Nutrient TMDL for Sheep Creek Dam in Grant County, North Dakota

Final: December 2007

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1.0 INTRODUCTION AND DESCRIPTION OF THE WATERSHED

Sheep Creek Dam is a slender, sinuous reservoir on Sheep Creek and is located in Grant County approximately four miles south and one-half mile west of Elgin, North Dakota. The reservoir is also located one-half mile upstream from the confluence of Sheep Creek and the Cannonball River. Recreation and flood control were the primary purposes behind the construction of Sheep Creek Dam. This multipurpose reservoir was constructed by damming Sheep Creek, a tributary of the Cannonball River. Cooperating entities and agencies included the U.S. Bureau of Outdoor Recreation (BOR), the North Dakota Game and Fish Department (NDGF), the Natural Resource Conservation Service (formerly Soil Conservation Service), and the Grant County Water Resource Board (WRB) (Figure 1). The contributing watershed of Sheep Creek Dam consists of 37,827 acres. Table 1 summarizes some of the geographical, hydrological, and physical characteristics of Sheep Creek Dam and its watershed.

Table 1. General Characteristics of Sheep Creek Dam and its Watershed.

Legal Name	Sheep Creek Dam
Major Drainage Basin	Lower Missouri River Basin
Nearest Municipality	Elgin, North Dakota
Assessment Unit ID	ND-10130204-001-L_00
County Location	Grant County, North Dakota
Physiographic Region	Missouri Plateau
Latitude	46.34255 N
Longitude	101.84885 W
Surface Area	83.4 acres
Watershed Area	37,827 acres
Average Depth	13.8 feet
Maximum Depth	34.4 feet
Volume	1,154.8 acre-feet
Tributaries	Sheep Creek
Type of Waterbody	Constructed Reservoir
Dam Type	Constructed Earthen Dam
Fishery Type	Rainbow and Cutthroat Trout, Large and Smallmouth Bass, Bluegill, Walleye, and Brown Trout

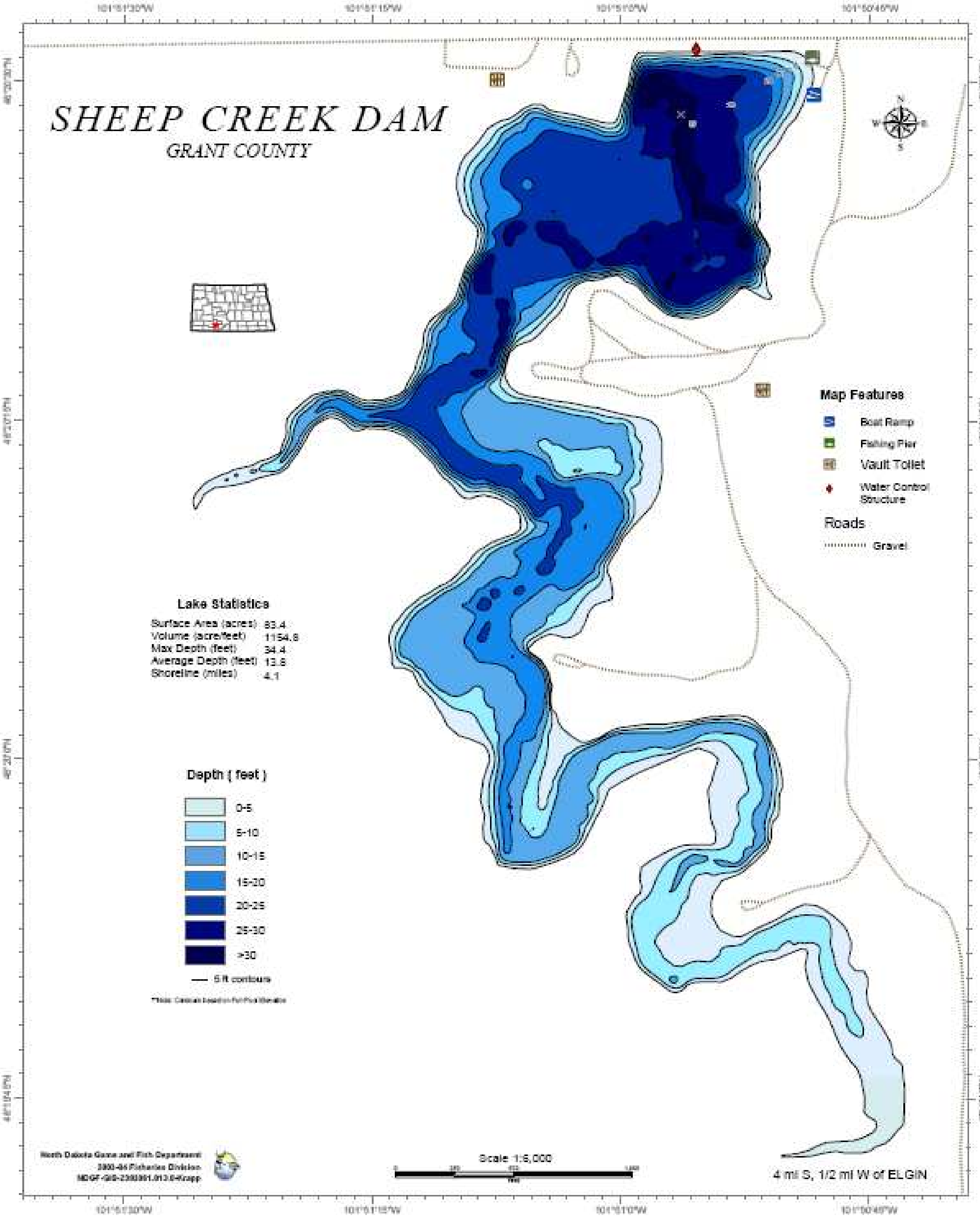

Figure 1. North Dakota Game and Fish Department Contour Map of Sheep Creek Dam.

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 Sheep Creek Dam as an impaired waterbody. Based on a Trophic State Index (TSI) score, recreational use of Sheep Creek Dam is impaired due to nutrient enrichment (Table 2). However, North Dakota's 2006 Section 303(d) list did not provide any potential sources of these impairments. Sheep Creek Dam is classified as a Class 2 cool-water fishery. Class 2 lakes or reservoirs are "waters capable of supporting natural reproduction and growth of cool water fishes (e.g., northern pike and walleye) and associated aquatic biota" (NDDoH, 2006).

The initial fishery established in Sheep Creek Dam was managed for rainbow trout. Chemical eradication was conducted in the reservoir in 1978 to remove undesirable fish species. Since that time, subsequent fish stockings have included rainbow trout, brown trout, cutthroat trout, bluegill, large and smallmouth bass, walleye, and northern pike. These recent stockings, which are assessed annually by the North Dakota Game and Fish Department, have turned Sheep Creek Dam into a productive fishery.

Table 2. Sheep Creek Dam Section 303(d) Listing Information (NDDoH, 2006).

Waterbody Name	Sheep Creek Dam
Assessment Unit ID	ND-10130204-001-L_00
Class	2 – Cool water fishery
Impaired Uses	Recreation; fully supporting but threatened
Causes	Nutrients/Eutrophication
Priority	High (1A)

1.2 Topography

Sheep Creek Dam and its watershed lie within the Missouri Plateau level IV ecoregion (43a), which is a portion of the larger Northwestern Great Plains level III ecoregion. The topography of the ecoregion and watershed is characterized by short grass prairie, rolling plains and occasional sandstone buttes. Glaciation has had little to no effect on the topography of the area encompassing the watershed, leaving original soils in place and a complex stream drainage pattern. Elevation ranges from 1,800-feet (msl) near Shields, North Dakota in southeastern Grant County to 2,700-feet (msl) at the top of Coffin Butte south of New Leipzig and southwest of Sheep Creek Dam in southwestern Grant County (Edland and Lee, 1988). Runoff from the watershed enters Sheep Creek, serving as an inlet to Sheep Creek Dam. Water leaving the dam serves as a tributary to the Cannonball River, confluencing downstream with Cedar Creek and eventually discharging into Lake Oahe near the town of Cannonball, North Dakota in Sioux County. Figure 2 shows the general shape and size of the Sheep Creek Dam watershed in Grant County, North Dakota.

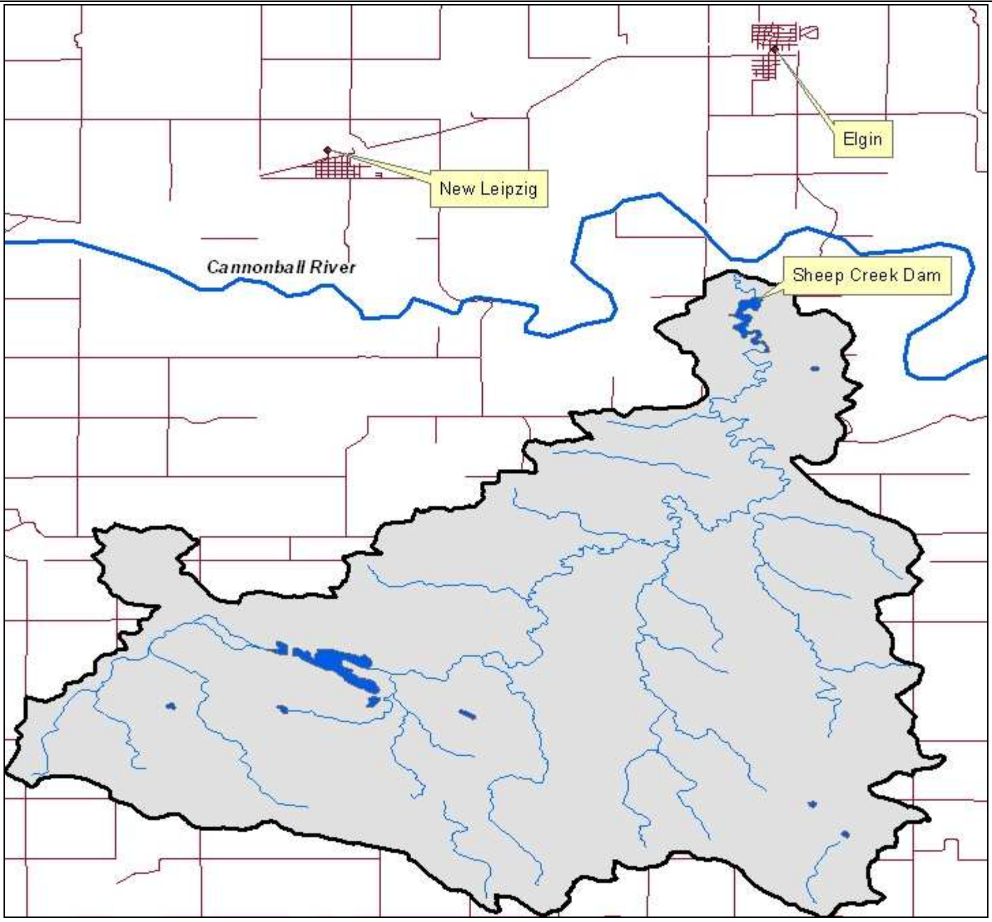

Figure 2. Sheep Creek Dam Watershed in Grant County, North Dakota.

1.3 Land Use/Land Cover

Land use within the Sheep Creek watershed is primarily agricultural (96 percent), with approximately 49 percent actively cultivated, 33 percent in rangeland, 8 percent in hayland, and 6 percent in the Conservation Reserve Program (CRP) (Table 3). Farmsteads, low density urban development, roads, and wildlife and wetland management areas comprise the remaining four percent of the watershed. One hundred percent of Sheep Creek Dam's shoreline is under public easement.

Hard Red spring wheat is the major agricultural crop grown in Grant County. However, other small grains and commonly grown crop varieties include barley, flax, and sunflowers. Soils within the watershed are moderately deep to shallow, formed from weathered loamy glacial till or soft bedrock. Generally, the soil is moderately fertile to fertile, well drained, and susceptible to wind and water erosion. Soil series in the Missouri Plateau level IV ecoregion (43a), encompassing the Sheep Creek Dam waterhed, include: Vebar, Chama, Amor, Williams, Rhoades, Belfield, Cabba, Flasher, Reeder, Regent, Parshall, Golva, and Zahl. Approximately five percent of Sheep Creek Dam's watershed is composed of badlands. Badlands are eroded formations composed of buttes and steeply eroded drainages. Potential native vegetation in undisturbed areas of the watershed may include blue grama, wheatgrass/needlegrass associations, little bluestem, and prairie sandreed.

Table 3. Land Use Within the Sheep Creek Dam Watershed.

Land Use Type	Acres	Percent of Total Acreage
Actively cultivated land	18,535	49
Rangeland	12,483	33
Hayland	3,026	8
Conservation Reserve Program (CRP)	2,270	6
Farmsteads, development, wet/wild management	1,513	4

1.4 Climate and Precipitation

The climate of southwestern North Dakota and the area encompassing Sheep Creek Dam 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.

Extreme seasonal variations in temperature are typical of the climate in this region. Mean monthly temperature in Mott, ND, a nearby municipality to Sheep Creek Dam, between 1948 and 2006 is shown in Figure 3, while mean monthly precipitation for the same time period is shown in Figure 4 (HPRCC[1], 2006). January is typically the coldest month of the year with a mean monthly temperature of 12° F (Figure 3). July and August are the warmest months of the year with mean monthly temperatures of 70° F and 68° F, respectively (Figure 3). Mean annual precipitation is 16.03 inches. 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 3.30 inches (Figure 4).

[1] The High Plains Regional Climate Center, formed in 1987, is recognized for their expertise in using automated weather stations. HPRCC obtains near real time data and includes all relevant National Weather Service surface weather data in its archive (HPRCC, 2006).

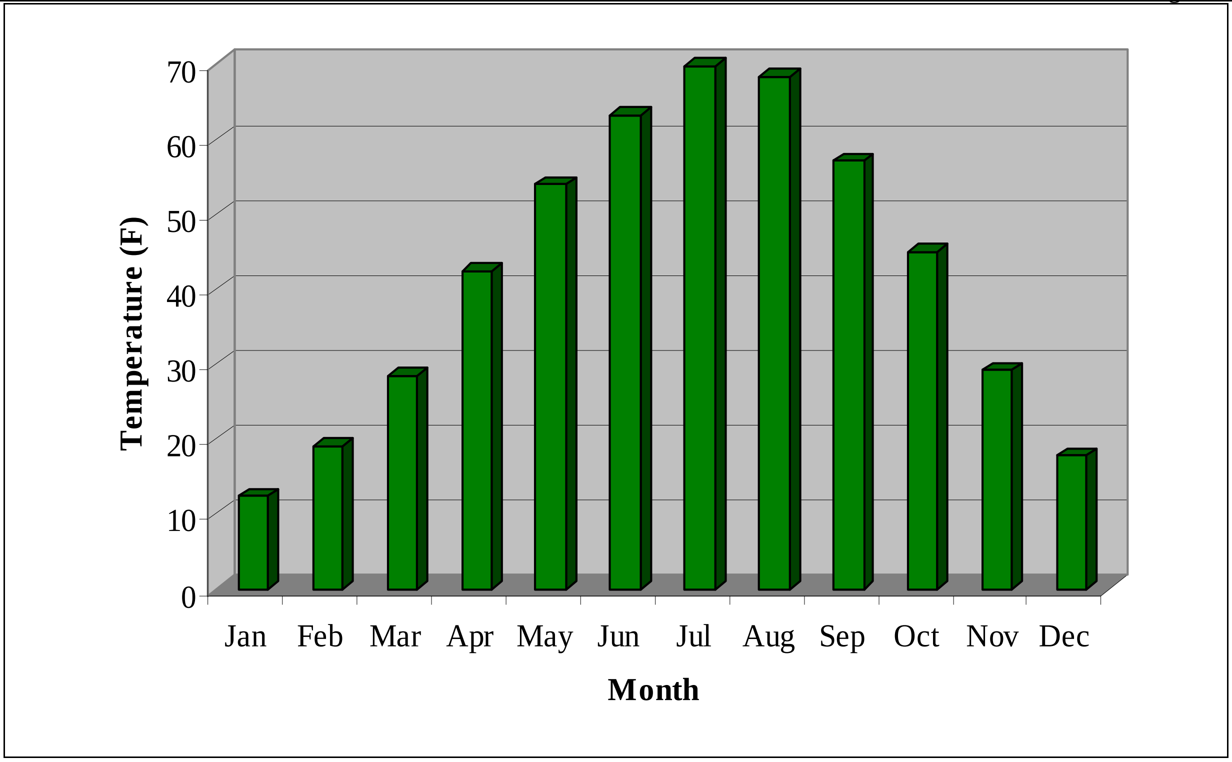

Figure 3. Mean Monthly Temperature From 1948-2006 at the High Plains Regional Climate Center (HPRCC), Mott, ND Weather Station.

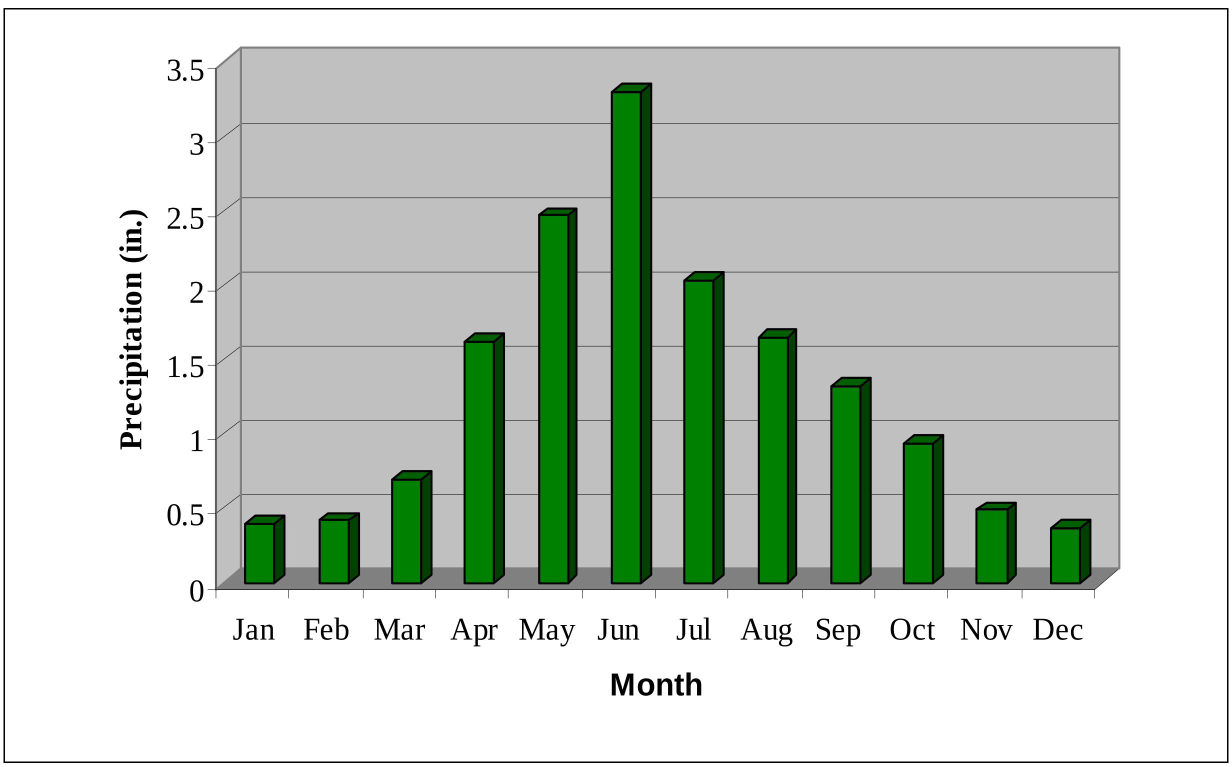

Figure 4. Mean Monthly Precipitation From 1948-2006 at the High Plains Regional Climate Center (HPRCC), Mott, ND Weather Station.

1.5 Available Water Quality Data

1.5.1 Lake Water Quality Assessment Project

A Lake Water Quality Assessment (LWQA) was conducted on Sheep Creek Dam during 1992-1993. Water quality samples were collected from the dam twice during the summer of 1992 and once during the winter of 1993. All samples were taken from one sample site located in the deepest portion of Sheep Creek Dam. Water column samples were analyzed from depths of one meter, four meters, and seven meters during the summer, while winter water column samples were taken at depths of one meter, three meters, and six meters.

LWQA data collected from Sheep Creek Dam during the 1992-1993 LWQA Project indicated that excessive amounts of the nutrients total phosphorus as P and nitrate plus nitrite as N were present in the reservoir. Nutrient concentrations ranged from 0.179-0.709 mg/L for total phosphorus as P and exceeded the state's restoration goal of 0.02 mg/L on all occasions. Nitrate plus nitrite as N concentrations ranged from 0.00-0.790 mg/L exceeding the state's restoration goal of 0.25 mg/L at the surface on July 8, 1992. Between July 1992 and February 1993, the ratio of nitrate plus nitrite as N and total phosphorus as P was 1.0:0.94, indicating nitrogen limitation. Concentrations of total dissolved solids (1,280 mg/L), total Kjeldahl nitrogen (2.42 mg/L), and ammonia (0.55 mg/L) in Sheep Creek Dam, were all above the state's long-term volume-weighted mean concentrations for all lakes measured. Volume-weighted mean concentrations are calculated by weighing the parameter analyzed by the percentage of water volume represented at each depth interval sampled.

LWQA data described Sheep Creek as a hypereutrophic lake. Supporting water quality data included total phosphorus as P concentrations between 0.179 and 0.709 mg/L and nitrate plus nitrate as N ranging between 0.00 and 0.790 mg/L for summer surface water. In addition, chlorophyll-*a* concentrations from 7 to 91 µg/L and Secchi Disk Transparency measurements between 1.0- and 1.4- meters were measured in the lake between July 1992 and February 1993. Supporting ancillary information included frequent nuisance algal blooms and rapid oxygen depletion below the hypolimnion during the summer and under ice cover conditions in the winter.

1.5.2 2004 Sheep Creek Dam TMDL Project

The Grant County Soil Conservation District (SCD) conducted monitoring for a TMDL development project on Sheep Creek Dam and its watershed from January 9, 2004 through November 3, 2004. The SCD followed the methodology for water quality sampling found in the Quality Assurance Project Plan (QAPP) for the Sheep Creek Dam TMDL Development Project (NDDoH, 2003). Sampling and analysis variables are shown in Table 4.

Table 4. Sheep Creek Dam TMDL Development Project Sampling and Analysis Variables.

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

Stream Monitoring

Stream sampling was conducted at one inlet and one outlet site on Sheep Creek (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 samples were taken 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 same sampling locations.

Reservoir Monitoring

Reservoir sampling was conducted monthly at the deepest site (Figure 5) except during the months of March and October 2004, when no samples were taken. During the month of August, sampling was conducted twice to account for temporal variation of lake water quality. Reservoir monitoring was conducted at depths of 1, 3, and 7 meters.

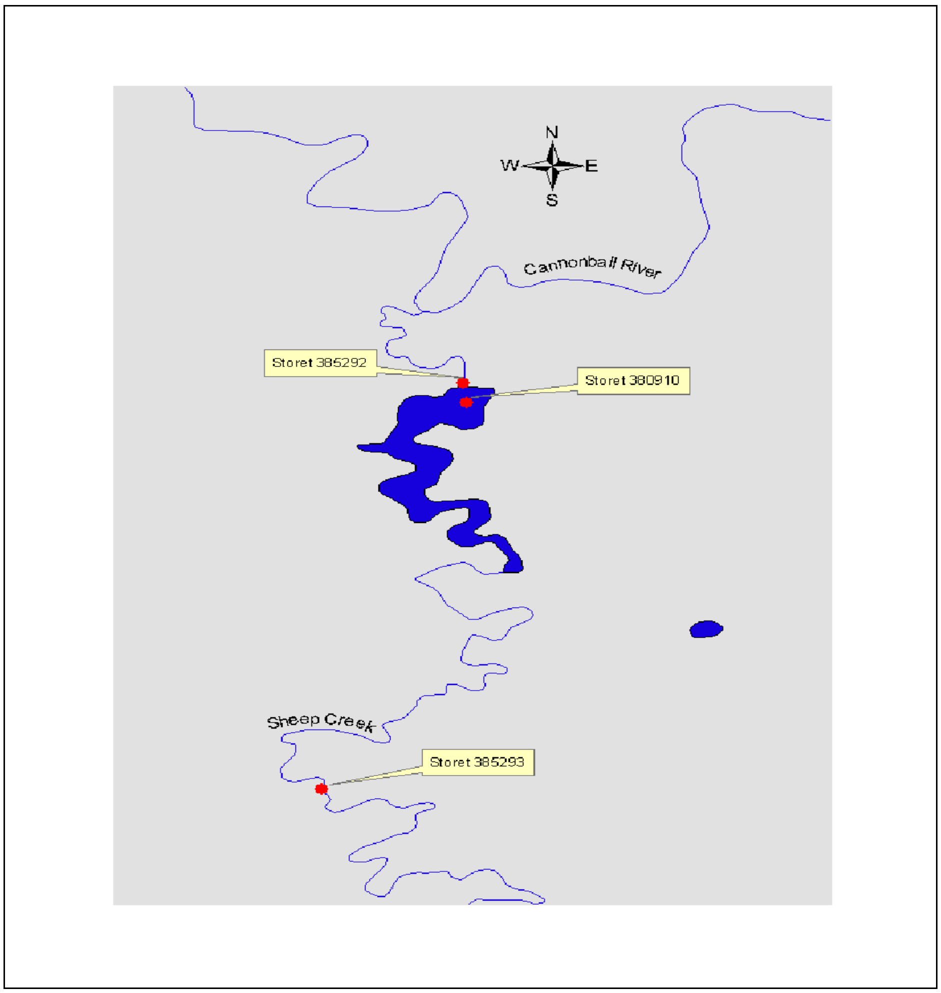

Figure 5. Sheep Creek Dam Sampling Locations and Station ID's.

In-Lake Nutrient Results

Surface water quality parameters were monitored at one in-lake site (380910) between January 2004 and November 2004. Sample parameters and average volume weighted mean concentrations are provided in Table 5. The average concentrations of total and dissolved phosphorus, total nitrogen, total Kjeldahl nitrogen, and nitrate plus nitrite as N were all greatest in the deepest part of the lake. Data collected from the in-lake site (380910) during 2004 in Sheep Creek Dam displayed an average total nitrogen to total phosphorus ratio of 6.1:1 throughout the sampling period (Table 5). This ratio indicates nitrogen limitation. Under such conditions, nitrogen fixing organisms like species of blue-green algae are typically favored.

Table 5. Water Quality Statistics from the Sheep Creek Dam Deepest Area Site (380910) in 2004.

Parameter	Deepest Site #380910					
	N	Max	Med	Avg	Min	Volume-weighted Mean
Total Phosphorus as P (mg/L)	10	0.488	0.241	0.237	0.133	0.254
Dissolved Phosphorus as P (mg/L)	10	0.284	0.207	0.196	0.078	0.216
Total Nitrogen as N (mg/L)	10	1.920	1.456	1.454	1.280	1.486
Total Kjeldahl Nitrogen as N (mg/L)	10	1.576	1.357	1.395	1.256	1.421
Nitrate/Nitrite as N (mg/L)	10	0.212	0.035	0.177	0.020	0.065
Chlorophyll-*a* (µg/L)	6	30.70	17.11	15.17	2.00	N/A
Secchi Disk Transparency (meters)	8	3.40	1.35	1.63	0.80	N/A

Nutrient concentrations from Sheep Creek Dam in 2004 were compared to data collected from Sheep Creek Dam during 1992-1993. Volume-weighted mean nutrient concentrations reported during the 1992-1993 LWQA were higher when compared to the 2004 Sheep Creek Dam Assessment. The 2004 Sheep Creek Dam Assessment showed reductions in nutrient concentrations such as nitrate-nitrite and total Kjeldahl nitrogen, while total phosphorus concentrations were slightly higher when compared to the 1992-1993 LWQA data (Table 6).

Table 6. Average Nutrient Concentration Comparisons at Sheep Creek Dam.

Parameter	Sheep Creek Dam 1992-1993	Sheep Creek Dam 2004
Nitrate/Nitrite (mg/L)	0.247	0.065
Total Kjeldahl Nitrogen (mg/L)	2.420	1.421
Total Phosphorus (mg/L)	0.231	0.254

Secchi Disk Transparency Results

Water clarity in a reservoir can be affected by many factors. Algal biomass, total suspended solids, and other debris all affect Secchi Disk Transparency measurements in a waterbody. Secchi Disk Transparency data were collected by the Grant County Soil Conservation District (SCD) staff between April 23, 2004 and November 3, 2004 (Table 7). The month of October was the only open water month lacking a measurement during the sampling period. As shown in Table 5, the average Secchi Disk Transparency measurement for the in-lake sampling site was 1.6 meters with a resulting Trophic Status Index (TSI) score of 54.8. The data indicates that visibility throughout the water column was lowest during April and May, which may be attributable to suspended sediment loading during spring runoff as it inhibits visibility in the water column. In addition, the sharp decline in Secchi Disk Transparency measurements between June and July is likely due to algal production that peaks during this time. The greatest Secchi Disk Transparency measurements in Sheep Creek Dam were measured during late fall.

Table 7. Average Monthly Secchi Disk Transparency Depths in Sheep Creek Dam in 2004.

Month	Average Secchi Disk Transparency (m)	Month	Average Secchi Disk Transparency (m)
January	N/A	July	1.2
February	N/A	August	1.6
March	N/A	September	1.2
April	0.8	October	N/A
May	1.0	November	3.4
June	2.2	December	N/A

Tributary Nutrient and Total Suspended Solids Results

Surface water quality parameters were monitored at one inlet stream site (385293) between March 2004 and July 2004 and at one outlet site (385292) between March 2004 and November 2004. Sample parameters and summary statistics are provided in Table 8. The average concentration of total phosphorus as P, dissolved phosphorus as P, total nitrogen as N, and total Kjeldahl nitrogen as N were all greater at the inlet tributary site. The average concentration of nitrate plus nitrite as N was slightly higher at the outlet tributary site. The data collected between the two tributary sites indicates nutrient retention in Sheep Creek Dam.

Table 8. Water Quality Statistics at the Inlet and Outlet Sites of Sheep Creek Dam in 2004.

Parameter	Inlet Stream Site #385293					Outlet Stream Site #385292				
	N	Min	Max	Med	Avg	N	Min	Max	Med	Avg
Total Phosphorus as P (mg/L)	22	0.054	0.892	0.106	0.217	30	0.030	0.560	0.110	0.160
Dissolved Phosphorus as P (mg/L)	20	0.009	0.691	0.060	0.135	28	0.000	0.480	0.030	0.090
Total Nitrogen as N (mg/L)	22	0.928	2.200	1.125	1.333	30	0.540	2.260	1.130	1.200
Total Kjeldahl Nitrogen as N (mg/L)	22	0.908	2.020	1.105	1.226	30	0.450	2.150	0.980	1.070
Nitrate/Nitrite as N (mg/L)	22	0.020	0.700	0.020	0.107	30	0.020	0.600	0.045	0.123

Fifty-two tributary total suspended solid (TSS) samples were collected by the Grant County Soil Conservation District between March 2004 and November 2004. TSS samples were collected from the inlet site (385293) and outlet site (385292) of Sheep Creek Dam (Figures 6 and 7).

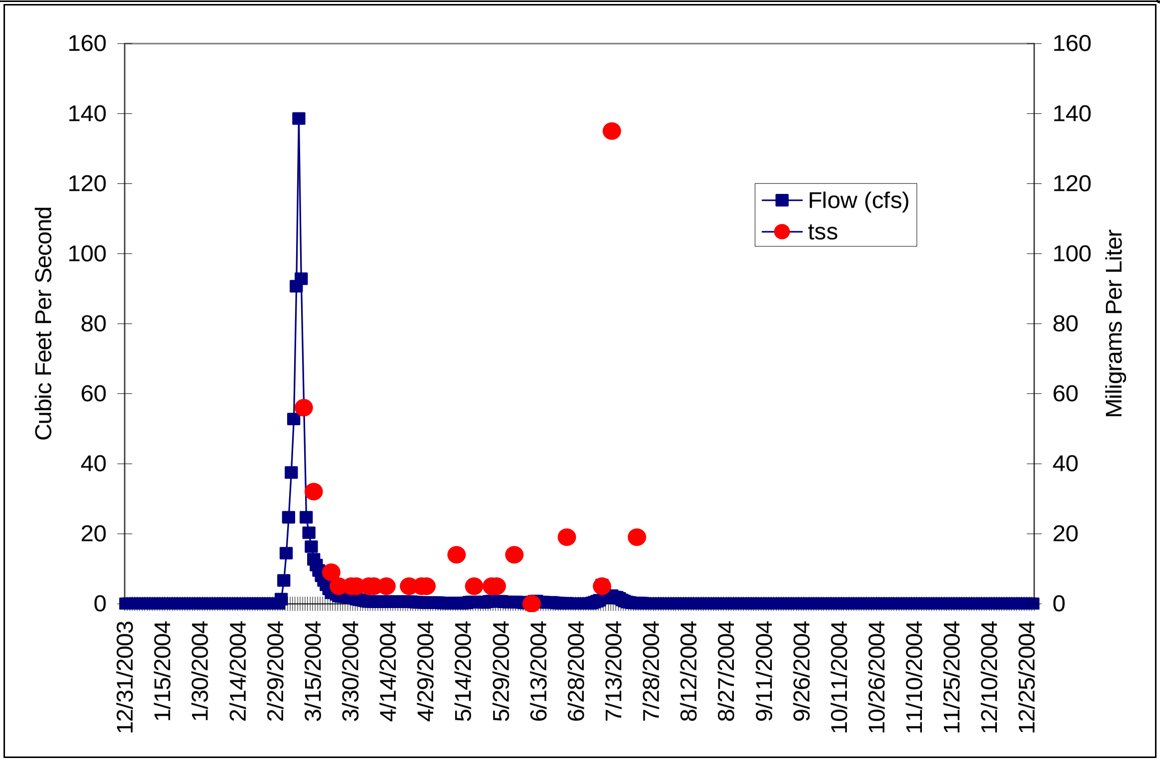

Figure 6. Total Suspended Solid Concentrations and Stream Discharge at Inlet Site 385293.

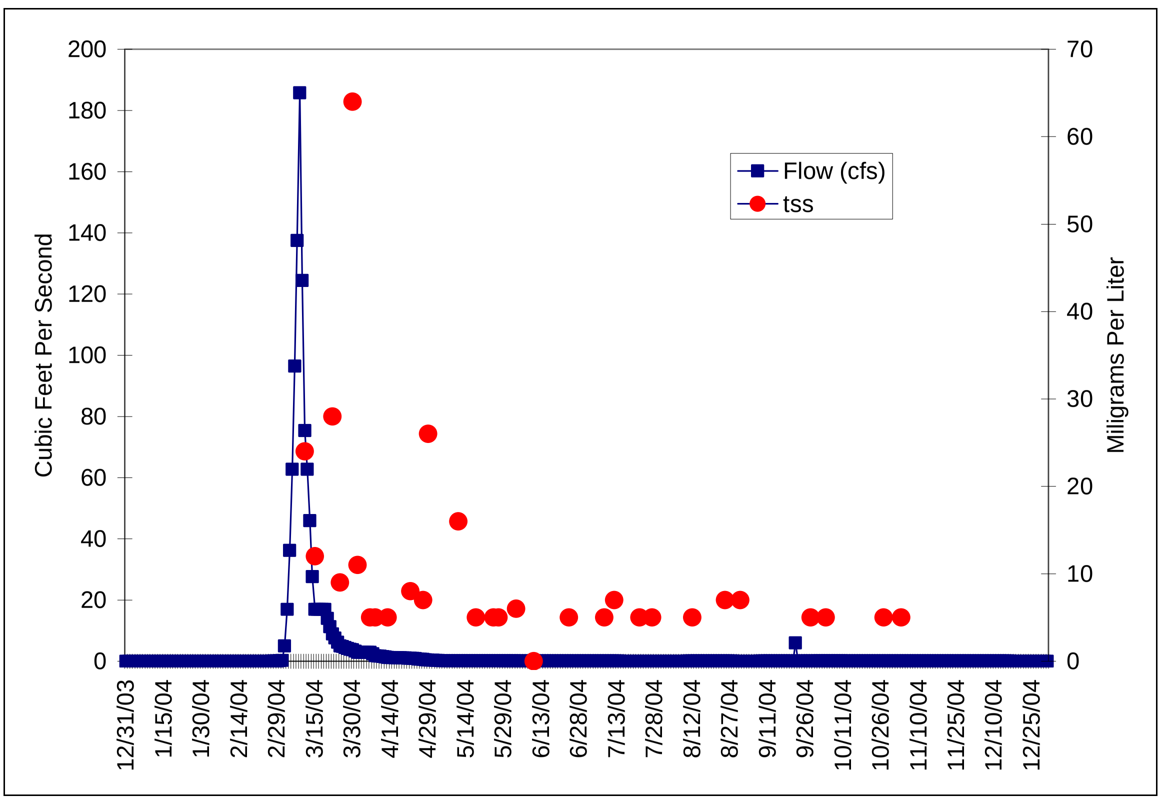

Figure 7. Total Suspended Solid Concentrations and Stream Discharge at Outlet Site 385292.

Table 9. Total Suspended Solid Concentrations at the Sheep Creek Dam Inlet and Outlet Sites, 2004.

Site ID	Site Description	Mean TSS (mg/L)	Median TSS (mg/L)
385293	Inlet	16.4	5
385292	Outlet	10.6	5

Mean TSS concentrations at the inlet and outlet sites were 16.4 and 10.6 mg/L, respectively indicating that suspended solids are being retained within the reservoir (Table 9). The median TSS concentrations at the inlet and outlet were both 5 mg/L which is more representative of the overall watershed condition. Although the mean TSS concentration indicates retention of TSS in Sheep Creek Dam, the median TSS concentration better represents the TSS condition of the lake throughout an entire year. The outliers in the graphs of the inlet and outlet, characteristic of a storm event, indicate how quickly such an event can alter TSS concentrations for a short period of time in a waterbody, similar to the July 12, 2004 sample of 135 mg/L at the inlet. These data also portray how flashy the watershed is in response to storm events. Although concentrations at the inlet may be high for a short period of time following a precipitation and runoff event, the median TSS concentration at the inlet and outlet of the reservoir throughout a given year is very similar suggesting that overall sediment retention is minimal.

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, sediment).

2.1 Narrative Water Quality Standards

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

Sheep Creek Dam is classified as a Class 2 cool water fishery. Class 2 fisheries are defined as waterbodies "capable of supporting natural reproduction and growth of cool water fishes (e.g., northern pike and walleye) and associated aquatic biota" (NDDoH, 2006). These waters are also capable of supporting the growth and marginal survival of cold water species and associated biota. All classified lakes in North Dakota are assigned aquatic life, recreation, irrigation, livestock watering, and wildlife beneficial uses. The beneficial use threatened in Sheep Creek Dam is recreation. The State Water Quality Standards state that lakes shall use the same numeric criteria as Class 1 streams. This includes the state standard for dissolved oxygen 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 10).

Table 10. 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 as 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 Sheep Creek Dam based on it's impaired recreational beneficial use. If the specific target is met, it is assumed the reservoir will meet the applicable water quality standards, including its designated beneficial uses.

3.1 Nutrient Target

A Carlson's Trophic State Index (TSI) target of 74 based on total phosphorus was chosen for the Sheep Creek Dam TMDL 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 phosphorus, chlorophyll-a, and Secchi Disk Transparency measurements (Carlson, 1977).

TSI values were calculated for total phosphorus, chlorophyll-*a*, and Secchi Disk Transparency at Sheep Creek Dam. The highest TSI value was for total phosphorus at 84, while chlorophyll-*a* and Secchi Disk Transparency values were 58 and 53, respectively (Table 11). Based on Carlson's TSI and water quality data collected between January 2004 and November 2004, Sheep Creek Dam was generally assessed as a hypereutrophic lake (Table 11). Hypereutrophic lakes are characterized by large growths of weeds, 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 can reflect poorly on the sport fishery. Due to frequent algal blooms and excessive weed growth, hypereutrophic lakes often become undesirable for recreational uses such as swimming and boating.

Table 11. Carlson's Trophic State Indices for Sheep Creek Dam.

Parameter	Relationship	Units	TSI Value	Trophic Status
Chlorophyll-*a*	TSI (Chl-a) = 30.6 + 9.81[ln(Chl-a)]	µg/L	58	eutrophic
Total Phosphorus (TP)	TSI (TP) = 4.15 + 14.42[ln(TP)]	µg/L	84	hypereutrophic
Secchi Disk (SD)	TSI (SD) = 60 - 14.41[ln(SD)]	meters	53	eutrophic

TSI < 35 - Oligotrophic (least productive)
TSI 35-50 Mesotrophic
TSI 50-65 Eutrophic
TSI > 65 - Hypereutrophic (most productive)

The reasons for the different estimated TSI values for Sheep Creek Dam are varied. According to the phosphorus TSI value, Sheep Creek Dam is a very productive, hypereutrophic lake (Table 11). 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 nonalgal particulates dominate light attenuation. It follows that, as is the case with Sheep Creek Dam, 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 more universally applicable 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 Disk Transparency index from the chlorophyll index can be used to identify conditions and causes relating to the reservoir's trophic state. Some possible interpretations of deviations of the index values are given in Table 12 below (updated from Carlson 1983).

Table 12. 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 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, for example, may cause the chlorophyll and Secchi depth indices to fall below the phosphorus index as the zooplankton remove algal cells from the water or Secchi Disk Transparency 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 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 hypereutrophic down to nearly mesotrophic. Given the size of the lake (83 acres), the likely amount of phosphorus in the bottom sediments available for internal cycling, the nearly constant wind in southwestern 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 Sheep Creek Dam, which would allow it to meet the narrative standards relating to recreation and aquatic life beneficial uses.

4.0 SIGNIFICANT SOURCES

There are no known point sources upstream of Sheep Creek Dam. It is assumed that the pollutants of concern originate from non-point sources. Most of the land upstream from Sheep Creek Dam is farmed. The remainder is used for pasture or kept as permanent herbaceous cover. There are no urban areas within the watershed or lake homes around the reservoir. However, there are small farmsteads spread throughout the watershed. The vast majority of nutrient loads are transported with overland runoff from agricultural areas. Existing land use and AGNPS modeling within the watershed indicate that the majority of NPS loading is likely coming from cropland (49 percent of land within the watershed is actively cultivated).

The United States Department of Agriculture's Stream Visual Assessment Protocol was used to assess the riparian area of tributaries to Sheep Creek Dam. The assessment indicated that of 31 sites evaluated, 11 were ranked as high fair, six were ranked as low fair, two were ranked as good, and twelve were poor. The three main categories considered during the evaluation were hydrology and streambanks, soil, and riparian vegetation. Priority resource issues listed as impacting Sheep Creek and it's tributaries include: excessive grazing and encroachment of introduced cool season grasses in the riparian area, nutrient enrichment at nearly every site, and excessive erosion and sedimentation.

With thirty-three percent of land in the watershed being rangeland or pasture, it is possible that nutrient loadings from cattle consistently grazing too long on the riparian area of the tributaries or actually wading in the streambed are significantly impacting the downstream reservoir. As a result, best management practices should also be implemented on land used for grazing in order to address loading from this type of land use.

5.0 TECHNICAL ANALYSIS

Establishing a relationship between in-stream water quality targets and pollutant source loading is a critical component of TMDL development. Identifying the cause-and-effect relationship between pollutant loads and the water quality response is necessary to evaluate the loading capacity 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 Sheep Creek Dam, 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 therefore, is 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. In the case of Sheep Creek Dam, the FLUX program estimated annual phosphorus loading for 2004 at 444.6 kg/yr. 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 Sheep Creek Dam'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, minimum, and maximum); and 3) an evaluation of trophic status. The output data from the Excel program were then used to calibrate the BATHTUB model.

When the input data from 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 factors. The BATHTUB model is then calibrated by combining tributary load estimates for the project period with in-lake water quality estimates. The model is termed calibrated when the predicted estimates for the trophic response variables are similar to observed estimates based on the project monitoring data. BATHTUB then has the ability to predict total phosphorus concentration, chlorophyll-*a* concentration, Secchi Disk Transparency, and the associated TSI scores as a means of expressing trophic response.

As stated above, BATHTUB can compare predicted vs. actual conditions. After calibration, the model was run based on observed concentrations of phosphorus and nitrogen to derive an estimated annual average total phosphorus load of 442.5 kg/yr and annual average nitrogen load of 3,658.6 kg/yr. 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 Sheep Creek Dam, BATHTUB modeled externally derived phosphorus. Phosphorus was used in the simulation model based on its known relationship to eutrophication and 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. 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 Sheep Creek Dam, the average annual total phosphorus and chlorophyll-*a* concentration in the lake would decrease and Secchi Disk Transparency depth would increase, but only phosphorus would be measurable. The large reduction in nutrient load should result in an improvement to the trophic status of Sheep Creek Dam that would be noticeable to the average lake user by reducing the intensity and frequency of algal blooms per year and through an overall improvement in the clarity. Through these improvements it is predicted that Sheep Creek Dam would maintain a eutrophic trophic status.

With a 50 percent reduction in external phosphorus load, the model predicts a reduction in Carlson's TSI score from 57.80 to 55.71 for chlorophyll-*a*, and 53.23 to 44.49 for Secchi Disk Transparency, corresponding to a trophic state ranging from hypereutrophic to eutrophic. 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 84.00 to 74.27 (Table 13).

Table 13. Observed and Predicted Values for Selected Trophic Response Variables Assuming 25, 50, and 75 Percent Reduction in External Phosphorus and Nitrogen Loading, (2004).

Variable	Observed Value	Predicted Value 25%	Predicted Value 50%	Predicted Value 75%
Total Phosphorus (mg/L)	0.254	0.192	0.129	0.068
Total Dissolved Phosphorus (mg/L)	0.216	0.155	0.095	0.039
Total Nitrogen (mg/L)	1.486	1.144	0.805	0.466
Organic Nitrogen (mg/L)	1.421	1.358	N/A	N/A
Chlorophyll-a (µg/L)	16.00	14.64	12.93	9.60
Secchi Disk Transparency (meters)	1.60	2.12	2.93	5.17
Carlson's TSI for Phosphorus	84.00	79.94	74.27	65.00
Carlson's TSI for Chlorophyll-*a*	57.80	56.93	55.71	52.78
Carlson's TSI for Secchi Disk	53.23	59.20	44.49	36.33

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 0.129 mg/L and an in-lake total nitrogen concentration of 0.805 mg/L nitrogen load. This reduction in phosphorus and nitrogen is predicted to result in a reservoir that is eutrophic throughout a given year with respect to cholorophyll-*a*, considered the algal biomass indicator (Figure 8).

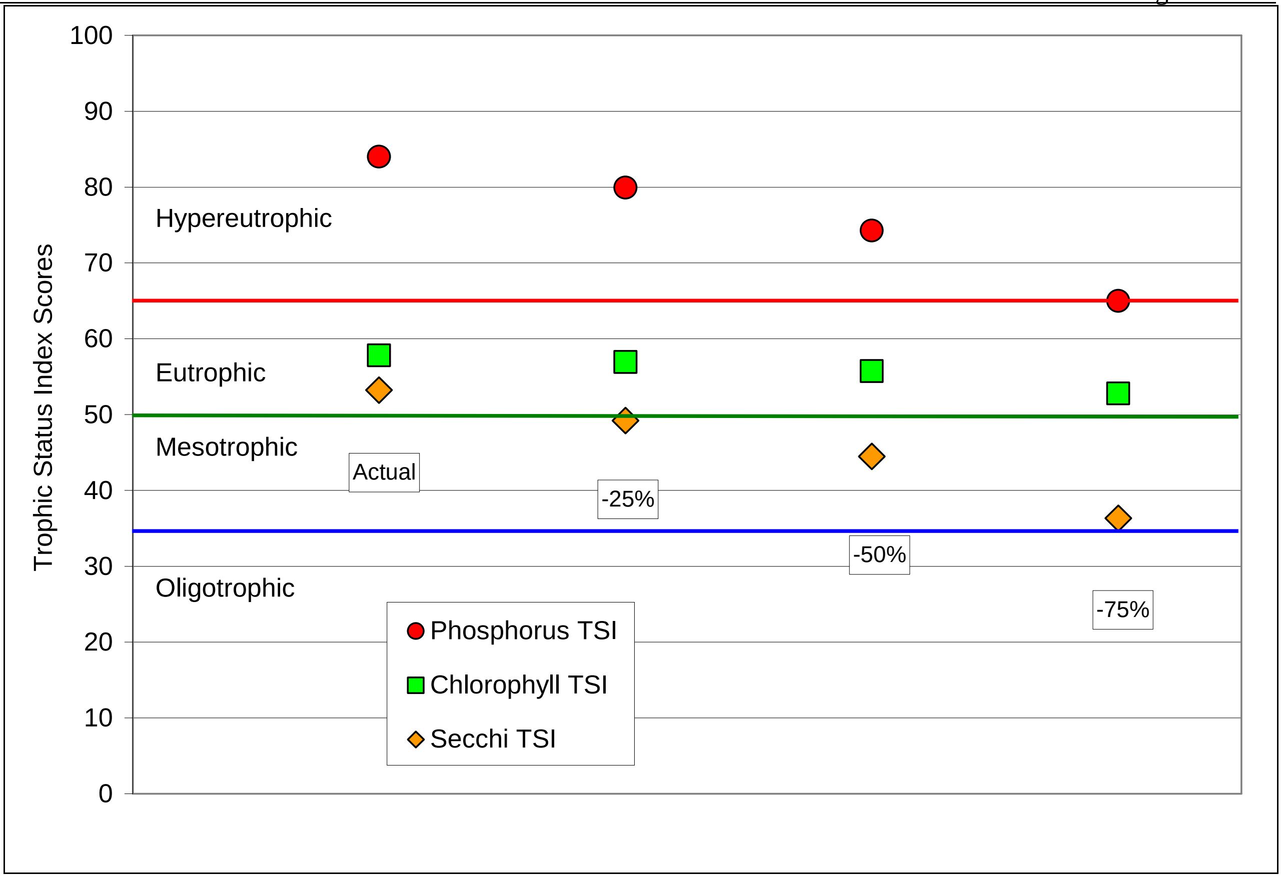

Figure 8. Predicted Trophic Response in Sheep Creek Dam to Phosphorus Load Reductions of 25, 50, and 75 Percent.

5.3 AGNPS Watershed Model

In order to identify significant nonpoint source (NPS) pollutant sources in the Sheep Creek Dam watershed and to assess the relative reductions in nutrient (nitrogen and phosphorus) and sediment 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 within the watershed; 2) identify critical pollutant source areas within the watershed; and 3) evaluate potential nutrient (nitrogen, 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 output, 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 Sheep Creek Dam 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, current annual run-off and annual nutrient yields were estimated for the watershed using the AGNPS model (Table 14).

Table 14. Runoff and Event Based Yield Summary for the Sheep Creek Dam Watershed.

Watershed studied is	Sheep Creek Dam
The Area of the Watershed is	37,827 acres
The Area of Each Cell is	40.00 acres
The Characteristic Storm Precipitation is	3.00 inches
The Storm Energy-intensity Value is	106.4
Values at the Watershed Outlet	
Outlet Cell	4
Runoff Volume	1.01 inches
Peak Runoff Rate	2,740.96 cfs
Total Nitrogen Yield in Sediment	0.36 lbs/acre
Total Soluble Nitrogen Yield in Runoff	0.29 lbs/acre
Soluble Nitrogen Concentration in Runoff	1.26 ppm
Total Phosphorus Yield in Sediment	0.18 lbs/acre
Total Soluble Phosphorus Yield in Runoff	0.04 lbs/acre
Soluble Phosphorus Concentration in Runoff	0.16 ppm
Total Soluble Chemical Oxygen Demand Yield in Runoff	15.88 lbs/acre
Soluble Chemical Oxygen Demand Concentration in Runoff	69.51 ppm
Total Event Based Sediment Load	2,115.25 tons
Mean Sediment Concentration	487.38 ppm
Total Sediment Yield	0.06 tons/acre

Additional modeling comparisons were made by changing land use practices on selected portions of the watershed. The watershed was divided into 945- 40 acre cells for evaluation. Each cell was evaluated for soil characteristics, terrain, and land-use characteristics (Table 15).

The AGNPS model predicted that based on the 2004 farming practices in the Sheep Creek Dam watershed, composed of a mixture of cropland, CRP and rangeland, the total nitrogen in sediment yield would be 0.36 pounds per acre and the total phosphorus in sediment yield would be 0.18 pounds per acre (Table 14). 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 row crop or small grain crops;
- Wheat rotations on land with less than 5 percent slope were put in a continuous wheat rotation;
- Total containment of waste from all concentrated livestock feeding operations in the watershed;
- All pasture land was converted to excellent condition; and

- All alfalfa in the watershed was left unchanged.

A total reduction in runoff yield of 0.15 lbs/acre (TN) in sediment and 0.07 lbs/acre (TP) in sediment is estimated to result from these practices (Table 15) resulting in an overall reduction of 42 percent TN in sediment and 39 percent TP in sediment in the watershed, respectively. As expected, soluble nutrient concentrations were sizably reduced by addressing the CAFOS in the watershed resulting in a total (sediment and soluble) phosphorus and nitrogen yield reduction of 45 and 37 percent, respectively.

Table 15. Sheep Creek Dam Watershed AGNPS Summary.

Watershed Studied			
Area of Watershed	37,827 acres		
Area of Each Cell	40.00 acres		
Characteristic Storm Precipitation	3.00 inches		
Storm Energy-Intensity Value	106.4 inches		
Values at the Watershed Outlet			
Original	**2004 Land Use Conditions**	**5% and greater slope to CRP**	**5% and greater slope to CRP + containment of 100% of CAFOs**
Number of Cells	945	945	945
Runoff Volume	1.01 inches	1.01 inches	1.01 inches
Peak Run-off Rate	2,740.96 cfs	2,740.96 cfs	2,740.96 cfs
Total Nitrogen Yield in Sediment	0.36 lbs/acre	0.21 lbs/acre	0.21 lbs/acre
Total Soluble Nitrogen Yield in Runoff	0.29 lbs/acre	0.29 lbs/acre	0.20 lbs/acre
Soluble Nitrogen Concentration in Runoff	1.26 ppm	1.26 ppm	0.87 ppm
Total Phosphorus Yield in Sediment	0.18 lbs/acre	0.11 lbs/acre	0.11 lbs/acre
Total Soluble Phosphorus Yield in Runoff	0.04 lbs/acre	0.04 lbs/acre	0.01 lbs/acre
Soluble Phosphorus Concentration in Runoff	0.16 ppm	0.16 ppm	0.05 ppm
Total Soluble Chemical Oxygen Demand Yield in Runoff	15.88 lbs/acre	15.88 lbs/acre	14.53 lbs/acre
Soluble Chemical Oxygen Demand Concentration in Runoff	69.51 ppm	69.51 ppm	63.61 ppm

Additional land management practices or situations that may significantly reduce nutrient runoff yields, although outside the scope of the land use model currently implyoyed, include exclusion of cattle from the riparian area, intensive grazing management, and the replacement or repair of possible faulty septic systems in the watershed. The United States Department of Agriculture's Stream Visual Assessment Protocol noted livestock access present on 25 of 31 sites evaluated, and estimated 24 farmstead sites in the watershed while conducting the stream assessment. Although not all farmsteads had residents, they were used to store grain and machinery or for livestock feeding.

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 Sheep Creek Dam is 442.5 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 221.25 kg of total phosphorus per year. A 10 % explicit margin of safety for the TMDL would be 22.13 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. Sheep Creek Dam's TMDL addresses seasonality because the BATHTUB model incorporates seasonal differences in its prediction of annual total phosphorus and nitrogen loadings.

7.0 TMDL

Table 16 and the following summarize the nutrient TMDL for Sheep Creek Dam 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; and

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

7.1 Nutrient TMDL

Table 16. Summary of the Phosphorus TMDL for Sheep Creek Dam.

TMDL Allocation	Total Phosphorus (kg/yr)	Explanation
Existing Load	442.50	Determined through the BATHTUB model
Loading Capacity	221.25	50% total reduction based on BATHTUB modeling
Waste load Allocation	0.0	No point sources
Load Allocation	199.12	Entire loading capacity minus MOS is allocated to non-point sources
MOS	22.13	10% of the loading capacity is reserved as an explicit margin of safety

Based on data collected in 2004, the existing load to Sheep Creek Dam is estimated at 442.5 kg. Based on the BATHTUB and AGNPS modeling results, a 50% reduction in the existing total phosphorus loading to Sheep Creek Dam will result in a predicted TMDL target total phosphorus concentration of 0.129 mg/L, therefore the TMDL or Loading Capacity is 221.25 kg. Assuming that 10% of the loading capacity (221.25 kg/yr) is explicitly assigned to the margin of safety (22.13 kg) and there are no point sources in the watershed, then all of the remaining loading capacity is assigned to the load allocation (199.12 kg/yr).

8.0 ALLOCATION

Sheep Creek Dam’s watershed is relatively small and supports extensive agriculture where cropland constitutes a majority of the land use. Sub-dividing it into smaller units, based on hydrology or type of conservation practice implemented, would not be practical. 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. There are 631- 40 acre cells within the Sheep Creek Dam watershed identified as “critical” by the AGNPS model (Figure 9). Critical cells are those with fallow, small grains, or land chiseled multiple times; as well as all feedlots, and land with a slope greater than five percent. These cells represent a total area of 25,240 acres or 67 percent of the watershed. Based on the AGNPS model results and our best professional judgment, if these critical areas in the watershed are targeted for treatment with BMPs (no till, nutrient management, grazing systems, native/tame grass seeding on steep slopes, etc.) and producers effectively exclude cattle from the riparian area of 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.

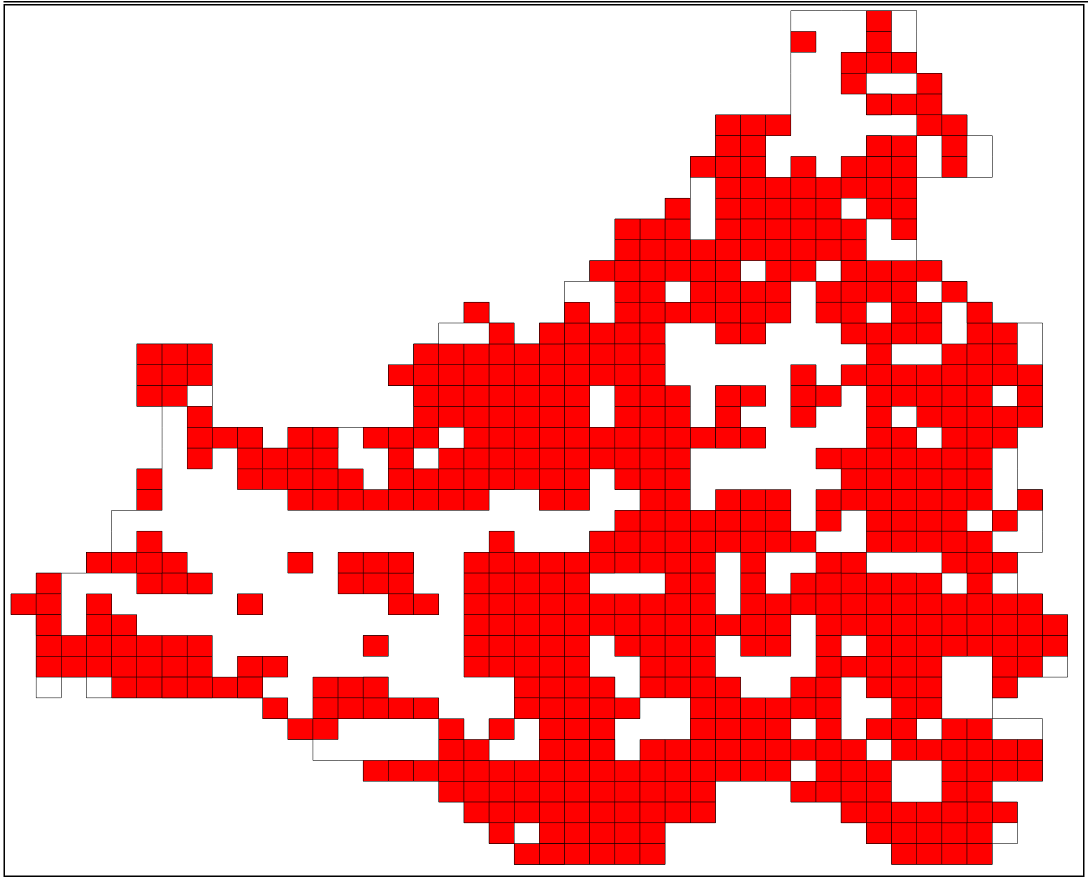

Figure 9. AGNPS Identification of Critical Areas for BMP Implementation.

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.

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 Sheep Creek Dam and its watershed to meet and protect its beneficial uses. Water quality monitoring should continue to assess the effects of the recommendations made in this TMDL. Monitoring may indicate that the loading capacity recommendations should be adjusted.

9.0 PUBLIC PARTICIPATION

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

- Grant County Soil Conservation District;
- Grant County Water Resource Board;
- Natural Resource Conservation Service (State Office and Grant County Field Office);

- North Dakota Game and Fish Department (Save Our Lakes Program);
- U.S. Environmental Protection Agency, Region VIII; and
- U.S. Fish & Wildlife Service.

In addition to mailing copies of this TMDL for Sheep Creek Dam 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 Grant County News, Published November 28, 2007
- The Bismarck Tribune, Published November 28, 2007

The 30-day public notice was held from November 28, 2007 through December 28, 2007. Comments were received from the Environmental Protection Agency, Region 8 and the North Dakota Game and Fish Department. Formal written comments received from the Environmental Protection Agency, Region 8 are provided in Appendix D. All informal editorial comments received from the EPA and the North Dakota Game and Fish Department were addressed and are on file in the North Dakota Department of Health office in Bismarck, North Dakota.

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). Once a watershed restoration plan (e.g., Section 319 Project Implementation Plan) is implemented, monitoring will be conducted in the reservoir beginning two years after implementation and extending 5 years after the implementation project is complete.

11.0 TMDL IMPLEMENTATION STRATEGY

Implementation of TMDLs is dependent upon the availability of Section 319 NPS funds and/or other watershed restoration programs (e.g. USDA Environmental 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 BMPs contained in the NPS pollution 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 Grant County as provided by the US Fish and Wildlife Service (Appendix C). 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 Sheep Creek Dam TMDL poses "No Adverse Effect" to those Threatened and Endangered species listed for Grant County.

As mentioned in Section 9.0, a copy of this TMDL report was sent to the US Fish and Wildlife Service for their review during the public comment period. No comments were received from the US Fish and Wildlife Service.

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Appendix A

A Calibrated Trophic Response Model (Bathtub) for Sheep Creek Dam
As a Tool to Evaluate Various Nutrient Reduction Alternatives
Based on Data Collected by the Grant County Soil Conservation District from
January 4, 2004 through November 3, 2004
Prepared by
Peter Wax
June 28, 2006

Introduction

In order to meet the project goals, as set forth by the project sponsors of improving the trophic condition of Sheep Creek Dam to levels capable of maintaining the reservoirs beneficial uses (e.g., fishing, recreation, and drinking water supply), and the objectives of this project, which are to: (1) develop a nutrient and sediment budget for the reservoir; (2) identify the primary sources and causes of nutrients and sediments to the reservoir; and (3) examine and make recommendations for reservoir restoration measures which will reduce documented nutrient and sediment loadings to the reservoir, a calibrated trophic response model was developed for Sheep Creek Dam. The model enables investigations into various nutrient reduction alternatives relative to the project goal of improving Sheep Creek Dam'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.

Methods

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

Tributary Data

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

Lake Data

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

Bathtub Model Calibration

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

Within the BATHTUB program the user can select from six schemes based on reservoir morphometry and the needs of the resource manager. Using BATHTUB the user can view the reservoir as a single spatially averaged reservoir or as single segmented reservoir. The user can also model parts of the reservoir, such as an embayment, or model a collection of reservoirs. For purposes of this project, Sheep Creek Dam 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 Sheep Creek Dam Bathtub Model.

Model Option	Model Selection	Calibration Factor
Conservative Substance	1 Computed	1.000
Phosphorus Balance	7 Settling Velocity	1.180
Phosphorus – Ortho P	7	0.800
Nitrogen Balance	5 Bachman Flushing	1.080
Organic Nitrogen	5	2.400
Chlorophyll-a	1 P, N, Light, T	1.000
Secchi Depth	1 Vs. Chla & Turbidity	4.000
Phosphorus Calibration	2 Concentrations	NA
Nitrogen Calibration	2 Concentrations	NA
Availability Factors	0 All Models Except 2	NA
Mass-Balance Tables	0 Use Observed Concentrations	NA

Results

The trophic response model, BATHTUB, has been calibrated to match Sheep Creek Dam's trophic response for the project period January 9, 2004 through November 3, 2004. 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 Sheep Creek Dam 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 0.253 mg L^{-1} and an annual average volume weighted total nitrogen concentration of 1.483 mg L^{-1} compared to observed values for total phosphorus and total nitrogen of 0.254 mg L^{-1} and 1.486 mg L^{-1}, respectively (Table 2). The BATHTUB model also predicts annual total phosphorus loading at 442.5 kg/yr and total nitrogen loading at 3,658 kg/yr.

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)	0.254	0.253
Total Nitrogen as N (mg/L)	1.486	1.483
Organic Nitrogen as N (mg/L)	1.421	1.411
Chlorophyll-a (μg/L)	16.00	15.60
Secchi Disk Transparency (meters)	1.60	1.68
Carlson’s TSI for Phosphorus	84.00	83.94
Carlson’s TSI for Chlorophyll-a	57.80	57.55
Carlson’s TSI for Secchi Disk	53.23	52.51

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

Model Predictions

Once the model is calibrated to existing conditions, the model can be used to evaluate the effectiveness of any number of nutrient reduction or lake restoration alternatives. This evaluation is accomplished by comparing the predicted trophic state, as reflected by Carlson’s TSI, with currently observed TSI values. Modeled nutrient reduction alternatives are presented in three basic categories: (1) reducing externally derived nutrient loads; (2) reducing internally available nutrients; and (3) reducing both external and internal nutrient loads. For Sheep Creek Dam 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).

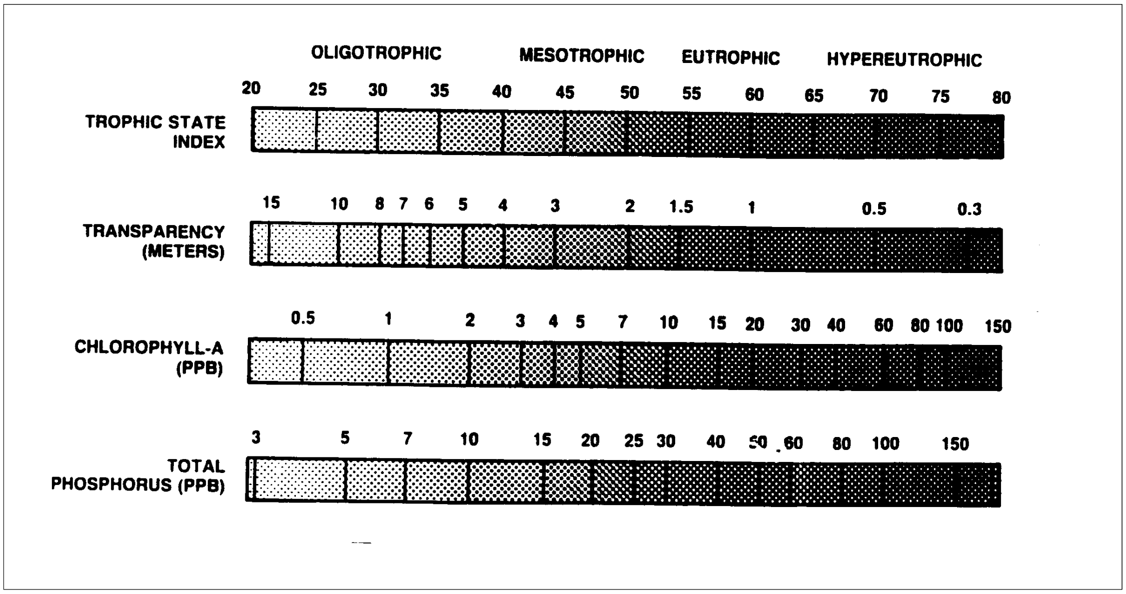

Figure 1. Graphic depiction of Carlson's Trophic Status Index

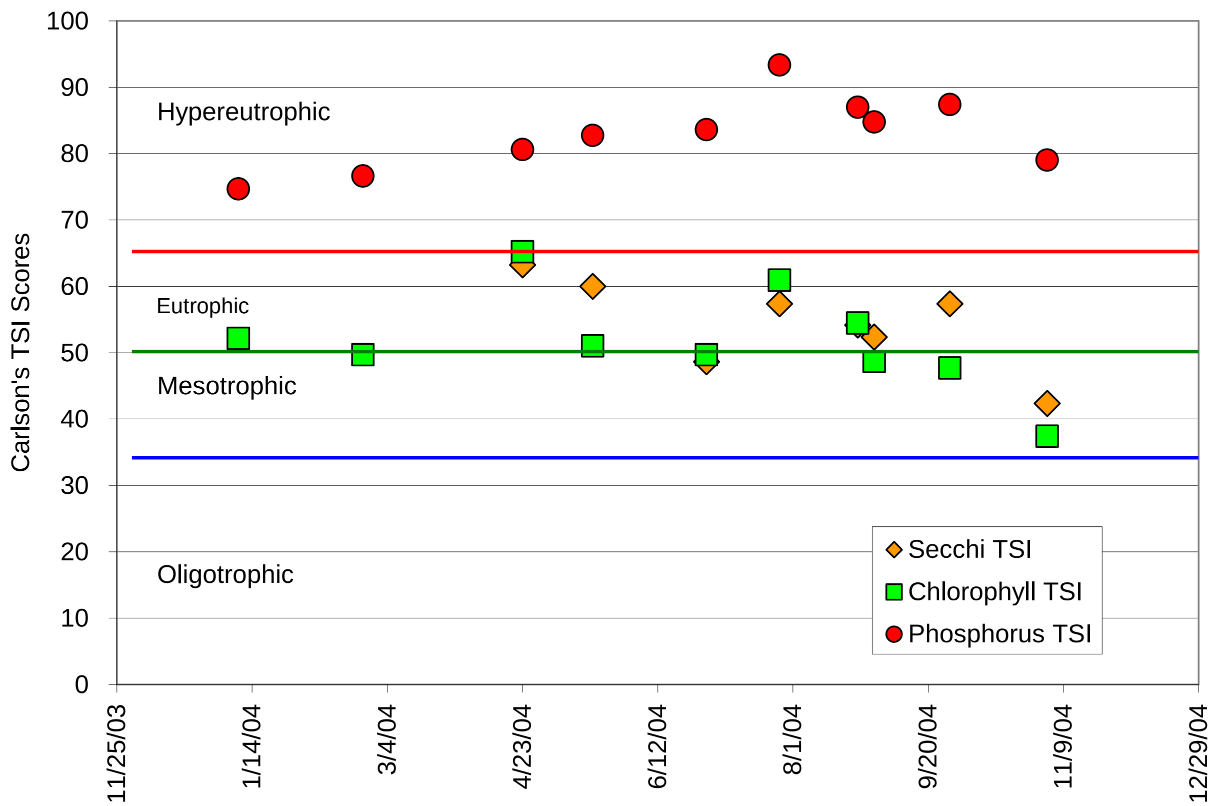

Figure 2. Temporal distribution of Carlson's Trophic Status Index scores for Sheep Creek Dam (1-9-2003 though 11-3-2004)

Predicted changes in trophic response to Sheep Creek Dam 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 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 Sheep Creek Dam by 75 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 a reduction in nutrient load would result in an improvement to the trophic status of Sheep Creek Dam that would be noticeable to the average lake as the reduction in the amount of green in the lake and overall clarity would increased to, or nearly to the mesotrophic range.

With a 75 percent reduction in external phosphorus and nitrogen load, the model predicts a reduction in Carlson's TSI score from 57.80 to 52.78 for chlorophyll-a and from 53.23 to 36.33 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)	0.254	0.192	0.129	0.068
Total Diss. Phosphorus as P (mg/L)	0.216	0.155	0.095	0.039
Total Nitrogen as N (mg/L)	1.486	1.144	0.805	0.466
Organic Nitrogen as N (mg/L)	1.421	1.358	NA	NA
Chlorophyll-a (μg/L)	16.00	14.64	12.93	9.60
Secchi Disk Transparency (meters)	1.60	2.12	2.93	5.17
Carlson's TSI for Phosphorus	84.00	79.94	74.27	65.00
Carlson's TSI for Chlorophyll-a	57.80	56.93	55.71	52.78
Carlson's TSI for Secchi Disc	53.23	59.20	44.49	36.33

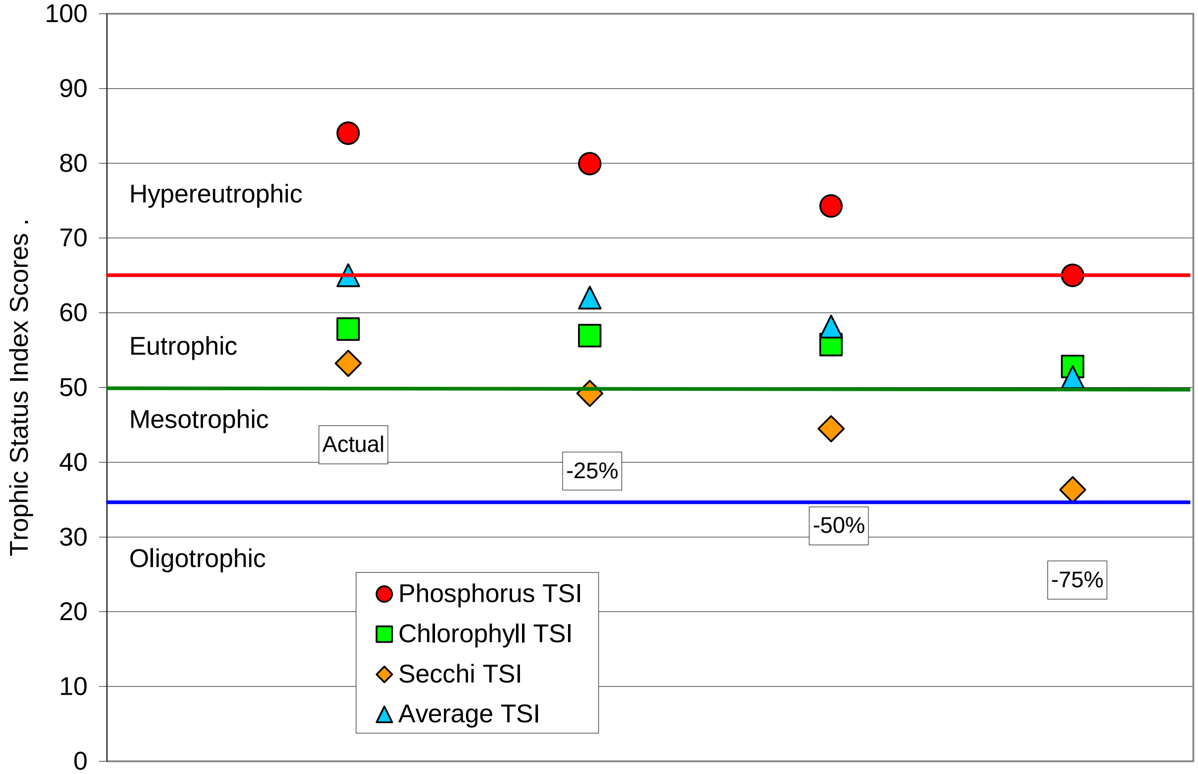

Figure 3. Predicted trophic response to phosphorus load reductions to Sheep Creek Dam of 25, 50, and 75 percent.

BATHTUB DATA

GROSS MASS BALANCE BASED UPON OBSERVED CONCENTRATIONS
COMPONENT: TOTAL P

ID	T	LOCATION	LOADING KG/YR	LOADING %(I)	VARIANCE KG/YR**2	VARIANCE %(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	Inlet	442.5	97.7	.512E+05	99.9	.511	250.0	2.9
2	4	Outlet	561.6	124.0	.168E+04	3.3	.073	208.0	3.7
		PRECIPITATION	10.3	2.3	.263E+02	.1	.500	.0	30.0
		TRIBUTARY INFLOW	442.5	97.7	.512E+05	99.9	.511	250.0	2.9
		***TOTAL INFLOW	452.8	100.0	.512E+05	100.0	.500	255.8	3.0
		GAUGED OUTFLOW	685.8	151.5	.000E+00	.0	.000	254.0	4.5
		ADVECTIVE OUTFLOW	-236.2	-52.2	.505E+05	98.7	.952	254.0	********
		***TOTAL OUTFLOW	449.6	99.3	.505E+05	98.7	.500	254.0	2.9
		***RETENTION	3.2	.7	.224E+04	4.4	9.999	.0	.0

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 -
5.18	.8560	254.0	.8500	1.1765	.0070

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	3658.6	91.5	.339E+07	99.1	.503	2067.0	23.9
2	4	Outlet	4074.3	101.8	.484E+05	1.4	.054	1509.0	26.6
		PRECIPITATION	342.0	8.5	.292E+05	.9	.500	.0	1000.0
		TRIBUTARY INFLOW	3658.6	91.5	.339E+07	99.1	.503	2067.0	23.9
		***TOTAL INFLOW	4000.6	100.0	.342E+07	100.0	.462	2260.2	26.1
		GAUGED OUTFLOW	4012.2	100.3	.000E+00	.0	.000	1486.0	26.2
		ADVECTIVE OUTFLOW	-1382.0	-34.5	.173E+07	50.6	.952	1486.0	********
		***TOTAL OUTFLOW	2630.2	65.7	.173E+07	50.6	.500	1486.0	17.1
		***RETENTION	1370.4	34.3	.337E+06	9.9	.424	.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 -
5.18	.8560	1486.0	.5628	1.7770	.3425

Appendix B
Flux Data

Sheep Creek Dam Inlet 385293 Flux Load Analysis

```
Sheep Creek Dam’s Inlet 385293. Data Collected by the Grant CO SCD
(Joyce Hummel) in 2004

 Average Sample Interval =   6.0 Days, Date Range = 20040311 to 20040722
 Maximum Sample Interval =    13 Days, Date Range = 20040610 to 20040624
 Percent of Total Flow Volume Occurring In This Interval =    .7%

 Total Flow Volume on Sampled Days =         81.7 hm3
 Total Flow Volume on All Days     =        645.3 hm3
 Percent of Total Flow Volume Sampled =    12.7%

 Maximum Sampled Flow Rate =       50.11 hm3/yr
 Maximum Total Flow Rate   =      123.84 hm3/yr
 Number of Days when Flow Exceeded Maximum Sampled Flow =  3 out of  363
 Percent of Total Flow Volume Occurring at Flow Rates Exceeding the
       Maximum Sampled Flow Rate =    44.6%
```

Sheep Creek Inlet 2004 VAR=nh3-4 METHOD= 3 IJC

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	321	14	14	5.7	.114	.412	.379	.433
2	22	5	5	6.0	1.745	1.946	.449	.875
3	20	3	3	88.4	28.520	22.073	1.553	.415
***	363	22	22	100.0	1.778	3.715		

```
 FLOW STATISTICS
 FLOW DURATION =     363.0 DAYS  =   .994 YEARS
 MEAN FLOW RATE =     1.778 HM3/YR
 TOTAL FLOW VOLUME =       1.77 HM3
 FLOW DATE RANGE   = 20031231 TO 20041227
 SAMPLE DATE RANGE = 20040311 TO 20040722
```

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	665.8	669.9	.2447E+06	376.84	.738
2 Q WTD C	844.2	849.4	.3980E+05	477.81	.235
3 IJC	889.5	895.0	.2171E+05	503.47	.165
4 REG-1	1249.8	1257.5	.1538E+11	707.39	98.610
5 REG-2	1320.4	1328.5	.1824E+12	747.33	321.476
6 REG-3	8663.0	8716.7	.1040E+12	4903.35	37.004

Sheep Creek Inlet 2004 VAR=no2+no3 METHOD= 3 IJC

Sheep Creek Inlet 2004 VAR=no2+no3 METHOD= 3 IJC

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	321	14	14	5.7	.114	.412	.153	.536
2	22	5	5	6.0	1.745	1.946	2.639	.212
3	20	3	3	88.4	28.520	22.073	1.349	.430
***	363	22	22	100.0	1.778	3.715		

```
 FLOW STATISTICS
 FLOW DURATION =     363.0 DAYS  =   .994 YEARS
```

MEAN FLOW RATE = 1.778 HM3/YR
TOTAL FLOW VOLUME = 1.77 HM3
FLOW DATE RANGE = 20031231 TO 20041227
SAMPLE DATE RANGE = 20040311 TO 20040722

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	811.1	816.1	.3418E+06	459.06	.716
2 Q WTD C	1031.2	1037.6	.3757E+05	583.68	.187
3 IJC	1076.6	1083.3	.1281E+05	609.38	.104
4 REG-1	1445.7	1454.6	.8244E+10	818.26	62.420
5 REG-2	1520.8	1530.2	.9270E+11	860.78	198.965
6 REG-3	7166.4	7210.8	.4569E+11	4056.24	29.642

Sheep Creek Inlet 2004 VAR=inorg-n METHOD= 3 IJC

Sheep Creek Inlet 2004 VAR=inorg-n METHOD= 3 IJC
COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	321	14	14	5.7	.114	.412	.265	.471
2	22	5	5	6.0	1.745	1.946	2.404	.295
3	20	3	3	88.4	28.520	22.073	1.429	.423
***	363	22	22	100.0	1.778	3.715		

FLOW STATISTICS
FLOW DURATION = 363.0 DAYS = .994 YEARS
MEAN FLOW RATE = 1.778 HM3/YR
TOTAL FLOW VOLUME = 1.77 HM3
FLOW DATE RANGE = 20031231 TO 20041227
SAMPLE DATE RANGE = 20040311 TO 20040722

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	1476.8	1486.0	.1165E+07	835.90	.726
2 Q WTD C	1875.4	1887.0	.1543E+06	1061.49	.208
3 IJC	1966.1	1978.3	.6776E+05	1112.85	.132
4 REG-1	2685.8	2702.4	.3985E+11	1520.18	73.868
5 REG-2	2830.7	2848.2	.4580E+12	1602.17	237.598
6 REG-3	15011.8	15104.9	.2382E+12	8496.83	32.314

Sheep Creek Inlet 2004 VAR=tn METHOD= 3 IJC

Sheep Creek Inlet 2004 VAR=tn METHOD= 3 IJC
COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	321	14	14	5.7	.114	.412	-.082	.568
2	22	5	5	6.0	1.745	1.946	.433	.109
3	20	3	3	88.4	28.520	22.073	.175	.374
***	363	22	22	100.0	1.778	3.715		

FLOW STATISTICS
FLOW DURATION = 363.0 DAYS = .994 YEARS
MEAN FLOW RATE = 1.778 HM3/YR
TOTAL FLOW VOLUME = 1.77 HM3
FLOW DATE RANGE = 20031231 TO 20041227
SAMPLE DATE RANGE = 20040311 TO 20040722

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	3158.9	3178.5	.3122E+07	1787.96	.556
2 Q WTD C	3588.1	3610.4	.7852E+05	2030.91	.078
3 IJC	3652.4	3675.0	.4384E+05	2067.29	.057
4 REG-1	3745.9	3769.2	.1754E+07	2120.23	.351

5 REG-2	3762.6	3786.0	.5884E+07	2129.69	.641
6 REG-3	3745.9	3769.2	.2594E+07	2120.23	.427

Sheep Creek Inlet 2004 VAR=td-p METHOD= 3 IJC

Sheep Creek Inlet 2004 VAR=td-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	335	15	15	8.7	.168	.465	-.475	.412
2	28	5	5	91.3	21.035	4.596	.517	.395
***	363	20	20	100.0	1.778	1.498		

FLOW STATISTICS
FLOW DURATION = 363.0 DAYS = .994 YEARS
MEAN FLOW RATE = 1.778 HM3/YR
TOTAL FLOW VOLUME = 1.77 HM3
FLOW DATE RANGE = 20031231 TO 20041227
SAMPLE DATE RANGE = 20040315 TO 20040722

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	115.7	116.4	.1395E+04	65.47	.321
2 Q WTD C	374.9	377.3	.9968E+04	212.22	.265
3 IJC	371.9	374.2	.1108E+05	210.49	.281
4 REG-1	598.2	601.9	.1046E+08	338.60	5.373
5 REG-2	1699.0	1709.6	.1872E+10	961.67	25.307
6 REG-3	622.7	626.6	.5384E+07	352.47	3.703

Sheep Creek Inlet 2004 VAR=tp METHOD= 2 Q WTD C

Sheep Creek Inlet 2004 VAR=tp METHOD= 3 IJC

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	321	14	14	5.7	.114	.412	-.394	.369
2	22	5	5	6.0	1.745	1.946	1.331	.355
3	20	3	3	88.4	28.520	22.073	-.292	.426
***	363	22	22	100.0	1.778	3.715		

FLOW STATISTICS
FLOW DURATION = 363.0 DAYS = .994 YEARS
MEAN FLOW RATE = 1.778 HM3/YR
TOTAL FLOW VOLUME = 1.77 HM3
FLOW DATE RANGE = 20031231 TO 20041227
SAMPLE DATE RANGE = 20040311 TO 20040722

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	408.4	410.9	.3187E+05	231.13	.434
2 Q WTD C	460.4	463.2	.6545E+04	260.57	.175
3 IJC	441.9	444.6	.2221E+04	250.12	.106
4 REG-1	436.2	438.9	.2480E+05	246.91	.359
5 REG-2	423.3	425.9	.2687E+05	239.61	.385
6 REG-3	467.3	470.2	.2596E+05	264.49	.343

Sheep Creek Inlet 2004 VAR=tss METHOD= 3 IJC

Sheep Creek Inlet 2004 VAR=tss METHOD= 3 IJC

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	321	13	13	5.7	.114	.410	-.762	.003

2	22	5	5	6.0	1.745	1.946	1.448	.603
3	20	3	3	88.4	28.520	22.073	.957	.294
***	363	21	21	100.0	1.778	3.870		

FLOW STATISTICS
FLOW DURATION = 363.0 DAYS = .994 YEARS
MEAN FLOW RATE = 1.778 HM3/YR
TOTAL FLOW VOLUME = 1.77 HM3
FLOW DATE RANGE = 20031231 TO 20041227
SAMPLE DATE RANGE = 20040311 TO 20040722

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	64709.9	65111.0	.2342E+10	36626.32	.743
2 Q WTD C	79536.0	80029.0	.8429E+09	45017.98	.363
3 IJC	85772.2	86303.9	.8246E+09	48547.75	.333
4 REG-1	101075.3	101701.8	.1061E+12	57209.41	3.202
5 REG-2	104664.8	105313.5	.8600E+12	59241.09	8.806
6 REG-3	123074.5	123837.4	.2834E+12	69661.14	4.299

Sheep Creek Dam Outlet 385292 Flux Load Analysis

Sheep Creek Dam's Outlet 385292. Data Collected by the Grant CO SCD (Joyce Hummel) in 2004

Average Sample Interval = 7.9 Days, Date Range = 20040311 to 20041103
Maximum Sample Interval = 27 Days, Date Range = 20040831 to 20040928
Percent of Total Flow Volume Occuring In This Interval = .6%

Total Flow Volume on Sampled Days = 109.3 hm3
Total Flow Volume on All Days = 989.6 hm3
Percent of Total Flow Volume Sampled = 11.0%

Maximum Sampled Flow Rate = 67.33 hm3/yr
Maximum Total Flow Rate = 166.03 hm3/yr
Number of Days when Flow Exceeded Maximum Sampled Flow = 4 out of 367
Percent of Total Flow Volume Occurring at Flow Rates Exceeding the Maximum Sampled Flow Rate = 49.1%

Sheep Creek Outlet 2004 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	326	22	22	3.2	.098	.193	.622	.003
2	20	5	5	6.1	2.996	2.927	-.044	.985
3	21	3	3	90.7	42.749	30.151	-.018	.946
***	367	30	30	100.0	2.697	3.644		

FLOW STATISTICS
FLOW DURATION = 367.0 DAYS = 1.005 YEARS
MEAN FLOW RATE = 2.697 HM3/YR
TOTAL FLOW VOLUME = 2.71 HM3
FLOW DATE RANGE = 20031231 TO 20041231
SAMPLE DATE RANGE = 20040311 TO 20041103

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	723.3	719.8	.1662E+06	266.95	.566
2 Q WTD C	964.3	959.7	.5788E+04	355.89	.079
3 IJC	978.8	974.1	.1140E+05	361.25	.110
4 REG-1	951.0	946.5	.1498E+06	351.00	.409
5 REG-2	957.1	952.6	.1743E+06	353.25	.438
6 REG-3	1127.0	1121.6	.2421E+06	415.94	.439

Sheep Creek Outlet 2004 VAR=no2+no3 METHOD= 2 Q WTD C

Sheep Creek Outlet 2004 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	326	22	22	3.2	.098	.193	.187	.104
2	20	5	5	6.1	2.996	2.927	2.570	.201
3	21	3	3	90.7	42.749	30.151	-.055	.738
***	367	30	30	100.0	2.697	3.644		

FLOW STATISTICS
FLOW DURATION = 367.0 DAYS = 1.005 YEARS
MEAN FLOW RATE = 2.697 HM3/YR
TOTAL FLOW VOLUME = 2.71 HM3
FLOW DATE RANGE = 20031231 TO 20041231

SAMPLE DATE RANGE = 20040311 TO 20041103

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	920.2	915.8	.2857E+06	339.62	.584
2 Q WTD C	1278.7	1272.6	.1347E+04	471.93	.029
3 IJC	1280.6	1274.5	.2064E+04	472.63	.036
4 REG-1	1257.8	1251.8	.1461E+06	464.21	.305
5 REG-2	1262.1	1256.1	.1928E+06	465.82	.350
6 REG-3	1314.3	1308.0	.1504E+06	485.07	.296

Sheep Creek Outlet 2004 VAR=inorg-n METHOD= 2 Q WTD C

Sheep Creek Outlet 2004 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	326	22	22	3.2	.098	.193	.478	.002
2	20	5	5	6.1	2.996	2.927	.600	.795
3	21	3	3	90.7	42.749	30.151	-.040	.839
***	367	30	30	100.0	2.697	3.644		

FLOW STATISTICS
FLOW DURATION = 367.0 DAYS = 1.005 YEARS
MEAN FLOW RATE = 2.697 HM3/YR
TOTAL FLOW VOLUME = 2.71 HM3
FLOW DATE RANGE = 20031231 TO 20041231
SAMPLE DATE RANGE = 20040311 TO 20041103

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	1643.5	1635.7	.8861E+06	606.57	.576
2 Q WTD C	2243.0	2232.3	.1063E+05	827.82	.046
3 IJC	2259.4	2248.6	.2246E+05	833.87	.067
4 REG-1	2207.9	2197.4	.6025E+06	814.88	.353
5 REG-2	2217.1	2206.5	.7488E+06	818.28	.392
6 REG-3	2394.5	2383.1	.6507E+06	883.74	.338

Sheep Creek Outlet 2004 VAR=tn METHOD= 2 Q WTD C

Sheep Creek Outlet 2004 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	326	22	22	3.2	.098	.193	.238	.000
2	20	5	5	6.1	2.996	2.927	.099	.819
3	21	3	3	90.7	42.749	30.151	-.167	.482
***	367	30	30	100.0	2.697	3.644		

FLOW STATISTICS
FLOW DURATION = 367.0 DAYS = 1.005 YEARS
MEAN FLOW RATE = 2.697 HM3/YR
TOTAL FLOW VOLUME = 2.71 HM3
FLOW DATE RANGE = 20031231 TO 20041231
SAMPLE DATE RANGE = 20040311 TO 20041103

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	3195.8	3180.5	.2236E+07	1179.48	.470
2 Q WTD C	4169.2	4149.3	.1342E+06	1538.76	.088
3 IJC	4089.7	4070.2	.4765E+05	1509.39	.054
4 REG-1	3939.0	3920.3	.1825E+07	1453.80	.345
5 REG-2	3976.2	3957.3	.2145E+07	1467.52	.370
6 REG-3	4123.8	4104.2	.1843E+07	1522.00	.331

Sheep Creek Outlet 2004 VAR=td-p METHOD= 2 Q WTD C

Sheep Creek Outlet 2004 VAR=td-p METHOD= 3 IJC

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	337	25	25	5.6	.166	.443	.495	.001
2	30	3	3	94.4	31.128	26.581	.038	.702
***	367	28	28	100.0	2.697	3.244		

FLOW STATISTICS
FLOW DURATION = 367.0 DAYS = 1.005 YEARS
MEAN FLOW RATE = 2.697 HM3/YR
TOTAL FLOW VOLUME = 2.71 HM3
FLOW DATE RANGE = 20031231 TO 20041231
SAMPLE DATE RANGE = 20040311 TO 20041103

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	462.6	460.4	.8881E+05	170.75	.647
2 Q WTD C	480.4	478.1	.1625E+03	177.29	.027
3 IJC	480.8	478.5	.1595E+03	177.45	.026
4 REG-1	472.0	469.7	.7520E+05	174.20	.584
5 REG-2	483.3	481.0	.2783E+06	178.39	1.097
6 REG-3	486.4	484.1	.1367E+06	179.53	.764

Sheep Creek Outlet 2004 VAR=tp METHOD= 3 IJC

Sheep Creek Outlet 2004 VAR=tp METHOD= 3 IJC

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	326	22	22	3.2	.098	.193	.341	.005
2	20	5	5	6.1	2.996	2.927	-.460	.594
3	21	3	3	90.7	42.749	30.151	-.135	.392
***	367	30	30	100.0	2.697	3.644		

FLOW STATISTICS
FLOW DURATION = 367.0 DAYS = 1.005 YEARS
MEAN FLOW RATE = 2.697 HM3/YR
TOTAL FLOW VOLUME = 2.71 HM3
FLOW DATE RANGE = 20031231 TO 20041231
SAMPLE DATE RANGE = 20040311 TO 20041103

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	446.7	444.6	.4158E+05	164.88	.459
2 Q WTD C	572.1	569.3	.2356E+04	211.13	.085
3 IJC	562.3	559.6	.1655E+04	207.53	.073
4 REG-1	543.3	540.7	.1327E+05	200.52	.213
5 REG-2	550.0	547.3	.1964E+05	202.97	.256
6 REG-3	556.8	554.2	.1469E+05	205.51	.219

Sheep Creek Outlet 2004 VAR=tss METHOD= 3 IJC

Sheep Creek Outlet 2004 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	326	21	21	3.2	.098	.199	.111	.135
2	20	5	5	6.1	2.996	2.927	1.264	.449

3	21	3	3	90.7	42.749	30.151	.022	.967
***	367	29	29	100.0	2.697	3.768		

FLOW STATISTICS
FLOW DURATION = 367.0 DAYS = 1.005 YEARS
MEAN FLOW RATE = 2.697 HM3/YR
TOTAL FLOW VOLUME = 2.71 HM3
FLOW DATE RANGE = 20031231 TO 20041231
SAMPLE DATE RANGE = 20040311 TO 20041103

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	43482.0	43274.7	.7322E+09	16048.09	.625
2 Q WTD C	59019.4	58737.9	.1017E+09	21782.52	.172
3 IJC	60830.5	60540.4	.1881E+09	22450.95	.227
4 REG-1	59490.4	59206.8	.1089E+10	21956.38	.557
5 REG-2	59568.5	59284.4	.1132E+10	21985.18	.567
6 REG-3	66460.8	66143.9	.9788E+09	24528.96	.473

Appendix C
List of Threatened and Endangered Species and Designated Critical Habitat

FEDERAL THREATENED AND ENDANGERED SPECIES
FOUND IN GRANT COUNTY
NORTH DAKOTA
May 2006

ENDANGERED SPECIES

Birds

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

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.

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.

Appendix D
EPA REGION VIII TMDL REVIEW FORM

Document Name:	**Sheep Creek Dam Nutrient TMDL**
Submitted by:	**Mike Ell, NDDoH**
Date Received:	**November 30, 2007**
Review Date:	**December 23, 2007**
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 – Sheep Creek Dam (reservoir) is located approximately 4.5 miles west of the city of Elgin in Grant County, North Dakota. It is an 83 acre man-made impoundment in the Upper Cannonball sub-basin of the Missouri River basin of North Dakota. Sheep Creek drains into the reservoir. Sheep Creek Dam is listed on the State's 2006 303(d) list as impaired for recreational use by nutrients/eutrophication. Approximately 37,827 acres of land drain to the lake from the watershed. Sheep Creek Dam is classified as a Class 2 cool 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 96 percent). Cropland acreage is approximately 49%, range/pasture is approximately 33% and hayland is approximately 8%.

2. Water Quality Standards

Criterion Description – Water Quality Standards

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

- ☒ Satisfies Criterion
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- ☐ 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 – Sheep Creek Dam is impaired for nutrients/eutrophication. 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 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.

Other applicable water quality standards are included on pages 12 - 13 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

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☐ 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 Sheep Creek Dam during the period of the assessment was 84. 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 74, which corresponds to a phosphorus concentration of 0.129 mg/L. This target is based on reducing the chlorophyll-*a* TSI value for the reservoir to within the eutrophic range as defined by Carlson and decreasing the productivity of the reservoir. This target is based on best professional judgement and will fully support its beneficial uses.

The water quality target used in this TMDL is: **maintain a mean annual total phosphorus TSI at or below 74.**

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
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- ☐ 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 considering various agricultural land use and land management factors. Cropland and pastureland are the primary sources identified. Approximately 49% of the landuse is cropland and 33% 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 technical analysis.*

- ☒ Satisfies Criterion
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- ☐ 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 the needed phosphorus reduction to achieve the desired water quality. The TMDL recommends a 50% reduction in external average annual total phosphorus loads to Sheep Creek Dam. Based on the loads measured during the period of the assessment and the technical analysis, the total phosphorus load (i.e., the loading capacity) should be 221.25 kg/yr to achieve the proposed total phosphorus TSI target. This reduction is based in large part on the BATHTUB mathematical modeling of the reservoir and its predicted response to nutrient load reductions. The FLUX model was used to facilitate the analysis and reduction of tributary inflow and outflow nutrient and sediment loadings for the Sheep Creek Dam. Output from the FLUX program is then provided as an input file to calibrate the BATHTUB eutrophication response model. The phosphorus reduction is predicted to result in a reservoir that is eutrophic throughout a given year as measured by the chlorophyll-*a* concentration.

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. The initial load reductions specified by this TMDL will be achieved through controls on the critical cells within the watershed to improve pasture conditions or improve tillage practices.

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 when establishing TMDLs , targets, and allocations.

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

SUMMARY – A 10% explicit margin of safety is included in the TMDL. It is anticipated that the load reductions from the BMPs applied to the critical cells in the watershed along with hypolimnetic withdrawal 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
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☐ 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 Sheep Creek Dam is a 221.25 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.

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

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

SUMMARY – This TMDL addresses the need to achieve further reductions in nutrients to attain water quality goals in Sheep Creek Dam. 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 land with a slope greater than five percent, cropland not currently using no till cultivation practices and pasture land in poor or fair condition. See the shaded cells in Figure 9 of the TMDL and the BMPs mentioned in Section 5.3. Additional land management practices that may significantly reduce nutrient runoff yields include exclusion of cattle from the riparian area, intensive grazing management and the replacement or repair of possible faulty septic systems in the watershed. There is a desire to move forward with controls in the areas of the basin where there is confidence that phosphorus reductions can be achieved through these BMPs.

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
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☐ 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 two newspapers.

10. Monitoring Strategy

Criterion Description – Monitoring Strategy

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

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

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

11. Restoration Strategy

Criterion Description – Restoration Strategy

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

☐ Satisfies Criterion
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☐ 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 with EPA and is not a requirement under the Clean Water Act for approving TMDLs. States are

- ☐ Satisfies Criterion
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- ☐ 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.