphorus or the Secchi depth index from the chlorophyll index can be used to identify conditions and causes relating to the reservoir's trophic state. Some possible interpretations in the deviations of the index values are given in Table 11 below (updated from Carlson 1983).

Table 11. Relationship 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.

It is possible therefore, that the chlorophyll and transparency indices may be close together, but both will fall below the phosphorus curve. This suggests that the algae are nitrogen-limited. Intense zooplankton grazing may also cause the chlorophyll and Secchi depth indices to fall below the phosphorus index as the zooplankton remove algal cells from the water or Secchi depth may fall below chlorophyll if the grazers selectively eliminate the smaller cells (Carlson 1996).

Studies have also shown that in shallow lakes, the percent reduction in total phosphorus was not as great as the reduction in loading (Cooke, et. al., 1986). This causes most total phosphorus TSI scores to be elevated above the other two TSI scores, therefore estimating a slightly higher trophic state for the lake than may actually be observed. Also, the improvement in Secchi disk depth of the water is not linearly related with a reduction in total phosphorus concentrations (Carlson, 1977).

The degree of improvement in Secchi depth, for an equal amount of phosphorus diverted, will become greater as a mesotrophic state is approached (Cooke, et.al., 1986).

While the target TSI score resulting from the 50 percent phosphorus load reduction will not bring the concentration of total phosphorus to the NDDoH State Water Quality Standard guideline goal for in-lake restoration (0.02 mg/L), it should be recognized that these are just guidelines. Lakes vary a great deal in North Dakota. Shallow lakes are especially hard to improve without addressing the internal phosphorus cycling, which comes at a higher cost. This reduction in phosphorus load should result in a change of trophic status for the lake from eutrophic down to nearly mesotrophic. Given the size of the lake (63 acres), the lake's recent history of dredging and the likely amount of phosphorus in the bottom sediments available for internal cycling, the nearly constant wind in northwestern North Dakota causing a mixing effect, and few cost effective ways to reduce in-lake nutrient cycling this was determined to be the best possible outcome for Mirror Lake. This target will allow it to meet the narrative standards relating to recreation and aquatic life beneficial uses.

3.2 Dissolved Oxygen Target

The state standard will be the dissolved oxygen target for Mirror Lake. The North Dakota State Water Quality Standard for dissolved oxygen is 5 mg/L expressed as a daily minimum" where up to 10 percent of representative samples collected during any three year period may be less than this value provided that lethal conditions are avoided. Further, since Mirror Lake is a Class III lake, this standard does not apply to the hypolimnion during periods of stratification.

4.0 SIGNIFICANT SOURCES

There are no known point sources upstream of Mirror Lake. It is assumed that the pollutants of concern originate from non-point sources. Most of the land upstream from Mirror Lake is farmed and in agricultural crop production. The remainder is used for pasture or kept as permanent herbaceous cover. Mirror Lake does reside on the south edge of the city of Hettinger. However, a stormwater diversion was installed which diverts most, if not all, of Hettinger's stormwater under Mirror Lake outleting into Flat Creek below Mirror Lake's outlet. There are no lake homes around the reservoir, although small farmsteads are spread throughout the watershed. In addition, the sparsely populated town of Bucyrus (26 residents according to 2000 population census), is approximately 8 miles upstream of Mirror Lake. With that in mind, it is expected that the vast majority of nutrient loads are transported with overland runoff from agricultural areas.

Existing land use and AGNPS modeling (based on 1997 land use conditions) within the watershed indicate that the majority of NPS loading is likely coming from cropland (approximately 43 percent of land within the watershed is actively cultivated). Additionally, with an estimated 33 percent of land in the watershed being rangeland or pasture, it is possible that cattle grazing too long in the riparian area of the tributaries or actually wading in the streambed are significantly contributing to nutrient loading. As a result, best management practices should also be implemented on land used for grazing in order to address loading from this source.

5.0 TECHNICAL ANALYSIS

Establishing a relationship between in-lake 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 (e.g., trophic condition) is necessary to evaluate the loading capacity and trophic response of the receiving waterbody. 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 utilized to estimate existing loads to Mirror Lake, as well as the technical analysis used to predict the trophic response of the reservoir to reductions in nutrient loading.

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, 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 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 (Appendix B) 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 Mirror Lake's trophic status. 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 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 (e.g., mean, median, min, max); and 3) an evaluation of trophic status. Output data from the Excel program were then used to evaluate calibration of the model.

When the input data from the 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 coefficients. 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 based on the project monitoring data. BATHTUB then has the ability to predict total phosphorus concentration, chlorophyll-*a* concentration, and Secchi Disk Transparency and the associated TSI scores in response to various nutrient load reduction scenarios.

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 321.7 kg and annual average nitrogen load of 2,146.8 kg (Appendix C). 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.

In the case of Mirror Lake, BATHTUB modeled externally derived phosphorus. Phosphorus was used in the simulation model based: 1) on its known relationship to eutrophication; and 2) that it is controllable with the implementation of watershed Best Management Practices (BMPs). Changes in trophic response were evaluated by reducing externally derived phosphorus loading by 25, 50, and 75 percent (Appendix C). Simulated reductions were achieved by reducing phosphorus concentrations in contributing tributaries and other external delivery sources. Flow was held constant due to uncertainty in estimating changes in hydraulic discharge with the implementation of BMPs.

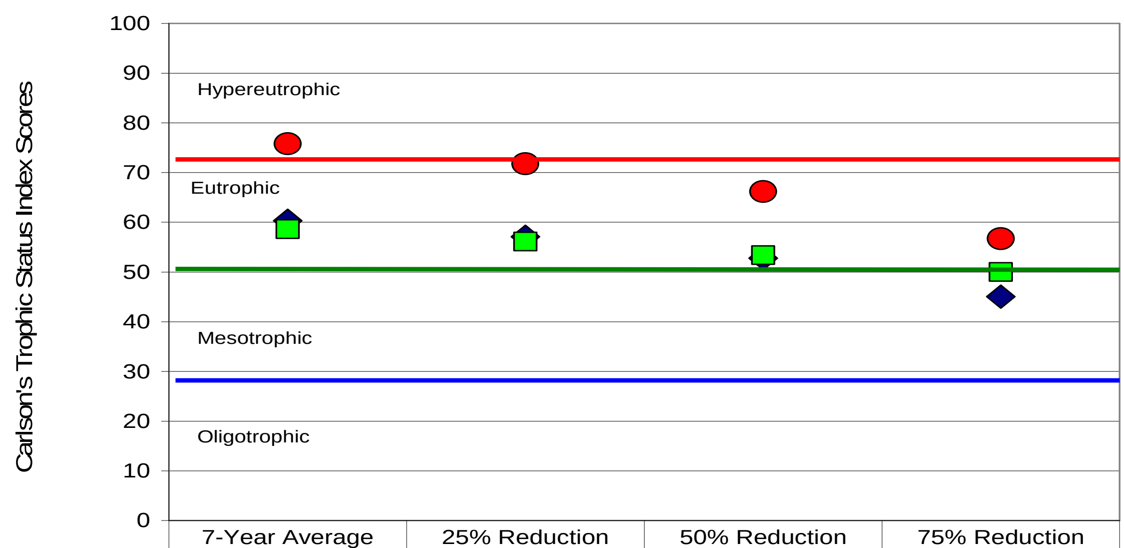
The model results indicated that if external phosphorus loading was reduced by 50 percent entering into Mirror Lake, the average annual total phosphorus and chlorophyll-*a* concentration in the lake would decrease and Secchi Disk Transparency depth would increase. The large reduction in nutrient load should result in an improvement to the trophic status of Mirror Lake that would be noticeable to the average lake user by reducing the intensity and frequency of algal blooms each year and through an improvement in the overall clarity. Through these improvements it is predicted that Mirror Lake would approach the mesotrophic trophic status range.

With a 50 percent reduction in external phosphorus load, the model predicts a reduction in Carlson's TSI score from 60.33 to 52.78 for chlorophyll-*a*, and 58.63 to 53.37 for Secchi Disk Transparency, corresponding to a trophic state ranging from eutrophic to nearly mesotrophic. More important for the long term health of the lake, a 50 percent reduction in phosphorus loading would reduce the total phosphorus TSI score from 75.81 to 66.18 which is a change from hypereutrophic to eutrophic (Table 12, Appendix D).

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)	0.144	0.109	0.074	0.038
Total Dissolved Phosphorus (mg/L)	0.700	0.053	0.035	0.016
Total Nitrogen (mg/L)	1.445	1.118	0.797	0.475
Organic Nitrogen (mg/L)	1.322	1.052	N/A	N/A
Chlorophyll-*a* (µg/L)	20.70	14.91	9.59	4.36
Secchi Disk Transparency (meters)	1.10	1.31	1.58	2.00
Carlson's TSI for Phosphorus	75.81	71.77	66.18	56.72
Carlson's TSI for Chlorophyll-a	60.33	57.11	52.78	45.04
Carlson's TSI for Secchi Disk	58.63	56.13	53.37	50.03

To acquire a noticeable change in the trophic status, the BATHTUB model predicts that a 50 percent reduction in total phosphorus load would achieve the in-lake total phosphorus concentration of 0.074 mg/L and an in-lake total nitrogen concentratnion of 0.797 mg/L. This reduction in phosphorus and nitrogen is predicted to result in a reservoir that is nearly mesotrophic throughout a given year with respect to Secchi Disk Transparency and chlorophyll (considered the algal biomass indicator) (Figure 10).



	7-Year Average	25% Reduction	50% Reduction	75% Reduction
TSI-Chlorophyll-a	60.33	57.11	52.78	45.04
TSI-Secchi Disk	58.63	56.13	53.37	50.03
TSI-Phopshorus	75.81	71.77	66.18	56.72

Figure 10. Predicted Trophic Response in Mirror Lake to Phosphorus Load Reductions of 25, 50, and 75 Percent.

5.3 AGNPS Watershed Model

In order to identify significant nonpoint source (NPS) pollutant sources in the Mirror Lake watershed and to assess the relative reductions in nutrient (nitrogen and phosphorus) loading that can be expected from the implementation of BMPs in the watershed, an AGNPS 3.65 Model analysis was employed. The primary objectives of the AGNPS 3.65 model analysis were to: 1) evaluate NPS pollutant contributions from within the watershed; 2) identify critical pollutant source contribution areas within the watershed; and 3) evaluate potential nutrient (nitrogen and phosphorus) load reductions that can be achieved through various BMP implementation scenarios.

The AGNPS 3.65 model is a single event model that has twenty input parameters. Sixteen parameters were used to calculate nutrient/sediment yield, surface runoff, and erosion. The parameters used include: receiving cell, aspect, SCS curve, percent slope, slope shape, slope length, Manning's roughness coefficient, K-factor, C-factor, P-factor, surface conditions constant, soil texture, fertilizer inputs, point source indicators, COD factor and channel indicator.

The AGNPS 3.65 model was used in conjunction with an intensive land-use survey to determine critical areas within the Mirror Lake watershed. Criteria used during the land-use assessment include percent cover on cropland and pasture/range conditions. These criteria were used to determine the C factor for each cell. The model was run using current conditions determined during the land use assessment. Based on land use and watershed characteristics observed during the TMDL study, annual run-off and annual nutrient yields were estimated for the watershed using the AGNPS model.

Additional modeling comparisons were made by changing land use practices on selected portions of the watershed. The watershed was divided into 1049, 40-acre cells for evaluation. Each cell was evaluated for soil characteristics, terrain, and land-use characteristics (Table 13).

Table 13. Mirror Lake Watershed AGNPS Summary.

Watershed Studied			
Area of Watershed	41,960 acres	41,960 acres	41,960 acres
Area of Each Cell	40 acres	40 acres	40 acres
Characteristic Storm Precipitation	3 inches	3 inches	3 inches
Storm Energy-Intensity Value	48.33 inches	48.33 inches	48.33 inches
Values at the Watershed Outlet			
Original	**1997 Land Use Conditions**	**5% and greater slope to CRP**	**5% and greater slope to CRP + no-till, continuous wheat rotations on <5%, and good pasture**
Number of Cells	1,049	1,049	1,049
Runoff Volume	1.10 inches	1.10 inches	1.10 inches
Peak Run-off Rate	4,894.77 cfs	4,894.77 cfs	4,894.77 cfs
Total Nitrogen Yield in Sediment	0.32 lbs/acre	0.28lbs/acre	0.16 lbs/acre
Total Soluble Nitrogen Yield in Runoff	0.22 lbs/acre	0.22 lbs/acre	0.22 lbs/acre
Soluble Nitrogen Concentration Runoff	0.88 ppm	0.88 ppm	0.88 ppm
Total Phosphorus Yield in Sediment	0.16 lbs/acre	0.14 lbs/acre	0.08 lbs/acre
Total Soluble Phosphorus Yield in Runoff	0.01 lbs/acre	0.01 lbs/acre	0.01 lbs/acre
Soluble Phosphorus Concentration in Runoff	0.05 ppm	0.05 ppm	0.05 ppm
Total Soluble Chemical Oxygen Demand Yield in Runoff	0.00 lbs/acre	0.00 lbs/acre	0.00 lbs/acre
Soluble Chemical Oxygen Demand Concentration in Runoff	0.00 ppm	0.00 ppm	0.00 ppm

The AGNPS model used for this TMDL was based on farming practices present in the Mirror Lake watershed in 1997 prior to implementation of the Section 319 watershed project. While dated, it is believed that this model is still representative of current cropping and grazing practices. The majority of BMP cost share dollars utilized in the Mirror Lake watershed during the Section 319 implementation project were applied to agricultural waste system issues, not the critical cropland acres in the watershed that were identified in the 1997 assessment. In addition, nutrient reductions from agricultural waste systems are not derived using the AGNPS model. Therefore, it is the department's best professional judgment that the land use data and the AGNPS model output is still a valid and reliable depiction of the watershed land use conditions and current cropping practices.

Based on these farming practices, composed of a mixture of cropland, CRP and rangeland, the total nitrogen in sediment yield would be 0.32 pounds per acre and the total phosphorus in sediment yield would be 0.16 pounds per acre (Table 13). However, by altering some of the land management practices in the watershed, a sizeable reduction in total nitrogen (TN) and total phosphorus (TP) yield and loading can be expected. The following changes were input into the AGNPS model:

- Land practices in cells with a land slope greater than 5 percent were converted to CRP;
- No till or zero till cultivation was applied to all remaining land;
- Cropped land with less than 5 percent slope were put in a continuous no-till wheat rotation;
- All pasture land was converted to "good" condition.

Through these practices the TN and TP in sediment yields were reduced to 0.16 lbs/acre and 0.08 lbs/acre, respectively (Table 14). This is an overall reduction of 50 percent in TN and TP yield in the watershed.

Additional land management practices or situations that may significantly reduce nutrient runoff yields, although outside the scope of the land use model currently employed, include exclusion of cattle from the riparian area, intensive grazing management in the watershed, additional improvements in the containment of feedlot waste, and the reduction of airborne sediment attached nutrient particulates directly deposited in the waterbody.

5.4 Dissolved Oxygen

Mirror Lake is listed as fully supporting, but threatened for fish and aquatic biota uses due to nutrients/eutrophication. However, dissolved oxygen levels were observed below the North Dakota water quality standard. The North Dakota water quality standard for dissolved oxygen is "5 mg/L as a daily minimum". Additionally, up to 10 percent of representative samples collected during any three year period may be less than this value provided that lethal conditions are avoided. For Mirror Lake, low dissolved oxygen levels, primarily in the hypolimnion during thermal stratification, appear to be related to excessive nutrient loading.

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.

AGNPS and BATHTUB models indicated that excessive nutrient loading is responsible for the low dissolved oxygen levels in Mirror 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 depletion 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 NDDoH's viewpoint that decreased nutrient loads at the watershed level will result in improved oxygen levels, the concern is that this process may take 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. Bi-national 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 the AF is positively correlated with average annual total phosphorous (TP) concentrations. The AF may also be used to quantify response to watershed restoration measures which makes 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 and 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 = 63.0 acres; 0.25 km^2), mean depth (z = 5.5 feet; 1.68 meters), and the ratio of mean depth to the surface area ($z/A_o^{0.5}$ = 0.003) for Mirror Lake which show that these parameters are within the range of lakes used by Nürnberg. Based on this information, the NDDoH is confident that Nürnberg's empirical nutrient-oxygen relationship holds true for North Dakota lakes and reservoirs in general and Mirror Lake specifically. The NDDoH is also confident that prescribed BMPs will reduce external loading of nutrients to Mirror Lake which will reduce algae blooms, thereby reducing hypolimnetic oxygen depletion rates resulting in increased oxygen levels over time.

Best professional judgment concludes that as levels of phosphorus are reduced by the implementation of best management practices, dissolved oxygen levels will improve. This is supported by the research of Thornton, et al (1990). They state that, "... as organic deposits were exhausted, oxygen conditions improved." 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 as part of any watershed improvement project in accordance with an approved Quality Assurance Project Plan.

5.5 Sedimentation/Siltation

As stated in Section 3.0, Water Quality Targets, this TMDL report only addressed TMDL for nutrients, as expressed as phosphorus, and dissolved oxygen. A separate report (NDDoH, draft March 2008) provides an analysis of available suspended sediment data and through multiple lines of evidence provides justification for de-listing Mirror Lake for its sediment impairment.

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 and set aside as an explicit MOS.

Assuming the combined "normal" year tributary load to Mirror Lake is 321.7 kg of total phosphorus and the goal of a 50% reduction in tributary load and internal cycling has been set as the TMDL, this would result in a target loading capacity of 160.9 kg of total phosphorus per year. A 10 % explicit margin of safety for the TMDL would be 16.1 kg per year.

Post-implementation monitoring and adaptive management during the implementation phase can also be used to assure attainment of the TMDL targets.

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. Mirror Lake's TMDL addresses seasonality because the BATHTUB model incorporates seasonal differences in its prediction of annual total phosphorus and nitrogen loadings.

7.0 TMDL

7.1 Nutrient TMDL

Table 14 and the following summarize the nutrient TMDL for Mirror Lake in terms of loading capacity (LC), waste load allocations (WLA), load allocations (LA), and a margin of safety (MOS). 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 = waste load 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, as is the case with this TMDL, explicitly by reserving a portion of the loading capacity.

Based on data collected between February 1995 and June 2002, excluding the year 1997, the existing load to Mirror Lake is estimated at 321.7 kg. Based on the BATHTUB and AGNPS modeling results, a 50% reduction in the existing total phosphorus loading to Mirror Lake will result in a predicted TMDL target total phosphorus concentration of 0.074 mg/L, therefore the TMDL or Loading Capacity is 160.9 kg. Assuming that 10% of the loading capacity (160.9 kg/yr) is explicitly assigned to the MOS (16.1 kg) and there are no point sources in the watershed, then all of the remaining LC (160.9 kg/yr) is assigned to the load allocation (144.8 kg/yr).

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 160.9 kg/yr was divided by 365 days. Based on this analysis, the phosphorus TMDL, expressed as an average daily load, is 0.4408 kg/day with the load allocation equal to 0.3967 kg/day and the MOS equal to 0.0441 kg/day.

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

Category	Total Phosphorus (kg/yr)	Explanation
Existing Load	321.7	Average annual loading determined through the BATHTUB model
Loading Capacity	160.9	50 percent total reduction based on BATHTUB modeling
Waste load Allocation	0.00	No point sources
Load Allocation	144.8	Entire loading capacity minus MOS is allocated to non-point sources
MOS	16.1	10% of the loading capacity is reserved as an explicit margin of safety

7.2 Dissolved Oxygen TMDL

As a result of the direct influence of eutrophication on increased biological oxygen demand and microbial respiration, it is anticipated that meeting the phosphorus load reduction target in Mirror Lake will address the dissolved oxygen impairment. A reduction in total phosphorus load to Mirror 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

Mirror Lake's watershed supports extensive agriculture where cropland constitutes a majority of the land-use. Sub-dividing Mirror Lake's watershed into smaller scale watersheds, based on hydrology or type of conservation practice implemented, would not be practical based on the watershed's size and land-use. It is assumed that this TMDL will be implemented by producers in the watershed on a volunteer basis. Phosphorus loads into the reservoir will be reduced by treating the AGNPS identified critical cells (Figure 7). There are 362 40-acre cells within the Mirror Lake watershed identified as "critical" by AGNPS modeling. Critical cells are those with fallow, small grains, or land chiseled multiple times; as well as all feedlots, and all land with a slopes greater than five percent. These cells represent a total area of 14,480 acres or 35 percent of the watershed. Based on our best professional judgement, if these critical areas in the watershed are targeted for treatment with BMPs (e.g., no till, nutrient management, grazing systems, native/tame grass seeding on steep slopes) and producers effectively exclude cattle from riparian areas in the watershed, thereby improving riparian health and the natural buffer of the tributaries, then the specified phosphorus load reduction is possible. Also, by effectively using the hypolimnetic draw down according to recommendations from the NDDoH and the North Dakota Game and Fish along with other BMP's to reduce internal phosphorus loading, an additional phosphorus load decrease and possible added improvement in winter dissolved oxygen levels can be expected.

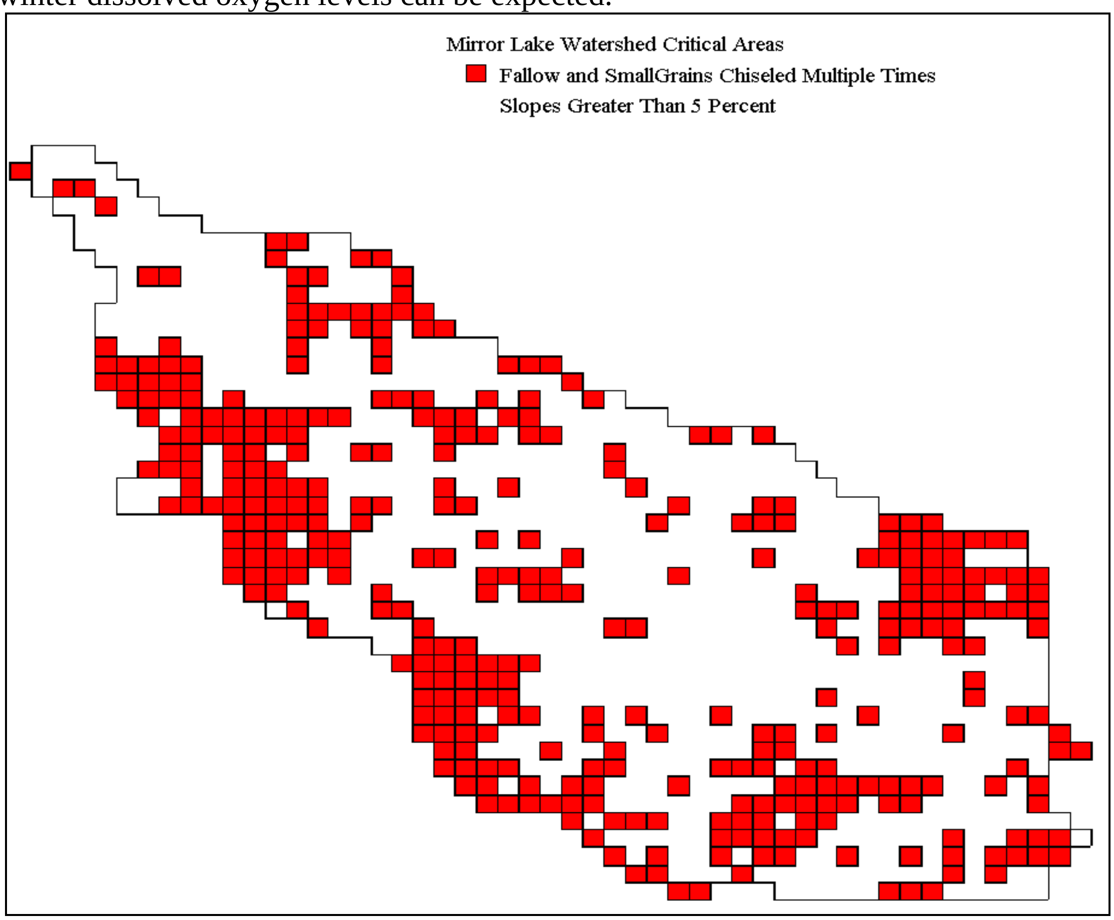


Figure 11. AgNPS Identification of Critical Areas for BMP Implementation.

While it is believed that instituting BMPs will result in the needed water quality improvements, the history of sediment and nutrient deposition may strongly effect internal nutrient cycling. The correct use of the hypolimnetic draw down may aid in improving water quality, as well as providing an additional margin of safety for the phosphorus TMDL. Additionally, public willingness towards accepting conservation practices will be necessary to facilitate the implementation of the additional BMPs that are needed in the lake's watershed.

The TMDL in this report is 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 must be accomplished for Mirror 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 to meet targets set for in this TMDL.

9.0 PUBLIC PARTICIPATION

To satisfy the public participation requirement of this TMDL, a hard copy of the TMDL for Mirror Lake 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:

- Adams County Soil Conservation District
- Adams County Water Resource Board
- Natural Resource Conservation Service (Adams County Field Office and State Office)
- U.S. Environmental Protection Agency, Region 8
- U.S. Fish and Wildlife Service
- North Dakota Game and Fish Department

In addition to mailing copies of this TMDL for Mirror Lake to interested parties, the TMDL was 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:

- The Adams County Record
- The Bismarck Tribune
- The Dickinson Press

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 from one individual. Copies of these comments and the Department's responses are provided in Appendices F-I.

10.0 MONITORING

To insure that BMPs implemented as part of any watershed restoration plan will reduce phosphorus loadings to levels prescribed in this TMDL, 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 chlorophyll-*a*. Once a watershed restoration plan (e.g., Section 319 Project Implementation Plan) is implemented, monitoring will be conducted in the lake beginning two years after implementation and extending 5 years after the implementation project is completed.

11.0 TMDL IMPLEMENTATION STRATEGY

Implementation of TMDLs is dependent upon the availability of Section 319 NPS funds and/or other watershed restoration programs (e.g. USDA Environment Quality Incentive Program), 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 the US EPA for approval. The implementation of the best management practices contained in the NPS pollution management PIP is voluntary. Therefore, success of any TMDL implementation project is ultimately dependent on the producers in the watershed to voluntarily implement BMPs needed to meet the TMDL goal.

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 ACT COMPLIANCE

The North Dakota Department of Health has reviewed the list of Threatened and Endangered Species in North Dakota as provided by the US Fish and Wildlife Service (Appendix E). 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 Mirror Lake TMDL poses “No Adverse Effect” to those Threatened and Endangered species listed for Grant County. In a letter dated January 7, 2008 (Appendix F) which was sent in response to the Department’s request for public comments on the Mirror Lake TMDL report, the US Fish and Wildlife Service concurred with the Department’s conclusion.

13.0 REFERENCES

Carlson, R.C., 1977. *A Trophic State Index for Lakes*. Limnology and Oceanography. 22:361-369.

Carlson, R.C., Simpson, J., 1996. *A Coordinators Guide to Volunteer Lake Monitoring Methods*. North American Lake Management Society.

Carpenter, S.R., Caraco, N.F., Correll, D.L., Howarth, R.W., Sharpley, A.N., Smith, V.H., 1998. Nonpoint Pollution of Surface Waters with Phosphorous and Nitrogen. *Ecological Applications* 8: 559-568.

Chapra, S., 1997. *Surface Water-Quality Monitoring*. The McGraw Hill Companies, Inc.

Dodds, W. K. 2002. Freshwater Ecology: Concepts and Environmental Applications. Academic Press, San Diego, California.

Forester, Deborah L., 2000. *Water Quality in the Credit River: 1964 to 1998*. M.A. Department of Geography/Institute for Environmental Studies, University of Toronto.

Hutchinson, G.E., 1973. *Eutrophication. The Scientific Background of a Contemporary Practical Problem.* American Science. 61:269-279.

MacDonald, L.H., Smart, A., and Wissmar, R.C., 1991. *Monitoring guidelines to evaluate effects of forestry activities on streams in the Pacific Northwest and Alaska*. EPA Publication EPA/910/9-91-001. U.S. Environmental Protection Agency Region 10, Seattle, WA.

Middlebrooks, E.J., Falkenborg, D.H., and Maloney, T.E., 1997. *Modeling the Eutrophication Process*. Ann Arbor Science Publishers Inc. Ann Arbor, MI.

NDAWN, 2006. *US Monthly Average Air Temperature and Precipitation Tables* [Online]. North Dakota Agricultural Weather Network. Available at http://ndawn.ndsu.nodak.edu/

NDDoH. 1997. *Sampling & Analysis Plan for the Mirror Lake Watershed Project*. North Dakota Department of Health, Division of Water Quality. Bismarck, North Dakota.

NDDoH. 2006. *North Dakota 2004 Integrated Section 305(b) Water Quality Assessment Report and Section 303(d) List of Waters Needing Total Maximum Daily Loads.* North Dakota Department of Health, Division of Water Quality. Bismarck, North Dakota.

NDDoH. 2006. *Standards of Quality for Waters of the State.* Chapter 33-16-02 of the North Dakota Century Code. North Dakota Department of Health, Division of Water Quality. Bismarck, North Dakota.

Nürnberg, Gertrud K., 1995. Quantifying Anoxia in Lakes. *Limnology and Oceanography* 40: 1100-1111.

NDDoH, draft March 2008. *De-Listing of Sediments for Mirror Lake in Adams County, North Dakota.* North Dakota Department of Health, Division of Water Quality. Bismarck, North Dakota.

Nürnberg, Gertrud, K., 1995. The Anoxic Factor, a Quantitative Measure of Anoxia and Fish Species Richness in Central Ontario Lakes. *Transactions of the American Fisheries Society* 124: 677-686.

Nürnberg, Gertrud, K., 1997. Coping with Water Quality Problems due to Hypolimnetic Anoxia in Central Ontario Lakes. *Water Qual. Res. J. Canada* 32: 391-405.

Nürnberg, Gertrud, K., 1998. Trophic State of Clear and Colored, Soft and Hardwater Lakes with Special Consideration of Nutrients, Anoxia, Phytoplankton and Fish. *Journal of Lake and Reservoir Management* 12: 432-447.

Thorton, Kent W, Kimmel, Bruce , Payne, Forrest E 1990, *Resevoir Limnology: Ecological Perspectives*. Wiley-Interscience Publication. New York.

Tunney, H., Carton O.T., 1997. *Phosphorus Loss from Soil to Water*. Cab International. New York, NY.

Ulmer, M.G., and Conta, J.F., 1987. *Soil Survey of Adams County, North Dakota.* United States Department of Agriculture, Soil Conservation Service, in cooperation with the North Dakota Agricultural Experiment Station, North Dakota Cooperative Extension Service, and North Dakota State Soil Conservation Committee.

Vollenweider, R.A., 1968. *Scientific Fundamentals of the Eutrophication of Lakes and lowing Waters, with Particular Reference to Nitrogen and Phosphorus as Factors in Eutrophication.* Technical Report DAS/CSI/68.27, Organization for Economic Cooperation and Development, Paris.

Walker, W.W., 1996. *Simplified Procedures for Eutrophication Assessment and Prediction: User Manual*. Instruction Report W-96-2. U.S. Army Corps of Engineer Waterways Experiment Station, Vicksburg, MS.

Wetzel, R.G. 1983, *Limnology*. 2nd ed. Saunders College Publishing. Fort Worth, TX.

Appendix A
Dissolved Oxygen and Temperature Data

Site #	Date	Depth	Temp	DO	Site #	Date	Depth	Temp	DO
380630	3/10/1995	0.5	4	15	380630	5/09/1995	0.5	11	8.4
380630	3/10/1995	1	4	15	380630	5/09/1995	1	11	8.3
380630	3/10/1995	2	5	9.2	380630	5/09/1995	2	11	8.4
380630	3/10/1995	3	6	4.2	380630	5/09/1995	3	11	8.0
					380630	5/09/1995	3.5	11	7.5
					380630	5/09/1995	4	12	6.5
					380630	5/09/1995	4.5	12	5.4
380630	6/14/1995	0.5	22	9.2	380630	7/23/1995	0.5	24	7.7
380630	6/14/1995	1	22	9.2	380630	7/23/1995	1	23	7.7
380630	6/14/1995	2	21	7.9	380630	7/23/1995	2	23	8.2
380630	6/14/1995	3	18	7.9	380630	7/23/1995	3	23	7.4
380630	6/14/1995	4	15	4.4	380630	7/23/1995	4	22	2.1
380630	6/14/1995	4.5	14	4.4	380630	7/23/1995	4.4	21	2.0
380630	9/24/1995	0.5	13	10.4	380630	2/08/1996	0.5	3	15
380630	9/24/1995	1	13	10	380630	2/08/1996	1	3	15
380630	9/24/1995	2	13	9.8	380630	2/08/1996	2	4	13.3
380630	9/24/1995	3	13	9.8	380630	2/08/1996	3	4	12.6
380630	9/24/1995	4	13	9.4	380630	2/08/1996	4	4	10.9
380630	9/24/1995	5	13	9.3					
380630	7/27/1996	0.5	22	10.3	380630	10/05/1996	0.5	13	10.6
380630	7/27/1996	1	21	10.1	380630	10/05/1996	1	12	10.7
380630	7/27/1996	2	21	9.8	380630	10/05/1996	2	11	10.8
380630	7/27/1996	3	21	3.3	380630	10/05/1996	3	10	9.2
380630	7/27/1996	4	20	3.3	380630	10/05/1996	4	10	8.9
380630	7/27/1996	4.5	20	3.0					
380630	2/02/1997	1	2	5.9	380630	1/15/1998	0.5	4	12.5
380630	2/02/1997	2	3	5.8	380630	1/15/1998	1	4	12.5
380630	2/02/1997	3	4	5.7	380630	1/15/1998	2	4	12.4
380630	2/02/1997	4	4	5.5	380630	1/15/1998	3	4	11.4
					380630	1/15/1998	3.5	4	10.1
380630	4/28/1998	1	11	8.8	380630	6/03/1998	0.5	15.6	8.6
380630	4/28/1998	2	10	9.1	380630	6/03/1998	1	15.6	8.1
380630	4/28/1998	3	10	8.9	380630	6/03/1998	2	15.6	8.1
380630	4/28/1998	4	10	8.7	380630	6/03/1998	3	15.6	8.0
380630	4/28/1998	5	10	8.4	380630	6/03/1998	3.5	15.5	6.1

Site #	Date	Depth	Temp	DO	Site #	Date	Depth	Temp	DO
380630	7/07/1998	0.5	22	8.3	380630	7/27/1998	0.5	26	13.5
380630	7/07/1998	1	22	8.6	380630	7/27/1998	1	24	14.4
380630	7/07/1998	2	22	6.6	380630	7/27/1998	2	24	14.4
380630	7/07/1998	3	22	2.4	380630	7/27/1998	3	24	12.6
380630	7/07/1998	3.5	22	2.3	380630	7/27/1998	3.5	24	6.5
380630	8/11/1998	0.5	22	8.0	380630	8/25/1998	0.5	24	6.0
380630	8/11/1998	1	22	8.3	380630	8/25/1998	1	24	6.5
380630	8/11/1998	2	22	8.3	380630	8/25/1998	2	23	5.6
380630	8/11/1998	3	22	3.6	380630	8/25/1998	3	22	5.2
380630	8/11/1998	4	21	3.4	380630	8/25/1998	3.5	21	5.2
380630	8/11/1998	4.5	21	3.3					
380630	9/14/1998	0.5	20	6.0	380630	9/29/1998	0.5	20	4.8
380630	9/14/1998	1	20	6.3	380630	9/29/1998	1	18.5	5.4
380630	9/14/1998	2	19	6.2	380630	9/29/1998	2	18	6.0
380630	9/14/1998	3	18	6.1	380630	9/29/1998	3	16.5	6.1
380630	9/14/1998	3.5	18	5.8	380630	9/29/1998	3.3	16	6.4
380630	11/20/1998	0.5	2	10.5	380630	2/09/1999	0.5	2	2.8
380630	11/20/1998	1	2	10.7	380630	2/09/1999	1	0	4.2
380630	11/20/1998	2	4	11.3	380630	2/09/1999	2	0	4.8
380630	11/20/1998	3	4	13.0	380630	2/09/1999	3	0	4.7
380630	11/20/1998	3.8	2	11.8	380630	2/09/1999	3.5	0	4.5
					380630	2/09/1999	4	0	4.1
					380630	2/09/1999	4.5	0	4.3
380630	4/28/1999	0.5	18	8.5	380630	7/07/1999	0.5	21.5	7.5
380630	4/28/1999	1	18	9.7	380630	7/07/1999	1	20.5	7.1
380630	4/28/1999	2	16.5	0.9	380630	7/07/1999	2	20	7.6
380630	4/28/1999	3	16	0.7	380630	7/07/1999	3	22	5.9
380630	4/28/1999	3.5	15	0.6	380630	7/07/1999	3.5	22	5.4
380630	4/28/1999	4	14	0.5	380630	7/07/1999	4	20	4.9
					380630	7/07/1999	4.5	20	4.2
380630	8/10/1999	0.5	21	2.5	380630	8/20/1999	0.5	23	5.5
380630	8/10/1999	1	21.5	2.2	380630	8/20/1999	1	22	6.3
380630	8/10/1999	2	22	1.9	380630	8/20/1999	2	21	6.1
380630	8/10/1999	3	22	2.2	380630	8/20/1999	3	20.5	2.5
380630	8/10/1999	3.5	22	2.2	380630	8/20/1999	3.5	20	2.2
380630	8/10/1999	4	21.5	1.9	380630	8/20/1999	4	20	2.2
					380630	8/20/1999	4.5	19.5	2.2

Site #	Date	Depth	Temp	DO	Site #	Date	Depth	Temp	DO
380630	9/09/1999	0.5	17	7.5	380630	5/26/2000	0.5	16.6	7.8
380630	9/09/1999	1	16	8.1	380630	5/26/2000	1	16.6	7.8
380630	9/09/1999	2	15	8.3	380630	5/26/2000	2	16.5	7.7
380630	9/09/1999	3	14.5	8.5	380630	5/26/2000	3	16.5	7.7
380630	9/09/1999	4	14	8.3	380630	5/26/2000	3.5	16.5	7.7
					380630	5/26/2000	4	16.5	7.6
380630	6/7/2000	0.5	20.6	8.5	380630	6/20/2000	0.5	20.7	9.3
380630	6/7/2000	1	20.3	8.5	380630	6/20/2000	1	19.9	9.2
380630	6/7/2000	2	18.9	8.1	380630	6/20/2000	2	19.5	8.9
380630	6/7/2000	3	17.9	6.5	380630	6/20/2000	3	19	8.1
380630	6/7/2000	3.5	17	4.3	380630	6/20/2000	4	18.2	4
380630	6/7/2000	4	16	2.8	380630	6/20/2000	5	19.8	0.6
380630	7/14/2000	0.5	25.5	8.7	380630	7/20/2000	0.5	23.2	7.9
380630	7/14/2000	1	25.4	8.6	380630	7/20/2000	1	22.9	8.2
380630	7/14/2000	2	25.5	6.2	380630	7/20/2000	2	22.5	7
380630	7/14/2000	3	23.9	3.8	380630	7/20/2000	3	22.4	6.8
380630	7/14/2000	4	22.3	0.2	380630	7/20/2000	4	22.3	7.1
380630	7/14/2000	4.7	21.8	0.3	380630	7/20/2000	4.8	22.3	6.9
380630	9/26/2000	0.5	10.9	8.6	380630	11/16/2000	0.5	0.5	13.1
380630	9/26/2000	1	10.7	8.6	380630	11/16/2000	1	0.9	12.6
380630	9/26/2000	2	10.7	8.6	380630	11/16/2000	2	1.8	8.5
380630	9/26/2000	3	10.6	8.6	380630	11/16/2000	3	2.3	6.5
380630	9/26/2000	3.5	10.6	8.6	380630	11/16/2000	3.5	2.5	5.6
380630	9/26/2000	4	10.6	8.6					
380630	12/19/2000	0.5	0.2	3.7	380630	1/09/2001	0.5	12	13.5
380630	12/19/2000	1	1.1	3.5	380630	1/09/2001	1	3	11.4
380630	12/19/2000	2	1.9	2.5	380630	1/09/2001	2	4	8.7
380630	12/19/2000	3	1.9	1.7	380630	1/09/2001	3	2	7.5
380630	12/19/2000	4	2	1.2	380630	1/09/2001	3.5	2	7
					380630	1/09/2001	4	2	7
380630	3/06/2001	0.5	10	10.2	380630	5/11/2001	0.5	20	15
380630	3/06/2001	1	4	10.6	380630	5/11/2001	1	14	14.7
380630	3/06/2001	2	2	9.4	380630	5/11/2001	2	14	13.8
380630	3/06/2001	3	2	7.8	380630	5/11/2001	3	13	12.3
380630	3/06/2001	3.5	2	7.9	380630	5/11/2001	4	12	12
380630	3/06/2001	4	2	6.6	380630	5/11/2001	4.5	12	11.6
380630	5/31/2001	0.5	17	15	380630	6/12/2001	0.5	19	15
380630	5/31/2001	1	16	15	380630	6/12/2001	1	19	15
380630	5/31/2001	2	16	14.5	380630	6/12/2001	2	19	14.5
380630	5/31/2001	3	15	8.4	380630	6/12/2001	3	18	13.7
380630	5/31/2001	4	14	7.8	380630	6/12/2001	4	16	11.8
380630	5/31/2001	4.4	14	9.3	380630	6/12/2001	4.5	15.5	9.8

Site #	Date	Depth	Temp	DO	Site #	Date	Depth	Temp	DO
380630	6/28/2001	0.5	26	11.7	380630	7/09/2001	0.5	24	9.8
380630	6/28/2001	1	25	12	380630	7/09/2001	1	24	11.2
380630	6/28/2001	2	23	10.9	380630	7/09/2001	2	23.5	9.5
380630	6/28/2001	3	22	10	380630	7/09/2001	3	22	8.7
380630	6/28/2001	4	20	10.2	380630	7/09/2001	4	21	6.5
380630	6/28/2001	4.4	18	9.7					
380630	8/7/2001	0.5	26	9.7	380630	8/21/2001	0.5	22	10.6
380630	8/7/2001	1	26	11.6	380630	8/21/2001	1	22	11.3
380630	8/7/2001	2	25.5	11.1	380630	8/21/2001	2	22	11.1
380630	8/7/2001	3	24	6.2	380630	8/21/2001	3	22	9.5
380630	8/7/2001	4	24	6.2	380630	8/21/2001	4	22	6.8
380630	9/05/2001	0.5	22	9.7	380630	9/18/2001	0.5	14	11.3
380630	9/05/2001	1	22.5	9.7	380630	9/18/2001	1	14	13.6
380630	9/05/2001	2	22.5	8.6	380630	9/18/2001	2	14	11.6
380630	9/05/2001	3	22	8	380630	9/18/2001	3	14	9.8
380630	9/05/2001	4	20	7.3	380630	9/18/2001	4	14	9.6
380630	10/21/2001	0.5	13	15					
380630	10/21/2001	1	10	15					
380630	10/21/2001	2	8	15					
380630	10/21/2001	3	8	15					
380630	10/21/2001	4	8	15					

Appendix B
Flux Data and Analysis

Mirror Lake Inlet 380381 Flux Load Analysis

Flat Creek Inlet 380381 (95-03)   VAR=NH3-4   METHOD= 4 REG-1

TABULATION OF MISSING DAILY FLOWS:

```
 Flow File =380381_Q.wk1                    ,   Station =Flow
 Daily Flows from 19950101 to 20031231
 Flow Dates Missing   : 19960101 - 19971231

 Summary:
 Reported Flows = 2556
 Missing Flows =   731
 Zero Flows =      787
 Positive Flows = 1769
```

Flat Creek Inlet 380381 (95-03)   VAR=NH3-4   METHOD= 4 REG-1

STRATIFICATION SCHEME:

	---- DATE ----		-- SEASON --		-------- FLOW --------	
STR	>=MIN	< MAX	>=MIN	< MAX	>=MIN	< MAX
1			0	0	.00	.66
2			0	0	.66	2.63
3			0	0	2.63	10.51
4			0	0	10.51	147.46

STR	SAMPLES	EVENTS	FLOWS	VOLUME %
1	26	26	2125	2.03
2	37	37	237	10.17
3	28	28	130	19.79
4	15	15	64	68.01
EXCLUDED	0	0	0	.00
TOTAL	106	106	2556	100.00

Flat Creek Inlet 380381 (95-03)   VAR=NH3-4   METHOD= 4 REG-1

Comparison of Sampled & Total Flow Distributions

	------ SAMPLED -----			------- TOTAL ------					
STRAT	N	MEAN	STD DEV	N	MEAN	STD DEV	DIFF	T	PROB(>T)
1	26	.21	.21	2125	.03	.10	.18	-4.23	.000
2	37	1.48	.52	237	1.44	.54	.04	-.41	.683
3	28	5.58	2.54	130	5.11	2.02	.47	-.93	.364
4	15	49.67	36.90	64	35.67	29.56	14.00	-1.37	.184
***	106	9.07	21.49	2556	1.31	7.31	7.76	-3.71	.001

```
 Average Sample Interval =  28.3 Days, Date Range = 19950313 to 20030527
 Maximum Sample Interval =   940 Days, Date Range = 19950828 to 19980326
 Percent of Total Flow Volume Occuring In This Interval =   1.2%

 Total Flow Volume on Sampled Days =        961.5 hm3
 Total Flow Volume on All Days     =       3356.7 hm3
 Percent of Total Flow Volume Sampled =    28.6%
```

Maximum Sampled Flow Rate = 126.51 hm3/yr
Maximum Total Flow Rate = 134.05 hm3/yr
Number of Days when Flow Exceeded Maximum Sampled Flow = 1 out of 2556
Percent of Total Flow Volume Occurring at Flow Rates Exceeding the
Maximum Sampled Flow Rate = 4.0%

Flat Creek Inlet 380381 (95-03) VAR=NH3-4 METHOD= 4 REG-1
COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	2125	26	26	2.0	.032	.209	.231	.122
2	237	37	37	10.2	1.440	1.478	.015	.968
3	130	28	28	19.8	5.111	5.584	.447	.145
4	64	15	15	68.0	35.670	49.667	.596	.214
***	2556	106	106	100.0	1.313	9.070		

FLOW STATISTICS
FLOW DURATION = 2556.0 DAYS = 6.998 YEARS
MEAN FLOW RATE = 1.313 HM3/YR
TOTAL FLOW VOLUME = 9.19 HM3
FLOW DATE RANGE = 19950101 TO 20031231
SAMPLE DATE RANGE = 19950313 TO 20030527

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	1831.5	261.7	.1028E+05	199.30	.387
2 Q WTD C	1083.8	154.9	.3589E+04	117.93	.387
3 IJC	1081.2	154.5	.3637E+04	117.65	.390
4 REG-1	888.5	127.0	.2383E+04	96.68	.385
5 REG-2	976.9	139.6	.2990E+04	106.31	.392
6 REG-3	1109.6	158.6	.7068E+04	120.74	.530

Flat Creek Inlet 380381 (95-03) VAR=NH3-4 METHOD= 4 REG-1
Load Time Series

				------Model------		----Interpolated----	
Date	Days	Sample Count	Volume (hm3)	Mass (kg)	Conc (ppb)	Mass (kg)	Conc (ppb)
1995	365.00	29	1.990	175.5	88.20	103.3	51.92
1998	365.00	15	.936	85.6	91.41	66.6	71.16
1999	365.00	16	1.287	124.4	96.69	97.9	76.11
2000	366.00	17	.186	14.5	77.76	12.4	66.58
2001	365.00	23	4.224	445.8	105.55	541.0	128.09
2002	365.00	0	.031	7.3	234.32	7.3	234.32
2003	365.00	6	.537	35.5	66.07	37.9	70.65
ALL	2556.04	106	9.190	888.5	96.68	866.4	94.28

Flat Creek Inlet 380381 (95-03)   VAR=NO2+NO3   METHOD= 4 REG-1

Comparison of Sampled & Total Flow Distributions

	SAMPLED			TOTAL					
STRAT	N	MEAN	STD DEV	N	MEAN	STD DEV	DIFF	T	PROB(>T)
1	26	.21	.21	2125	.03	.10	.18	-4.23	.000
2	37	1.48	.52	237	1.44	.54	.04	-.41	.683
3	28	5.58	2.54	130	5.11	2.02	.47	-.93	.364
4	15	49.67	36.90	64	35.67	29.56	14.00	-1.37	.184
***	106	9.07	21.49	2556	1.31	7.31	7.76	-3.71	.001

Average Sample Interval = 28.3 Days, Date Range = 19950313 to 20030527
Maximum Sample Interval =   940 Days, Date Range = 19950828 to 19980326
Percent of Total Flow Volume Occuring In This Interval =   1.2%

Total Flow Volume on Sampled Days =   961.5 hm3
Total Flow Volume on All Days   =   3356.7 hm3
Percent of Total Flow Volume Sampled =   28.6%

Maximum Sampled Flow Rate =   126.51 hm3/yr
Maximum Total Flow Rate   =   134.05 hm3/yr
Number of Days when Flow Exceeded Maximum Sampled Flow = 1 out of 2556
Percent of Total Flow Volume Occurring at Flow Rates Exceeding the
Maximum Sampled Flow Rate =   4.0%

Flat Creek Inlet 380381 (95-03)   VAR=NO2+NO3   METHOD= 4 REG-1

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	2125	26	26	2.0	.032	.209	.073	.540
2	237	37	37	10.2	1.440	1.478	-.088	.760
3	130	28	28	19.8	5.111	5.584	.690	.143
4	64	15	15	68.0	35.670	49.667	.763	.166
***	2556	106	106	100.0	1.313	9.070		

FLOW STATISTICS
FLOW DURATION =   2556.0 DAYS = 6.998 YEARS
MEAN FLOW RATE =   1.313 HM3/YR
TOTAL FLOW VOLUME =   9.19 HM3
FLOW DATE RANGE   = 19950101 TO 20031231
SAMPLE DATE RANGE = 19950313 TO 20030527

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	2055.5	293.7	.7689E+04	223.66	.299
2 Q WTD C	1457.3	208.2	.1992E+04	158.57	.214
3 IJC	1473.5	210.6	.2003E+04	160.34	.213
4 REG-1	1156.3	165.2	.1424E+04	125.83	.228
5 REG-2	1224.5	175.0	.1372E+04	133.24	.212
6 REG-3	2061.9	294.6	.1608E+05	224.36	.430

Flat Creek Inlet 380381 (95-03) VAR=INORG-N METHOD= 4 REG-1

Comparison of Sampled & Total Flow Distributions

	------ SAMPLED -----			------- TOTAL ------				
STRAT	N	MEAN	STD DEV	N	MEAN	STD DEV	DIFF	T PROB(>T)
1	26	.21	.21	2125	.03	.10	.18 -4.23	.000
2	37	1.48	.52	237	1.44	.54	.04 -.41	.683
3	28	5.58	2.54	130	5.11	2.02	.47 -.93	.364
4	15	49.67	36.90	64	35.67	29.56	14.00 -1.37	.184
***	106	9.07	21.49	2556	1.31	7.31	7.76 -3.71	.001

Average Sample Interval = 28.3 Days, Date Range = 19950313 to 20030527
Maximum Sample Interval = 940 Days, Date Range = 19950828 to 19980326
Percent of Total Flow Volume Occuring In This Interval = 1.2%

Total Flow Volume on Sampled Days = 961.5 hm3
Total Flow Volume on All Days = 3356.7 hm3
Percent of Total Flow Volume Sampled = 28.6%

Maximum Sampled Flow Rate = 126.51 hm3/yr
Maximum Total Flow Rate = 134.05 hm3/yr
Number of Days when Flow Exceeded Maximum Sampled Flow = 1 out of 2556
Percent of Total Flow Volume Occurring at Flow Rates Exceeding the
Maximum Sampled Flow Rate = 4.0%

Flat Creek Inlet 380381 (95-03) VAR=INORG-N METHOD= 4 REG-1

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	2125	26	26	2.0	.032	.209	.192	.169
2	237	37	37	10.2	1.440	1.478	-.038	.878
3	130	28	28	19.8	5.111	5.584	.835	.016
4	64	15	15	68.0	35.670	49.667	.642	.137
***	2556	106	106	100.0	1.313	9.070		

FLOW STATISTICS
FLOW DURATION = 2556.0 DAYS = 6.998 YEARS
MEAN FLOW RATE = 1.313 HM3/YR
TOTAL FLOW VOLUME = 9.19 HM3
FLOW DATE RANGE = 19950101 TO 20031231
SAMPLE DATE RANGE = 19950313 TO 20030527

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	3887.0	555.4	.2659E+05	422.96	.294
2 Q WTD C	2541.0	363.1	.7788E+04	276.50	.243
3 IJC	2554.7	365.1	.7661E+04	277.99	.240
4 REG-1	2072.5	296.2	.5332E+04	225.52	.247
5 REG-2	2220.6	317.3	.6293E+04	241.64	.250
6 REG-3	2694.4	385.0	.2080E+05	293.19	.375

Flat Creek Inlet 380381 (95-03) VAR=TKN METHOD= 4 REG-1

Comparison of Sampled & Total Flow Distributions

STRAT	N	MEAN	STD DEV	N	MEAN	STD DEV	DIFF	T	PROB(>T)
	------ SAMPLED -----			------- TOTAL ------					
1	26	.21	.21	2125	.03	.10	.18	-4.23	.000
2	37	1.48	.52	237	1.44	.54	.04	-.41	.683
3	28	5.58	2.54	130	5.11	2.02	.47	-.93	.364
4	15	49.67	36.90	64	35.67	29.56	14.00	-1.37	.184
***	106	9.07	21.49	2556	1.31	7.31	7.76	-3.71	.001

Average Sample Interval = 28.3 Days, Date Range = 19950313 to 20030527
Maximum Sample Interval = 940 Days, Date Range = 19950828 to 19980326
Percent of Total Flow Volume Occuring In This Interval = 1.2%

Total Flow Volume on Sampled Days = 961.5 hm3
Total Flow Volume on All Days = 3356.7 hm3
Percent of Total Flow Volume Sampled = 28.6%

Maximum Sampled Flow Rate = 126.51 hm3/yr
Maximum Total Flow Rate = 134.05 hm3/yr
Number of Days when Flow Exceeded Maximum Sampled Flow = 1 out of 2556
Percent of Total Flow Volume Occurring at Flow Rates Exceeding the
Maximum Sampled Flow Rate = 4.0%

Flat Creek Inlet 380381 (95-03) VAR=TKN METHOD= 4 REG-1

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	2125	26	26	2.0	.032	.209	.062	.015
2	237	37	37	10.2	1.440	1.478	-.312	.053
3	130	28	28	19.8	5.111	5.584	.009	.937
4	64	15	15	68.0	35.670	49.667	-.004	.964
***	2556	106	106	100.0	1.313	9.070		

FLOW STATISTICS
FLOW DURATION = 2556.0 DAYS = 6.998 YEARS
MEAN FLOW RATE = 1.313 HM3/YR
TOTAL FLOW VOLUME = 9.19 HM3
FLOW DATE RANGE = 19950101 TO 20031231
SAMPLE DATE RANGE = 19950313 TO 20030527

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	19803.3	2829.9	.1788E+06	2154.89	.149
2 Q WTD C	13766.3	1967.2	.1681E+05	1497.97	.066
3 IJC	13783.3	1969.6	.1747E+05	1499.82	.067
4 REG-1	13747.8	1964.5	.1124E+05	1495.96	.054
5 REG-2	13838.6	1977.5	.1214E+05	1505.85	.056
6 REG-3	13720.7	1960.7	.1326E+05	1493.02	.059

Flat Creek Inlet 380381 (95-03)   VAR=TOT-N   METHOD= 4 REG-1

Comparison of Sampled & Total Flow Distributions

STRAT	N (SAMPLED)	MEAN (SAMPLED)	STD DEV (SAMPLED)	N (TOTAL)	MEAN (TOTAL)	STD DEV (TOTAL)	DIFF	T	PROB(>T)
1	26	.21	.21	2125	.03	.10	.18	-4.23	.000
2	37	1.48	.52	237	1.44	.54	.04	-.41	.683
3	28	5.58	2.54	130	5.11	2.02	.47	-.93	.364
4	15	49.67	36.90	64	35.67	29.56	14.00	-1.37	.184
***	106	9.07	21.49	2556	1.31	7.31	7.76	-3.71	.001

Average Sample Interval = 28.3 Days, Date Range = 19950313 to 20030527
Maximum Sample Interval =   940 Days, Date Range = 19950828 to 19980326
Percent of Total Flow Volume Occuring In This Interval =   1.2%

Total Flow Volume on Sampled Days =   961.5 hm3
Total Flow Volume on All Days   =   3356.7 hm3
Percent of Total Flow Volume Sampled =   28.6%

Maximum Sampled Flow Rate =   126.51 hm3/yr
Maximum Total Flow Rate   =   134.05 hm3/yr
Number of Days when Flow Exceeded Maximum Sampled Flow = 1 out of 2556
Percent of Total Flow Volume Occurring at Flow Rates Exceeding the
Maximum Sampled Flow Rate =   4.0%

Flat Creek Inlet 380381 (95-03)   VAR=TOT-N   METHOD= 4 REG-1

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	2125	26	26	2.0	.032	.209	.066	.019
2	237	37	37	10.2	1.440	1.478	-.309	.050
3	130	28	28	19.8	5.111	5.584	.046	.703
4	64	15	15	68.0	35.670	49.667	.042	.714
***	2556	106	106	100.0	1.313	9.070		

FLOW STATISTICS
FLOW DURATION =   2556.0 DAYS = 6.998 YEARS
MEAN FLOW RATE =   1.313 HM3/YR
TOTAL FLOW VOLUME =   9.19 HM3
FLOW DATE RANGE   = 19950101 TO 20031231
SAMPLE DATE RANGE = 19950313 TO 20030527

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	21858.7	3123.6	.2487E+06	2378.55	.160
2 Q WTD C	15223.5	2175.4	.2604E+05	1656.54	.074
3 IJC	15256.8	2180.2	.2703E+05	1660.16	.075
4 REG-1	15029.9	2147.8	.1706E+05	1635.47	.061
5 REG-2	15161.6	2166.6	.1812E+05	1649.81	.062
6 REG-3	15026.7	2147.3	.2124E+05	1635.12	.068

Flat Creek Inlet 380381 (95-03)   VAR=TOT-P   METHOD= 4 REG-1

Comparison of Sampled & Total Flow Distributions

STRAT	SAMPLED N	SAMPLED MEAN	SAMPLED STD DEV	TOTAL N	TOTAL MEAN	TOTAL STD DEV	DIFF	T	PROB(>T)
1	26	.21	.21	2125	.03	.10	.18	-4.23	.000
2	37	1.48	.52	237	1.44	.54	.04	-.41	.683
3	28	5.58	2.54	130	5.11	2.02	.47	-.93	.364
4	15	49.67	36.90	64	35.67	29.56	14.00	-1.37	.184
***	106	9.07	21.49	2556	1.31	7.31	7.76	-3.71	.001

Average Sample Interval = 28.3 Days, Date Range = 19950313 to 20030527
Maximum Sample Interval =   940 Days, Date Range = 19950828 to 19980326
Percent of Total Flow Volume Occuring In This Interval =   1.2%

Total Flow Volume on Sampled Days =   961.5 hm3
Total Flow Volume on All Days   =   3356.7 hm3
Percent of Total Flow Volume Sampled =   28.6%

Maximum Sampled Flow Rate =   126.51 hm3/yr
Maximum Total Flow Rate   =   134.05 hm3/yr
Number of Days when Flow Exceeded Maximum Sampled Flow = 1 out of 2556
Percent of Total Flow Volume Occurring at Flow Rates Exceeding the
Maximum Sampled Flow Rate =   4.0%

Flat Creek Inlet 380381 (95-03)   VAR=TOT-P   METHOD= 4 REG-1

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	2125	26	26	2.0	.032	.209	.140	.128
2	237	37	37	10.2	1.440	1.478	-.490	.235
3	130	28	28	19.8	5.111	5.584	.410	.250
4	64	15	15	68.0	35.670	49.667	.303	.153
***	2556	106	106	100.0	1.313	9.070		

FLOW STATISTICS
FLOW DURATION =   2556.0 DAYS = 6.998 YEARS
MEAN FLOW RATE =   1.313 HM3/YR
TOTAL FLOW VOLUME =   9.19 HM3
FLOW DATE RANGE   = 19950101 TO 20031231
SAMPLE DATE RANGE = 19950313 TO 20030527

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	3433.2	490.6	.1127E+05	373.59	.216
2 Q WTD C	2463.9	352.1	.1825E+04	268.11	.121
3 IJC	2472.6	353.3	.1848E+04	269.06	.122
4 REG-1	2249.3	321.4	.1466E+04	244.76	.119
5 REG-2	2302.9	329.1	.1623E+04	250.59	.122
6 REG-3	2436.1	348.1	.2465E+04	265.09	.143

Flat Creek Inlet 380381 (95-03) VAR=TSS METHOD= 4 REG-1

Comparison of Sampled & Total Flow Distributions

STRAT	N (SAMPLED)	MEAN (SAMPLED)	STD DEV (SAMPLED)	N (TOTAL)	MEAN (TOTAL)	STD DEV (TOTAL)	DIFF	T	PROB(>T)
1	26	.21	.21	2125	.03	.10	.18	-4.23	.000
2	37	1.48	.52	237	1.44	.54	.04	-.41	.683
3	28	5.58	2.54	130	5.11	2.02	.47	-.93	.364
4	15	49.67	36.90	64	35.67	29.56	14.00	-1.37	.184
***	106	9.07	21.49	2556	1.31	7.31	7.76	-3.71	.001

Average Sample Interval = 28.3 Days, Date Range = 19950313 to 20030527
Maximum Sample Interval = 940 Days, Date Range = 19950828 to 19980326
Percent of Total Flow Volume Occuring In This Interval = 1.2%

Total Flow Volume on Sampled Days = 961.5 hm3
Total Flow Volume on All Days = 3356.7 hm3
Percent of Total Flow Volume Sampled = 28.6%

Maximum Sampled Flow Rate = 126.51 hm3/yr
Maximum Total Flow Rate = 134.05 hm3/yr
Number of Days when Flow Exceeded Maximum Sampled Flow = 1 out of 2556
Percent of Total Flow Volume Occurring at Flow Rates Exceeding the
Maximum Sampled Flow Rate = 4.0%

Flat Creek Inlet 380381 (95-03) VAR=TSS METHOD= 4 REG-1

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	2125	26	26	2.0	.032	.209	.026	.612
2	237	37	37	10.2	1.440	1.478	-.182	.511
3	130	28	28	19.8	5.111	5.584	-.043	.637
4	64	15	15	68.0	35.670	49.667	.654	.010
***	2556	106	106	100.0	1.313	9.070		

FLOW STATISTICS
FLOW DURATION = 2556.0 DAYS = 6.998 YEARS
MEAN FLOW RATE = 1.313 HM3/YR
TOTAL FLOW VOLUME = 9.19 HM3
FLOW DATE RANGE = 19950101 TO 20031231
SAMPLE DATE RANGE = 19950313 TO 20030527

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	205519.4	29368.5	.8264E+08	22363.54	.310
2 Q WTD C	146482.4	20932.2	.1912E+08	15939.45	.209
3 IJC	148898.7	21277.5	.1969E+08	16202.37	.209
4 REG-1	121561.2	17371.0	.7460E+07	13227.65	.157
5 REG-2	127509.3	18221.0	.8222E+07	13874.89	.157
6 REG-3	120914.7	17278.6	.1199E+08	13157.31	.200

Mirror Lake Outlet 380382 Flux Load Analysis

Lake Outlet VAR=NH3-4 METHOD= 2 Q WTD C

TABULATION OF MISSING DAILY FLOWS:

Flow File =380382_Q.wk1 , Station =cfs
Daily Flows from 19950101 to 20031231
Flow Dates Missing : 19960101 - 19971231

Summary:
Reported Flows = 2556
Missing Flows = 731
Zero Flows = 787
Positive Flows = 1769

Lake Outlet VAR=NH3-4 METHOD= 2 Q WTD C

STRATIFICATION SCHEME:

	---- DATE ----		-- SEASON --		-------- FLOW --------	
STR	>=MIN	< MAX	>=MIN	< MAX	>=MIN	< MAX
1			0	0	.00	1.37
2			0	0	1.37	153.35

STR	SAMPLES	EVENTS	FLOWS	VOLUME %
1	64	64	2231	5.01
2	66	66	325	94.99
EXCLUDED	0	0	0	.00
TOTAL	130	130	2556	100.00

Lake Outlet 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	2231	64	64	5.0	.078	.396	.171	.006
2	325	66	66	95.0	10.203	13.075	.033	.816
***	2556	130	130	100.0	1.366	6.833		

FLOW STATISTICS
FLOW DURATION = 2556.0 DAYS = 6.998 YEARS
MEAN FLOW RATE = 1.366 HM3/YR
TOTAL FLOW VOLUME = 9.56 HM3
FLOW DATE RANGE = 19950101 TO 20031231
SAMPLE DATE RANGE = 19950310 TO 20030624

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	3755.1	536.6	.1603E+05	392.89	.236
2 Q WTD C	2345.6	335.2	.6774E+04	245.42	.246
3 IJC	2327.3	332.6	.7115E+04	243.51	.254
4 REG-1	2280.1	325.8	.6030E+04	238.56	.238
5 REG-2	2395.6	342.3	.6551E+04	250.65	.236
6 REG-3	2960.9	423.1	.1453E+05	309.79	.285

Lake Outlet **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	2231	64	64	5.0	.078	.396	.198	.002
2	325	66	66	95.0	10.203	13.075	.091	.543
***	2556	130	130	100.0	1.366	6.833		

FLOW STATISTICS
FLOW DURATION = 2556.0 DAYS = 6.998 YEARS
MEAN FLOW RATE = 1.366 HM3/YR
TOTAL FLOW VOLUME = 9.56 HM3
FLOW DATE RANGE = 19950101 TO 20031231
SAMPLE DATE RANGE = 19950310 TO 20030624

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	3322.7	474.8	.1044E+05	347.65	.215
2 Q WTD C	2093.5	299.2	.4073E+04	219.04	.213
3 IJC	2079.9	297.2	.4411E+04	217.62	.223
4 REG-1	2004.0	286.4	.3735E+04	209.68	.213
5 REG-2	2125.0	303.7	.4758E+04	222.34	.227
6 REG-3	3106.1	443.9	.1236E+05	324.99	.250

Lake Outlet **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	2231	64	64	5.0	.078	.396	.194	.001
2	325	66	66	95.0	10.203	13.075	.051	.706
***	2556	130	130	100.0	1.366	6.833		

FLOW STATISTICS
FLOW DURATION = 2556.0 DAYS = 6.998 YEARS
MEAN FLOW RATE = 1.366 HM3/YR
TOTAL FLOW VOLUME = 9.56 HM3
FLOW DATE RANGE = 19950101 TO 20031231
SAMPLE DATE RANGE = 19950310 TO 20030624

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	7077.8	1011.4	.4972E+05	740.54	.220
2 Q WTD C	4439.1	634.3	.2016E+05	464.46	.224
3 IJC	4407.2	629.8	.2157E+05	461.12	.233
4 REG-1	4288.4	612.8	.1820E+05	448.69	.220
5 REG-2	4531.1	647.5	.2100E+05	474.08	.224
6 REG-3	5854.4	836.6	.4108E+05	612.55	.242

Lake Outlet **VAR=TKN** **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	2231	64	64	5.0	.078	.396	.012	.660
2	325	66	66	95.0	10.203	13.075	.006	.866
***	2556	130	130	100.0	1.366	6.833		

FLOW STATISTICS
FLOW DURATION = 2556.0 DAYS = 6.998 YEARS
MEAN FLOW RATE = 1.366 HM3/YR
TOTAL FLOW VOLUME = 9.56 HM3
FLOW DATE RANGE = 19950101 TO 20031231
SAMPLE DATE RANGE = 19950310 TO 20030624

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	18623.7	2661.3	.2566E+06	1948.59	.190
2 Q WTD C	12575.5	1797.0	.7180E+05	1315.77	.149
3 IJC	12478.0	1783.1	.8024E+05	1305.57	.159
4 REG-1	12543.2	1792.4	.6534E+05	1312.39	.143
5 REG-2	12583.7	1798.2	.7715E+05	1316.63	.154
6 REG-3	12737.0	1820.1	.4054E+05	1332.66	.111

Lake Outlet **VAR=TOT-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	2231	9	9	5.0	.078	.513	-.201	.122
2	325	20	20	95.0	10.203	16.211	-.001	.988
***	2556	29	29	100.0	1.366	11.339		

FLOW STATISTICS
FLOW DURATION = 2556.0 DAYS = 6.998 YEARS
MEAN FLOW RATE = 1.366 HM3/YR
TOTAL FLOW VOLUME = 9.56 HM3
FLOW DATE RANGE = 19950101 TO 20031231
SAMPLE DATE RANGE = 19950310 TO 19950705

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	21561.6	3081.1	.1156E+07	2255.98	.349
2 Q WTD C	11912.6	1702.3	.3137E+05	1246.41	.104
3 IJC	11709.3	1673.2	.2206E+05	1225.14	.089
4 REG-1	12160.5	1737.7	.2727E+05	1272.35	.095
5 REG-2	11638.2	1663.1	.1803E+05	1217.70	.081
6 REG-3	13051.2	1865.0	.5428E+05	1365.54	.125

Lake Outlet **VAR=TOT-P** **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	2231	9	9	5.0	.078	.513	.106	.665
2	325	20	20	95.0	10.203	16.211	.045	.788
***	2556	29	29	100.0	1.366	11.339		

FLOW STATISTICS
FLOW DURATION = 2556.0 DAYS = 6.998 YEARS
MEAN FLOW RATE = 1.366 HM3/YR
TOTAL FLOW VOLUME = 9.56 HM3
FLOW DATE RANGE = 19950101 TO 20031231
SAMPLE DATE RANGE = 19950310 TO 19950705

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	2403.3	343.4	.1126E+05	251.46	.309
2 Q WTD C	1250.6	178.7	.3658E+04	130.85	.338
3 IJC	1185.4	169.4	.3866E+04	124.03	.367
4 REG-1	1211.7	173.1	.3853E+04	126.78	.359
5 REG-2	1228.7	175.6	.4196E+04	128.56	.369
6 REG-3	1706.0	243.8	.5784E+04	178.50	.312

Lake Outlet **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	2231	9	9	5.0	.078	.513	.312	.444
2	325	20	20	95.0	10.203	16.211	-.069	.484
***	2556	29	29	100.0	1.366	11.339		

FLOW STATISTICS
FLOW DURATION = 2556.0 DAYS = 6.998 YEARS
MEAN FLOW RATE = 1.366 HM3/YR
TOTAL FLOW VOLUME = 9.56 HM3
FLOW DATE RANGE = 19950101 TO 20031231
SAMPLE DATE RANGE = 19950310 TO 19950705

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	387590.4	55386.3	.1056E+10	40553.39	.587
2 Q WTD C	124631.7	17809.8	.2632E+08	13040.15	.288
3 IJC	124365.5	17771.7	.2496E+08	13012.30	.281
4 REG-1	110449.8	15783.2	.7460E+07	11556.30	.173
5 REG-2	141441.2	20211.8	.5135E+08	14798.92	.355
6 REG-3	108992.2	15574.9	.1660E+08	11403.79	.262

Mirror Lake Stormwater Outfall 380383 Flux Load Analysis

```
Storm Water Outfall 380383        VAR=inorg     METHOD= 2 Q WTD C
TABULATION OF MISSING DAILY FLOWS:

 Flow File =380383_Q.wk1                    ,   Station =cfs
 Daily Flows from 19950101 to 20031231
 Flow Dates Missing   : 19960101 - 19971231

 Summary:
 Reported Flows = 2556
 Missing Flows =   731
 Zero Flows =     1673
 Positive Flows =  883

 Storm Water Outfall 380383        VAR=inorg     METHOD= 2 Q WTD C
 Comparison of Sampled & Total Flow Distributions
       ------ SAMPLED -----     ------- TOTAL ------
 STRAT   N     MEAN  STD DEV      N     MEAN  STD DEV     DIFF    T PROB(>T)
  1     30     6.31     5.53   2556      .04      .17     6.27  -6.21   .000
***     30     6.31     5.53   2556      .04      .17     6.27  -6.21   .000

 Average Sample Interval =   6.0 Days, Date Range = 19950313 to 19950910
 Maximum Sample Interval =    53 Days, Date Range = 19950705 to 19950828
 Percent of Total Flow Volume Occuring In This Interval =   1.0%

 Total Flow Volume on Sampled Days =          4.3 hm3
 Total Flow Volume on All Days     =        101.5 hm3
 Percent of Total Flow Volume Sampled =     4.2%

 Maximum Sampled Flow Rate =       16.09 hm3/yr
 Maximum Total Flow Rate   =        2.67 hm3/yr
 Number of Days when Flow Exceeded Maximum Sampled Flow =  0 out of 2556
 Percent of Total Flow Volume Occurring at Flow Rates Exceeding the
       Maximum Sampled Flow Rate =      .0%

 Storm Water Outfall 380383        VAR=inorg     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      2556  30  30 100.0         .040        6.306       -.074   .452
***      2556  30  30 100.0         .040        6.306

 FLOW STATISTICS
 FLOW DURATION =    2556.0 DAYS  =  6.998 YEARS
 MEAN FLOW RATE =      .040 HM3/YR
 TOTAL FLOW VOLUME =       .28 HM3
 FLOW DATE RANGE   = 19950101 TO 20031231
 SAMPLE DATE RANGE = 19950313 TO 19950910
```

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	11839.6	1691.9	.1293E+06	42617.04	.213
2 Q WTD C	74.5	10.7	.2871E+01	268.32	.159
3 IJC	74.4	10.6	.2882E+01	267.73	.160
4 REG-1	108.7	15.5	.1007E+03	391.26	.646
5 REG-2	44.0	6.3	.1762E+03	158.53	2.109
6 REG-3	117.4	16.8	.3469E+02	422.47	.351

Storm Water Outfall 380383 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	2556	30	30	100.0	.040	6.306	-.037	.363
***	2556	30	30	100.0	.040	6.306		

FLOW STATISTICS
FLOW DURATION = 2556.0 DAYS = 6.998 YEARS
MEAN FLOW RATE = .040 HM3/YR
TOTAL FLOW VOLUME = .28 HM3
FLOW DATE RANGE = 19950101 TO 20031231
SAMPLE DATE RANGE = 19950313 TO 19950910

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	72706.4	10389.7	.3099E+07	261709.50	.169
2 Q WTD C	457.8	65.4	.2304E+02	1647.72	.073
3 IJC	457.3	65.3	.2315E+02	1646.11	.074
4 REG-1	550.9	78.7	.5063E+03	1982.86	.286
5 REG-2	385.6	55.1	.5726E+03	1388.15	.434
6 REG-3	558.8	79.8	.1678E+03	2011.33	.162

Storm Water Outfall 380383 VAR=tp 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	2556	30	30	100.0	.040	6.306	.068	.341
***	2556	30	30	100.0	.040	6.306		

FLOW STATISTICS
FLOW DURATION = 2556.0 DAYS = 6.998 YEARS
MEAN FLOW RATE = .040 HM3/YR
TOTAL FLOW VOLUME = .28 HM3
FLOW DATE RANGE = 19950101 TO 20031231
SAMPLE DATE RANGE = 19950313 TO 19950910

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	12304.7	1758.3	.2057E+06	44291.22	.258
2 Q WTD C	77.5	11.1	.4486E+01	278.86	.191
3 IJC	77.7	11.1	.4662E+01	279.86	.194
4 REG-1	54.8	7.8	.1344E+01	197.32	.148
5 REG-2	87.5	12.5	.7285E+01	314.95	.216
6 REG-3	60.4	8.6	.1777E+01	217.51	.154

Storm Water Outfall 380383 VAR=n2n3n 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	2556	30	30	100.0	.040	6.306	-.040	.750
***	2556	30	30	100.0	.040	6.306		

FLOW STATISTICS
FLOW DURATION = 2556.0 DAYS = 6.998 YEARS
MEAN FLOW RATE = .040 HM3/YR
TOTAL FLOW VOLUME = .28 HM3
FLOW DATE RANGE = 19950101 TO 20031231
SAMPLE DATE RANGE = 19950313 TO 19950910

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	18439.6	2635.0	.2681E+06	66374.20	.196
2 Q WTD C	116.1	16.6	.4644E+01	417.89	.130
3 IJC	116.0	16.6	.4817E+01	417.38	.132
4 REG-1	142.1	20.3	.9463E+02	511.51	.479
5 REG-2	95.7	13.7	.9384E+02	344.39	.709
6 REG-3	214.9	30.7	.2596E+03	773.45	.525

Storm Water Outfall 380383 VAR=tkn 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	2556	30	30	100.0	.040	6.306	-.063	.198
***	2556	30	30	100.0	.040	6.306		

FLOW STATISTICS
FLOW DURATION = 2556.0 DAYS = 6.998 YEARS
MEAN FLOW RATE = .040 HM3/YR
TOTAL FLOW VOLUME = .28 HM3
FLOW DATE RANGE = 19950101 TO 20031231
SAMPLE DATE RANGE = 19950313 TO 19950910

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	54270.5	7755.2	.1839E+07	195348.80	.175
2 Q WTD C	341.7	48.8	.1703E+02	1229.91	.085
3 IJC	341.4	48.8	.1702E+02	1228.82	.085
4 REG-1	471.3	67.4	.6736E+03	1696.63	.385
5 REG-2	230.3	32.9	.1010E+04	829.00	.966
6 REG-3	458.2	65.5	.1755E+03	1649.17	.202

Storm Water Outfall 380383 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	2556	30	30	100.0	.040	6.306	.312	.164
***	2556	30	30	100.0	.040	6.306		

FLOW STATISTICS
FLOW DURATION = 2556.0 DAYS = 6.998 YEARS
MEAN FLOW RATE = .040 HM3/YR
TOTAL FLOW VOLUME = .28 HM3
FLOW DATE RANGE = 19950101 TO 20031231
SAMPLE DATE RANGE = 19950313 TO 19950910

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	2624086.0	374979.4	.3925E+11	9445502.00	.528
2 Q WTD C	16521.2	2360.9	.1409E+07	59468.62	.503
3 IJC	16720.4	2389.3	.1483E+07	60185.68	.510
4 REG-1	3402.1	486.2	.1222E+06	12245.97	.719
5 REG-2	13511.7	1930.8	.9476E+06	48635.86	.504
6 REG-3	10063.4	1438.1	.9445E+06	36223.74	.676

Appendix C
BATHTUB Model Results

CASE: Mirror Lake (95-03) Calibrated Model

HYDRAULIC AND DISPERSION PARAMETERS:

SEG	OUT	NET INFLOW HM3/YR	RESIDENCE TIME YRS	OVERFLOW RATE M/YR	MEAN VELOCITY KM/YR	----DISPERSION----- ESTIMATED KM2/YR	NUMERIC KM2/YR	EXCHANGE RATE HM3/YR
1	0	1.31	.32550	5.1	2.8	14.	1.	0.

CASE: Mirror Lake 95-03

GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	---- FLOW (HM3/YR) ---- MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Inlet	169.806	1.313	.000E+00	.000	.008
2	4	Outlet	170.061	1.366	.000E+00	.000	.008
TRIBUTARY INFLOW			169.806	1.313	.000E+00	.000	.008
***TOTAL INFLOW			170.061	1.313	.000E+00	.000	.008
GAUGED OUTFLOW			170.061	1.366	.000E+00	.000	.008
ADVECTIVE OUTFLOW			.000	-.053	.000E+00	.000	10843.830
***TOTAL OUTFLOW			170.061	1.313	.000E+00	.000	.008

GROSS MASS BALANCE BASED UPON OBSERVED CONCENTRATIONS

COMPONENT: TOTAL P

ID	T	LOCATION	----- LOADING ---- KG/YR	%(I)	--- VARIANCE --- KG/YR**2	%(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	Inlet	321.7	97.7	.000E+00	.0	.000	245.0	1.9
2	4	Outlet	178.9	54.3	.000E+00	.0	.000	131.0	1.1
PRECIPITATION			7.6	2.3	.146E+02	100.0	.500	.0	30.0
TRIBUTARY INFLOW			321.7	97.7	.000E+00	.0	.000	245.0	1.9
***TOTAL INFLOW			329.3	100.0	.146E+02	100.0	.012	250.8	1.9
GAUGED OUTFLOW			196.7	59.7	.000E+00	.0	.000	144.0	1.2
ADVECTIVE OUTFLOW			-7.6	-2.3	.000E+00	.0	.000	144.0	********
***TOTAL OUTFLOW			189.1	57.4	.000E+00	.0	.000	144.0	1.1
***RETENTION			140.3	42.6	.146E+02	100.0	.027	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	------ TOTAL P ------ POOL CONC MG/M3	RESIDENCE TIME YRS	TURNOVER RATIO -	RETENTION COEF -
5.15	.3255	144.0	.1869	37.4593	.4259

GROSS MASS BALANCE BASED UPON OBSERVED CONCENTRATIONS

COMPONENT: TOTAL N

ID	T	LOCATION	LOADING KG/YR	LOADING %(I)	VARIANCE KG/YR**2	VARIANCE %(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	Inlet	2146.8	89.4	.000E+00	.0	.000	1635.0	12.6
2	4	Outlet	1702.0	70.9	.000E+00	.0	.000	1246.0	10.0
		PRECIPITATION	255.0	10.6	.163E+05	100.0	.500	.0	1000.0
		TRIBUTARY INFLOW	2146.8	89.4	.000E+00	.0	.000	1635.0	12.6
		***TOTAL INFLOW	2401.8	100.0	.163E+05	100.0	.053	1829.2	14.1
		GAUGED OUTFLOW	1973.9	82.2	.000E+00	.0	.000	1445.0	11.6
		ADVECTIVE OUTFLOW	-76.6	-3.2	.000E+00	.0	.000	1445.0	********
		***TOTAL OUTFLOW	1897.3	79.0	.000E+00	.0	.000	1445.0	11.2
		***RETENTION	504.5	21.0	.163E+05	100.0	.253	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL N POOL CONC MG/M3	TOTAL N RESIDENCE TIME YRS	TOTAL N TURNOVER RATIO -	TOTAL N RETENTION COEF -
5.15	.3255	1445.0	.2571	27.2235	.2100

CASE: Mirror Lake (95-03) 25% Reduction

HYDRAULIC AND DISPERSION PARAMETERS:

SEG	OUT	NET INFLOW HM3/YR	RESIDENCE TIME YRS	OVERFLOW RATE M/YR	MEAN VELOCITY KM/YR	----DISPERSION----- ESTIMATED KM2/YR	NUMERIC KM2/YR	EXCHANGE RATE HM3/YR
1	0	1.31	.32550	5.1	2.8	14.	1.	0.

CASE: Mirror Lake 95-03 less 25%

GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	---- FLOW (HM3/YR) ---- MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Inlet	169.806	1.313	.000E+00	.000	.008
2	4	Outlet	170.061	1.366	.000E+00	.000	.008
TRIBUTARY INFLOW			169.806	1.313	.000E+00	.000	.008
***TOTAL INFLOW			170.061	1.313	.000E+00	.000	.008
GAUGED OUTFLOW			170.061	1.366	.000E+00	.000	.008
ADVECTIVE OUTFLOW			.000	-.053	.000E+00	.000	10843.830
***TOTAL OUTFLOW			170.061	1.313	.000E+00	.000	.008

GROSS MASS BALANCE BASED UPON OBSERVED CONCENTRATIONS
COMPONENT: TOTAL P

ID	T	LOCATION	----- LOADING ---- KG/YR	%(I)	--- VARIANCE --- KG/YR**2	%(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	Inlet	241.6	96.9	.000E+00	.0	.000	184.0	1.4
2	4	Outlet	178.9	71.8	.000E+00	.0	.000	131.0	1.1
PRECIPITATION			7.6	3.1	.146E+02	100.0	.500	.0	30.0
TRIBUTARY INFLOW			241.6	96.9	.000E+00	.0	.000	184.0	1.4
***TOTAL INFLOW			249.2	100.0	.146E+02	100.0	.015	189.8	1.5
GAUGED OUTFLOW			196.7	78.9	.000E+00	.0	.000	144.0	1.2
ADVECTIVE OUTFLOW			-7.6	-3.1	.000E+00	.0	.000	144.0	********
***TOTAL OUTFLOW			189.1	75.9	.000E+00	.0	.000	144.0	1.1
***RETENTION			60.2	24.1	.146E+02	100.0	.064	.0	.0

HYDRAULIC OVERFLOW RATE M/YR	RESIDENCE TIME YRS	-------------- TOTAL P -------------- POOL CONC MG/M3	RESIDENCE TIME YRS	TURNOVER RATIO -	RETENTION COEF -
5.15	.3255	144.0	.2469	28.3493	.2414

GROSS MASS BALANCE BASED UPON OBSERVED CONCENTRATIONS

COMPONENT: TOTAL N

ID	T	LOCATION	LOADING KG/YR	LOADING %(I)	VARIANCE KG/YR**2	VARIANCE %(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	Inlet	1609.7	86.3	.000E+00	.0	.000	1226.0	9.5
2	4	Outlet	1702.0	91.3	.000E+00	.0	.000	1246.0	10.0
		PRECIPITATION	255.0	13.7	.163E+05	100.0	.500	.0	1000.0
		TRIBUTARY INFLOW	1609.7	86.3	.000E+00	.0	.000	1226.0	9.5
		***TOTAL INFLOW	1864.7	100.0	.163E+05	100.0	.068	1420.2	11.0
		GAUGED OUTFLOW	1973.9	105.9	.000E+00	.0	.000	1445.0	11.6
		ADVECTIVE OUTFLOW	-76.6	-4.1	.000E+00	.0	.000	1445.0	********
		***TOTAL OUTFLOW	1897.3	101.7	.000E+00	.0	.000	1445.0	11.2
		***RETENTION	-32.5	-1.7	.163E+05	100.0	3.917	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL N POOL CONC MG/M3	TOTAL N RESIDENCE TIME YRS	TOTAL N TURNOVER RATIO -	TOTAL N RETENTION COEF -
5.15	.3255	1445.0	.3312	21.1365	-.0175

CASE: Mirror Lake (95-03) 50% Reduction

HYDRAULIC AND DISPERSION PARAMETERS:

SEG	OUT	NET INFLOW HM3/YR	RESIDENCE TIME YRS	OVERFLOW RATE M/YR	MEAN VELOCITY KM/YR	----DISPERSION----- ESTIMATED KM2/YR	NUMERIC KM2/YR	EXCHANGE RATE HM3/YR
1	0	1.31	.32550	5.1	2.8	14.	1.	0.

GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	---- FLOW (HM3/YR) ---- MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Inlet	169.806	1.313	.000E+00	.000	.008
2	4	Outlet	170.061	1.366	.000E+00	.000	.008
TRIBUTARY INFLOW			169.806	1.313	.000E+00	.000	.008
***TOTAL INFLOW			170.061	1.313	.000E+00	.000	.008
GAUGED OUTFLOW			170.061	1.366	.000E+00	.000	.008
ADVECTIVE OUTFLOW			.000	-.053	.000E+00	.000	10843.830
***TOTAL OUTFLOW			170.061	1.313	.000E+00	.000	.008

GROSS MASS BALANCE BASED UPON OBSERVED CONCENTRATIONS

COMPONENT: TOTAL P

ID	T	LOCATION	----- LOADING ---- KG/YR	%(I)	--- VARIANCE --- KG/YR**2	%(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	Inlet	161.5	95.5	.000E+00	.0	.000	123.0	1.0
2	4	Outlet	178.9	105.8	.000E+00	.0	.000	131.0	1.1
PRECIPITATION			7.6	4.5	.146E+02	100.0	.500	.0	30.0
TRIBUTARY INFLOW			161.5	95.5	.000E+00	.0	.000	123.0	1.0
***TOTAL INFLOW			169.1	100.0	.146E+02	100.0	.023	128.8	1.0
GAUGED OUTFLOW			196.7	116.3	.000E+00	.0	.000	144.0	1.2
ADVECTIVE OUTFLOW			-7.6	-4.5	.000E+00	.0	.000	144.0	********
***TOTAL OUTFLOW			189.1	111.8	.000E+00	.0	.000	144.0	1.1
***RETENTION			-19.9	-11.8	.146E+02	100.0	.192	.0	.0

HYDRAULIC OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	TOTAL P RESIDENCE TIME YRS	TOTAL P TURNOVER RATIO -	TOTAL P RETENTION COEF -
5.15	.3255	144.0	.3638	19.2394	-.1178

GROSS MASS BALANCE BASED UPON OBSERVED CONCENTRATIONS

COMPONENT: TOTAL N

ID	T	LOCATION	LOADING KG/YR	LOADING %(I)	VARIANCE KG/YR**2	VARIANCE %(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	Inlet	1074.0	80.8	.000E+00	.0	.000	818.0	6.3
2	4	Outlet	1702.0	128.1	.000E+00	.0	.000	1246.0	10.0

	LOADING KG/YR	LOADING %(I)	VARIANCE KG/YR**2	VARIANCE %(I)	CV	CONC MG/M3	EXPORT KG/KM2
PRECIPITATION	255.0	19.2	.163E+05	100.0	.500	.0	1000.0
TRIBUTARY INFLOW	1074.0	80.8	.000E+00	.0	.000	818.0	6.3
***TOTAL INFLOW	1329.0	100.0	.163E+05	100.0	.096	1012.2	7.8
GAUGED OUTFLOW	1973.9	148.5	.000E+00	.0	.000	1445.0	11.6
ADVECTIVE OUTFLOW	-76.6	-5.8	.000E+00	.0	.000	1445.0	********
***TOTAL OUTFLOW	1897.3	142.8	.000E+00	.0	.000	1445.0	11.2
***RETENTION	-568.3	-42.8	.163E+05	100.0	.224	.0	.0

OVERFLOW RATE	HYDRAULIC RESIDENCE TIME	TOTAL N POOL CONC	TOTAL N RESIDENCE TIME	TOTAL N TURNOVER RATIO	TOTAL N RETENTION COEF
M/YR	YRS	MG/M3	YRS	-	-
5.15	.3255	1445.0	.4647	15.0644	-.4276

CASE: Mirror Lake (95-03) 75% Reduction

HYDRAULIC AND DISPERSION PARAMETERS:

SEG	OUT	NET INFLOW HM3/YR	RESIDENCE TIME YRS	OVERFLOW RATE M/YR	MEAN VELOCITY KM/YR	----DISPERSION----- ESTIMATED KM2/YR	NUMERIC KM2/YR	EXCHANGE RATE HM3/YR
1	0	1.31	.32550	5.1	2.8	14.	1.	0.

CASE: Mirror Lake 95-03

GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	---- FLOW (HM3/YR) ---- MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Inlet	169.806	1.313	.000E+00	.000	.008
2	4	Outlet	170.061	1.366	.000E+00	.000	.008
TRIBUTARY INFLOW			169.806	1.313	.000E+00	.000	.008
***TOTAL INFLOW			170.061	1.313	.000E+00	.000	.008
GAUGED OUTFLOW			170.061	1.366	.000E+00	.000	.008
ADVECTIVE OUTFLOW			.000	-.053	.000E+00	.000	10843.830
***TOTAL OUTFLOW			170.061	1.313	.000E+00	.000	.008

GROSS MASS BALANCE BASED UPON OBSERVED CONCENTRATIONS
COMPONENT: TOTAL P

ID	T	LOCATION	----- LOADING ---- KG/YR	%(I)	--- VARIANCE --- KG/YR**2	%(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	Inlet	80.1	91.3	.000E+00	.0	.000	61.0	.5
2	4	Outlet	178.9	203.9	.000E+00	.0	.000	131.0	1.1
PRECIPITATION			7.6	8.7	.146E+02	100.0	.500	.0	30.0
TRIBUTARY INFLOW			80.1	91.3	.000E+00	.0	.000	61.0	.5
***TOTAL INFLOW			87.7	100.0	.146E+02	100.0	.044	66.8	.5
GAUGED OUTFLOW			196.7	224.2	.000E+00	.0	.000	144.0	1.2
ADVECTIVE OUTFLOW			-7.6	-8.7	.000E+00	.0	.000	144.0	********
***TOTAL OUTFLOW			189.1	215.5	.000E+00	.0	.000	144.0	1.1
***RETENTION			-101.3	-115.5	.146E+02	100.0	.038	.0	.0

HYDRAULIC OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	TOTAL P RESIDENCE TIME YRS	TOTAL P TURNOVER RATIO -	TOTAL P RETENTION COEF -
5.15	.3255	144.0	.7014	9.9801	-1.1548

GROSS MASS BALANCE BASED UPON OBSERVED CONCENTRATIONS

COMPONENT: TOTAL N

ID	T	LOCATION	LOADING KG/YR	LOADING %(I)	VARIANCE KG/YR**2	VARIANCE %(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	Inlet	537.0	67.8	.000E+00	.0	.000	409.0	3.2
2	4	Outlet	1702.0	214.9	.000E+00	.0	.000	1246.0	10.0
		PRECIPITATION	255.0	32.2	.163E+05	100.0	.500	.0	1000.0
		TRIBUTARY INFLOW	537.0	67.8	.000E+00	.0	.000	409.0	3.2
		***TOTAL INFLOW	792.0	100.0	.163E+05	100.0	.161	603.2	4.7
		GAUGED OUTFLOW	1973.9	249.2	.000E+00	.0	.000	1445.0	11.6
		ADVECTIVE OUTFLOW	-76.6	-9.7	.000E+00	.0	.000	1445.0	********
		***TOTAL OUTFLOW	1897.3	239.6	.000E+00	.0	.000	1445.0	11.2
		***RETENTION	-1105.3	-139.6	.163E+05	100.0	.115	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL N POOL CONC MG/M3	TOTAL N RESIDENCE TIME YRS	TOTAL N TURNOVER RATIO -	TOTAL N RETENTION COEF -
5.15	.3255	1445.0	.7797	8.9774	-1.3955

Appendix D

A Calibrated Trophic Response Model (BATHTUB) for Mirror Lake as a Tool to Evaluate Various Nutrient Reduction Alternatives

Based on Data Collected by the Adams County Soil Conservation District from February 21, 1995 through June 24, 2003

Prepared by
Peter Wax
August, 2006

Introduction

In order to meet the project goals, as set forth by the project sponsors of improving the trophic condition of Mirror Lake to levels capable of maintaining the reservoirs beneficial uses (e.g., fishing, recreation, and drinking water supply), and the project objectives 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 Mirror Lake. The model enables investigations into various nutrient reduction alternatives relative to the project goal of improving Mirror 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, achievable and socially acceptable.

<u>Methods</u>

For purposes of this project, the BATHTUB program was used 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.

<u>Tributary Data</u>

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).

<u>Lake Data</u>

Mirror 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.

<u>Bathtub Model Calibration</u>

As stated previously, the BATHTUB eutrophic response model was selected for this project as a means of evaluating the effects of various nutrient reduction alternatives on the trophic status of Mirror 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 a 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, Mirror 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 Mirror Lake Bathtub Model.

Model Option	Model Selection	Calibration Factor
Conservative Substance	0 Not Computed	1.00
Phosphorus Balance	5 Vollenweider	0.90
Phosphorus – Ortho P		1.72
Nitrogen Balance	5 Bachman Flushing	0.94
Organic Nitrogen		2.00
Chlorophyll-a	1 P, N, Light, T	0.46
Secchi Depth	1 Vs. Chla & Turbidity	1.00
Phosphorus Calibration	2 Concentrations	NA
Nitrogen Calibration	2 Concentrations	NA
Availability Factors	2 All Models Except 2	NA
Mass-Balance Tables	0 Use Observed Concentrations	NA

Results

The trophic response model, BATHTUB, was calibrated to match Mirror Lake's trophic response for the project period February 21, 1995 through June 6, 2003. 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 Mirror 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 model predicts that the reservoir has an annual volume weighted average total phosphorus concentration of 0.144 mg L^{-1} and an annual average volume weighted total nitrogen concentration of 1.440 mg L^{-1} compared to observed values for total phosphorus and total nitrogen of 0.144 mg L^{-1} and 1.445 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) (Carlson 1977) 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)	0.144	0.144
Total Nitrogen as N (mg/L)	1.445	1.440
Organic Nitrogen as N (mg/L)	1.322	1.307
Chlorophyll-a (μg/L)	20.70	20.48
Secchi Disk Transparency (meters)	1.10	1.11
Carlson's TSI for Phosphorus	75.81	75.79
Carlson's TSI for Chlorophyll-a	60.33	60.22
Carlson's TSI for Secchi Disk	58.63	58.54

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 suggest Mirror Lake is hypereutrophic, while the TSI value chlorophyll-a, and sechhi disk indicated the reservoir is eutrophic. Figure 2 is a graphic that shows the annual temporal distribution of Mirror Lake's trophic state based on the three parameters total phosphorus as phosphate, 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 Mirror 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).

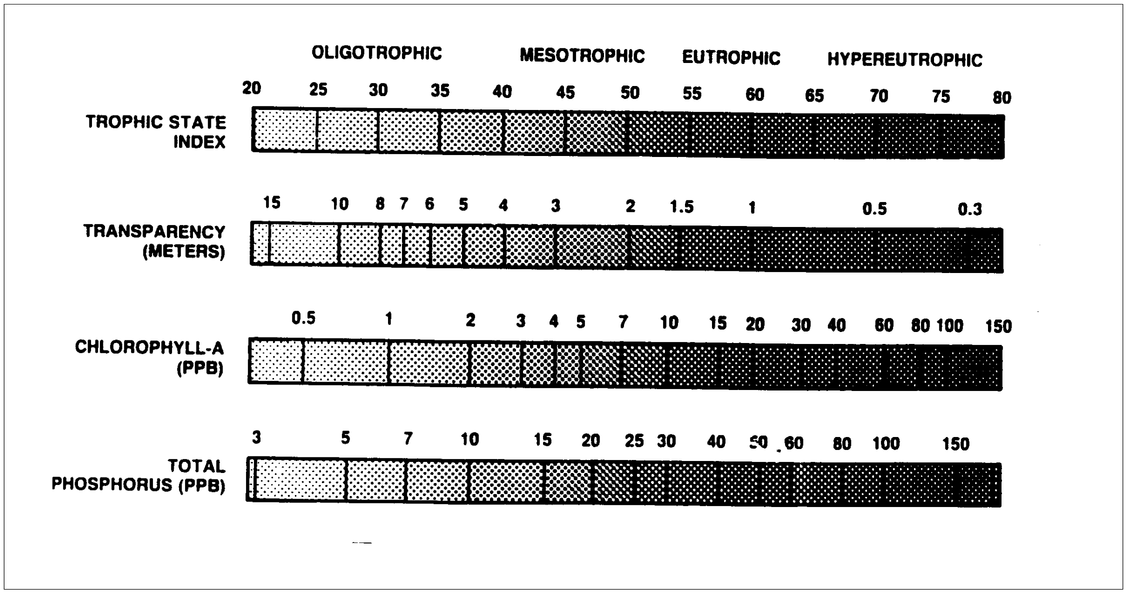


Figure 1. Graphic depiction of Carlson's Trophic Status Index

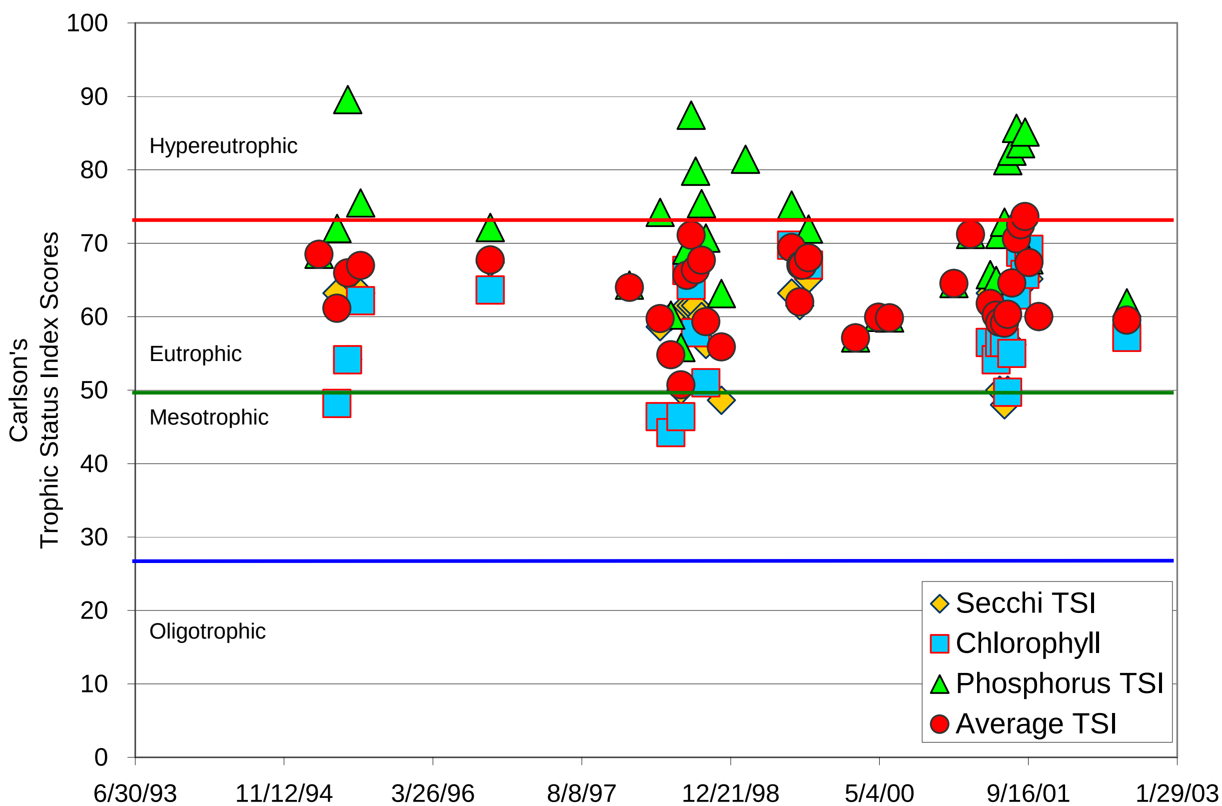


Figure 2. Temporal distribution of Carlosn's Trophic Status Index scores for Mirror Lake (2-21-1995 though 6-24-2003)

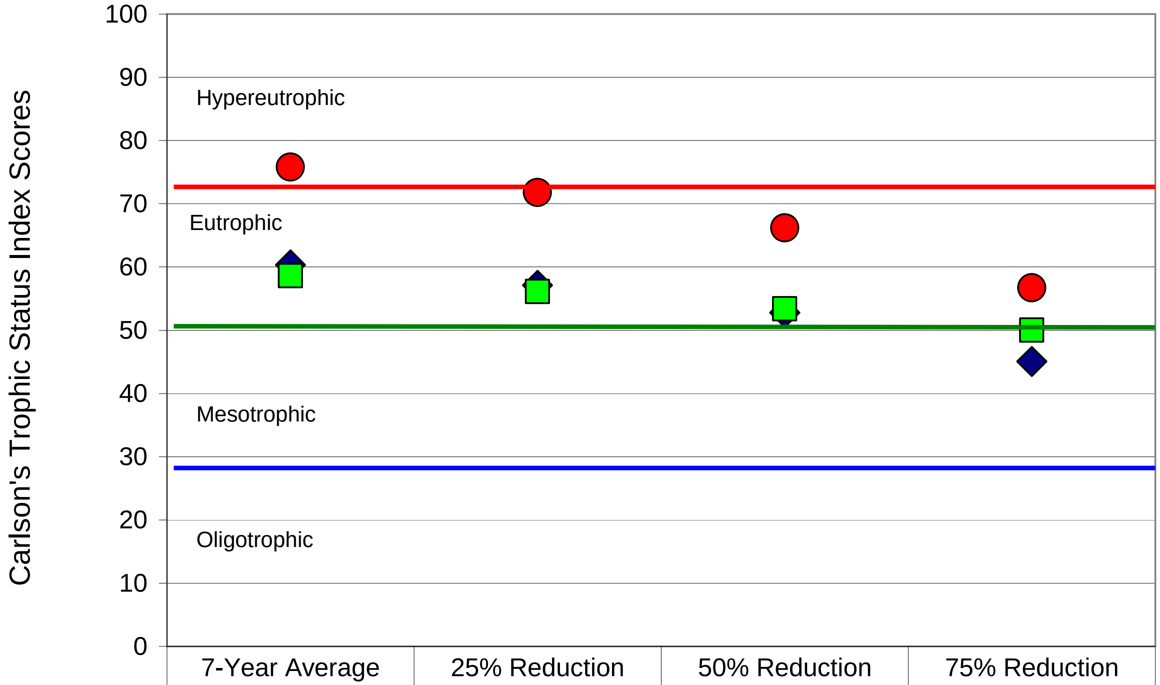
Predicted changes in trophic response to Mirror Lake were evaluated by reducing externally derived phosphorus loads by 25, 50, and 75 percent. These reductions were simulated in the model by reducing the phosphorus and nitrogen concentrations in the contributing tributary and other external delivery sources 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.

The model results indicate that if it were possible to reduce external phosphorus loading to Mirror Lake by 50 percent, the average annual total phosphorus and chlorophyll-a concentrations in the lake would decrease and secchi disk transparency depth would increase measurably (Table 3, Figure 3). It is also likely, that this large of a reduction in nutrient load would result in an improvement to the trophic status of Mirror Lake that would be noticeable to the average lake user as the reduction in the amount of green in the lake and overall clarity would increase nearly to the mesotrophic range.

With a 50 percent reduction in external phosphorus and nitrogen load, the Bathtub model predicts a reduction in Carlson's TSI score from 60.33 to 52.78 for chlorophyll-a and from 58.63 to 53.37 for secchi disk transparency, corresponding to a trophic state of eutrophic and mesotrophic, respectively.

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.

		Predicted		
Variable	Observed	25 %	50 %	75 %
Total Phosphorus as P (mg/L)	0.144	0.109	0.074	0.038
Total Diss. Phosphorus as P (mg/L)	0.700	0.053	0.035	0.016
Total Nitrogen as N (mg/L)	1.445	1.118	0.797	0.475
Organic Nitrogen as N (mg/L)	1.322	1.052	-----	-----
Chlorophyll-a (μg/L)	20.70	14.91	9.59	4.36
Secchi Disk Transparency (meters)	1.10	1.31	1.58	2.00
Carlson's TSI for Phosphorus	75.81	71.77	66.18	56.72
Carlson's TSI for Chlorophyll-a	60.33	57.11	52.78	45.04
Carlson's TSI for Secchi Disk	58.63	56.13	53.37	50.03



	7-Year Average	25% Reduction	50% Reduction	75% Reduction
TSI-Chlorophyll-a	60.33	57.11	52.78	45.04
TSI-Secchi Disk	58.63	56.13	53.37	50.03
TSI-Phopshorus	75.81	71.77	66.18	56.72

Figure 3. Predicted trophic response to phosphorus load reductions to Mirror Lake of 25, 50, and 75 percent.

Appendix E
US Fish and Wildlife Service List of Threatened and Endangered Species and Designated Critical Habitat in North Dakota

FEDERAL THREATENED, ENDANGERED, AND CANDIDATE SPECIES
AND DESIGNATED CRITICAL HABITAT FOUND IN
NORTH DAKOTA
March 2005

ENDANGERED SPECIES

Birds

Interior least tern (Sterna antillarum): Nests along midstream sandbars of the Missouri and Yellowstone Rivers.

Whooping crane (Grus Americana): Migrates through west and central counties during spring and fall. Prefers to roost on wetlands and stock dams with good visibility. Young adult summered in North Dakota in 1989, 1990, and 1993. Total population 140-150 birds.

Fish

Pallid sturgeon (Scaphirhynchus albus): Known only from the Missouri and Yellowstone Rivers. No reproduction has been documented in 15 years.

Mammals

Black-footed ferret (Mustela nigripes): Exclusively associated with prairie dog towns. No records of occurrence in recent years, although there is potential for reintroduction in the future.

Gray wolf (Canis lupus): Occasional visitor in North Dakota. Most frequently observed in the Turtle Mountains area.

THREATENED SPECIES

Birds

Bald eagle (Haliaeetus leucocephalus): Migrates spring and fall statewide but primarily along the major river courses. It concentrates along the Missouri River during winter and is known to nest in the floodplain forest.

Piping plover (Charadrius melodus): Nests on midstream sandbars of the Missouri and Yellowstone Rivers and along shorelines of saline wetlands. More nest in North Dakota than any other state.

Plants

W. prairie-fringed orchid (Platanthera praeclara): Locally common in moist swales on Sheyenne National Grasslands. Largest known U.S. population is on the Sheyenne.

CANDIDATE SPECIES

Invertebrates

Dakota skipper (Hesperia dacotae): Found in native prairie containing a high diversity of wildflowers and grasses. Habitat includes two prairie types: 1) low (wet) prairie dominated by bluestem grasses, wood lily, harebell, and smooth camas; 2) upland (dry) prairie on ridges and hillsides dominated by bluestem grasses, needlegrass, pale purple and upright coneflowers and blanketflower.

DESIGNATED CRITICAL HABITAT

Birds

Piping Plover - Alkali Lakes and Wetlands - Critical habitat includes: (1) shallow, seasonally to permanently flooded, mixosaline to hypersaline wetlands with sandy to gravelly, sparsely vegetated beaches, salt-encrusted mud flats, and/or gravelly salt flats; (2) springs and fens along edges of alkali lakes and wetlands; and (3) adjacent uplands 200 feet (61 meters) above the high water mark of the alkali lake or wetland.

Piping Plover - Missouri River - Critical habitat includes sparsely vegetated channel sandbars, sand and gravel beaches on islands, temporary pools on sandbars and islands, and the interface with the river.

Piping Plover - Lake Sakakawea and Oahe - Critical habitat includes sparsely vegetated shoreline beaches, peninsulas, islands composed of sand, gravel, or shale, and their interface with the water bodies.

Appendix F

Comment Letter 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

RECEIVED
JAN 07 2008
DIV. OF WATER QUALITY

JAN 04 2007

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 Mirror Lake Nutrient and Dissolved Oxygen Total Maximum Daily Load report, and offers the following comments.

The North Dakota Department of Health (Department) has identified Mirror Lake, Adams County, as being water quality limited and needing total maximum daily loads (TMDL). Mirror Lake, a man-made reservoir, is on the Department's Section 303(d) List of Impaired Waters. Aquatic life in the reservoir is listed as impaired due to nutrients, sedimentation, and low dissolved oxygen. The draft TMDL indicates there are no waste allocations from point sources in the watershed. Pollutant loads are attributed to nonpoint sources.

The draft document provides discussion on identifying the pollutant reductions needed and actions that should be taken to achieve water quality standards for Mirror Lake. The Service supports the Department's efforts to restore water quality to fully support aquatic life within the reservoir.

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

Thank you for the opportunity to comment on the draft document. 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
Review Comments Provided by the US EPA Region 8

EPA Region VIII TMDL Review Form

Document Name:	**Mirror Lake Nutrient and Dissolved Oxygen TMDLs**
Submitted by:	**Mike Ell, NDDoH**
Date Received:	**December 26, 2007**
Review Date:	**January 28, 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 12 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
12. Endangered Species Act Compliance

Each of the 12 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*

☒ 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 – Mirror Lake is located at the southern edge of the city of Hettinger in south-central Adams County, North Dakota. It is a 63 acre man-made impoundment in the Lower Missouri River basin of North Dakota. Flat Creek is the main tributary that drains into the reservoir. Mirror Lake is listed on the State's 2006 303(d) list as impaired for fish and other aquatic biota uses by nutrients/eutrophication, low dissolved oxygen and sedimentation/siltation. Approximately 41,960 acres of land drain to the lake from the watershed. Mirror Lake is classified as a Class 3 warm water fishery, and is listed as a high priority (i.e., 1A) for TMDL development. The majority of the land use in this watershed is agricultural (approximately 86 percent). Cropland acreage is approximately 43%, range/pasture is approximately 25%, and hayland is approximately 18%.

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

☒ 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 – Mirror Lake is impaired for dissolved oxygen and nutrients/eutrophication 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: NO3 as N = 0.25 mg/L; PO4 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 13 - 14 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

☐ 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 Mirror Lake during the period of the assessment was 76. 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 66, which corresponds to a phosphorus concentration of 0.074 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 TMDL does not contain a target for sediment because the assessment concludes that the reservoir is not impaired for sediment. The report recommends removing Mirror Lake sediment as a cause of impairment from the next Section 303(d) list.

The water quality targets used in this TMDL are: **maintain a mean annual total phosphorus TSI at or below 66; maintain a dissolved oxygen level of not less than 5 mg/L.**

COMMENTS – Mirror Lake is listed (i.e., 2006 303(d) list) 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.

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

☒ 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. Approximately 43% of the landuse is cropland and 25% is range/pasture land in the watershed.

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 Mirror 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 Mirror Lake.

The Agricultural Non-Point Source Model (AGNPS) 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 Mirror 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

☒ 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 – To account for the uncertainty associated with known sources and the load reductions necessary to reach the water quality target of TP TSI = 66, a 10% 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.

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.

☐ 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 established for Mirror Lake is a 160.9 kg/yr total phosphorus load to the lake (50% reduction in external annual total phosphorus load). This is the "measured 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 Mirror Lake will address the dissolved oxygen impairment.

COMMENTS – In November 2006 EPA issued the 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. In June 2007 EPA made available a technical document "Options for the Expression of Daily Loads in TMDLs."

The Mirror Lake TMDL needs to be revised to include a "daily" expression of load consistent with the Friends of the Earth decision and the technical guidance. The technical guidance is available at: http://www.epa.gov/owow/tmdl/draft_daily_loads_tech.pdf.

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

☒ 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 – This TMDL addresses the need to achieve reductions in nutrients to attain water quality goals in Mirror 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 fallow, small grains, or land chiseled multiple times, as well as all feedlots, and all land with a slopes greater than five percent. See the shaded cells in Figure 11 of the TMDL. Also, if landowners of pasture can effectively exclude cattle from riparian areas in the watershed it would improve the riparian health and the natural buffer of the tributaries flowing into Mirror Lake.

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

- ☒ 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 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

- ☐ 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 – 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 is not *currently a regulatory requirement, but is considered a value added component of a TMDL 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 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.

12. Endangered Species Act Compliance

Criterion Description – Endangered Species Act Compliance

EPA's approval of a TMDL may constitute an action subject to the provisions of Section 7 of the Endangered Species Act (ESA). EPA will consult, as appropriate, with the US Fish and Wildlife Service (USFWS) to determine if there is an effect on listed endangered and threatened species pertaining to EPA's approval of the TMDL. The responsibility to consult with the USFWS lies

☐ 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 – NDDoH will coordinate with the USFWS on potential impacts of this TMDL on endangered and threatened species.

Appendix H
Comment Letter and Attachment Provided by Mark Baker

RECEIVED
JAN 24 2008
DIV. OF WATER QUALITY

Concerned,

I am writing in response to an inquiry of "TMDLs", the Mirror Lake project.

In compiling information pertaining to Mirror Lake it is quite obvious the gears running this machine don't quite mesh very well.

I have included a letter submitted to our Park Board Dist. from the Game & Fish Dept. Not dated as I can see, however giving data poignant to the time period of the Solar Bee and Pond Doctor infastructure. Making the letter perhaps five yrs. old.

On inquest the Solar Bee people stated at the Park Board meeting, they had taken their own water tests, also they said they had submitted a water report.

All tales and misinformation put aside, I believe the water quality of Mirror Lake has become alarmingly very good. The drought years with very minimal water being induced, I am surprised.

The dikes which were built at the extension office directly upstream I believe to be more important

than most people could even imagine.
One point I believe overlooked in the studies of silt and debris washing into the lake, is the point of all water coming from upstream any farther than 1.25 miles (one and one quarter) actually washes through a man made pond - a dug-out per-sey.

Another point I would like to stress is from the letter of Emil Berard (Ret.) stating to have a body of water which we can all be proud of a lost of regimen.

The area west of the walk bridge - be it north or south of Highway 12 not being relevent - an area dug out for the sediments to congregate before washing any farther into the lake.

As such states depth of the lake depreciating 4 feet since we dug it out - 1982.

In accord of tales told - A plan to raise the spillway to increase the depth of the lake - Perhaps a plan of prevention should be looked at first.

Believe me
I'm interested in our lake

Mark

Mark A. Baker
America Box 2
Hettinger, ND 58639
[redacted]

"VARIETY IN HUNTING AND FISHING"
NORTH DAKOTA GAME AND FISH DEPARTMENT
100 NORTH BISMARCK EXPRESSWAY BISMARCK, NORTH DAKOTA 58501-5095 PHONE 701-328-6300 FAX 701-328-6352

Mr. Theo Schalesky
Hettinger Park District
PO Box 103
Hettinger, ND 58639-0103

Greetings to the Park Board:

Thanks for the SolarBee history materials and your interest in trying to improve recreation at Mirror Lake. Sorry it has taken so long to address this project and your questions on what could be done to alleviate persisting problems.

What began as a review of SolarBee (Pond Doctor) activities at the lake has evolved into a compilation of available water quality information and an updating of the fisheries management plan for Mirror Lake. I will discuss each briefly.

First, we should all agree that the ultimate source of many lake problems since reconstruction originated in the watershed. Several studies to include the 1980 EPA 314 pre-construction evaluation, the 1989-93 Clean Lakes Assessment and the 1995 Nutrient Budget Analysis (Water Quality Assessment) conclude that excess nutrients reach and accumulate in the lake. This is expected any time you place a dam on a natural waterway. Much has been done in recent years to reduce or limit the source(s) of this problem to include impoundment and diversion of the city's storm water. Unfortunately, watershed problems are expected to increase as more agricultural lands come out of CRP protection. You will need to work with the Soil Conservation District (SCD) to minimize agricultural impacts to the lake. Enclosed are "Save Our Lakes" materials which explain our Department objectives and some of the tools needed to protect Mirror Lake from further degradation.

I believe that the SolarBee "function principle" is the same as that passed down from the Lake Aid Units, Koffler Units or Wadler Units the Game and Fish Department invented in the early 1970's. All units use simple surface displacement of sub-surface or hypolimnetic water. I consider them Band-Aids to buy time like air/oxygen induction circulation, alum treatments or even excavation. They don't change the nutrient imports, only internal cycling which isn't always a good response. For example, the SolarBee notes dated 7/29/02 reference no fish kill because Pond Doctors (SolarBee) were present during a hot, dry year when the lake did not get flushed to remove nutrients. I contend that the absence of any fish kill had more to do with no new nutrients entering the lake (lack of runoff) since the equipment operation duration was interrupted by breakdowns and repairs in April, May and August. The 1995 study also states that inflows are more detrimental than internal nutrient cycling.

SolarBee notes for January 29, 2001 recommend against using the hypolimnetic discharge system (HDS) because their units were getting "complete processing of the waters (top to bottom)" and there was no need to discharge BAD waters (there would be no bad water). Unfortunately, the units were not always working as determined from the 1/2/2001 repair records and oxygen profiles collected in June, July, August and December of 2000 after the units were installed (May, 2000). When oxygen readings approach 1 ppm, I question electronic D.O. equipment standardization limitations to detect anoxic conditions. The HDS was designed as a tool to help evacuate excess nutrients when conditions/opportunity exist to balance the nutrient budget. SolarBee notes dated 4/17/01 dismissed a significant fish kill as a beneficial occurrence for the fishery in Mirror Lake. Summer or winter fish kills are not taken lightly by the Game and Fish Department, especially when they involve the loss of Quality to Preferred to Memorable size fish by national standards. The majority of game fish lost in the 2001 winterkill were quality size or larger and the extent of the kill (15,000-20,000 fish) was not a fabrication by me or anyone else doing the kill survey. This kill was investigated twice (4/6/01 and 4/12/01) in an effort to quantify impacts to the fishery. I was sorry to read that the citizens of Hettinger consider our strained relationship grounds to exaggerate the facts. Enclosed are pictures of that fish kill to include kill counts, documentation criteria and personnel contacted. In most cases kills are also witnessed by the local game wardens. One picture shows no evidence that the Pond Doctors were operational. Fish kills were also documented in 2004 and 2005.

Nothing in the water quality data suggests an improvement in the eutrophication process ongoing in Mirror Lake. Limited dissolved oxygen profiles would indicate that stratification and anoxic bottom waters can still be expected in late July to early August. That's what we found 7/20/05 when we tested the low water drawdown system (HDS) shortly after the new circulation units were installed. At that visit, the lake was a solid mat of dying blue-green algae creating enough plankton turbidity to cause a significant macrophyte die off and strong odor. The HDS releases were also anoxic.

The quality of a lake's fishery is directly related to water quality and watershed quality. Mirror Lake's work priority score and fishery classification have been downgraded twice since 1985 post-construction due to deteriorating quality and use. The fishery has gone from walleye and bass predators to northern pike and rough fish have transitioned from white suckers to black bullheads. Pan fish like bluegill have declined from 17 fish per net hour to 0.5 fish while crappie and perch populations remain low but stable, even with frequent fish kills. All are clear signs of what this lake is now capable of supporting. Enclosed are population sampling summaries since 1985.

Your question: What can be done to save Mirror Lake?

Much of what needed to be done at Mirror Lake or what could still be done is discussed in the 1995-2000 Fisheries Management Plan. I will forward a copy of the 2006-2010 plan when completed. The following statement/observation is taken directly from the environmental section of the old plan (1995).

"Inadequate watershed protection has contributed to premature water quality deterioration following lake rehabilitation. This lake is currently classified as eutrophic following restoration from a hypereutrophic condition. Internal nutrient cycling through macrophytes is nearly maximized to where phytoplankton bloom density and frequency are expected to increase. This would ultimately result in reduced habitat suitability for desired sport fish species and reduced recreational opportunities."

The lake has since reverted back to the hypereutrophic condition present before reconstruction. This suggests that there is an excessive watershed delivery rate for silt and nutrients. Based on the 1995 loading estimates, Mirror Lake displayed a net increase in nitrogen and phosphorus equal to fertilization rates of 181 and 23 pounds per acre respectively. The nutrient retention rate doubled what was already available for macrophyte and algae production from internal cycling. The good news is that the nutrient loading rates would have nearly doubled without the storm water diversion system.

The Mirror Lake nutrient "budget" is something we want to decline. In a perfect world that would mean less silt and nutrients going into the lake than coming out of the lake. This is by far the most important improvement the Park Board and citizens of Hettinger need to strive towards. That means working with the SCD and agricultural producers to use the Best Management Practices (BMP's) available to protect watershed runoff into Flat Creek. That means zero tolerance! If you don't start a lake project with that objective, you won't succeed.

Lake/watershed development or improvement considerations should include:

1. Sub-impoundments/desedimentation structures in the watershed or upper lake area should be investigated as options for improving water quality. The old bridge crossing north of Highway 12 and creek mouth downstream from the walking bridge may be good sites to slow and filter runoff events.

2. Maintenance and use of the low-water drawdown (HDS) and storm sewer discharge systems are critical to nutrient evacuation. The HDS was last used in the spring of 1999 and 2000, and then tested by the Department on 7/20/2005. We may now have a key to test equipment functionality but good communications and local operations are needed to use this system effectively.

3. If SolarBee (Pond Doctor) or other artificial circulation is used, consider not using these systems in the winter if open water cannot be maintained. Without open water, ammonia cannot be vented which contributes to winter stress or fish kill and operations contribute to accelerated internal nutrient cycling.

4. Shore access is a serious problem. Plastic sheeting and rock could be used to cover vegetation in the boat ramp area, but then where do you go if most of the lake is choked with vegetation? Shore excavation much like that done on the east shore of North Lemmon would create fishing areas and remove silt/nutrients, but sacrifice surface acres. With a drawdown, this procedure could be expanded to create islands with the material excavated to deepen the shoreline. This would be much less expensive than hauling material away.

5. Alum treatment to bind stored nutrient accumulations may be a consideration although I have no experience with this procedure. It should be considered if bottom substrate is disturbed.

6. Reduce the internal nutrient cycling through a combination of sediment removal, aeration and large-scale macrophyte removal.

7. Enclosed is a research paper entitled "Effects of Microbial Intervention on a Hypereutrophic Basin in Northern New Mexico." This may be an option to address the foul odor emissions from Mirror Lake.

8. The fishery will continue to fluctuate relative to the extent and frequency of fish kills. Biomanipulation was effective in removing white sucker problems in the early 1990's. Netting in combination with northern pike predator stocking has helped to nearly

eliminate suckers from Mirror Lake. Russ Ziegler and his class need to be congratulated for their efforts to control black bullheads. Nearly 100 pounds per acre were removed last spring (2005). This project needs to continue if local volunteer help is available. I requested to stock walleye last year to develop a better predator base for bullheads, but they were not stocked per my request. Bullheads, like suckers, are also an undesirable bottom feeding species which contribute to turbidity and internal nutrient cycling.

9. Pelicans and cormorants frequent Mirror Lake and are considered serious fish predators. Efforts should be made to haze these birds off the lake permanently. This would also reduce the risk of spreading migratory avian diseases locally.

All of these ideas are nothing more than Band-Aids if the source of the problem isn't addressed first. Area residents, including professionals, didn't believe our suggestion that siltation was still a problem back in the early 1990's. However, based on State Water Commission data when the low-water system was installed, the lake storage capacity has decreased from 530 acre feet to 350 acre feet on the 2003-04 map (enclosed). Maximum depth declined from 18 feet post-construction to 14.3 feet in a matter of twenty years. Regardless of how much has been lost, it has been too much.

I hope this has helped to answer your questions and gives you some ways to help Mirror Lake. Please have Russ call me if interested in trapping more bullheads this spring. Thanks for your interest and concern.

Sincerely,

Emil Berard
Western District Fisheries Supervisor
North Dakota Game and Fish Department
225 30th Avenue SW
Dickinson, ND 58601

cc: Greg Power, Fisheries Chief
Harriet Howe

P.S. Someone from the Park Board should attend the Shallow Lakes Forum in April (announcement enclosed).

Appendix I

Department Response to US EPA Region 8 Comments

During the 30 day public notice soliciting comment and participation for the Mirror Lake Nutrient and Dissolved Oxygen TMDL, the North Dakota Department of Health received specific comments from the US EPA Region 8 on recommended changes and/or additions to the report. Below are the comments provided and the Departments' response.

Comment from EPA: "Mirror Lake is listed (i.e., 2006 303(d) list) 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 3.0, TMDL Targets, that specifically states that this TMDL report only pertains to nutrients, as expressed as phosphorus, and dissolved oxygen. Language in this section further states that based on an analysis of existing suspended sediment data presented in a draft report entitled "De-Listing of Sediments for Mirror Lake in Adams County, North Dakota" (NDDoH, draft March 2008) suspended sediment is not believed to be a cause for aquatic life impairment to Mirror Lake

Comment from EPA: "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."

NDDoH Response: An additional section (Section 5.5) has been added to Section 5.0, Technical Analysis, describing the analysis of existing suspended data and its associated draft report.

Comment from EPA: 'In November 2006 EPA issued the 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. In June 2007 EPA made available a technical document "Options for the Expression of Daily Loads in TMDLs." '

"The Mirror Lake TMDL needs to be revised to include a "daily" expression of load consistent with the Friends of the Earth decision and the technical guidance. The technical guidance is available at: http://www.epa.gov/owow/tmdl/draft_daily_loads_tech.pdf."

NDDoH Response: An additional paragraph has been added to Section 7.1, Nutrient TMDL, which provides an expression of the annual total phosphorus TMDL, load allocation, and Margin of Safety as a daily load.