Nutrient and Dissolved Oxygen TMDLs for Braddock Dam in Emmons County, North Dakota

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1.0 INTRODUCTION AND DESCRIPTION OF THE WATERSHED

Braddock Dam (also referred to as Braddock Lake), located southwest of Braddock, ND (Figure 1), is a 91.2 acre multipurpose reservoir built in 1939 under the Works Project Administration (WPA) (NDDoH, 1993).

The recreational opportunities on Braddock Dam include fishing, boating, hiking, and swimming. Braddock Dam's recreational area is public friendly with a picnic area, outdoor toilets, boat ramp, and parking (Figure 2). Public use of Braddock Dam is a sporadic, depending on water quality and the productivity of the fishery (NDDoH, 1993).

The Braddock Dam watershed lies entirely within the level IV ecoregion, Missouri Coteau Slope ecoregion (42c). The Missouri Coteau Slope ecoregion declines in elevation from the Missouri Coteau ecoregion (42a) to the Missouri River. Unlike the Missouri Coteau ecoregion (42a) where there is a paucity of streams, the Missouri Coteau Slope has a simple drainage pattern and fewer wetland depressions. Due to the level to gently rolling topography, there is more cropland than on the Missouri Coteau (42a). Cattle graze on the steeper land that occurs along drainages (Figure 3). The youthful morainal landscape has significant surface irregularity and a high concentration of wetlands. The rise in elevation along the eastern boundary defines the beginning of the Great Plains. Land use is transitional between the intensive dryland farming in the Drift Plains ecoregion (46i) located to the east, and the predominance of cattle ranching and farming to the west within the Missouri Coteau ecoregion (43a) (USGS, 2006). Table 1 summarizes some of the geographical, hydrological, and physical characteristics of Braddock Dam and its watershed.

Table 1. General Characteristics of Braddock Dam and the Braddock Dam Watershed.

Legal Name	Braddock Dam
Major Drainage Basin	Missouri River Basin
Nearest Municipality	Braddock, North Dakota
Assessment Unit ID	ND-10130103-003-L_00
County Location	Emmons County
Physiographic Region	Missouri Coteau
Watershed Area	40,817.68 acres
Surface Area	91.2 acres
Average Depth	4.9 feet
Maximum Depth	17.8 feet
Volume	430.0 acre/feet
Tributaries	Unnamed Tributary
Type of Waterbody	Reservoir
Dam Type	Earthen Dam
Fishery Type	Northern Pike, Large mouth bass, Walleye, Perch, Crappie and Bluegill

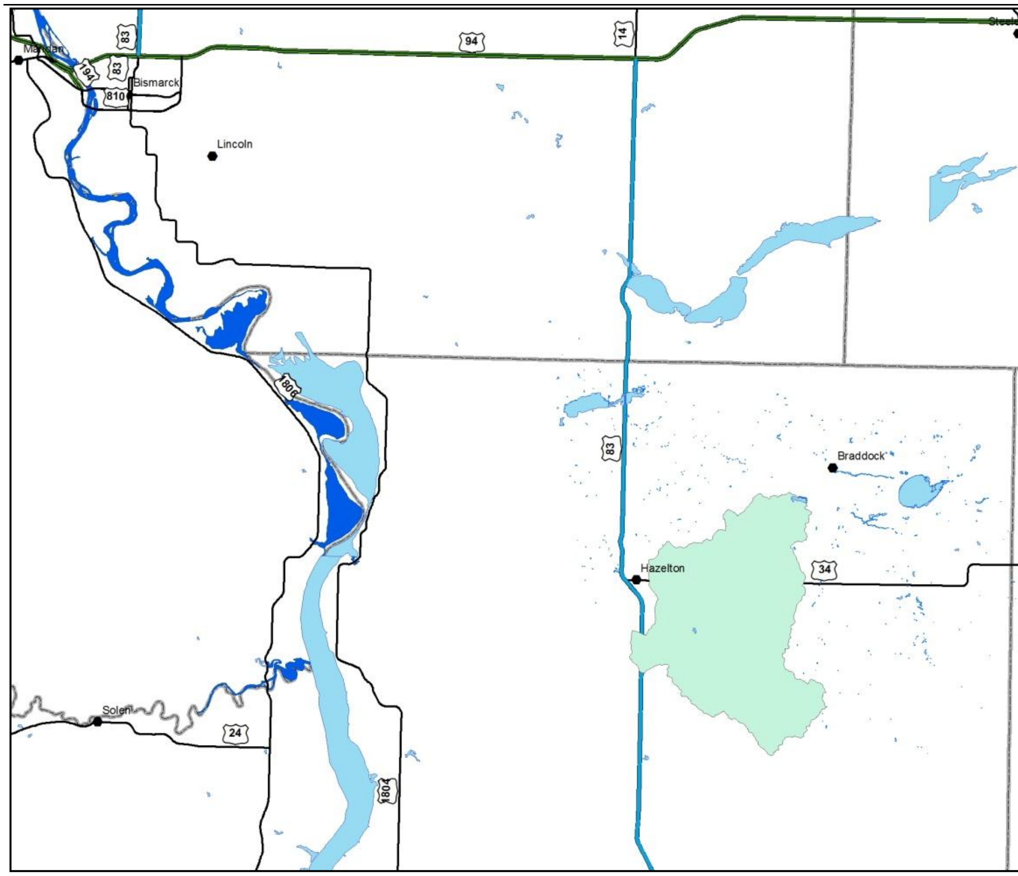

Figure 1. General Location of the Braddock Dam Watershed.

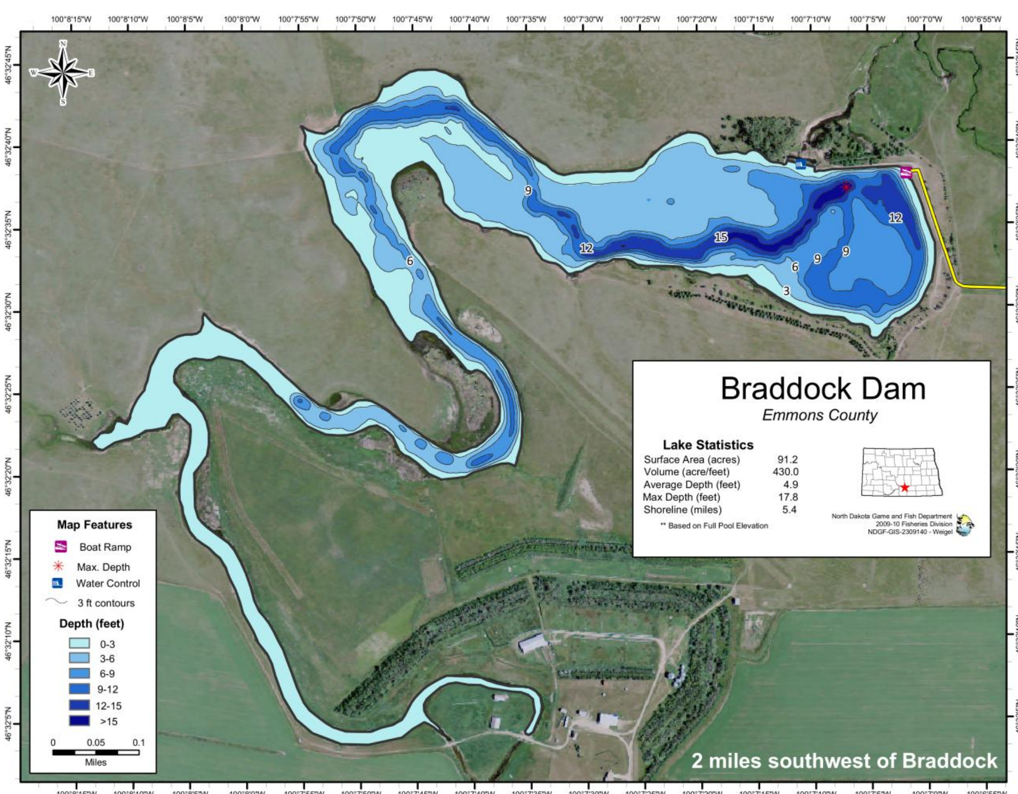

Figure 2. North Dakota Game and Fish Countour Map of Braddock Dam.

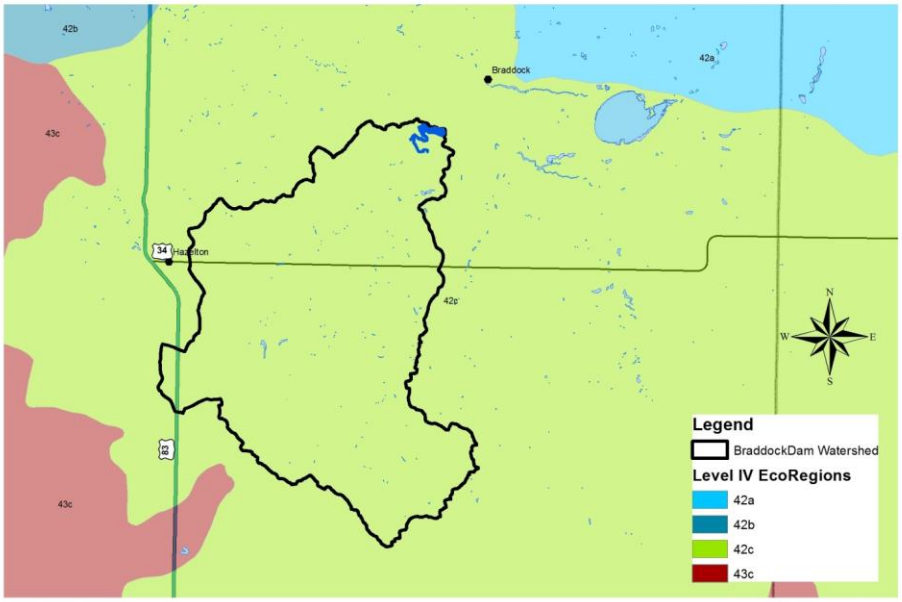

Figure 3. Level IV Ecoregions in the Braddock Dam Watershed.

1.1 Clean Water Act Section 303(d) Listing Information

As part of the 2012 Section 303(d) List of Impaired Waters Need Total Maximum Daily Loads (i.e., 2012 TMDL List), the North Dakota Department of Health (NDDoH) has assessed Braddock Dam as "fully supporting, but threatened" (i.e., impaired) for "fish and other aquatic biota" (i.e., aquatic life) and recreation uses (NDDoH, 2012). It should be noted that this assessment was first done for the 1998 Section 303(d) listing cycle using the 1992-1993 LWQA total phosphorus data as the primary trophic status indicator (Table 2). As described in the 2012 TMDL list, the causes of the aquatic life use impairment were described as "sedimentation/siltation", "nutrient/eutrophication/ biological indicators", and "low dissolved oxygen", while the cause of the recreation use impairment was described as only "nutrient/eutrophication/biological indicators." North Dakota's 2012 TMDL list did not provide information on any potential sources of these impairments.

This TMDL report addresses both the aquatic life and recreation impairments caused by "nutrient/eutrophication/biological indicators" and the aquatic life impairment caused by "low dissolved oxygen." Sediment remains as a Section 303(d) TMDL listed pollutant threatening aquatic life use. Once the suspended sediment data that we collected as part of the watershed assessment project are made available (NDDoH, 2009), these data will be analyzed and a TMDL will be prepared to address this pollutant.

Braddock Dam has been classified as a Class 3 warm water fishery, "Waters capable of supporting natural reproduction and growth of warm water fishes (e.g., largemouth bass and bluegill) and associated aquatic biota. Some cool water species may also be present." (NDDoH, 2011).

1.2 Land Use/Land Cover

Land use in the Braddock Dam watershed is primarily agricultural. According to the 2010 National Agricultural Statistical Service (NASS) land survey data, approximately

75 percent of the land is active cropland, 19 percent pasture/grassland, four (4) percent developed open space, and two (2) percent in other land uses. The majority of the crops grown consist of spring wheat, sunflower, and soybeans, corn, barley and winter wheat (Figure 4).

Table 2.Braddock Dam Section 303(d) Listing Information (NDDoH, 2012).

Assessment Unit ID	ND-10130103-003-L_00
Waterbody Name	Braddock Dam
Class	Class 3, Warm water fishery
Impaired Uses	Fish and Other Aquatic Biota, Recreation (Fully supporting, but threatened)
Causes	Sedimentation, Nutrient/Eutrophication Biological Indicators, and Low Dissolved Oxygen
Priority	High
First Appeared on 303(d) list	1998

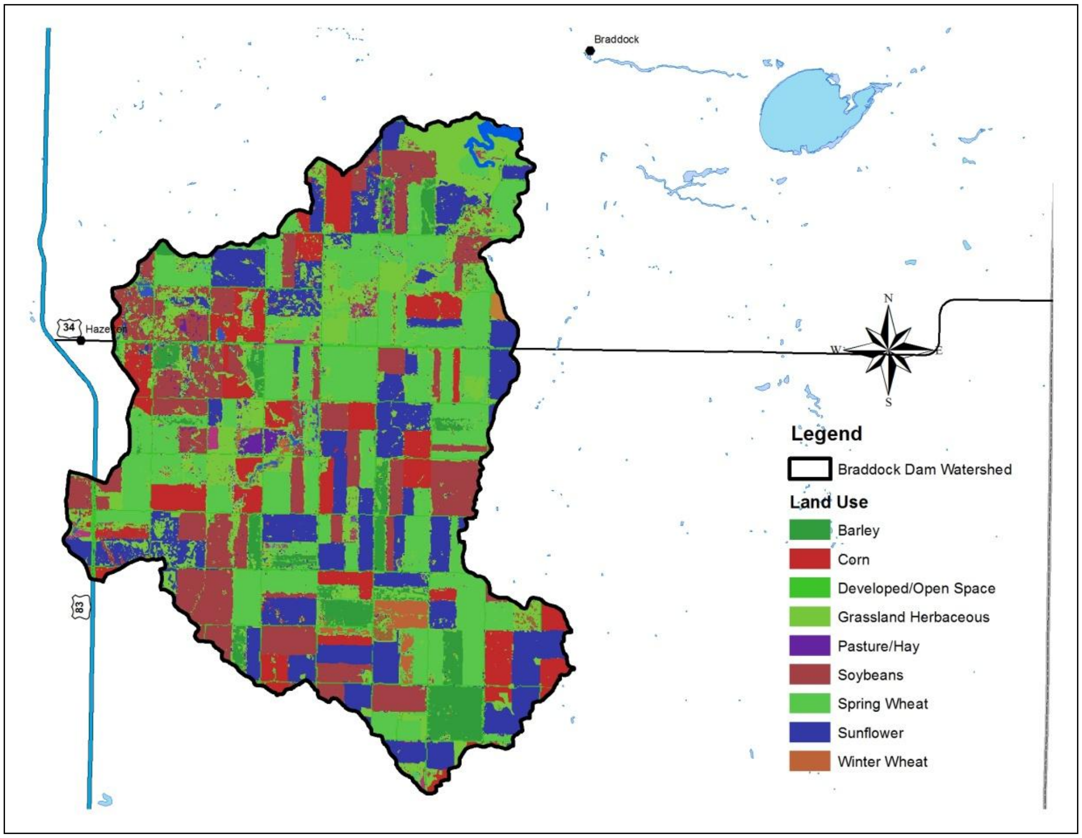

Figure 4. Braddock Dam Watershed Land Use Map (Based on the 2010 National Agricultural Statistical Survey).

1.3 Climate and Precipitation

Emmons County has a subhumid climate characterized by warm summers with frequent hot days and occasional cool days. Winters are very cold influenced by blasts of arctic air surging over the area. Precipitation occurs primarily during the warm period and is normally heavy in late spring and early summer. Total average annual precipitation for Emmons County is about 19 inches. Average seasonal snowfall is approximately 43 inches. Figure 5 shows the average monthly precipitation for Emmons County from 1948-2011, as represented by the High Plains Regional Climate Center (HPRCC) weather station located in Hazelton, ND.

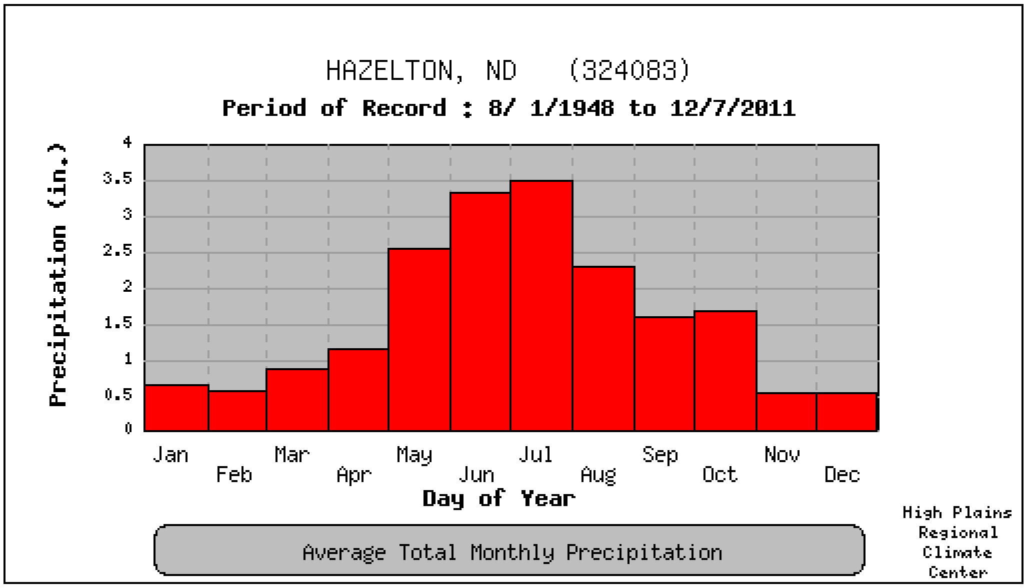

Figure 5. Average Total Monthly Precipitation at Hazelton, North Dakota from 1948-2011 (Data from the High Plains Regional Climate Center Station located at Hazelton, ND).

1.4 Available Water Quality Data

1.4.1 1992-1993 Lake Water Quality Assessment Project

In the early 1990's through a grant from the EPA Clean Lakes Program the NDDoH conducted a Lake Water Quality Assessment Project (LWQA) on 111 lakes and reservoirs in the state. The objective of the LWQA project was to describe the general physical and chemical condition of the state's lakes and reservoirs (NDDoH, 1993).

In cooperation with the North Dakota Game and Fish Department, lakes and reservoirs were targeted based on specific criteria. Those criteria consisted of geographic distribution, local and regional significance, fishing and recreational potential and relative trophic condition. Lakes received the highest priority if they had insufficient historical monitoring information (NDDoH, 1993).

Braddock Dam was one of the reservoirs targeted for the 1992-1993 LWQA. As such, monitoring consisted of two samples collected in the summer of 1992 and one during the winter of 1993. The samples were collected at one site located in the deepest area of the lake. The 1992-1993 LWQA Project characterized Braddock Dam as having mean surface concentration of total phosphorus of 0.28 mg/L, which exceeded the State's guideline goal for lake maintenance and improvement of 0.02 mg/L. Nitrate + nitrite as N exhibited a volume weighted mean concentration of 0.021 mg/L, which suggests Braddock Dam was a nitrogen limited waterbody.

While there was no evidence of thermal stratification in Braddock Dam during 1992-1993 (Figure 7), the lake did experience significant dissolved oxygen depletion near the lake's bottom during summer and throughout the lake's water column during winter (Figure 8).

1.4.2 2010-2011 Braddock Dam TMDL Development and Watershed Assessment Project

The Emmons County Soil Conservation District (SCD) conducted a TMDL development and watershed assessment of Braddock Dam and its watershed in 2010 and 2011. Sampling was conducted at one tributary inlet site (385538), at the outlet from Braddock Dam (385539), and at one reservoir site located in the deepest area of the reservoir (381365). Monitoring sites are identified in Table 3 and Figure 6.

The Emmons County SCD followed the methodology for water quality sampling found in the Quality Assurance Project Plan (QAPP) for the Long Lake Creek/Braddock Dam TMDL Development and Watershed Assessment Project (NDDoH, 2009).

Stream Monitoring

Stream sampling was conducted in 2010 and 2011. 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, typically when stream discharge is greatest and less frequent samples collected during the summer and fall. Sampling was discontinued during the winter during ice cover. Stream sampling was also terminated if the stream stopped flowing. If the stream began to flow again, water quality sampling was reinitiated.

Lake Monitoring

In order to accurately account for temporal variation in lake water quality, the lake was sampled twice per month during the open water season and monthly under ice cover conditions. Lake sampling was conducted only in 2010.

Table 3. General Information for Water Sampling Sites for Braddock Dam.

Sample Site	Site ID	Dates Sampled		Latitude	Longitude
		Start	End		
Stream Sites					
Inlet	385538	March 2010	October 2011	46.51624	-100.1427
Outlet	385539	March 2010	October 2011	46.54442	-100.11942
Lake Sites					
Deepest	381365	April 2010	September 2010	46.54252	-100.11901

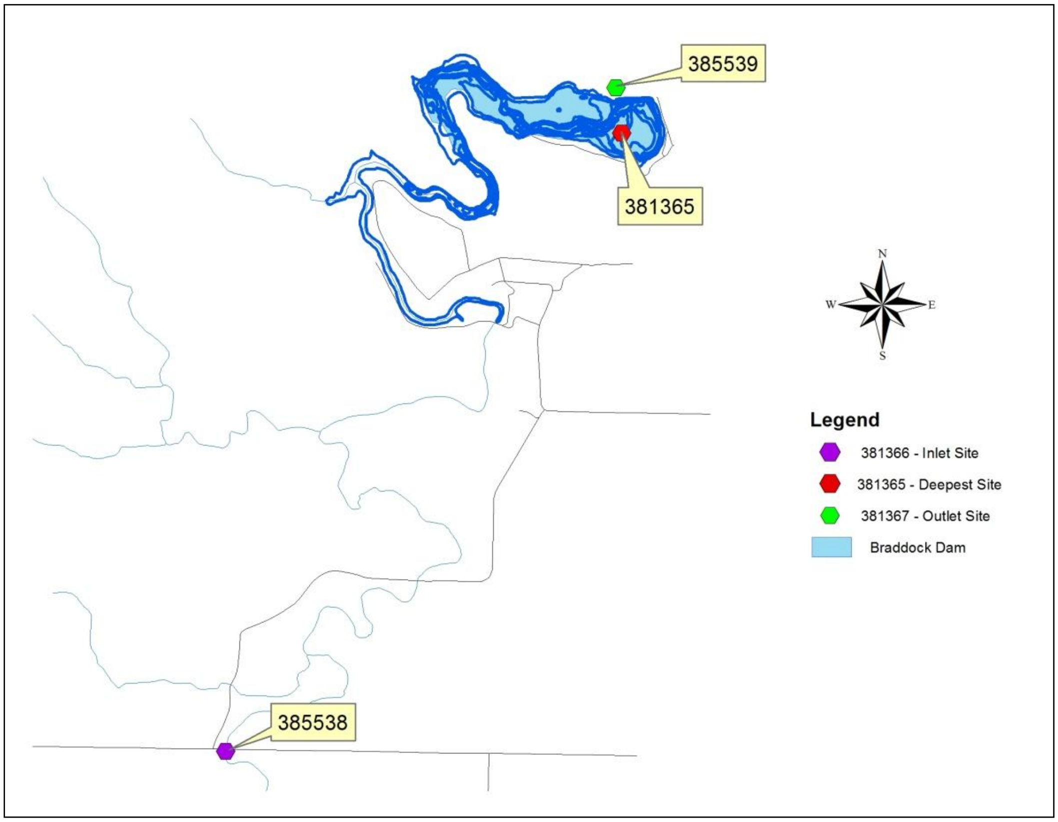

Figure 6. Stream and Lake Sampling Sites for Braddock Dam.

1.4.3 2010 Water Quality Data

Water quality was monitored by the Emmons County SCD in Braddock Dam Dam at the deepest site (381365) between April 2010 and September 2010. Table 4 shows the resulting data used to calibrate the BATHTUB/CNET model used in the TMDL.

Table 4. 2010 Growing Season Total Phosphorus, Chlorophyll-a and Total Nitrogen Water Quality Data.

Statistic	TP (µg/L)	Chlorophyll-a (µg/L)	TN (mg/L)
N	33	10	33
Average	210.4	27.5	1.37
Minimum	46.0	1.5	0.99
Maximum	644.0	106.0	2.04
Median	236.0	17.6	1.36

1.4.4 2010 Secchi Disk Transparency Data

Secchi disk transparency data were collected during the open water period by the the Emmons County SCD between April and September 2010. The average Secchi disk transparency for the 2010 sampling period was 1.43 meters (Table 5).

Table 5. 2010 Secchi Disk Transparency Measurements in Braddock Dam Deepest Site 381365.

Date	Secchi Disk Transparency (meters)	Date	Secchi Disk Transparency (meters)
4/20/2010	1.1	8/31/2010	0.8
7/6/2010	2.0	9/13/2010	0.5
8/9/2010	1.6	9/27/2010	2.1

1.4.6 2010 Temperature/Dissolved Oxygen Profiles

Braddock Dam showed no evidence of thermal stratification during the April through September 2010 sampling period (Figure 7). While there were no measurements that exceeded the 5 mg/L dissolved oxygen standard, there was evidence of significant oxygen depletion near the lakes bottom and supersaturated oxygen concentrations near the lakes surface (Figure 8)

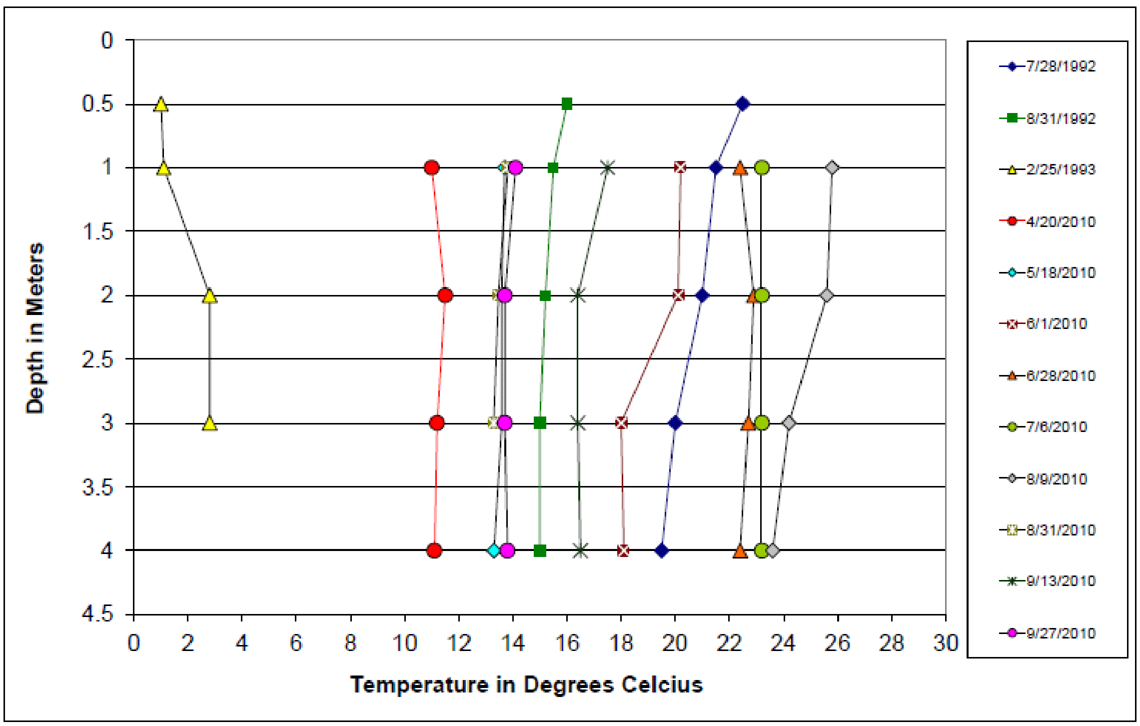

Figure 7. Braddock Dam Temperature Profiles Taken in 1992, 1993 and 2010.

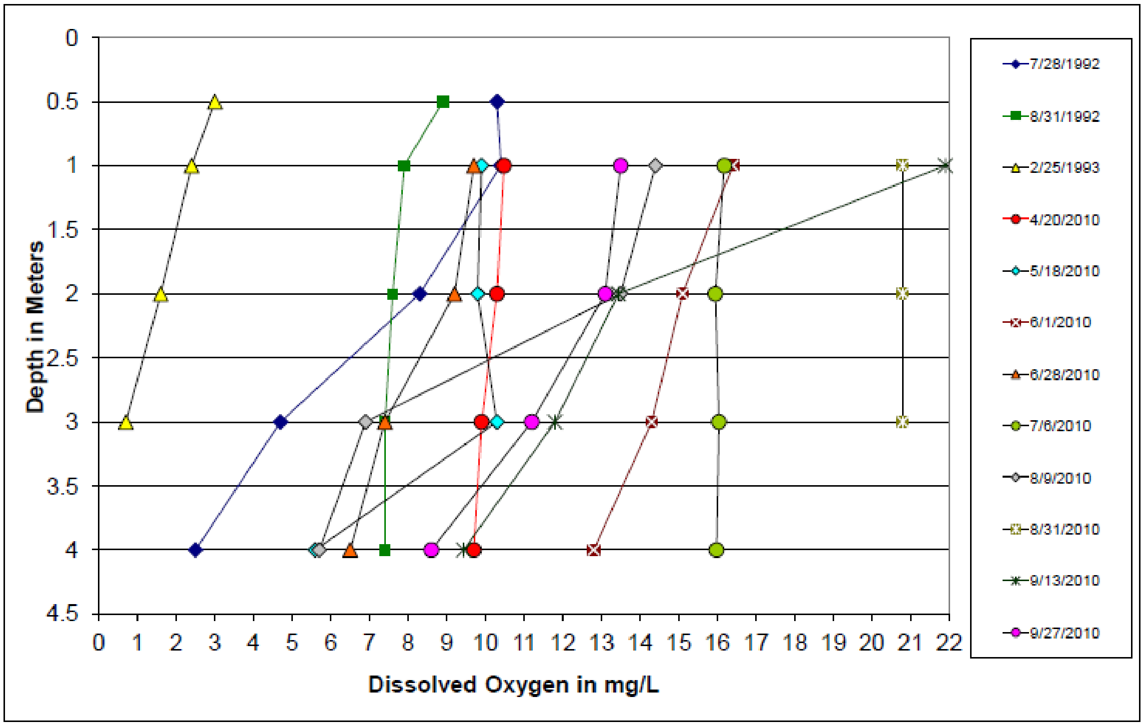

Figure 8. Braddock Dam Dissolved Oxygen Profiles Taken in 1992, 1993 and 2010.

2.0 WATER QUALITY STANDARDS

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

2.1 Narrative Water Quality Standards

The NDDoH 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, 2011).

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

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

3) Directly or indirectly cause concentrations of pollutants to exceed applicable standards of the receiving waters.

In addition to the narrative standards, the NDDoH has set a biological goal for all surface waters in the state. The goal states that "the biological condition of surface waters shall be similar to that of sites or waterbodies determined by the department to be regional reference sites," (NDDoH, 2011).

2.2 Numeric Water Quality Standards

Braddock Dam is classified as a Class 3 warm water fishery. Class 3 fisheries are defined as waterbodies "capable of supporting natural reproduction and growth of warm water fishes (i.e. largemouth bass and bluegill) and associated aquatic biota. Some cool water species may also be present" (NDDoH, 2011). All classified lakes in North Dakota are assigned aquatic life, recreation, irrigation, livestock watering, and wildlife beneficial uses. The North Dakota State Water Quality Standards (NDDoH, 2011) state that lakes shall use the same numeric criteria as Class 1 streams, including the State standard for dissolved nitrate as N, of 1.0 mg/L, where up to 10 percent of samples may exceed the 1.0 mg/L, and State guideline nutrient goals for lakes and reservoirs (Table 6).

Table 6. Numeric Standards Applicable for North Dakota Lakes and Reservoirs (NDDoH , 2011).

State Water Quality Standard	Parameter	Guidelines	Limit
Numeric Standard for Class I and Classified Lakes	Nitrates (dissolved)	1.0 mg/L	Maximum allowed[1]
	Dissolved Oxygen	5 mg/L	Daily Minimum[2]
Guidelines for Goals in a Lake Improvement or Maintenance Program	NO3 as N	0.25 mg/L	Goal
	PO4 as P	0.02 mg/L	Goal

1 "Up to 10% of samples may exceed"

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

3.0 TMDL TARGETS

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

3.1 TSI Target Based on Chlorophyll-a

The state's narrative water quality standards (see Section 2.1) form the basis for aquatic life and recreation use assessment for Section 305(b) reporting and Section 303(d) TMDL listing. In the case of this TMDL, the state's narrative water quality standards also form the basis for setting the TMDL target. State water quality standards contain narrative criteria that require lakes and reservoirs to be "free from" substances "which are toxic or harmful to humans, animals, plants, or resident aquatic biota" or are "in sufficient amounts to be unsightly or deleterious." Narrative standards also prohibit the "discharge of pollutants" (e.g., organic enrichment, nutrients, or sediment), "which alone or in combination with other substances, shall impair existing or reasonable beneficial uses of the receiving waters."

The chlorophyll-a trophic status indicator is used by the NDDoH as the primary means to assess whether a lake or reservoir is meeting the narrative standards (NDDoH, 2011). Trophic status is a measure of the productivity of a lake or reservoir and is directly related to the level of nutrients (i.e., phosphorus and nitrogen) entering the lake or reservoir from its watershed and/or from the internal recycling of nutrients. Highly productive lakes, termed "hypereutrophic," contain excessive phosphorus and are characterized by dense growths of weeds, blue-green algal blooms, low transparency, and low dissolved oxygen (DO) concentrations. These lakes experience frequent fish kills and are generally characterized as having excessive rough fish populations (carp, bullhead, and sucker) and poor sport fisheries (Table 7). Due to the frequent algal blooms and excessive weed growth, these lakes are also undesirable for recreational uses such as swimming and boating.

Mesotrophic and eutrophic lakes, on the other hand, generally have lower phosphorus concentrations, low to moderate levels of algae and aquatic plant growth, high transparency, and adequate DO concentrations throughout the year. Mesotrophic lakes do not experience algal blooms, while eutrophic lakes may occasionally experience algal blooms of short duration, typically a few days to a week (Table 7).

Therefore, for purposes of this TMDL report, it can be concluded that hypereutrophic lakes do not fully support a sustainable sport fishery and are limited in recreational uses, whereas eutrophic and mesotrophic lakes fully support both aquatic life and recreation use.

Due to the relationship between trophic status indicators and the aquatic community (as reflected by the fishery) or between trophic status indicators and the frequency of algal blooms, trophic status is an effective indicator of aquatic life and recreation use support in lakes and reservoirs (Table 7).

While the three trophic state indicators, chlorophyll-*a*, Secchi disk transparency, and total phosphorus, used in Carlson's TSI each independently estimate algal biomass and should produce the same index value for a given combination of variable values, often they do not. While transparency and phosphorus may co-vary with trophic state, many times the changes in observed in a lake's transparency are not caused by changes in algal biomass, but may be due to particulate sediment. Total phosphorus may or may not be strongly related to algal biomass due to light limitation and/or nitrogen and carbon limitation. Therefore, neither transparency nor phosphorus is an independent estimator of trophic state (Carlson and Simpson, 1996). For these reasons, the NDDoH gives priority to chlorophyll-*a* as the primary trophic state indicator because this variable is the most accurate of the three at predicting algal biomass (Carlson, 1980).

Table 7. Water Quality and Beneficial Use Changes That Occur as the Amount of Algae (expressed as Chlorophyll-a concentration) Changes Along the Trophic State Gradient (from Carlson and Simpson, 1996).

TSI Score	Chlorophyll-a (µg/L)	Secchi Disk Transparency (m)	Total Phosphorus (µg/L)	Attributes	Fisheries & Recreation
<30	<0.95	>8	<6	**Oligotrophy**: Clear water, oxygen throughout the year in the hypolimnion	Salmonid fisheries dominate
30-40	0.95-2.6	8-4	6-12	Hypolimnia of shallower lakes may become anoxic	Salmonid fisheries in deep lakes only
40-50	2.6-7.3	4-2	12-24	**Mesotrophy**: Water moderately clear; increasing probability of hypolimnetic anoxia during summer	Hypolimnetic anoxia results in loss of salmonids. Walleye may predominate
50-60	7.3-20	2-1	24-48	**Eutrophy**: Anoxic hypolimnia, macrophyte problems possible	Warm-water fisheries only. Bass may dominate.
60-70	20-56	0.5-1	48-96	Blue-green algae dominate, algal scums and macrophyte problems	Nuisance macrophytes, algal scums, and low transparency may discourage swimming and boating.
70-80	56-155	0.25-0.5	96-192	**Hypereutrophy**: (light limited productivity). Dense algae and macrophytes	
>80	>155	<0.25	192-384	Algal scums, few macrophytes	Rough fish dominate; summer fish kills possible

The same conclusion was also reached by a multi-state project team consisting of lake managers and water quality specialists from North Dakota, South Dakota, Montana, Wyoming and EPA Region 8. This group concluded that for lakes and reservoirs in the plains region of EPA Region 8, an average growing season chlorophyll-a concentration of 20 µg/L or less should be the basis for nutrient criteria development for lakes and reservoirs in the plains region (including North Dakota) and that this chlorophyll-a target would be protective of all of a lake or reservoir's beneficial uses, including recreation and aquatic life (Houston Engineering, 2011). The report, prepared by Houston Engineering, also concluded that most lakes and reservoirs in the plains region typically have high total phosphorus concentrations, but maintain relatively low productivity, and that due to this condition, chlorophyll-a is a better measure of a lake or reservoirs trophic status than is total phosphorus (Houston Engineering, 2011).

Water quality data collected in the lake in 2010 showed an average chlorophyll-a concentration of 27.5 μg/l, an average total phosphorus concentration of 210.4 μg/L, an average Secchi Depth of 1.2 meters, and an average total nitrogen concentration of 1.4 mg/l. Based on these data, Braddock Dam is generally assessed as a eutrophic lake (Table 8).

Table 8. Carlson's Trophic State Indices for Braddock Dam.

Parameter	Relationship	Units	TSI Value	Trophic Status
Chlorophyll-a	TSI (Chl-a) = 30.6 + 9.81[ln(Chl-a)]	μg/L	63.1	Eutrophic
Total Phosphorus (TP)	TSI (TP) = 4.15 + 14.42[(ln(TP)]	μg/L	81.3	Hypereutrophic
Secchi Depth (SD)	TSI (SD) = 60 - 14.41[ln(SD)]	meters	57.4	Eutrophic
Total Nitrogen (TN)	TSI (TN) = 54.45 + 14.43[ln(TN)]	mg/L	59.3	Eutrophic

TSI < 30 - Oligotrophic (least productive) TSI 30-50 Mesotrophic
TSI 50-65 Eutrophic TSI > 65 - Hypereutrophic (most productive)

Based only on the total phosphorus data and corresponding TSI value of 81.3, Braddock Dam would be considered a hypereutrophic reservoir (Table 8). However, Carlson and Simpson (1996) suggest that if the phosphorus TSI value is higher than the chlorophyll-a and Secchi disk transparency TSI value (as is the case with Braddock Dam), then algae does not dominate light attenuation, and some other factor, such as nitrogen limitation, zooplankton grazing, or toxics may be limiting algal biomass in the lake (Table 9).

Table 9. Relationships Between TSI Variables and Conditions.

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

As stated previously, the NDDoH has established an in-lake growing season average chlorophyll-a concentration goal of 20 μg/L for most lake and reservoir nutrient TMDLs, including this TMDL for Braddock Dam. This chlorophyll-a goal corresponds to a chlorophyll-a TSI of 60 which is in the eutrophic range and, as such, will be a trophic state sufficient to maintain both aquatic life and recreation uses of most lakes and reservoirs in the state, including Braddock Dam.

Through the use of a calibrated water quality model like CNET (see Section 5.2), the average growing season TP load corresponding to an average growing season chlorophyll-a concentration of 20 μg/L can be estimated. For this TMDL, a 40 percent reduction in the observed total phosphorus load, or 3,058 kg, is estimated to be needed to achieve the TMDL goal for Braddock Dam.

3.2 Dissolved Oxygen TMDL Target

The North Dakota State Water Quality Standard for dissolved oxygen is "5 mg/L as a daily minimum", and where up to 10% of representative samples collected during any three year period may be less than this value provided that lethal conditions are avoided. This will be the dissolved oxygen TMDL target for Braddock Dam

4.0 SIGNIFICANT SOURCES

There are no known point sources located with the Braddock Dam watershed. The pollutants of concern originate from non-point sources.

5.0 TECHNICAL ANALYSIS

Establishing a relationship between in-stream water quality targets and pollutant source loading is a critical component of TMDL development. Identifying the cause-and-effect relationship between pollutant loads and the water quality response is necessary to evaluate the loading capacity of the receiving 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 used to estimate existing loads to Braddock Dam and the predicted trophic response of the reservoir to reductions in loading capacity.

5.1 Tributary Load Analysis

The NDDoH provided the daily flow and tributary chemistry data files to use in estimating total phosphorus loads to Braddock Dam over the growing season, defined as the period of time from April 1 through November 30. FLUX32 (http://www.wes.army.mil/el/elmodels/emiinfo.html) was used to facilitate the analysis, to reduce the gaged inflow and outflow data, and to estimate growing season phosphorus loads. FLUX32 is an interactive program used for analyzing streamflow data and estimating loads (mass transports) of nutrients and other water quality constituents passing a tributary sampling point over a given period of time.

The FLUX32 program was used to estimate the annual growing season total phosphorus (TP) load for the gaged area upstream of Braddock Dam and the gaged outflow from the lake. Mean daily flow data were provided by the NDDoH for the years 2010 and 2011, as well as several flow measurements paired with corresponding TP measurements. Because the water quality goal for the lake is based upon a growing season mean chlorophyll-a concentration, the data analysis was performed for the months of April through November. The screen/filter option in FLUX32 was used to exclude data outside the defined growing season for both 2010 and 2011.

The basic approach of FLUX32 is to use one of several calculation techniques to map the flow/concentration relationship developed from the sample record onto the entire flow record. FLUX32 has the ability to stratify the data into groups based upon streamflow, date, and/or season for the purpose of reducing the error in the load estimate. To check for any relationships or trends in the data that would indicate that stratification of the data could be used to improve the results, various plots of the sample flows and concentrations were developed and analyzed.

5.2 BATHTUB/CNET Trophic Response Model

The CNET model was selected to simulate the eutrophication response within Braddock Dam. CNET is a modified version of the BATHTUB water quality model (Walker, 1996, http://wwwalker.net/bathtub/index.htm). Both BATHTUB and CNET perform 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 reservoirs.

CNET is a spreadsheet model currently available as a "beta" version from Dr. William W. Walker. The primary benefit of using CNET over BATHTUB is that the user can modify the CNET model to implement a Monte Carlo approach. To complete the Monte Carlo modeling, the CNET model was linked with a program called Crystal Ball. Crystal Ball is proprietary software developed by Oracle (http://www.oracle.com/us/products/applications/crystalball/index.html) and is applicable to Monte Carlo or stochastic simulation and analysis. Stochastic modeling is an approach where model parameters and forcing data (e.g., precipitation) used in the equations to compute the annual mean concentration of total phosphorus (TP), chorophyll-a (chl-*a*), and Secchi Disk (SD) are allowed to vary according to their statistical distribution and therefore their probability of occurrence. This allows the effect of parameter uncertainty and normal variability in the inputs (e.g., amount of surface runoff which varies annually depending upon the amount of precipitation) to be quantified when computing the mean concentration of TP, chl-*a*, and SD.

The CNET model was developed in three phases. The first two phases involve the analysis and reduction of the tributary and in-lake water quality data, respectively. 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.

As described in Section 5.1, the tributary data were analyzed and reduced by the FLUX32 program. Output for the FLUX32 program is then used as input to the CNET model.

In addition to the estimated loads from the FLUX32 program, the CNET model requires information about each components of the water budget and nutrient mass balance in order to estimate in-lake water quality concentrations. The development of the water budget and nutrient mass balances can be found in Appendix B.

The reservoir water quality data needed to calibrate the model were reduced and summarized in Excel using three computational functions. These include: 1) the ability to display concentrations as a function of depth, location, or date; 2) summary statistics (mean, median, etc.); and 3) evaluation of the trophic status. The reservoir water quality data were summarized as the 2010 growing season average.

When the input data from FLUX and Excel programs are entered into the CNET model, the user has the ability to compare predicted conditions (model output) to actual measured concentrations. The model is considered calibrated when the predicted concentrations for the trophic response variables are similar to observed concentrations based on the monitoring data. CNET then has the ability to predict total phosphorus concentration, chlorophyll-a concentration, and Secchi disk depth based on changes in total phosphorus loading.

The CNET model was calibrated to estimate the mean growing season (April through November) concentrations of total phosphorus, chlorophyll-a, and Secchi depth based on the observed growing season total phosphorus load of 5,097 kg. Further, it is estimated that 4,953 kg comes from surface water runoff, 133 kg from internal loading, and 11 kg from atmospheric deposition (see nutrient budget in Appendix B). Incremental reductions in the growing season total phosphorus loads were simulated using CNET to show the trophic effect of lowering loads to Braddock Dam. A series of model scenarios were performed, where each scenario reflected an incremental reduction of 10% in the total growing season total phosphorus load to Braddock Dam. Appendix C provides a more detailed description of the modeling process, including figures showing the effects of reducing April through November TP loads to Braddock Dam.

The loading capacity of Braddock Dam was computed using a stochastic approach based on the hydrology and water quality simulated by the CNET model. The loading capacity (maximum allowable load) for the reservoir was defined as the growing season TP load resulting in a seasonal mean chlorophyll-a concentration for the 50^{th} percentile non-exceedance value of 20.0 μg/L. The mean seasonal chlorophyll-a concentration is shown by Figure 9. The curve nearest to the value 20.0 μg/L of chlorophyll-a for the 50 percentile value is used to estimate the loading capacity. The value of 20.0 μg/L of chlorophyll-a represents the growing season mean chlorophyll-a eutrophication goal for nondegradation and corresponds to a TSI value of 60 (eutrophic). Figure 9 shows the curve with a chlorophyll-a concentration closest to 20.0 μg/l for the 50^{th} percentile value is for a total TP load of 3,058 during the April – November growing season.

5.3 AnnAGNPS Watershed Model

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

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

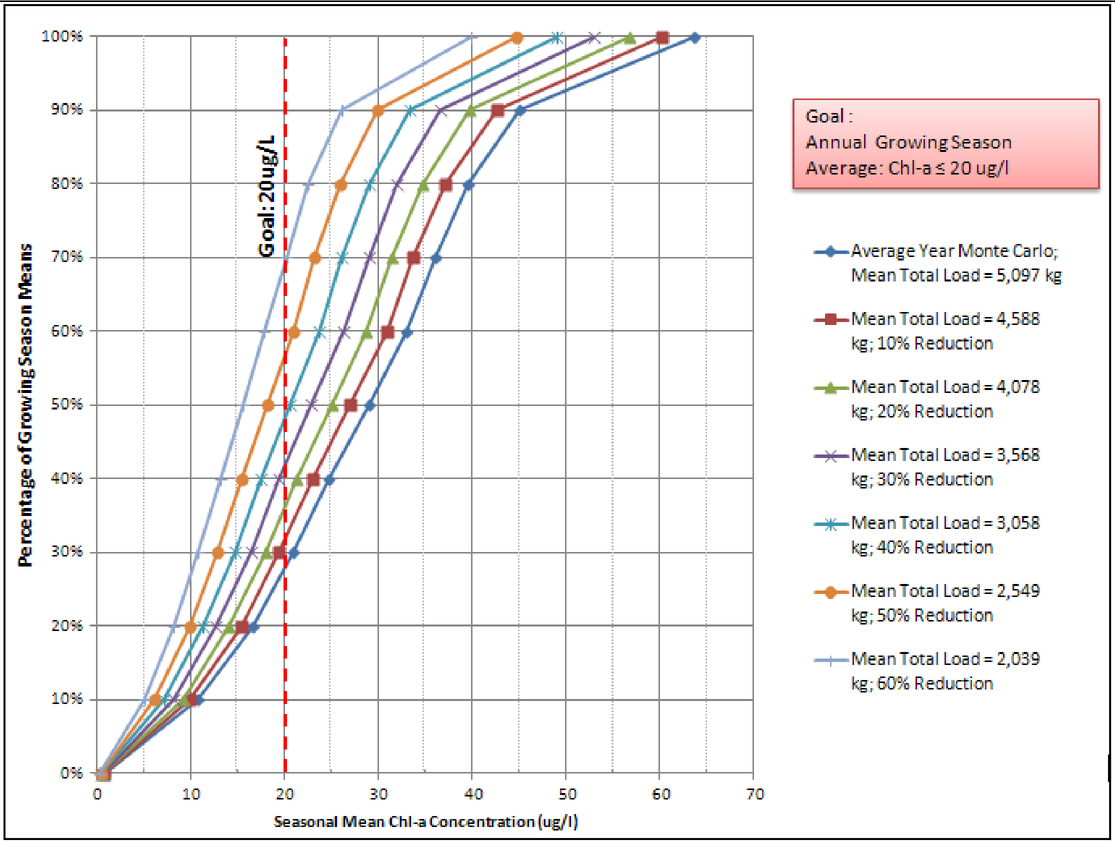

Figure 9. Braddock Dam Frequency Distribution Growing Season (April through November) Mean Chlorophyll-a Concentrations Resulting from Select Load Reduction Scenarios.

The AnnAGNPS model is able to partition soluble nutrients between surface runoff and infiltration. Sediment-attached nutrients are also calculated in the stream system. Sediment is divided into five particle size classes (clay, silt, sand, small aggregate, and large aggregate) and are moved separately through the stream reaches. AnnAGNPS uses various models to develop an annualized load in the watershed. These models account for surface runoff, soil moisture, erosion, nutrients, and reach routing. Each model serves a particular purpose and function in simulating the NPS processes occurring in the watershed.

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

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

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

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

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

Input parameters are used to verify the model. Some input parameters may be repeated for each cell, soil type, landuse, feedlot, and channel reach. Default values are available for some input parameters, others can be simplified because of duplication. Daily climatic input data can be obtained through weather generators, local data, and/or both. Geographical input data including cell boundaries, land slope, slope direction, and landuse can be generated by GIS or DEM (Digital Elevation Models).
Output data is expressed through an event based report for stream reaches and a source accounting report for land or reach components. Output parameters are selected by the user for the desired watershed source locations (specific cells, reaches, feedlots, point sources, or gullies) for any simulation period. Source accounting for land or reach components are calculated as a fraction of a pollutant load passing through any reach in the stream network that came from the user identified watershed source locations. Event based output data is defined as event quantities for user selected parameters at desired stream reach locations.

AnnAGNPS was utilized for the Braddock Dam TMDL Development and Watershed Assessment project. The Braddock Dam watershed delineation began with downloading a 30-meter digital elevation model (DEM) of Emmons County. Delineation is defined as drawing a boundary and dividing the land within the boundary into subwatersheds in such a matter that each subwatershed has uniformed hydrological parameters (land slope, elevation, etc.).

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

A five year simulation period was run on the Braddock Dam watershed at its present condition to provide a best estimation of the current land use practices applied to the soils and slopes of the watershed to obtain nutrient loads from the individual cells as well as the watershed as a whole. Major land use in the Braddock Dam watershed was identified as wheat, winter wheat, barley, corn, soybeans, dry beans, sunflowers, pasture, rangeland, and residential/urban. Air seeders and conventional tillage were used in the cropland field operations. Crop rotations were determined from three years of land survey data from the National Agricultural Statistical Service (NASS). Typical planting of the fields was done in late April early May with fertilizer being applied at planting in specific amounts determined by crop type, harvest occurred in late September to mid October, spring tillage was done in early May with a chisel. Fertilizer application rates of metaphosphate, 16-52-0 (mono-ammonium phosphate), and multiple forms of anhydrous ammonia (i.e. 80-21-0, 80-26-0, etc.) were determined by the crop rotation and entered into the model.

The compiled data was used to assess the watershed to identify "critical cells" located in the watershed for potential best management practice (BMP) implementation (Figure 10). Critical cells were determined to be cells in the watershed providing an estimated annual phosphorus yield of 0.059 lbs/acre/year or greater.

5.4 Dissolved Oxygen

Based largely on dissolved oxygen data collected in 1992-1993, Braddock Dam was originally listed as fully supporting, but threatened for "fish and other aquatic biota" use because dissolved oxygen levels were observed below the North Dakota water quality standard of 5.0 mg/L as a daily minimum and where up to 10% of representative samples collected during any three year period may be less than this value provided that lethal conditions are avoided. For Braddock Dam, low dissolved oxygen levels appear to be related to excessive algal and weed growth due to nutrient loadings.

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

The CNET model indicated that excessive nutrient loading is occurring and is primarily responsible for the low dissolved oxygen levels in Braddock Dam. Wetzel (1983) summarized, "The loading of organic matter to the hypolimnion and sediments of productive eutrophic lakes increases the consumption of dissolved oxygen. As a result, the oxygen content of the hypolimnion is reduced progressively during the period of summer stratification."

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

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

Nürnberg (1996) developed a model that quantified duration (days) and extent of lake oxygen depletion. The CNET model indicate that excessive nutrient loading is responsible for the low dissolved oxygen depletion, referred to as an anoxic factor (AF). This model showed that AF is positively correlated with average annual total phosphorous (TP) concentrations. The AF may also be used to quantify response to watershed restoration measures which makes it very useful for TMDL development. Nürnberg (1996), developed several regression models that show nutrients control all trophic state indicators related to oxygen and phytoplankton in lakes/reservoirs. These models were developed from water quality characteristics using a suite of North km^{-1} American lakes. The morphometric parameters such as surface area (A_o = 91.2 acres; 0.37 km^2), mean depth (z = 4.9 feet; 1.49 meters) were calculated, and the ratio of mean depth to the surface area is ($z/A_o^{0.5}$ = 2.44) for Braddock Dam. This shows that these parameters are within the range of lakes used by Nürnberg. Based on this information, the Nürnberg's empirical nutrient-oxygen relationship holds true for North Dakota lakes and reservoirs. Prescribed BMPs will reduce external loading of nutrients to the reservoir, which will reduce algae blooms and organic enrichment, and therefore increase dissolved oxygen concentrations to acceptable levels over time.

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 shall 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 percent of the loading capacity will be used as an explicit MOS.

Assuming the existing annual phosphorus load to Braddock Dam from tributary sources and internal cycling is 5,097 kg/season and the TMDL chlorophyll-a goal is the annual average growing season concentration of 20 µg/L, then this would result in a TMDL target total phosphorus loading capacity of 3,058 kg of total phosphorus per season. Based on a 10 percent explicit margin of safety, the MOS for the Braddock Dam TMDL would be 306 kg of phosphorus per season.

Monitoring and adaptive management during the implementation phase, along with post-implementation monitoring related to the effectiveness of the TMDL controls, will be used to ensure the attainment of the 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. The Braddock Dam TMDL addresses seasonality because the CNET and AnnAGNPS models incorporate seasonal differences in their prediction of total phosphorus and nitrogen loadings.

7.0 TMDL

Table 10 summarizes the nutrient TMDL for Braddock Dam in terms of loading capacity, wasteload allocations, load allocations, and a margin of safety. The TMDL can be generically described by the following equation.

TMDL = LC = WLA + LA + MOS

where

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

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

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

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

7.1 Nutrient TMDL

Table 10. Summary of the Phosphorus TMDL for Braddock Dam.

Category	Total Phosphorus (kg/yr)	Explanation
Existing Load	5097	From observed data
Loading Capacity	3058	Total TP load from Monte Carlo modeling corresponding to an annual average growing season chlorophyll-a concentration of 20.0 µg/L
Wasteload Allocation	0	No point sources
Load Allocation	2,752	Entire loading capacity minus MOS is allocated to non-point sources
MOS	306	10% of the loading capacity (kg/yr) is reserved as an explicit margin of safety

Based on data collected in 2010 thru 2011, the existing annual total phosphorus load to Braddock Dam is estimated at 5,097 kg. Assuming a 40 % reduction in the current loading will result in Braddock Dam attaining and maintaining an annual average growing season TMDL target mean chlorophyll-a concentration of 20.0 µg/L, the phosphorus TMDL or Loading Capacity is 3,058 kg per season. Assuming 10 percent of the loading capacity, 306 kg/year is explicitly assigned to the MOS and there are no point sources in the watershed all of the remaining loading capacity, 2,752 kg/year is assigned to the load allocation.

In November 2006 EPA issued a memorandum "Establishing TMDL "Daily" Loads in Light of the Decision by the U.S. Court of Appeals for the D.C. Circuit in Friends of the Earth, Inc. v. EPA et. al., No. 05-5015 (April 25, 2006) and Implications for NPDES Permits," which recommends that all TMDLs and associated load allocations and wasteload allocations include a daily time increment in conjunction with other appropriate temporal expressions that may be necessary to implement the relevant water quality standard. While the North Dakota Department of Health believes that the appropriate temporal expression for phosphorus loading to lakes and reservoirs is as an annual load, the phosphorus TMDL has also been expressed as a daily load. In order to express this phosphorus TMDL as a daily load the annual loading capacity of 3,058 kg/season was divided by 365 days. Based on this analysis, the phosphorus TMDL, expressed as an average daily load, is 8.37 kg/day with the load allocation equal to 7.54 kg/day and the MOS equal to 0.84 kg/day.

7.2 Dissolved Oxygen TMDL

As a result of the direct influence of eutrophication on increased biological oxygen demand and microbial respiration, it is anticipated that meeting the chlorophyll-a concentration target for Braddock Dam will address the dissolved oxygen impairment. A reduction in chlorophyll-a concentration due to the resulting lower algal biomass levels in the water column, would reduce the biological oxygen demand exerted by the decomposition of these primary producers. The reduction in biological oxygen demand is therefore assumed to result in attainment of the dissolved oxygen standard.

8.0 ALLOCATION

A 40 percent total phosphorus load reduction target was established for the entire Braddock Dam watershed. This reduction was set based on the CNET model, which predicted that under similar hydraulic conditions, an external total phosphorus load reduction of 40 percent would lower the average growing season chlorophyll-a concentration from 27.5 µg/L (equivalent to an average growing season TSI of 63.1) to 20.0 µg/L (equivalent to an average growing season total phosphorus TSI of 60.0).

Using the AnnAGNPS model, it was determined that cells with a phosphorus yield of 0.059 lbs/acre/yr or greater as priority areas in the watershed (Figure 10). These priority areas account for approximately 8,618 acres or 21 percent of the watershed and are agriculturally based. These cells are the critical cells which should be examined by an implementation project to determine the necessity and types of BMP's to be implemented. Based on the AnnAGNPS model, if BMP's are implemented on these critical areas, it is estimated that the phosphorus load would be reduced by 50 percent, thereby meeting the TMDL goal.

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

9.0 PUBLIC PARTICIPATION

To satisfy the public participation requirements of this TMDL, a letter was sent to the following participating agencies notifying them that the draft report was available for review and public comment. Those included in the mailing were as follows:

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

In addition to notifying specific agencies of the draft TMDL report's availability, the TMDL was posted on the North Dakota Department of Health, Division of Water Quality web site at http://www.ndhealth.gov/WQ/SW/Z2_TMDL/TMDLs_Under_PublicComment/B_Under_Public_Comment.htm. A 30 day public notice soliciting comment and participation was also published in the Emmons County Record.

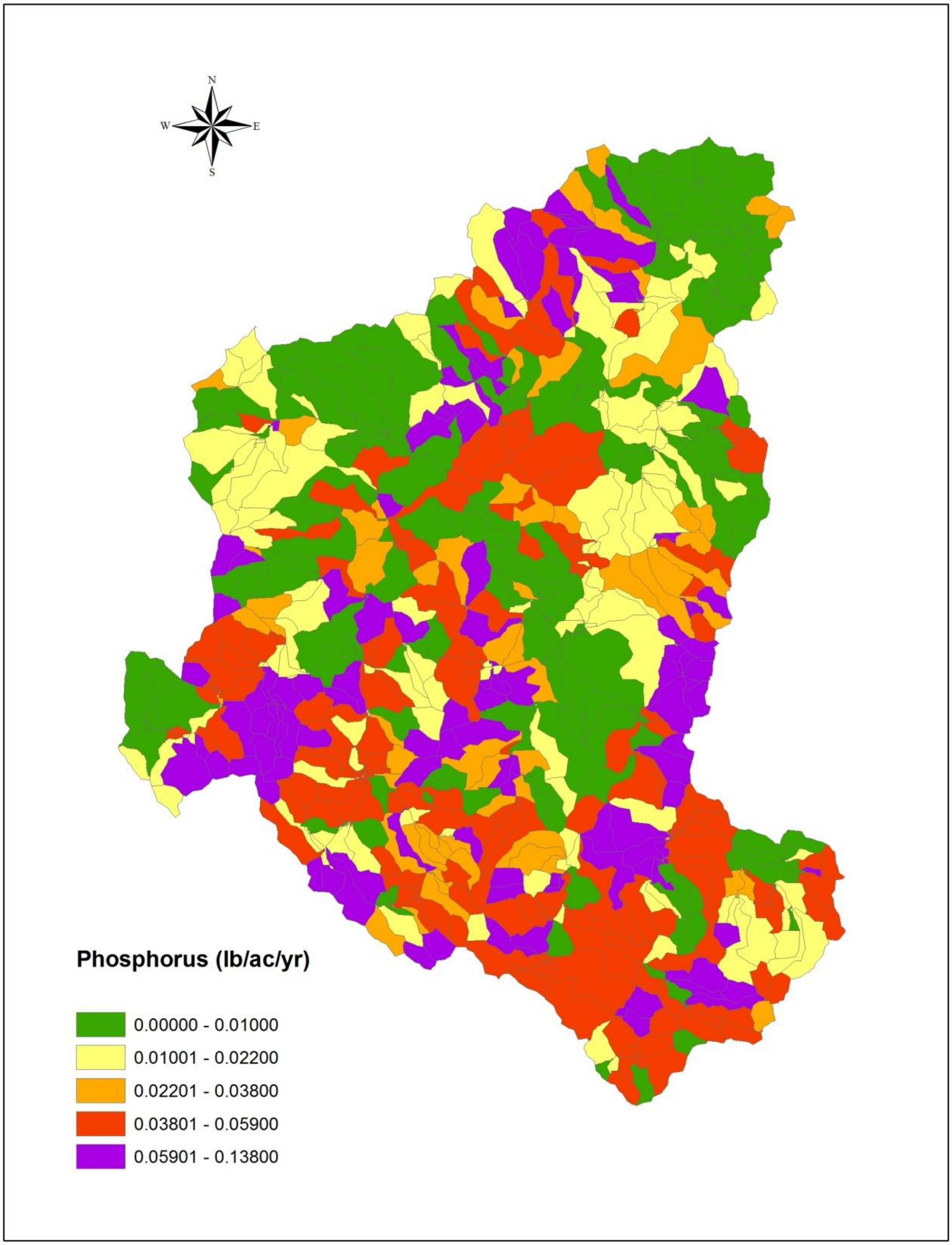

Figure 10. AnnAGNPS Model Identification of Critical Areas for BMP Implementation.

10.0 MONITORING

To insure that the BMPs implemented as a part of any watershed restoration plan will reduce phosphorus levels, 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. Once a watershed restoration plan (e.g. 319 PIP) is implemented, monitoring will be conducted in the lake/reservoir beginning two years after implementation and extending five years after the implementation project is complete.

11.0 TMDL IMPLEMENTATION STRATEGY

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

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

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Appendix A
Flux Analysis for Braddock Dam

Estimate of Total Phosphorus Load in Gaged Inflow and Outflow

The NDDoH provided HEI with daily flow and tributary chemistry data files to use in estimating total phosphorus loads to Braddock Dam over the growing season, defined as the period of time from April 1 through November 30. FLUX32[1] was used to facilitate the analysis, to reduce the gaged inflow and outflow data, and to estimate growing season phosphorus loads. FLUX32 is an interactive program used for analyzing streamflow data and estimating loads (mass transports) of nutrients and other water quality constituents passing a tributary sampling point over a given period of time.

The FLUX32 program was used to estimate the annual growing season total phosphorus (TP) load for the gaged area upstream of Braddock Dam and the gaged outflow from the lake. Mean daily flow data were provided by the NDDoH for the years 2010 and 2011, as well as several flow measurements paired with corresponding TP measurements. Because the water quality goal for the lake is based upon a growing season mean chlorophyll-a concentration, the data analysis was performed for the months of April through November. The screen/filter option in FLUX32 was used to exclude data outside the defined growing season for both 2010 and 2011.

The basic approach of FLUX32 is to use one of several calculation techniques to map the flow/concentration relationship developed from the sample record onto the entire flow record. FLUX32 has the ability to stratify the data into groups based upon streamflow, date, and/or season for the purpose of reducing the error in the load estimate. To check for any relationships or trends in the data that would indicate that stratification of the data could be used to improve the results, various plots of the sample flows and concentrations were developed and analyzed (see below for the stratification methods employed to estimate the growing season loads). The following sections describe individual data analyses for the gaged inflow to and gaged outflow from Braddock Dam.

Gaged Inflow to Braddock Dam

The daily streamflow and chemistry data files provided by the NDDoH representing the gaged inflow to Braddock Dam from the West Branch of Long Lake Creek, consisted of two full years of mean daily flow measurements, along with 46 TP measurements paired with corresponding mean flow daily values. **Figure 1** shows the 58.3 square mile gaged area and the

[1] http://www.wes.army.mil/el/elmodels/emiinfo.html

5.4 ungaged area draining to Braddock Dam. **Figure 2** is a histogram comparing the frequency distributions between the mean daily flows and the sampled flows, which shows the extent to which the flow range was sampled is reasonable.

Figure 1: Gaged and Ungaged Areas Draining to Braddock Dam.

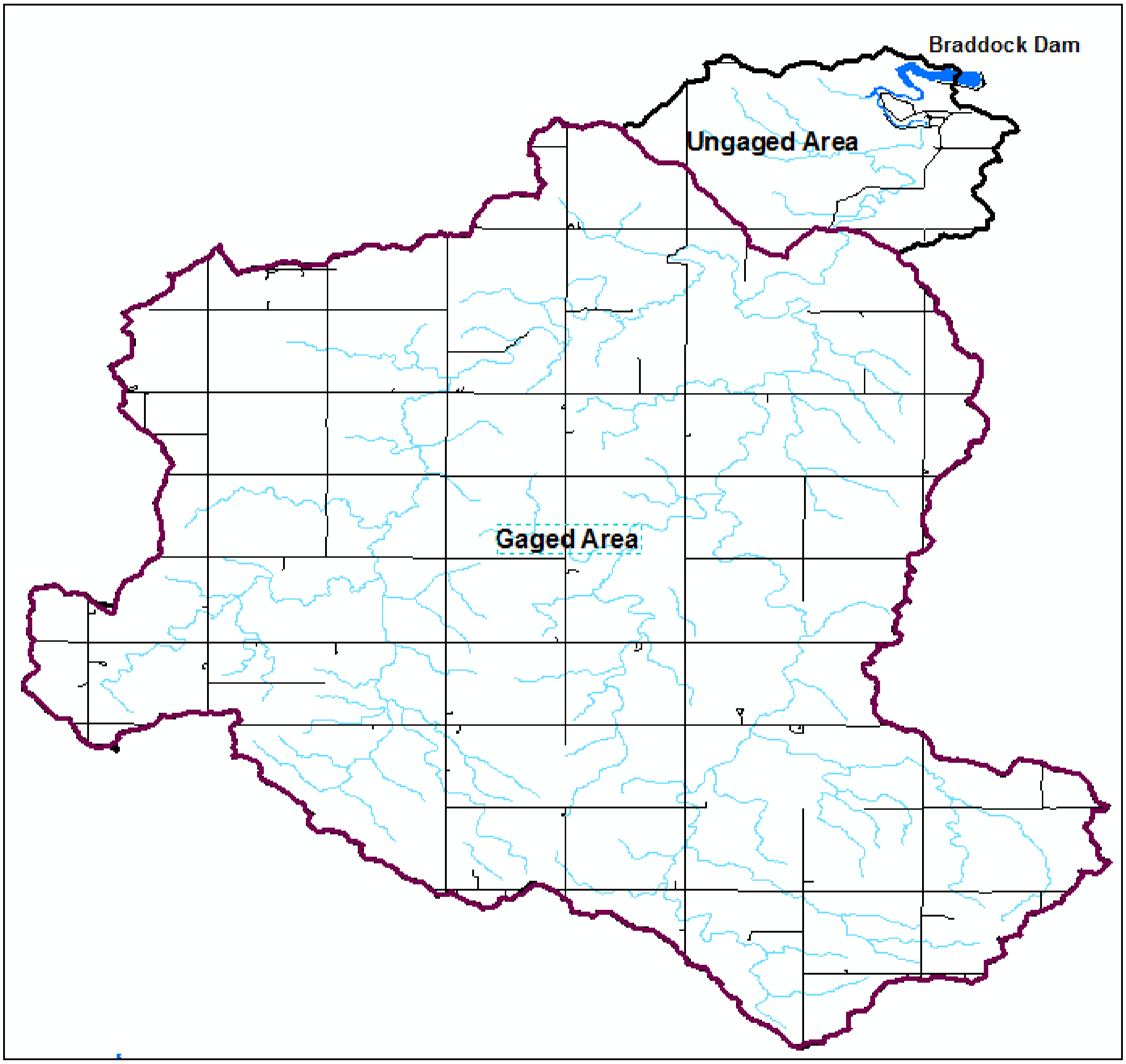
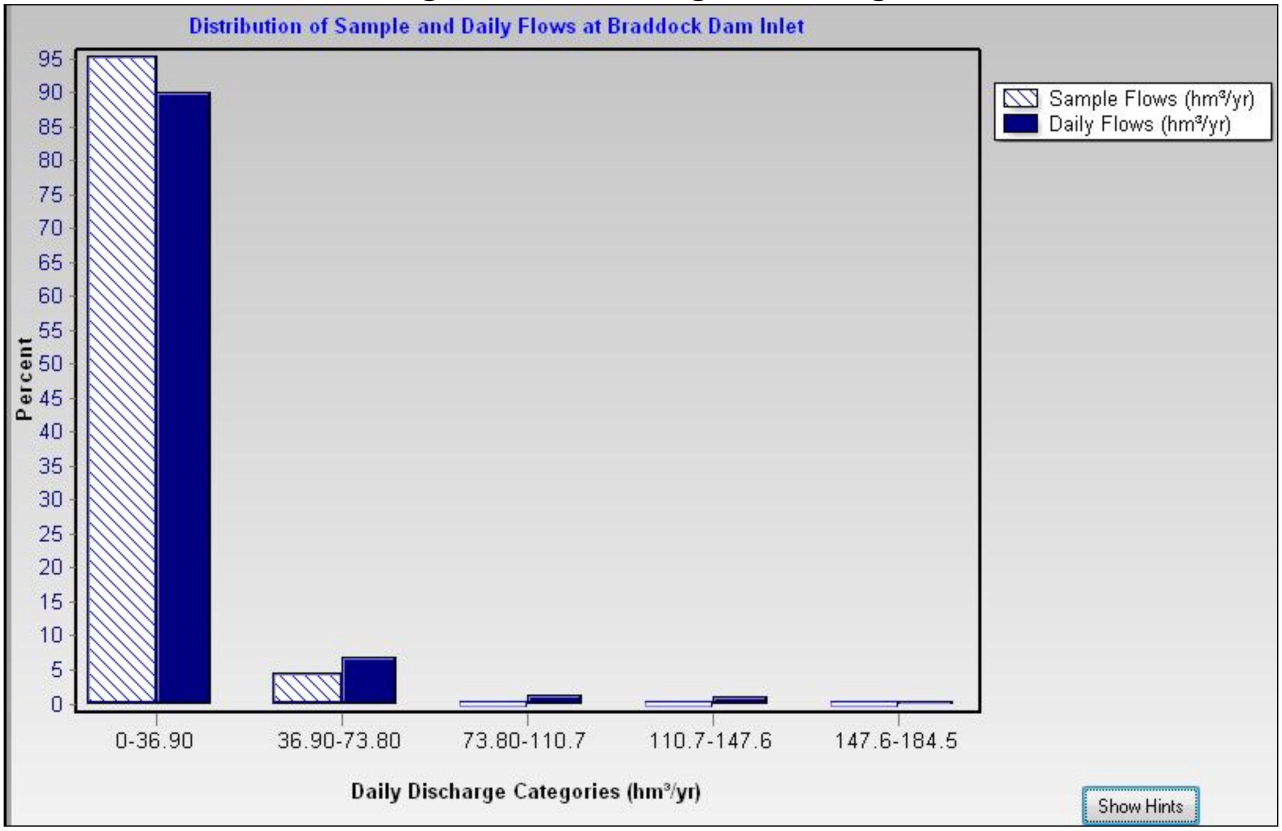


Figure 2: Distribution of Sample and Mean Daily Streamflows at the West Branch of Long Lake Creek during the Growing Seasons of 2010 and 2011



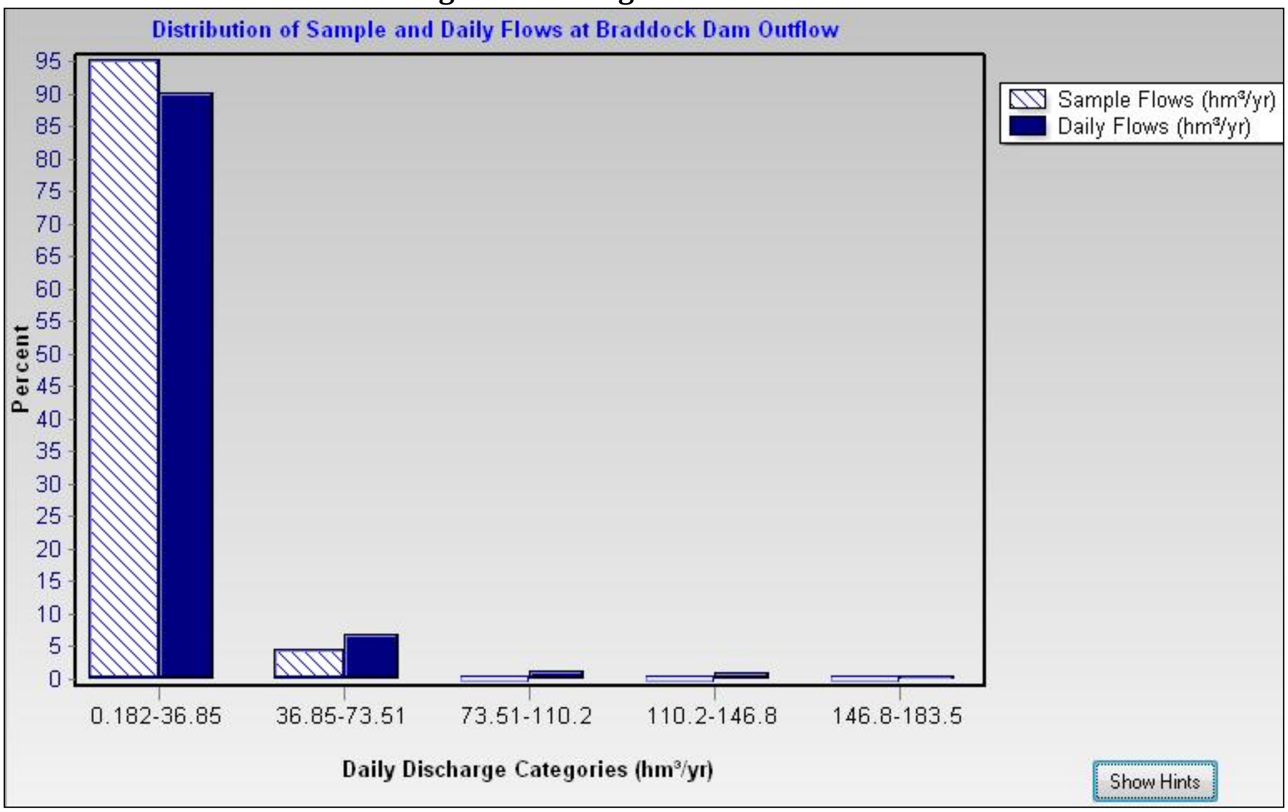
Plots of the relationship between sampled streamflows and TP concentrations indicate no statistical relationship between flow and concentration. There appears to be a seasonal pattern with regard to TP concentration in the 2011 data, but not in the 2010 data. FLUX32 calculations for various stratification schemes showed no apparent benefit to stratifying the data. Therefore, the growing season TP loads were estimated loads using no stratification method.

FLUX32 includes six calculation techniques to "map" the streamflow/concentration relationship developed from the sample record onto the entire streamflow record to estimate the mass discharge and associated error statistics. Method 2, which bases the loading estimate on the flow-weighted average concentration times the mean flow over the averaging period, resulted in the lowest coefficient of variation (0.14) for the seasonal TP load, and therefore, is the "best" estimate. The resulting total TP load estimated for the combined April through November, 2010 and 2011 growing seasons at the gaged inlet to Braddock Dam is 9,069 kg, with an average estimated April through November growing season TP load of 4,535 kg. The estimated average growing season TP yield is 0.27 pounds/acre.

<u>Gaged Outflow from Braddock Dam</u>

The mean daily outflow data from Braddock Dam, as well as the paired sample and streamflow data over the years 2010 and 2011 provided by the NDDoH, were read into the FLUX32 Program. The data consisted of two full years of mean daily streamflow measurements leaving Braddock Dam and 45 paired streamflow flow and TP measurements. **Figure 3** is a histogram comparing the frequency distributions between the mean daily flows and the sampled flows, which shows the extent to which the flow range was sampled is reasonable.

Figure 3: Distribution of Sample and Mean Daily Streamflows at the Outlet to Braddock Dam during the Growing Seasons of 2010 and 2011.



Plots of the sampled streamflows and TP concentrations indicated no statistical relationship between concentration and flow. However, there did appear to be a significant seasonal trend in both 2010 and 2011. Stratification based upon season is often useful in situations with highly regulated flows, such as a reservoir outflow station. The selected stratification regime is presented in **Table 1.**

Table 1: Stratification Applied to FLUX32 Load Calculations for Braddock Dam Outlet.

Stratum	Lower Limit	Upper Limit
Season 1	04/01	06/20
Season 2	06/21	10/04
Season 3	10/06	11/30

Of the six calculation techniques included within FLUX32, it was found that Method 2 resulted in the lowest coefficient of variation (0.14), and therefore represents the “best” estimate of the growing season TP load leaving Braddock Dam. The resulting total TP load estimated for the combined growing seasons of 2010 and 2011 at the gaged outlet from Braddock Dam is 5,054 kg, with an annual average estimated April through November growing season TP load of 2,527 kg/year.

Appendix B
Braddock Dam Hydrologic and Nutrient Budgets

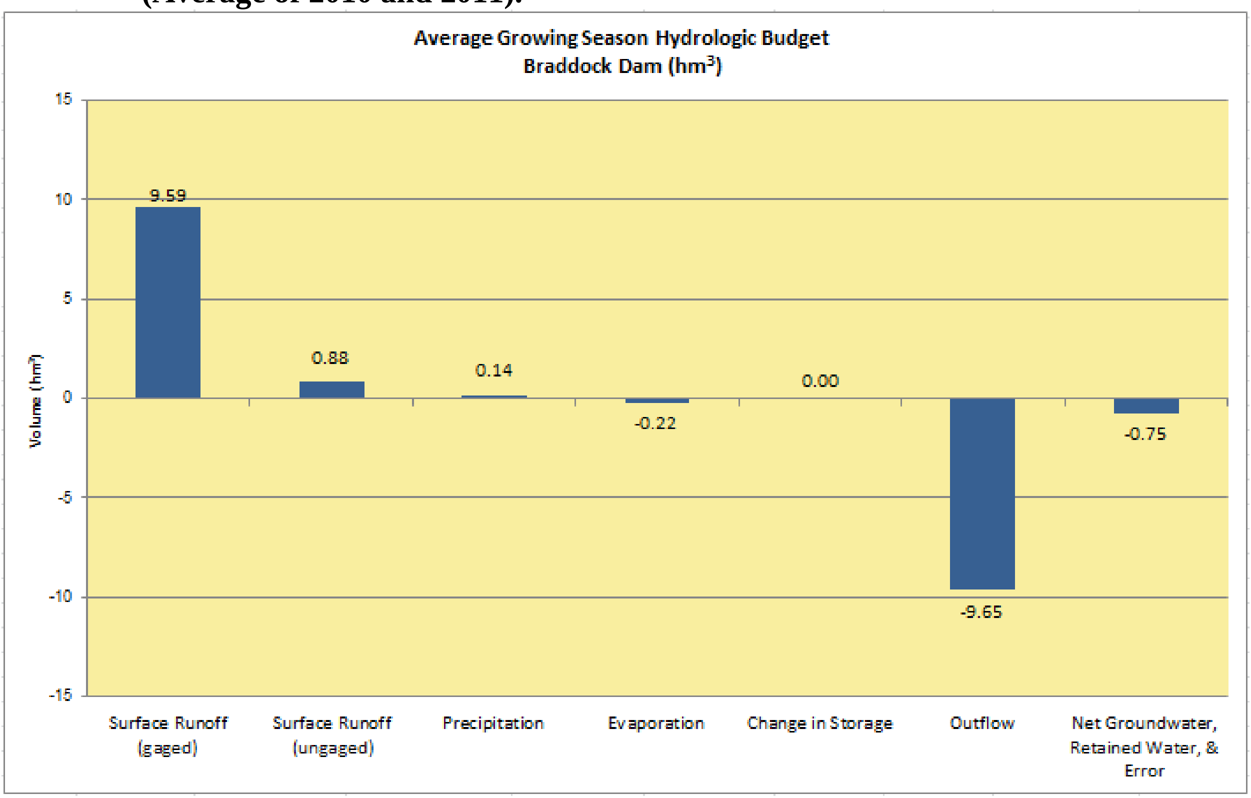
Hydrology Budget for Existing Conditions

For input into the water quality model, a hydrology budget for Braddock Dam was developed for the average annual growing season (April through November) for the years 2010 and 2011. **Table 2** lists the terms in the hydrology budget along with the corresponding data sources and estimation methods for each term. **Figure 4** shows the resulting volumes for each term of the hydrologic budget.

Table 2: Hydrology Budget Terms and Data Sources / Estimation Methods.

Hydrology Budget Term	Data Source / Estimation Method
Precipitation to Lake Surface	58-year average for period of record from National Climatic Data Center station near Linton, ND (Station ND325210). Multiplied by surface area of lake to estimate volume.
Gaged Surface Water Runoff	Streamflow data provided by NDDoH
Ungaged Surface Water Runoff	Unit runoff from gaged streamflow provided by NDDoH applied to the ungaged drainage area
Lake Evaporation	58-year average for period of record from National Climatic Data Center station near Linton, ND (Station ND 325210). Multiplied by surface area of lake to estimate volume.
Groundwater	No estimate – this term is lumped into error term
Surface Water Outflow	Outflow data provided by NDDoH
Error Term	By difference of water in minus water out

Figure 4: Braddock Dam April through November Hydrologic Budget (Average of 2010 and 2011).



The 2010 and 2011 average unit runoff in inches over the growing season for the gaged inlet (58.3 mi^2) to Braddock Dam was estimated at 2.5 inches. For comparison, **Table 3** shows the average growing season (April – November) unit runoff computed for three nearby USGS Gages.

Table 3: Unit Runoff over Growing Season for nearby USGS Gages

USGS Gage	Period of Record	Drainage Area (mi^2)	% Contributing Area	Average Unit Runoff (inches)
06354580 BEAVER CREEK BL LINTON, ND	1990 – 2009	765	87 %	0.7
06354500 BEAVER CREEK AT LINTON, ND	1950 – 1988	717	86 %	8.9
06349215 LONG LAKE CREEK AB LONG LAKE NR MOFFIT, ND	1989 – 2003	280	100 %	0.9

Total Phosphorus Mass Balance for Existing Conditions

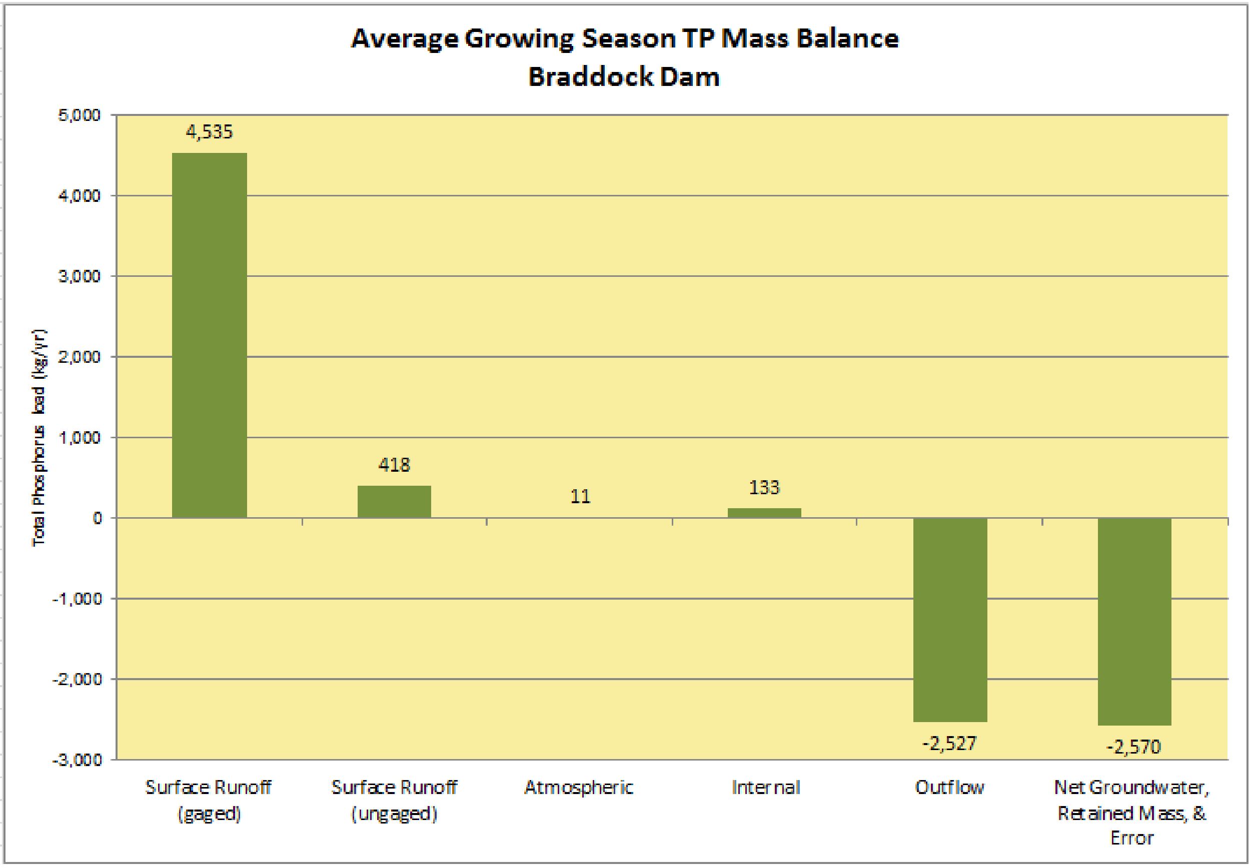
For input into the water quality model, a total phosphorus mass balance for Braddock Dam was developed for the average annual growing season (April t- November). **Table 4** shows the estimated terms for the TP budget and the corresponding data sources and estimation methods. **Figure 5** shows the resulting loads for each mass balance term. The percentage of the total phosphorus load retained by Braddock Dam is 50%, assuming the net groundwater, retained mass and the error term is in fact retained mass.

Table 4: Total Phosphorus Mass Balance Terms and Data Sources / Estimation Methods

TP Mass Balance Term	Data Source / Estimation Method
Gaged Surface Water Runoff	FLUX estimated values based on data provided by NDDoH
Ungaged Surface Water Runoff	Unit yield computed from the FLUX estimated load for the gaged drainage area applied to the ungaged drainage area
Atmospheric Deposition to the Lake Surface	Values from NDDoH Atmospheric Deposition Program [2]
Internal Loading	Median predicted release rate for 30 Minnesota lakes (1.48 mg/m^2-day)
Groundwater	No estimate – this term is lumped into error term
Surface Water Outflow	FLUX estimated values based on data provided by NDDoH
Error Term	By difference of mass in minus mass out

Figure 5: Braddock Dam April through November Total Phosphorus Mass Balance (Average of 2010 and 2011).

[2] "Ambient Air Quality, Precipitation Chemistry and Atmospheric Deposition in North Dakota, 1980-1984." North Dakota State Department of Health. Mark R. Deutschman and Michael J. Ell, October, 1986.


Average Growing Season TP Mass Balance
Braddock Dam
Total Phosphorus load (kg/yr)
5,000
4,000
3,000
2,000
1,000
0
-1,000
-2,000
-3,000
4,535
418
11
133
-2,527
-2,570
Surface Runoff (gaged)
Surface Runoff (ungaged)
Atmospheric
Internal
Outflow
Net Groundwater, Retained Mass, & Error

Appendix C
A Calibrated Trophic Response Model (CNET) for Braddock Dam

Existing Conditions BATHTUB/CNET Model and Estimate of the Loading Capacity

The CNET model was selected to simulate the eutrophication response within Braddock Dam. CNET is a modified version of the BATHTUB water quality model (http://wwwalker.net/bathtub/index.htm), which performs water and nutrient balance calculations in a steady state. CNET is a spreadsheet model currently available as a "beta" version from Dr. William W. Walker. The primary benefit of using CNET over BATHTUB is that the user can modify the CNET model to implement a Monte Carlo approach. To complete the Monte Carlo modeling, the CNET model was linked with a program called Crystal Ball. Crystal Ball is proprietary software developed by Oracle (http://www.oracle.com/us/products/applications/crystalball/index.html) and is applicable to Monte Carlo or stochastic simulation and analysis. Stochastic modeling is an approach where model parameters and input values (*e.g.*, precipitation) used in the equations to compute the annual mean concentration of total phosphorus (TP), chorophyll-a (chl-*a*), and Secchi Disk (SD) are allowed to vary according to their statistical distribution and therefore their probability of occurrence. This allows the effect of parameter uncertainty and normal variability in the inputs (*e.g.,* amount of surface runoff which varies annually depending upon the amount of precipitation) to be quantified when computing the summer season mean concentration of TP, chl-*a*, and SD.

The Crystal Ball software performed multiple probabilistic simulations of the water quality model. Many trial values (1,000 trials in this study case) were generated, with each trial representing a different permutation of model parameters and input values within the bounds established by the statistical distributions. The many trials resulted in a computed distribution of annual mean TP concentrations rather than a single, fixed output based upon only one possible combination of model parameters and inputs. **Table 5** shows the values which were allowed to vary in the Monte Carlo simulation and the statistical distribution for each parameter. The other necessary inputs to the CNET model (the internal loading and groundwater + error terms, for example) were held constant throughout all model simulations.

Table 5: Model Inputs used in the Monte Carlo Analysis.

Model Input	Statistical Distribution	Basis for Distribution	Distribution Truncated at Extreme Values?	Correlation	
				Considered?	Input Correlated With
Precipitation	Normal	1949 – 2006 NCDC station near Linton, ND (ND325210)	Yes (low)	No	- -
Evaporation	Log Normal	1949 – 2006 NCDC station near Linton, ND (ND325210)	Yes (low)	No	- -
Atmospheric Load	Uniform	Distribution Assumed	No	No	- -
Surface Water Runoff Volume	Normal	1987 – 2002 Apr–Nov volume USGS 06349215 Long Lake Creek AB Long Lkae NR Moffit, ND	Yes (low)	No	- -
Surface Runoff Load	Normal	Assumed same distribution as Runoff Volume	Yes (low)	No	- -

The input parameters to the CNET model consist of the volumes and loads resulting from the hydrologic budget and TP mass balance, both based on 2010 and 2011 growing season averages, as described in this memo. Prior to completing the Monte Carlo modeling analysis, the Braddock Dam CNET model was calibrated to the mean growing season in-lake measured TP, chl-*a*, and SD for 2010, as provided by the NDDoH. **Table 6** presents the details of the 2010 in-lake water quality data.

Table 6: 2010 Growing Season In-Lake Water Quality Data

Statistic	TP (µg/L)	Chl-A (µg/L)	Secchi Depth (m)
n	33	10	9
Average	210.4	27.5	1.2
Minimum	46.0	1.5	0.2
Maximum	644.0	106.0	2.0
Median	236.0	17.6	1.5
25th Percentile	112.0	3.9	0.8
50th Percentile	236.0	17.6	1.5
75th Percentile	284.0	30.9	1.5
Std.Dev	133.9	32.9	0.6

The following CNET models were used in the simulations:

- Total phosphorus sedimentation model: Second-order;
- Chlorophyll-*a* response model: P, Linear; and
- Secchi-disk Transparency response model: Secchi vs. Chl-a and Turbidity.

The goal of the CNET model calibration was to adjust each sedimentation and response models' calibration coefficient to reduce the errors between observed and simulated values. **Table 7** shows the results of model calibration.

Table 7: CNET Model Calibration Results for the Average 2010-2011 Growing Seasons

Parameter	Calibration Coefficient	Measured (2010)	Modeled	Absolute Difference	Percent Difference
Total Phosphorus	1.25	210.0 ppb	210.5 ppb	0.5 ppb	0.2 %
Chlorophyll-a	0.46	27.5 ppb	27.1 ppb	-0.4 ppb	-1.5 %
Secchi Disk	1.79	1.2 meters	1.21 meters	0.01 meters	0.8 %

Eutrophication Response

Based on guidance provided by the NDDoH, an in-lake growing season Chl-a concentration goal of 20 µg/L has been established for Braddock Dam. By using the model, the growing season TP load corresponding to 20 µg/L of Chl-a is established. To simulate the load reductions and establish the maximum allowable TP load (i.e., loading capacity) which can occur while achieving the 20 µg/L for Chl-a goal, a series of model simulations were performed. Each simulation reflected a reduction in the total amount of TP entering Braddock Dam during the growing season of April through November, while computing the anticipated response within the lake. The goal of the modeling was to identify the loading capacity for Braddock Dam during the April 1 through November 30 growing season.

Figure 5 above shows the 2010-2011 average TP mass balance for Braddock Dam (i.e., developed over the average 2010 and 2011 growing season, from April through November), which was used in the CNET model. Results show that Braddock Dam currently receives a total growing season TP loading of approximately 5,097 kg. About 4,953 kg of that TP load comes from surface water runoff; 133 kg from internal loading, and 11 kg from atmospheric deposition. The total TP loads entering the lake were sequentially reduced by 10%, 20%, 30%, 40%, 50%, and 60% within the CNET model to evaluate the lake's eutrophication response.

Figures 6-11 show the effects of reducing April through November TP loads to Braddock Dam for the mean TP, Chl-*a* and Secchi disk depth within the lake (based on the CNET model). Results are presented both in terms of the seasonal mean concentrations, as shown by the column graphs, and the results of the Monte Carlo analysis. The Monte Carlo analysis results are presented as a series of lines, where each line represents a statistical distribution of the seasonal mean value for a specific TP load.

Figure 6: Braddock Dam Growing Season (April through November) Mean TP Concentrations under Select Load Reduction Scenarios; Current Conditions = 5,097 kg/season.

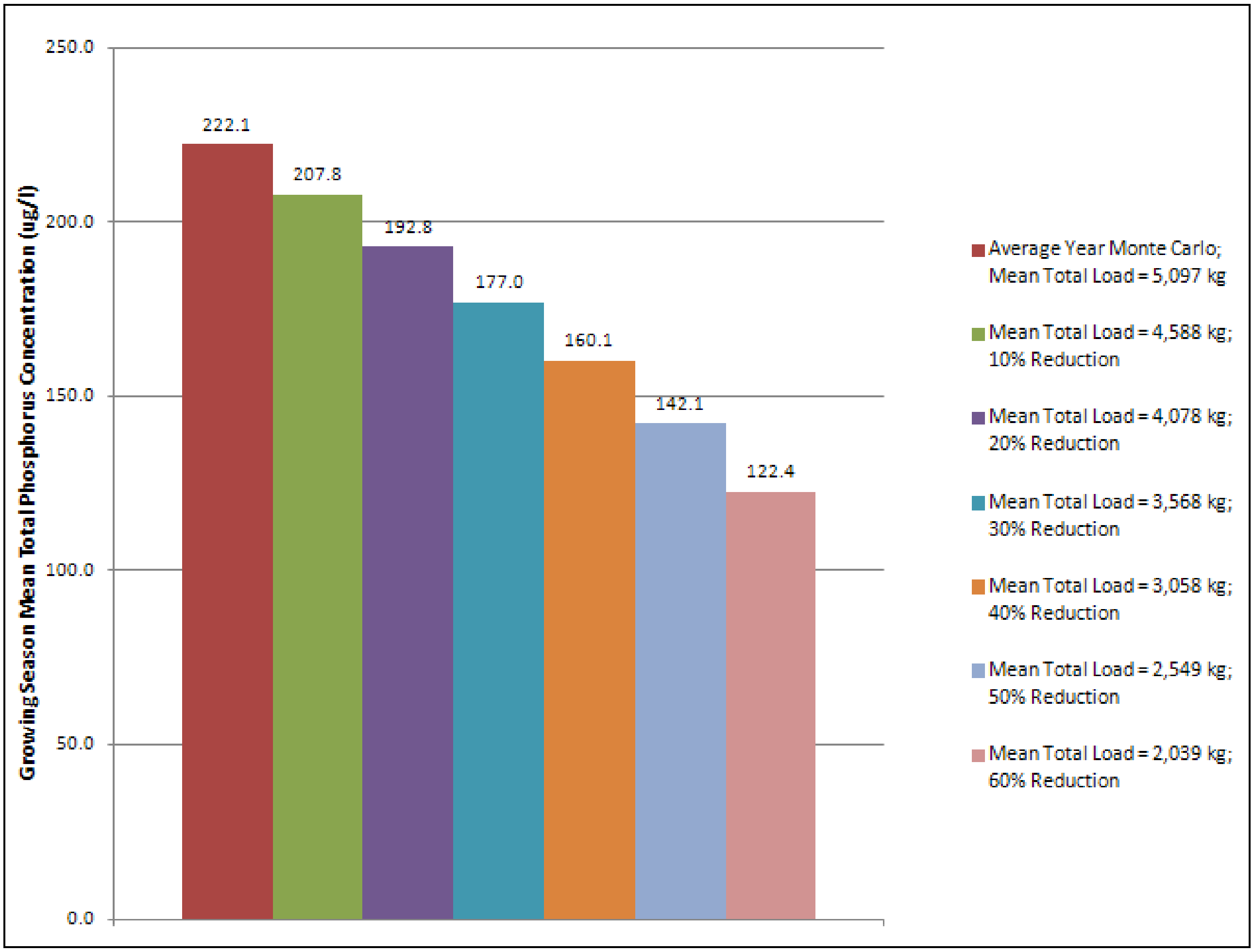


Figure 7: Braddock Dam Frequency Distribution of Growing Season (April through November) Mean TP Concentrations Resulting from Select Load Reduction Scenarios; Current Conditions = 5,097 kg/season.

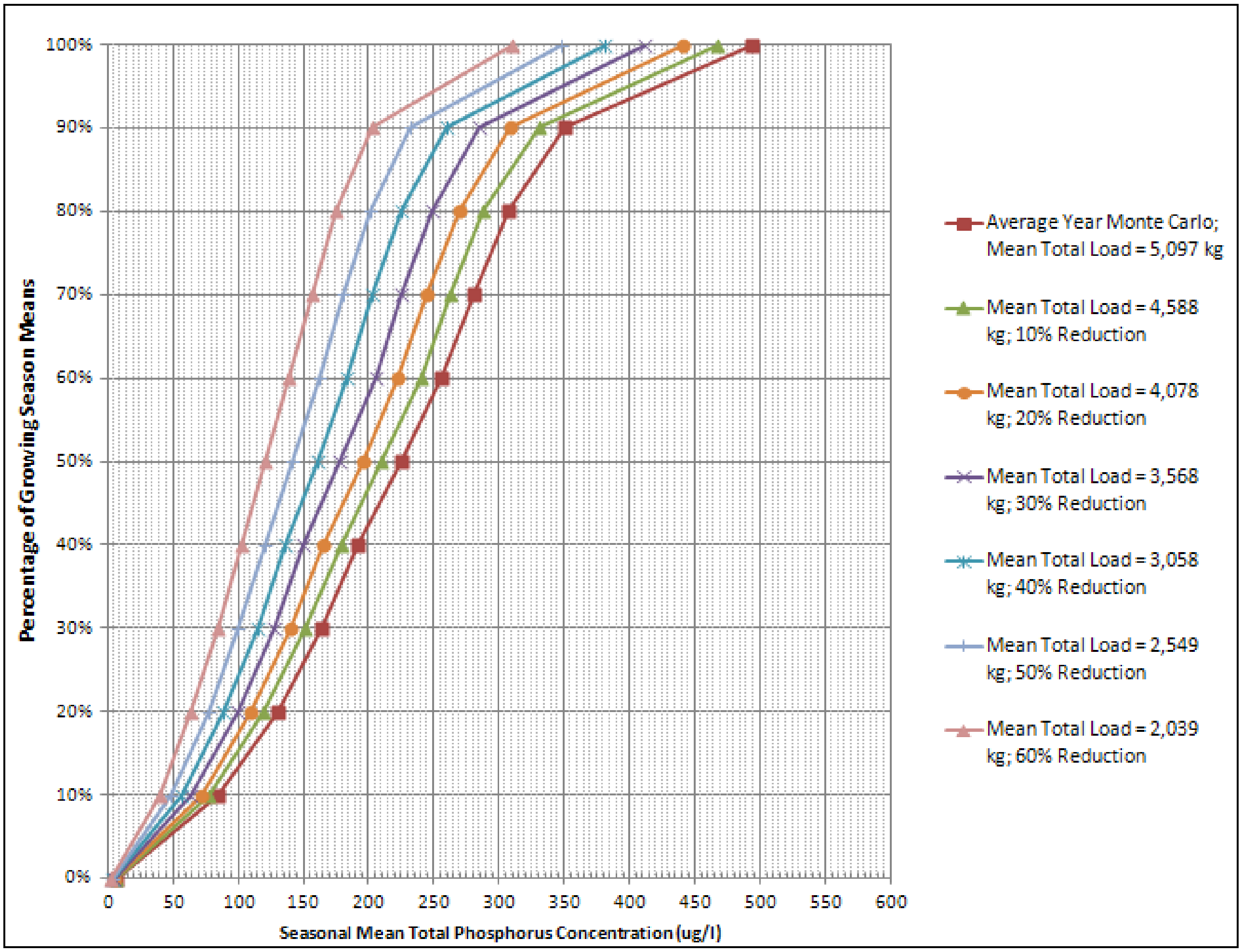


Figure 8: Braddock Dam Growing Season (April through November) Mean Chl-a Concentrations under Select TP Load Reduction Scenarios; Current Conditions = 5,097 kg/season.

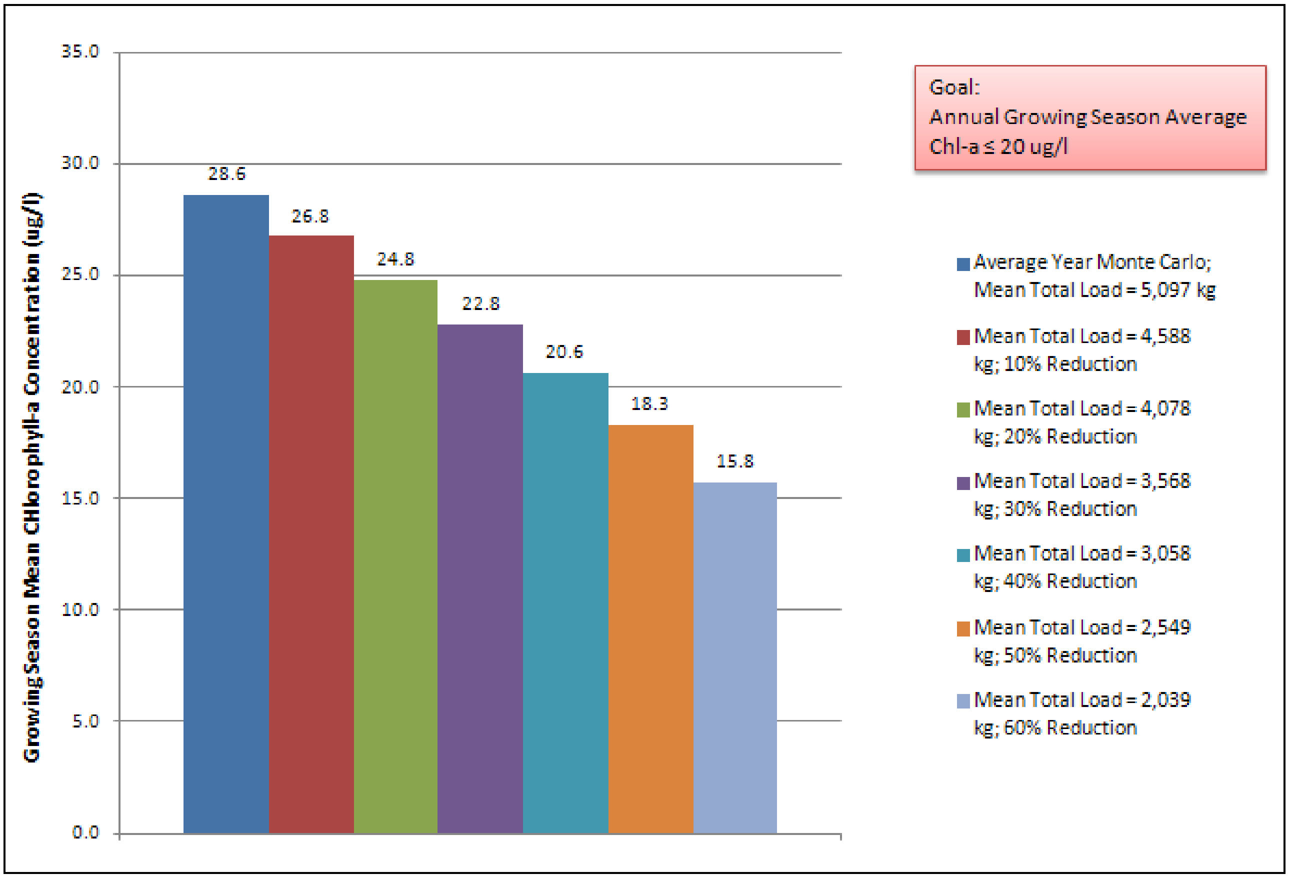


Figure 9: Braddock Dam Frequency Distribution Growing Season (April through November) Mean Chl-a Concentrations Resulting from Select Load Reduction Scenarios; Current Conditions = 5,097 kg/season.

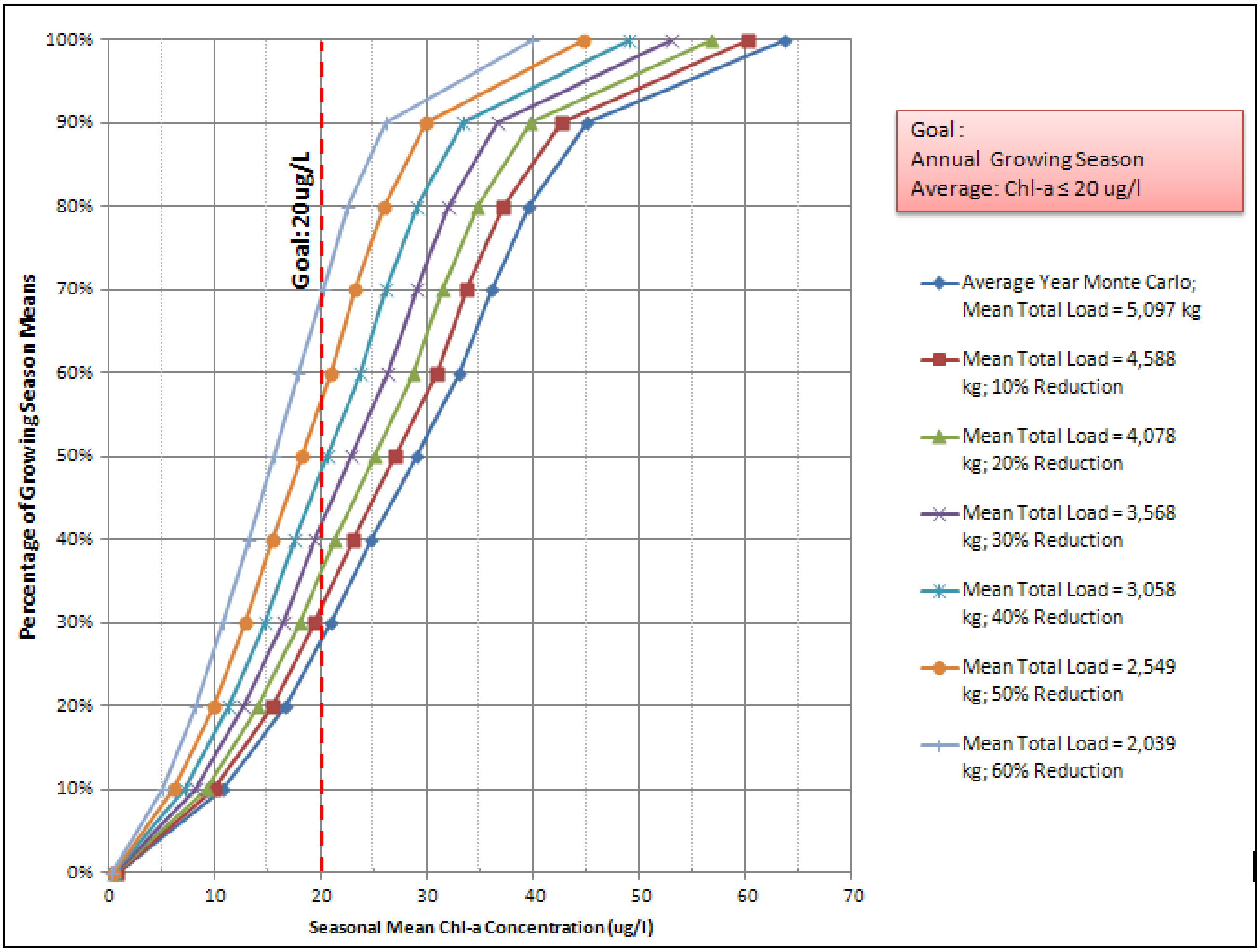


Figure 10: Braddock Dam Growing Season (April through November) Mean Secchi Disk Depth under Select Load Reduction Scenarios; Current Conditions = 5,097 kg/season.

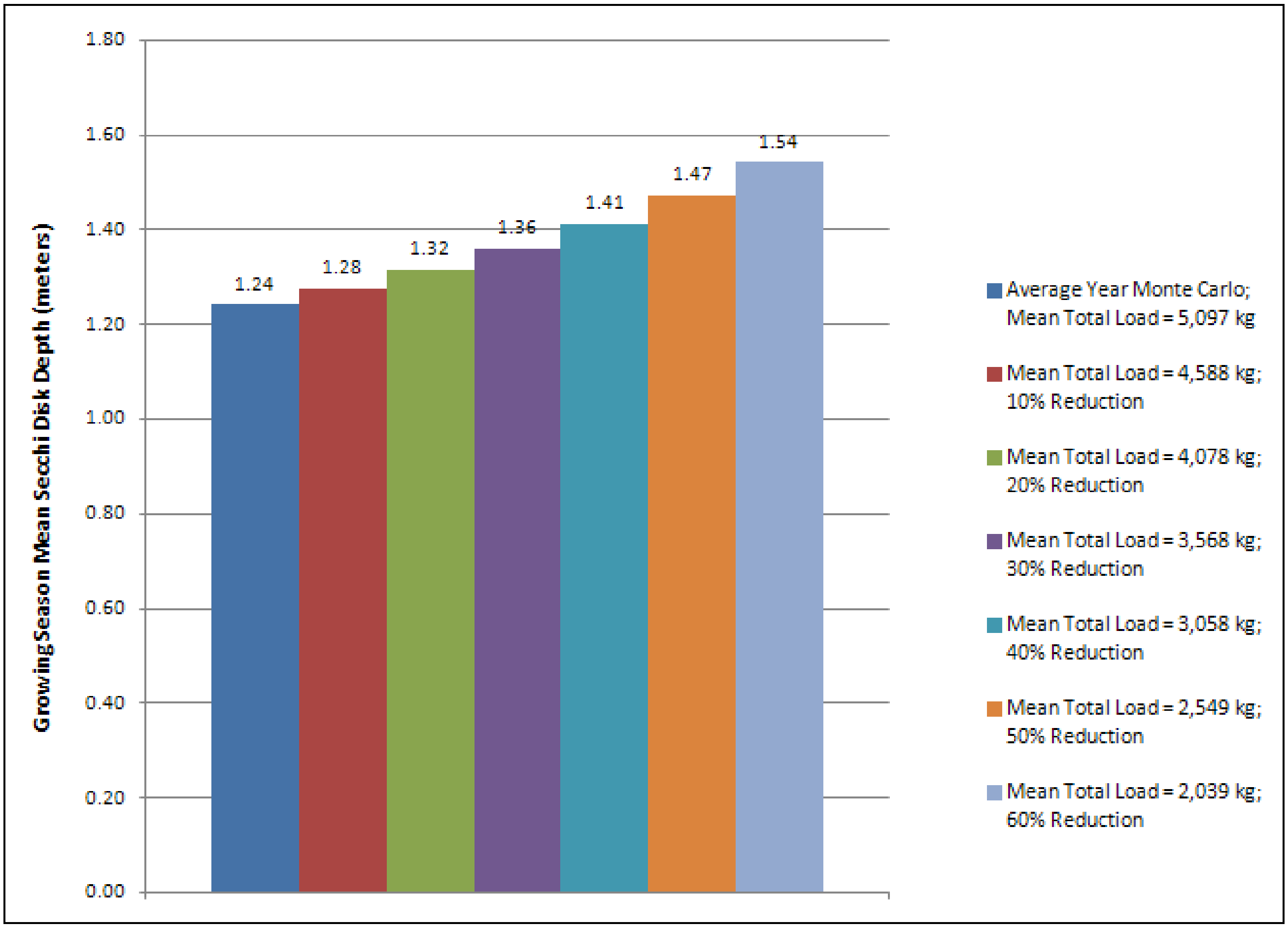
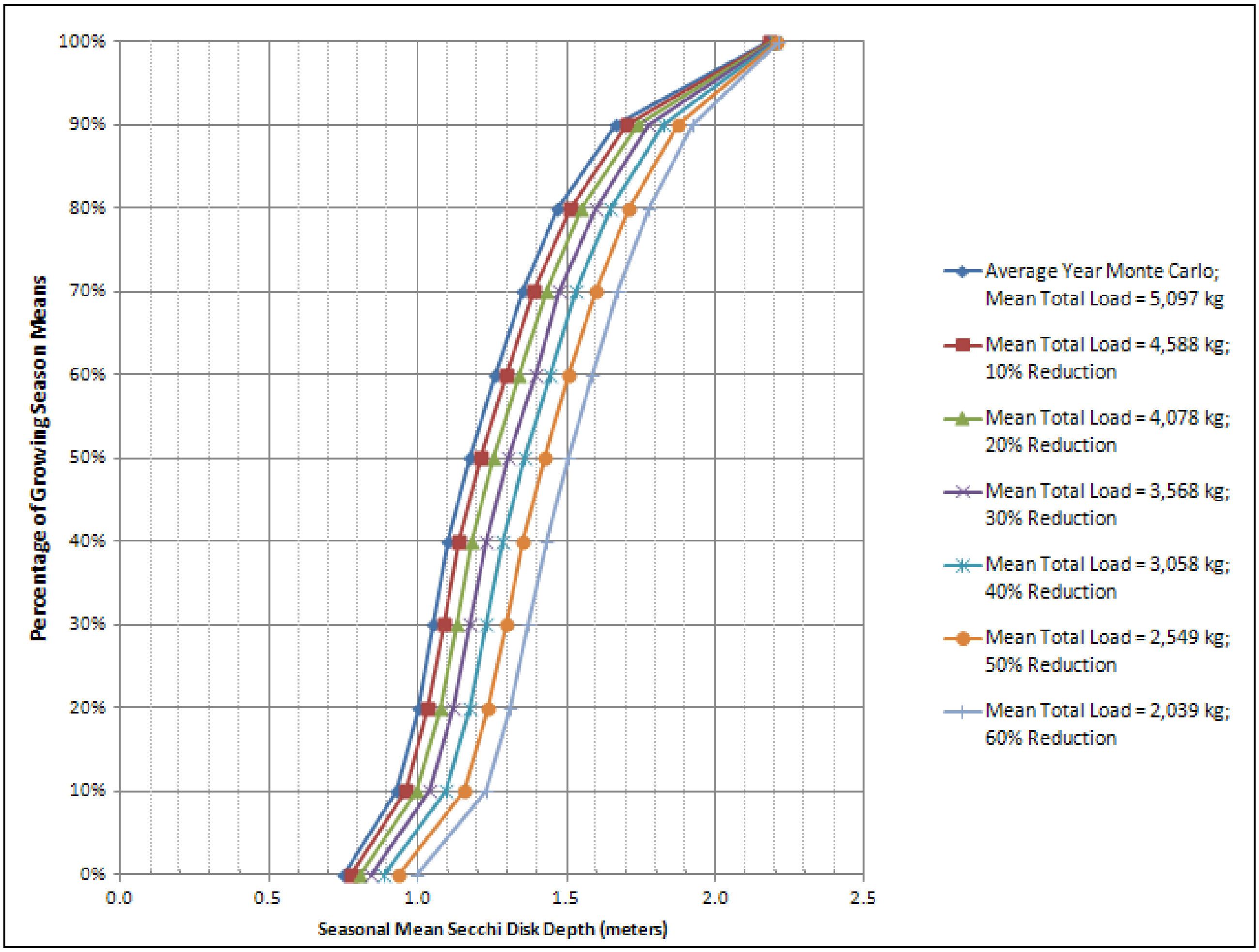


Figure 11: Braddock Dam Frequency Distribution of Growing Season (April through November) Mean Secchi Disk Depth Resulting from Select Load Reduction; Current Conditions = 5,097 kg/season.



Loading Capacity and TMDL Equation

The loading capacity is the maximum allowable TP load to Braddock Dam which can occur while still achieving the in-lake Chl-a concentration goal set at 20 µg/L. The loading capacity computed for Braddock Dam is allocated between non-point sources (i.e., the load allocation or LA in a TMDL study), point sources (i.e., the wasteload allocation or WLA in a TMDL study), and the margin of safety (MOS). The LA component of the loading capacity includes existing and future nonpoint sources (i.e., surface water runoff, internal load, and atmospheric deposition). There are no permitted point sources within the Braddock Dam watershed so the WLA term is zero. The MOS used is an explicit expression, intended to reflect the lack of knowledge and uncertainty in establishing the load capacity.

In this study, the loading capacity of Braddock Dam was computed using a stochastic approach based on the hydrology and water quality simulated by the CNET modeling. The loading capacity (allowable load) for the lake was defined as the growing season TP which reduces the seasonal mean Chl-a concentration for the 50^{th} percentile non-exceedance value to the goal of 20µg/L. Per guidance provided by the NDDoH, the explicit MOS is 10% of the loading capacity.

Results of the loading capacity analysis can be seen in **Figure 9**. A line at 20µg/L represents the average growing season Chl-a concentration eutrophication goal. Results of this analysis show that about a 40%, or 2,039 kg, growing season TP load reduction is needed to achieve the Chl-a goal of 20 µg/L. This would reduce the total load to the lake from 5,097 kg to 3,058 kg. **Table 8** shows the TMDL equation for Braddock Dam.

Table 8: Braddock Lake Annual Growing Season Loading Capacity and TMDL equation to Meet 20 µg/L Chl-a goal.

	Loading (kg/season)	=	Load Allocation (kg/season)	+	Wasteload Allocation** (kg/season)	+	Margin of Safety (kg/season)
Current Condition	5,097	=	5,097	+	0	+	0
Chl-a Goal: 20 µg/L	3,058	=	2,752	+	0	+	306

As summarized in **Table 8**, it is estimated that the current 5,097 kg/growing season TP load to Braddock Dam would have to be reduced to 3,058 kg/season to meet the Chl-a goal of 20 µg/L, 50% of the time. The total load would have to be reduced by 40%; or 2,039 kg/season. The atmospheric loading of 11 kg/season is beyond the control of the EC SCD, so the reduction would need to come from surface runoff TP loading and internal TP loading from the phosphorus-laden bottom sediments. Any combination of surface runoff or internal load reduction equaling 2,039 kg/season is believed to be able to achieve the Chl-a goal of 20 µg/L.

Appendix D
US EPA Region 8 Public Notice Review and Comments

EPA REGION 8 TMDL REVIEW FORM AND DECISION DOCUMENT

TMDL Document Info:

Document Name:	**Nutrient and Dissolved Oxygen TMDLs for Braddock Dam in Emmons County, North Dakota**
Submitted by:	**Mike Ell, North Dakota Department of Health**
Date Received:	**August 20, 2012**
Review Date:	**October 3, 2012**
Reviewer:	**Vern Berry, US Environmental Protection Agency**
Rough Draft / Public Notice / Final Draft?	**Public Notice**
Notes:	

Reviewers Final Recommendation(s) to EPA Administrator (used for final draft review only):

☐ Approve
☐ Partial Approval
☐ Disapprove
☐ Insufficient Information

Approval Notes to the Administrator:

This document provides a standard format for EPA Region 8 to provide comments to state TMDL programs on TMDL documents submitted to EPA for either formal or informal review. All TMDL documents are evaluated against the TMDL review elements identified in the following 8 sections:

1. Problem Description
   a. ...TMDL Document Submittal
   b. Identification of the Waterbody, Impairments, and Study Boundaries
   c. Water Quality Standards
2. Water Quality Target
3. Pollutant Source Analysis
4. TMDL Technical Analysis
   a. Data Set Description
   b. Waste Load Allocations (WLA)
   c. Load Allocations (LA)
   d. Margin of Safety (MOS)
   e. Seasonality and variations in assimilative capacity
5. Public Participation
6. Monitoring Strategy
7. Restoration Strategy
8. Daily Loading Expression

Under Section 303(d) of the Clean Water Act, waterbodies that are not attaining one or more water quality standard (WQS) are considered “impaired.” When the cause of the impairment is determined to be a pollutant, a TMDL analysis is required to assess the appropriate maximum allowable pollutant loading rate. A TMDL document consists of a technical analysis conducted to: (1) assess the maximum pollutant loading rate that a waterbody is able to assimilate while maintaining water quality standards; and (2) allocate that assimilative capacity among the known sources of that pollutant**.** A well written TMDL document will describe a path forward that may be used by those who implement the TMDL recommendations to attain and maintain WQS.

Each of the following eight sections describes the factors that EPA Region 8 staff considers when reviewing TMDL documents. Also included in each section is a list of EPA's review elements relative to that section, a brief summary of the EPA reviewer's findings, and the reviewer's comments and/or suggestions. Use of the verb "must" in this review form denotes information that is required to be submitted because it relates to elements of the TMDL required by the CWA and by regulation. Use of the term "should" below denotes information that is generally necessary for EPA to determine if a submitted TMDL is approvable.

This review form is intended to ensure compliance with the Clean Water Act and that the reviewed documents are technically sound and the conclusions are technically defensible.

1. Problem Description

A TMDL document needs to provide a clear explanation of the problem it is intended to address. Included in that description should be a definitive portrayal of the physical boundaries to which the TMDL applies, as well as a clear description of the impairments that the TMDL intends to address and the associated pollutant(s) causing those impairments. While the existence of one or more impairment and stressor may be known, it is important that a comprehensive evaluation of the water quality be conducted prior to development of the TMDL to ensure that all water quality problems and associated stressors are identified. Typically, this step is conducted prior to the 303(d) listing of a waterbody through the monitoring and assessment program. The designated uses and water quality criteria for the waterbody should be examined against available data to provide an evaluation of the water quality relative to all applicable water quality standards. If, as part of this exercise, additional WQS problems are discovered and additional stressor pollutants are identified, consideration should be given to concurrently evaluating TMDLs for those additional pollutants. If it is determined that insufficient data is available to make such an evaluation, this should be noted in the TMDL document.

1.1 TMDL Document Submittal

When a TMDL document is submitted to EPA requesting review or approval, the submittal package should include a notification identifying the document being submitted and the purpose of the submission.

Review Elements:

☒ Each TMDL document submitted to EPA should include a notification of the document status (e.g., pre-public notice, public notice, final), and a request for EPA review.

☐ Each TMDL document submitted to EPA for final review and approval should be accompanied by a submittal letter that explicitly states that the submittal is a final TMDL submitted under Section 303(d) of the Clean Water Act for EPA review and approval. This clearly establishes the State's/Tribe's intent to submit, and EPA's duty to review, the TMDL under the statute**.** The submittal letter should contain such identifying information as the name and location of the waterbody and the pollutant(s) of concern, which matches similar identifying information in the TMDL document for which a review is being requested.

Recommendation:
☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information ☐ N/A

Summary: *The notification of the availability of the public notice draft TMDL document was submitted to EPA via a letter received on August 20, 2012. The letter includes the details of the public notice, explains how to obtain a copy of the TMDL, and requests the submittal of comments to NDDoH by September 17, 2012.*

Comments: *No comments.*

1.2 Identification of the Waterbody, Impairments, and Study Boundaries

The TMDL document should provide an unambiguous description of the waterbody to which the TMDL is intended to apply and the impairments the TMDL is intended to address. The document should also clearly delineate the physical boundaries of the waterbody and the geographical extent of the watershed area studied. Any additional information needed to tie the TMDL document back to a current 303(d) listing should also be included.

Review Elements:

☒ The TMDL document should clearly identify the pollutant and waterbody segment(s) for which the TMDL is being established. If the TMDL document is submitted to fulfill a TMDL development requirement for a waterbody on the state's current EPA approved 303(d) list, the TMDL document submittal should clearly identify the waterbody and associated impairment(s) as they appear on the State's/Tribe's current EPA approved 303(d) list, including a full waterbody description, assessment unit/waterbody ID, and the priority ranking of the waterbody. This information is necessary to ensure that the administrative record and the national TMDL tracking database properly link the TMDL document to the 303(d) listed waterbody and impairment(s).

☒ One or more maps should be included in the TMDL document showing the general location of the waterbody and, to the maximum extent practical, any other features necessary and/or relevant to the understanding of the TMDL analysis, including but not limited to: watershed boundaries, locations of major pollutant sources, major tributaries included in the analysis, location of sampling points, location of discharge gauges, land use patterns, and the location of nearby waterbodies used to provide surrogate information or reference conditions. Clear and concise descriptions of all key features and their relationship to the waterbody and water quality data should be provided for all key and/or relevant features not represented on the map

☒ If information is available, the waterbody segment to which the TMDL applies should be identified/geo-referenced using the National Hydrography Dataset (NHD). If the boundaries of the TMDL do not correspond to the Waterbody ID(s) (WBID), Entity ID information or reach code (RCH_Code) information should be provided. If NHD data is not available for the waterbody, an alternative geographical referencing system that unambiguously identifies the physical boundaries to which the TMDL applies may be substituted.

Recommendation:
☐ Approve ☒ Partial Approval ☐ Disapprove ☐ Insufficient Information

Summary:

Physical Setting and Listing History*:*

The Braddock Dam reservoir (also known as Braddock Lake) is located on the West Branch of Long Lake Creek, approximately two miles southwest of Braddock, North Dakota. The Braddock Dam construction was completed in 1939 and when filled with water created a 91.2-acre reservoir designed for flood control and recreational benefits. The reservoir is located in Emmons County and receives water from a watershed drainage area of approximately 40,818 acres. Braddock Dam is part of the Apple Creek sub-basin which is part of the larger Missouri River basin watershed.

North Dakota Administrative Code, 33-16-02.1, Appendix II, Standards of Quality of Waters of the State, assigns the following classification for Braddock Dam. The bene□cial water uses and *parameter limitations designated for Class I streams shall apply to all classified lakes and reservoirs. For lakes not listed, the following default classification applies: Class 4.*

Braddock Dam; ND-10130103-003-L_00; Class 3.

Impairment status*:*
The 2012 North Dakota Integrated Report identifies Braddock Dam as not supporting the following beneficial uses:

Assessment Unit	**Designated Use / Support Status**	**Impairment Cause**	**TMDL Priority**
Braddock Dam ND-10130103-003-L_00	*Fish and Other Aquatic Biota / Fully Supporting but Threatened*	*Nutrient / Eutrophication Biological Indicators*	*High*
	Fish and Other Aquatic Biota / Fully Supporting but Threatened	*Sedimentation / Siltation*	*High*
	Fish and Other Aquatic Biota / Fully Supporting but Threatened	*Dissolved Oxygen*	*High*
	Recreation / Fully Supporting but Threatened	*Nutrient / Eutrophication Biological Indicators*	*High*

Comments: *The 2012 303(d) list shows Braddock Dam as 91.2 acres in size. This is consistent with the acreage given in Table 1, however the listing information used in the TMDL appears to be based on the 2010 303(d) list (see Table 2). The 2010 303(d) list information for Braddock Dam showed the size as 69.5 acres. Also, the Table 2 303(d) listing information is missing the dissolved oxygen impairment and has an error in the assessment unit ID. We suggest revising the TMDL to be consistent with the 2012 303(d) listing information.*

Section 1.1 seems to indicate that this TMDL document only addresses the nutrient / eutrophication / biological indicators impairment, whereas the title of the document seems to indicate that it addresses the dissolved oxygen impairment too. We suggest that revising one or the other to be consistent.

We suggest adding a sentence to Section 1.1, Clean Water Act Section 303(d) Listing Information, that addresses the sedimentation / siltation impairment in Braddock Dam and include any plans for development of a TMDL to address the sediment impairment.

1.3 Water Quality Standards

TMDL documents should provide a complete description of the water quality standards for the waterbodies addressed, including a listing of the designated uses and an indication of whether the uses are being met, not being met, or not assessed. If a designated use was not assessed as part of the TMDL analysis (or not otherwise recently assessed), the documents should provide a reason for the lack of assessment (e.g., sufficient data was not available at this time to assess whether or not this designated use was being met).

Water quality criteria (WQC) are established as a component of water quality standard at levels considered necessary to protect the designated uses assigned to that waterbody. WQC identify quantifiable targets and/or qualitative water quality goals which, if attained and maintained, are intended to ensure that the designated uses for the waterbody are protected. TMDLs result in maintaining and attaining water quality standards by determining the appropriate maximum pollutant loading rate to meet water quality criteria, either directly, or through a surrogate measurable target. The TMDL document should include a description of all applicable water quality criteria for the impaired designated uses and address whether or not the criteria are being attained, not attained, or not evaluated as part of the analysis. If the criteria were not evaluated as part of the analysis, a reason should be cited (e.g. insufficient data were available to determine if this water quality criterion is being attained).

Review Elements:

☒ The TMDL must include a description of the applicable State/Tribal water quality standard, including the designated use(s) of the waterbody, the applicable numeric or narrative water quality criterion, and the anti-degradation policy. (40 C.F.R. §130.7(c)(1)).

☒ The purpose of a TMDL analysis is to determine the assimilative capacity of the waterbody that corresponds to the existing water quality standards for that waterbody, and to allocate that assimilative capacity between the identified sources. Therefore, <u>all TMDL documents must be written to meet the existing water quality standards</u> for that waterbody (CWA §303(d)(1)(C)). *Note: In some circumstances, the load reductions determined to be necessary by the TMDL analysis may prove to be infeasible and may possibly indicate that the existing water quality standards and/or assessment methodologies may be erroneous. However, the TMDL must still be determined based on existing water quality standards. Adjustments to water quality standards and/or assessment methodologies may be evaluated separately, from the TMDL.*

☒ The TMDL document should describe the relationship between the pollutant of concern and the water quality standard the pollutant load is intended to meet. This information is necessary for EPA to evaluate whether or not attainment of the prescribed pollutant loadings will result in attainment of the water quality standard in question.

☒ If a standard includes multiple criteria for the pollutant of concern, the document should demonstrate that the TMDL value will result in attainment of all related criteria for the pollutant. For example, both acute and chronic values (if present in the WQS) should be addressed in the document, including consideration of magnitude, frequency and duration requirements.

Recommendation:

☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

Summary: *Braddock Dam is classified as a Class 3 warm water fishery. Class 3 fisheries are defined as waterbodies "capable of supporting natural reproduction and growth of warm water fishes (i.e. largemouth bass and bluegill) and associated aquatic biota. Some cool water species may also be present." All classified lakes in North Dakota are assigned aquatic life, recreation, irrigation, livestock watering, and wildlife beneficial uses. The North Dakota State Water Quality Standards state that lakes shall use the same numeric criteria as Class 1 streams, including the State standard for dissolved nitrate as N, of 1.0 mg/L, where up to 10 percent of samples may exceed the 1.0 mg/L, and State guideline nutrient goals for lakes and reservoirs.*

Table 8. Numeric Standards Applicable for North Dakota Lakes and Reservoirs.

State Water Quality Standard	Parameter	Guidelines	Limit
Numeric Standard for Class I and Classified Lakes	Nitrates (dissolved)	1.0 mg/L	Maximum allowed[1]
	Dissolved oxygen	5 mg/L	Daily mimimum[2]
Guidelines for Goals in a Lake Improvement or Maintenance Program	NO3 as N	0.25 mg/L	Goal
	PO4 as P	0.02 mg/L	Goal

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

The Braddock Dam impairments addressed by this TMDL document include nutrients / eutrophication / biological indicators and dissolved oxygen. 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.)*

Other applicable water quality standards are included on pages 8 - 9 of the TMDL report.

Comments: *No comments.*

2. Water Quality Targets

TMDL analyses establish numeric targets that are used to determine whether water quality standards are being achieved. Quantified water quality targets or endpoints should be provided to evaluate each listed pollutant/water body combination addressed by the TMDL, and should 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 water quality target. For pollutants with narrative standards, the narrative standard should be translated into a measurable value. At a minimum, one target is required for each pollutant/water body combination. It is generally desirable, however, to include several targets that represent achievement of the standard and support of beneficial uses (e.g., for a sediment impairment issue it may be appropriate to include a variety of targets representing water column sediment such as TSS, embeddedness, stream morphology, up-slope conditions and a measure of biota).

Review Elements:

☒ The TMDL should identify a numeric water quality target(s) for each waterbody pollutant combination. The TMDL target is a quantitative value used to measure whether or not the applicable water quality standard is attained. *Generally, the pollutant of concern and the numeric water quality target are, respectively, the chemical causing the impairment and the numeric criteria for that chemical (e.g., chromium) contained in the water quality standard. Occasionally, the pollutant of concern is different from the parameter that is the subject of the numeric water quality target (e.g., when the pollutant of concern is phosphorus and the numeric water quality target is expressed as a numerical dissolved oxygen criterion). In such cases, the TMDL should explain the linkage between the pollutant(s) of concern, and express the quantitative relationship between the TMDL target and pollutant of concern. In all cases, TMDL targets must represent the attainment of current water quality standards.*

☒ When a numeric TMDL target is established to ensure the attainment of a narrative water quality criterion, the numeric target, the methodology used to determine the numeric target, and the link between the pollutant of concern and the narrative water quality criterion should all be described in the TMDL document. Any additional information supporting the numeric target and linkage should also be included in the document.

Recommendation:
☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

Summary: *The main water quality target for this TMDL is based on interpretation of narrative provisions found in the State's 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. 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 chlorophyll-a trophic status indicator is used by the NDDoH as the primary means to assess whether a lake or reservoir is meeting the narrative standards. Trophic status is a measure of the productivity of a lake or reservoir and is directly related to the level of nutrients (i.e., *phosphorus and nitrogen) entering the lake or reservoir from its watershed and/or from the internal recycling of nutrients. The NDDoH has established an in-lake growing season average chlorophyll-a concentration goal of 20 µg/L for most lake and reservoir nutrient TMDLs, including this TMDL for Braddock Dam. This chlorophyll-a goal corresponds to a chlorophyll-a TSI of 60 which is in the eutrophic range and, as such, will be a trophic state sufficient to maintain both aquatic life and recreation uses of most lakes and reservoirs in the state, including Braddock Dam.*

Due to the relationship between trophic status indicators and the aquatic community (as reflected by the fishery) or between trophic status indicators and the frequency of algal blooms, trophic status is an effective indicator of aquatic life and recreation use support in lakes and reservoirs. While the three trophic state indicators, chlorophyll-a, Secchi disk transparency, and total phosphorus, used in Carlson's TSI each independently estimate algal biomass and should produce the same index value for a given combination of variable values, often they do not. Transparency and phosphorus may co-vary with trophic state, many times the changes in observed in a lake's transparency are not caused by changes in algal biomass, but may be due to particulate sediment. Total phosphorus may or may not be strongly related to algal biomass due to light limitation and/or nitrogen and carbon limitation. Therefore, neither transparency nor phosphorus is an independent estimator of trophic state. For these reasons, the NDDoH gives priority to chlorophyll-a as the primary trophic state indicator because this variable is the most accurate of the three at predicting algal biomass.

The same conclusion was also reached by a multi-state project team consisting of lake managers and water quality specialists from North Dakota, South Dakota, Montana, Wyoming and EPA Region 8. This group concluded that for lakes and reservoirs in the plains region of EPA Region 8, an average growing season chlorophyll-a concentration of 20 µg/L or less should be the basis for nutrient criteria development for lakes and reservoirs in the plains region (including North Dakota) and that this chlorophyll-a target would be protective of all of a lake or reservoir's beneficial uses, including recreation and aquatic life. A report, prepared by Houston Engineering, concluded that most lakes and reservoirs in the plains region typically have high total phosphorus concentrations, but maintain relatively low productivity, and that due to this condition, chlorophyll-a is a better measure of a lake or reservoirs trophic status than is total phosphorus.

Water quality data collected in the lake in 2010 (see Table 6 in Appendix C) showed an average chlorophyll-a concentration of 27.5 µg/l, an average total phosphorus concentration of 210.4 µg/L, an average Secchi Depth of 1.2 meters, and an average total nitrogen concentration of 1.4 mg/l. Based on these data, Braddock Dam is generally assessed as a eutrophic lake.

The North Dakota State Water Quality Standard for dissolved oxygen is 5 mg/L as a daily minimum, and where up to 10% of representative samples collected during any three year period may be less than this value provided that lethal conditions are avoided. This is the dissolved oxygen TMDL target for Braddock Dam.

Comments: *No comments.*

3. Pollutant Source Analysis

A TMDL analysis is conducted when a pollutant load is known or suspected to be exceeding the loading capacity of the waterbody. Logically then, a TMDL analysis should consider all sources of the pollutant of concern in some manner. The detail provided in the source assessment step drives the rigor of the pollutant load allocation. In other words, it is only possible to specifically allocate quantifiable loads or load reductions to each identified source (or source category) when the relative load contribution from each source has been estimated. Therefore, the pollutant load from each identified source (or source category) should be specified and quantified. This may 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 may be appropriate. The approach should be clearly defined in the document.

Review Elements:

☒ The TMDL should include an identification of the point and nonpoint sources of the pollutant of concern, including the geographical location of the source(s) and the quantity of the loading, e.g., lbs/per day. This information is necessary for EPA to evaluate the WLA, LA and MOS components of the TMDL.

☒ The level of detail provided in the source assessment should be commensurate with the nature of the watershed and the nature of the pollutant being studied. Where it is possible to separate natural background from nonpoint sources, the TMDL should include a description of both the natural background loads and the nonpoint source loads.

☒ Natural background loads should not be assumed to be the difference between the sum of known and quantified anthropogenic sources and the existing *in situ* loads (e.g. measured in stream) unless it can be demonstrated that the anthropogenic sources of the pollutant of concern have been identified, characterized, and quantified.

☒ The sampling data relied upon to discover, characterize, and quantify the pollutant sources should be included in the document (e.g. a data appendix) along with a description of how the data were analyzed to characterize and quantify the pollutant sources. A discussion of the known deficiencies and/or gaps in the data set and their potential implications should also be included.

Recommendation:
☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

Summary: *The TMDL document includes the landuse breakdown for the watershed based on the 2010 National Agricultural Statistics Service (NASS) data. In 2010, the dominant land use in the watershed that drains to Braddock Dam was agriculture. Approximately 75 percent of the landuse in the watershed was cropland, 19 percent was grassland/pastureland, and the remaining 6 percent was wetlands, forest, developed space, barren or fallow/idle cropland. The majority of the crops grown consisted of spring wheat, corn, barley, sunflowers, soybeans and winter wheat.*

TMDL identifies the major sources of phosphorus as coming from nonpoint source agricultural landuses within the watershed. There are no known point sources upstream of Braddock Dam. A nutrient loading analysis was performed using the Annualized Agricultural Nonpoint Source (AnnAGNPS) model which looked at various agricultural land uses and land management *practices in the watershed (see Section 5.3 AnnAGNPS Watershed Model in the TMDL document). A five year simulation period was run on the Braddock Dam watershed at its present condition to provide a best estimation of the current land use practices applied to the soils and slopes of the watershed to obtain nutrient loads from the individual cells as well as the watershed as a whole. Major land use in the Braddock Dam watershed was identified as wheat, winter wheat, barley, corn, soybeans, dry beans, sunflowers, pasture, rangeland, and residential/urban. Crop rotations were determined from three years of land survey data from the National Agricultural Statistical Service. The compiled data was used to assess the watershed to identify "critical cells" located in the watershed for potential best management practice implementation (see Figure 10 in the TMDL document). Critical cells were determined to be cells in the watershed providing an estimated annual phosphorus yield of 0.059 lbs/acre/year or greater.*

The CNET model indicated that excessive nutrient loading is occurring and is primarily responsible for the low dissolved oxygen levels in Braddock Dam. Therefore, the nutrient loading sources to Braddock Dam are the same sources contributing to the dissolved oxygen impairment in the lake.

Comments: *No comments.*

4. TMDL Technical Analysis

TMDL determinations should be supported by an analysis of the available data, discussion of the known deficiencies and/or gaps in the data set, and an appropriate level of technical analysis. This 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.

A TMDL analysis determines the maximum pollutant loading rate that may be allowed to a waterbody without violating water quality standards. The TMDL analysis should demonstrate an understanding of the relationship between the rate of pollutant loading into the waterbody and the resultant water quality impacts. This stressor → response relationship between the pollutant and impairment and between the selected targets, sources, TMDLs, and load allocations needs to be clearly articulated and supported by an appropriate level of technical analysis. Every effort should be made to be as detailed as possible, and to base all conclusions on the best available scientific principles.

The pollutant loading allocation is at the heart of the TMDL analysis. TMDLs apportion responsibility for taking actions by allocating 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 division of responsibility.

The pollutant loading allocation that will result in achievement of the water quality target is expressed in the form of the standard TMDL equation:

$$TMDL = \sum WLAs + \sum LAs + MOS$$

Where:

TMDL	=	Total Maximum Daily Load (also called the Loading Capacity)
LAs	=	Load Allocations
WLAs	=	Wasteload Allocations
MOS	=	Margin Of Safety

Review Elements:

☒ A TMDL must identify the loading capacity of a waterbody for the applicable pollutant, taking into consideration temporal variations in that capacity. EPA regulations define loading capacity as the greatest amount of a pollutant that a water can receive without violating water quality standards (40 C.F.R. §130.2(f)).

☒ The total loading capacity of the waterbody should be clearly demonstrated to equate back to the pollutant load allocations through a balanced TMDL equation. In instances where numerous LA, WLA and seasonal TMDL capacities make expression in the form of an equation cumbersome, a table may be substituted as long as it is clear that the total TMDL capacity equates to the sum of the allocations.

☒ The TMDL document should describe the methodology and technical analysis used to establish and quantify the cause-and-effect relationship between the numeric target and the identified pollutant sources. In many instances, this method will be a water quality model.

☒ It is necessary for EPA staff to be aware of any assumptions used in the technical analysis to understand and evaluate the methodology used to derive the TMDL value and associated loading allocations. Therefore, the TMDL document should contain a description of any important assumptions (including the basis for those assumptions) made in developing the TMDL, including but not limited to:

(1) the spatial extent of the watershed in which the impaired waterbody is located and the spatial extent of the TMDL technical analysis;
(2) the distribution of land use in the watershed (e.g., urban, forested, agriculture);
(3) a presentation of relevant information affecting the characterization of the pollutant of concern and its allocation to sources such as population characteristics, wildlife resources, industrial activities etc…;
(4) present and future growth trends, if taken into consideration in determining the TMDL and preparing the TMDL document (e.g., the TMDL could include the design capacity of an existing or planned wastewater treatment facility);
(5) an explanation and analytical basis for expressing the TMDL through surrogate measures, if applicable. Surrogate measures are parameters such as percent fines and turbidity for sediment impairments; chlorophyll *a* and phosphorus loadings for excess algae; length of riparian buffer; or number of acres of best management practices.

☒ The TMDL document should contain documentation supporting the TMDL analysis, including an inventory of the data set used, a description of the methodology used to analyze the data, a discussion of strengths and weaknesses in the analytical process, and the results from any water quality modeling used. This information is necessary for EPA to review the loading capacity determination, and the associated load, wasteload, and margin of safety allocations.

☒ TMDLs must take critical conditions (e.g., steam flow, loading, and water quality parameters, seasonality, etc…) into account as part of the analysis of loading capacity (40 C.F.R. §130.7(c)(1)). TMDLs should define applicable critical conditions and describe the approach used to determine both point and nonpoint source loadings under such critical conditions. In particular, the document should discuss the approach used to compute and allocate nonpoint source loadings, e.g., meteorological conditions and land use distribution.

☐ Where both nonpoint sources and NPDES permitted point sources are included in the TMDL loading allocation, and attainment of the TMDL target depends on reductions in the nonpoint source loads, the TMDL document must include a demonstration that nonpoint source loading reductions needed to implement the load allocations are actually practicable [40 CFR 130.2(i) and 122.44(d)].

Recommendation:
☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

Summary: *The technical analysis should describe the cause and effect relationship between the identified pollutant sources, the numeric targets, and achievement of water quality standards. It should also include a description of the analytical processes used, results from water quality modeling, assumptions and other pertinent information. The technical analysis for the Braddock Dam watershed TMDL describes how the nutrient loads were derived in order to meet the applicable water quality standards for the 303(d) impaired waterbody.*

In order to determine the cause and effect relationship between the water quality target and the identified sources, various models and loading analysis were utilized. The FLUX32 model was used to facilitate the analysis and reduction of the tributary inflow and the reservoir outflow water quality data for nutrients and sediment, as well as flow data into and out of Braddock Dam. Output from the FLUX32 program was then used as an input file to calibrate the CNET/BATHTUB eutrophication response model. The CNET/BATHTUB model was used to evaluate and predict the effects of various nutrient reduction scenarios, and the subsequent eutrophication response in Braddock Dam reservoir.

The CNET model was selected to simulate the eutrophication response within Braddock Dam. CNET is a modified version of the BATHTUB water quality model. Both BATHTUB and CNET perform 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 reservoirs. CNET is a spreadsheet model currently available as a "beta" version from Dr. William W. Walker. The primary benefit of using CNET over BATHTUB is that the user can modify the CNET model to implement a Monte Carlo approach. This allows the effect of parameter uncertainty and normal variability in the inputs (e.g., amount of surface runoff which varies annually depending upon the amount of precipitation) to be quantified when computing the mean concentration of TP, chl-a, and SD.

The loading capacity of Braddock Dam was computed using a stochastic approach based on the hydrology and water quality simulated by the CNET model. The loading capacity for the *reservoir was defined as the growing season TP load resulting in a seasonal mean Chl-a concentration for the 50th percentile non-exceedance value of 20.0 μg/L. The curve nearest to the value 20.0 μg/L of chlorophyll-a for the 50 percentile value is used to estimate the loading capacity. The value of 20.0 μg/L of chlorophyll-a represents the growing season mean Chl-a eutrophication goal for nondegradation and corresponds to a TSI value of 60.0.*

Through the use CNET, the average growing season TP load, corresponding to an average growing season chlorophyll-a concentration of 20 μg/L, can be estimated. For this TMDL, a 40 percent reduction in the observed total phosphorus load is estimated to be needed to achieve the TMDL goal for Braddock Dam. The resulting loading capacity is 3,058 kg/year during the April – November growing season. Section 5.2 and Appendix C of the TMDL document contain additional details of how the CNET model was used in development of the nutrient TMDL for Braddock Dam.

High levels of nutrients can lead to eutrophication, which is defined as the undesirable growth of algae and other aquatic plants. In turn, eutrophication can lead to increased biological oxygen demand and oxygen depletion due to the respiration of microbes that decompose the dead algae and other organic material. The CNET model indicated that excessive nutrient loading is occurring and is primarily responsible for the low dissolved oxygen levels in Braddock Dam. As a result of the direct influence of eutrophication on increased biological oxygen demand and microbial respiration, it is anticipated that meeting the chlorophyll-a concentration target for Braddock Dam will address the dissolved oxygen impairment. A reduction in chlorophyll-a concentration due to the resulting lower algal biomass levels in the water column, would reduce the biological oxygen demand exerted by the decomposition of these primary producers. The reduction in biological oxygen demand is therefore assumed to result in attainment of the dissolved oxygen standard.

Comments: *No Comments.*

4.1 Data Set Description

TMDL documents should include a thorough description and summary of all available water quality data that are relevant to the water quality assessment and TMDL analysis. An inventory of the data used for the TMDL analysis should be provided to document, for the record, the data used in decision making. This also provides the reader with the opportunity to independently review the data. The TMDL analysis should make use of all readily available data for the waterbody under analysis unless the TMDL writer determines that the data are not relevant or appropriate. For relevant data that were known but rejected, an explanation of why the data were not utilized should be provided (e.g., samples exceeded holding times, data collected prior to a specific date were not considered timely, etc…).

Review Elements:

☒ TMDL documents should include a thorough description and summary of all available water quality data that are relevant to the water quality assessment and TMDL analysis such that the water quality impairments are clearly defined and linked to the impaired beneficial uses and appropriate water quality criteria.

☐ The TMDL document submitted should be accompanied by the data set utilized during the TMDL analysis. If possible, it is preferred that the data set be provided in an electronic format and referenced in the document. If electronic submission of the data is not possible, the data set may be included as an appendix to the document.

Recommendation:
☐ Approve ☒ Partial Approval ☐ Disapprove ☐ Insufficient Information

***Summary**: The Braddock Dam TMDL data description and summary are included in the Available Water Quality Data section (Section 1.4). Recent water quality monitoring was conducted from March 2010 – October 2011. Sampling was conducted at one tributary inlet site, at the outlet from Braddock Dam and at one reservoir site located in deepest area of the reservoir. Tables 4 and 5 summarize the water quality data collected in the reservoir.*

***Comments:** Section 5.4 mentions low dissolved oxygen levels in Braddock Lake that were recorded as being below the water quality standard of 5.0 mg/L. However, no dissolved oxygen data summary tables, dissolved oxygen profile graphs, or data sets are provided in either the Available Water Quality Data section or in the TMDL appendices. We recommend adding the dissolved oxygen data to the TMDL document.*

4.2 Waste Load Allocations (WLA):

Waste Load Allocations represent point source pollutant loads to the waterbody. Point source loads are typically better understood and more easily monitored and quantified than nonpoint source loads. Whenever practical, each point source should be given a separate waste load allocation. All NPDES permitted dischargers that discharge the pollutant under analysis directly to the waterbody should be identified and given separate waste load allocations. The finalized WLAs are required to be incorporated into future NPDES permit renewals.

Review Elements:

☒ EPA regulations require that a TMDL include WLAs, which identify the portion of the loading capacity allocated to individual existing and future point source(s) (40 C.F.R. §130.2(h), 40 C.F.R. §130.2(i)). In some cases, WLAs may cover more than one discharger, e.g., if the source is contained within a general permit. If no allocations are to be made to point sources, then the TMDL should include a value of zero for the WLA.

☐ All NPDES permitted dischargers given WLA as part of the TMDL should be identified in the TMDL, including the specific NPDES permit numbers, their geographical locations, and their associated waste load allocations.

Recommendation:
☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

***Summary**: There are no permitted point sources in the Braddock Dam watershed. Therefore the WLA for this TMDL is zero (see Table 10 in the TMDL document).*

***Comments**: No comments.*

4.3 Load Allocations (LA):

Load allocations include the nonpoint source, natural, and background loads. These types of loads are typically more difficult to quantify than point source loads, and may include a significant degree of uncertainty. Often it is necessary to group these loads into larger categories and estimate the loading rates based on limited monitoring data and/or modeling results. The background load represents a composite of all upstream pollutant loads into the waterbody. In addition to the upstream nonpoint and upstream natural load, the background load often includes upstream point source loads that are not given specific waste load allocations in this particular TMDL analysis. In instances where nonpoint source loading rates are particularly difficult to quantify, a performance-based allocation approach, in which a detailed monitoring plan and adaptive management strategy are employed for the application of BMPs, may be appropriate.

Review Elements:

☒ EPA regulations require that TMDL expressions include LAs which identify the portion of the loading capacity attributed to nonpoint sources and to natural background. Load allocations may range from reasonably accurate estimates to gross allotments (40 C.F.R. §130.2(g)). Load allocations may be included for both existing and future nonpoint source loads. Where possible, load allocations should be described separately for natural background and nonpoint sources.

☒ Load allocations assigned to natural background loads should not be assumed to be the difference between the sum of known and quantified anthropogenic sources and the existing *in situ* loads (e.g., measured in stream) unless it can be demonstrated that the anthropogenic sources of the pollutant of concern have been identified and given proper load or waste load allocations.

Recommendation:
☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

Summary: *The Technical Analysis section of the TMDL describes how the phosphorus loading capacity for the reservoir was derived and allocated to sources in the watershed. There are no point sources in the watershed upstream of Braddock Dam; therefore most of the loading capacity was allocated to nonpoint sources in the watershed. Ten percent of the loading capacity was allocated as an explicit margin of safety. See Table 10 in the TMDL document for the specific allocation values.*

Comments: *No comments.*

4.4 Margin of Safety (MOS):

Natural systems are inherently complex. Any mathematical relationship used to quantify the stressor → response relationship between pollutant loading rates and the resultant water quality impacts, no matter how rigorous, will include some level of uncertainty and error. To compensate for this uncertainty and ensure water quality standards will be attained, a margin of safety is required as a component of each TMDL. The MOS may take the form of a explicit load allocation (e.g., 10 lbs/day), or may be implicitly built into the TMDL analysis through the use of conservative assumptions and values for the various factors that determine the TMDL pollutant load → water quality effect relationship. Whether explicit or implicit, the MOS should be supported by an appropriate level of discussion that addresses the level of uncertainty in the various components of the TMDL technical analysis, the assumptions used in that analysis, and the relative effect of those assumptions on the final TMDL. The discussion should demonstrate that the MOS used is sufficient to ensure that the water quality standards would be attained if the TMDL pollutant loading rates are met. In cases where there is substantial uncertainty regarding the linkage between the proposed allocations and achievement of water quality standards, it may be necessary to employ a phased or adaptive management approach (e.g., establish a monitoring plan to determine if the proposed allocations are, in fact, leading to the desired water quality improvements).

Review Elements:

☒ TMDLs must include a margin of safety (MOS) to account for any lack of knowledge concerning the relationship between load and wasteload allocations and water quality (CWA §303(d) (1) (C), 40 C.F.R. §130.7(c)(1)). EPA's 1991 TMDL Guidance explains that the MOS may be implicit (i.e., incorporated into the TMDL through conservative assumptions in the analysis) or explicit (i.e., expressed in the TMDL as loadings set aside for the MOS).

☐ If the MOS is implicit, the conservative assumptions in the analysis that account for the MOS should be identified and described. The document should discuss why the assumptions are considered conservative and the effect of the assumption on the final TMDL value determined.

☒ If the MOS is explicit, the loading set aside for the MOS should be identified. The document should discuss how the explicit MOS chosen is related to the uncertainty and/or potential error in the linkage analysis between the WQS, the TMDL target, and the TMDL loading rate.

☐ If, rather than an explicit or implicit MOS, the TMDL relies upon a phased approach to deal with large and/or unquantifiable uncertainties in the linkage analysis, the document should include a description of the planned phases for the TMDL as well as a monitoring plan and adaptive management strategy.

Recommendation:
☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

Summary: *The Braddock Dam TMDL includes an explicit MOS derived by calculating 10 percent of the loading capacity.*

Comments*:* *No comments.*

4.5 Seasonality and variations in assimilative capacity:

The TMDL relationship is a factor of both the loading rate of the pollutant to the waterbody and the amount of pollutant the waterbody can assimilate and still attain water quality standards. Water quality standards often vary based on seasonal considerations. Therefore, it is appropriate that the TMDL analysis consider seasonal variations, such as critical flow periods (high flow, low flow), when establishing TMDLs, targets, and allocations.

Review Elements:

☒ The statute and regulations require that a TMDL be established with consideration of seasonal variations. The TMDL must describe the method chosen for including seasonal variability as a factor. (CWA §303(d)(1)(C), 40 C.F.R. §130.7(c)(1)).

Recommendation:
☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

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

Comments: *No comments.*

5. Public Participation

EPA regulations require that the establishment of TMDLs be conducted in a process open to the public, and that the public be afforded an opportunity to participate. To meaningfully participate in the TMDL process it is necessary that stakeholders, including members of the general public, be able to understand the problem and the proposed solution. TMDL documents should include language that explains the issues to the general public in understandable terms, as well as provides additional detailed technical information for the scientific community. Notifications or solicitations for comments regarding the TMDL should be made available to the general public, widely circulated, and clearly identify the product as a TMDL and the fact that it will be submitted to EPA for review. When the final TMDL is submitted to EPA for approval, a copy of the comments received by the state and the state responses to those comments should be included with the document.

Review Elements:

☒ The TMDL must include a description of the public participation process used during the development of the TMDL (40 C.F.R. §130.7(c)(1)(ii)).

☐ TMDLs submitted to EPA for review and approval should include a summary of significant comments and the State's/Tribe's responses to those comments.

Recommendation:
☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

Summary: *The TMDL document 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. Letters notifying stakeholders of the availability of the draft TMDL document were mailed to stakeholders in the watershed during public comment. Also, the draft*

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

Comments: *No comments.*

6. Monitoring Strategy

TMDLs may have significant uncertainty associated with the 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 document to articulate the means by which the TMDL will be evaluated in the field, and to provide for future supplemental data that will address any uncertainties that may exist when the document is prepared.

Review Elements:

☐ When a TMDL involves both NPDES permitted point source(s) and nonpoint source(s) allocations, and attainment of the TMDL target depends on reductions in the nonpoint source loads, the TMDL document should include a monitoring plan that describes the additional data to be collected to determine if the load reductions provided for in the TMDL are occurring.

☐ Under certain circumstances, a phased TMDL approach may be utilized when limited existing data are relied upon to develop a TMDL, and the State believes that the use of additional data or data based on better analytical techniques would likely increase the accuracy of the TMDL load calculation and merit development of a second phase TMDL. EPA recommends that a phased TMDL document or its implementation plan include a monitoring plan and a scheduled timeframe for revision of the TMDL. These elements would not be an intrinsic part of the TMDL and would not be approved by EPA, but may be necessary to support a rationale for approving the TMDL. http://www.epa.gov/owow/tmdl/tmdl_clarification_letter.pdf

Recommendation:
☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

Summary: *To insure that the BMPs implemented as a part of any watershed restoration plan will reduce phosphorus levels, water quality monitoring will be conducted in accordance with an approved Quality Assurance Project Plan. Specifically, monitoring will be conducted for all variables that are currently causing impairments to the beneficial uses of the waterbody. Once a watershed restoration plan (e.g. 319 PIP) is implemented, monitoring will be conducted in the lake/reservoir beginning two years after implementation and extending five years after the implementation project is complete.*

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

Comments: *No comments.*

7. Restoration Strategy

The overall purpose of the TMDL analysis is to determine what actions are necessary to ensure that the pollutant load in a waterbody does not result in water quality impairment. Adding additional detail regarding the proposed approach for the restoration of water quality is not currently a regulatory requirement, but is considered a value added component of a TMDL document. During the TMDL analytical process, information is often gained that may serve to point restoration efforts in the right direction and help ensure that resources are spent in the most efficient manner possible. For example, watershed models used to analyze the linkage between the pollutant loading rates and resultant water quality impacts might also be used to conduct "what if" scenarios to help direct BMP installations to locations that provide the greatest pollutant reductions. Once a TMDL has been written and approved, it is often the responsibility of other water quality programs to see that it is implemented. The level of quality and detail provided in the restoration strategy will greatly influence the future success in achieving the needed pollutant load reductions.

Review Elements:

☐ EPA is not required to and does not approve TMDL implementation plans. However, in cases where a WLA is dependent upon the achievement of a LA, "reasonable assurance" is required to demonstrate the necessary LA called for in the document is practicable. A discussion of the BMPs (or other load reduction measures) that are to be relied upon to achieve the LA(s), and programs and funding sources that will be relied upon to implement the load reductions called for in the document, may be included in the implementation/restoration section of the TMDL document to support a demonstration of "reasonable assurance".

Recommendation:
☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

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

Comments: *No comments.*

8. Daily Loading Expression

The goal of a TMDL analysis is to determine what actions are necessary to attain and maintain WQS. The appropriate averaging period that corresponds to this goal will vary depending on the pollutant and the nature of the waterbody under analysis. When selecting an appropriate averaging period for a TMDL analysis, primary concern should be given to the nature of the pollutant in question and the achievement of the underlying WQS. However, recent federal appeals court decisions have pointed out that the title TMDL implies a "daily" loading rate. While the most appropriate averaging period to be used for developing a TMDL analysis may vary according to the pollutant, a daily loading rate can provide a more practical indication of whether or not the overall needed load reductions are being achieved. When limited monitoring resources are available, a daily loading target that takes into account the natural variability of the system can serve as a useful indicator for whether or not the overall load reductions are likely to be met. Therefore, a daily expression of the required pollutant loading rate is a required element in all TMDLs, in addition to any other load averaging periods that may have been used to conduct the TMDL analysis. The level of effort spent to develop the daily load indicator should be based on the overall utility it can provide as an indicator for the total load reductions needed.

Review Elements:

☒ The document should include an expression of the TMDL in terms of a daily load. However, the TMDL may also be expressed in temporal terms other than daily (e.g., an annual or monthly load). If the document expresses the TMDL in additional "non-daily" terms the document should explain why it is appropriate or advantageous to express the TMDL in the additional unit of measurement chosen.

Recommendation:
☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

Summary: *The Braddock Dam nutrient TMDL includes a daily phosphorus load expressed as 8.4 kg per day. The NDDoH believes that describing the phosphorus load as an annual load is more realistic and protective of the waterbody. Most phosphorus based eutrophication models use annual phosphorus loads, because seasonality and unpredictable precipitation patterns make a daily load unrealistic. EPA recognizes that, under the specific circumstances, the state may deem the annual load the most appropriate timeframe (i.e., the TSI water quality target is based on an interpretation of narrative water quality standards which naturally does not include an averaging period). EPA notes that the Braddock Dam TMDL calculations for phosphorus include an approximated daily load derived through simple division of the annual load by the number of days in a year. This should be considered an "average" daily load that typically will not match the actual phosphorus load reaching the reservoir on a given day.*

Comments: *No comments.*

Appendix E
NDDoH's Response to Comments Received from US EPA Region 8

US EPA Region 8 Comments: The 2012 303(d) list shows Braddock Dam as 91.2 acres in size. This is consistent with the acreage given in Table 1, however the listing information used in the TMDL appears to be based on the 2010 303(d) list (see Table 2). The 2010 303(d) list information for Braddock Dam showed the size as 69.5 acres. Also, the Table 2 303(d) listing information is missing the dissolved oxygen impairment and has an error in the assessment unit ID. We suggest revising the TMDL to be consistent with the 2012 303(d) listing information.

Section 1.1 seems to indicate that this TMDL document only addresses the nutrient / eutrophication / biological indicators impairment, whereas the title of the document seems to indicate that it addresses the dissolved oxygen impairment too. We suggest that revising one or the other to be consistent.

We suggest adding a sentence to Section 1.1, Clean Water Act Section 303(d) Listing Information, that addresses the sedimentation / siltation impairment in Braddock Dam and include any plans for development of a TMDL to address the sediment impairment.

NDDoH Response: Table 2 and the associated narrative in Section 1.1 was changed to reflect information provided in the 2012 Section 303(d) listing. This includes the addition of the dissolved oxygen impairment and the correction to the assessment unit ID.

The second paragraph in Section 1.1 was revised to reflect the addition the dissolved oxygen impairment in the report which is consistent with the title of the report.

Additional language was added to the second paragraph in Section 1.1 which explains the NDDoH's plans for addressing the sediment/siltation impairment in the future.

US EPA Region 8 Comments: Section 5.4 mentions low dissolved oxygen levels in Braddock Lake that were recorded as being below the water quality standard of 5.0 mg/L. However, no dissolved oxygen data summary tables, dissolved oxygen profile graphs, or data sets are provided in either the Available Water Quality Data section or in the TMDL appendices. We recommend adding the dissolved oxygen data to the TMDL document.

NDDoH Response: The NDDoH has added Section 1.4.5 entitled "Temperature/Dissolved Oxygen Profile Data." This section and the associated temperature and dissolved oxygen profile graphs provided in Figures 7 and 8 describe the temperature and oxygen profile data collected in 1992, 1993 and 2010. The first paragraph in Section 5.4 was also revised to better explain the NDDoH's reason for the dissolved oxygen impairment listing.