# Nutrient and Dissolved Oxygen TMDLs for McDowell Dam in Burleigh County, North Dakota

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# for McDowell Dam in
# Burleigh County, North Dakota

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# 1.0 INTRODUCTION AND DESCRIPTION OF THE WATERSHED

McDowell Dam is located in Burleigh County, North Dakota, 5 miles east of Bismarck. The reservoir was created in 1976 with the construction of a dam on a small tributary to Apple Creek, which is a tributary to the Missouri River. It covers 51.1 acres and has a mean depth of 15.6 feet and a maximum depth of 42.4 feet. Table 1 summarizes some of the geographical, hydrological, and physical characteristics of McDowell Dam.

**Table 1. General Characteristics of McDowell Dam and the McDowell Dam Watershed.**

| | |
|---|---|
| **Legal Name** | McDowell Dam |
| **Major Drainage Basin** | Apple Creek and Missouri River |
| **Nearest Municipality** | Bismarck , ND |
| **Assessmnet Unit ID** | ND-10130103-014-L_00 |
| **County** | Burleigh County, ND |
| **Latitude** | 46.82664 |
| **Longitude** | -100.63093 |
| **Surface Area** | 51.1 acres |
| **Watershed Area** | 3959 acres |
| **Average Depth** | 15.6 feet |
| **Maximum Depth** | 42.4 feet |
| **Volume** | 802 acre-feet |
| **Tributaries** | Small, unnamed tributary in the northwest portion of the lake |
| **Outlets** | Gated structure |
| **Type of Waterbody** | Constructed reservoir - 1976 |
| **Fishery Type** | Class 3 – warm water fishery – bluegill, largemouth bass, rainbow trout |
| **Classified Beneficial Uses** | Recreation, agriculture, aquatic life, warm water fishery |

## 1.1 Clean Water Act Section 303(d) Listing Information

As part of the Clean Water Act Section 303(d) Total Maximum Daily Load (TMDL) listing process, the North Dakota Department of Health (NDDoH) has identified McDowell Dam as an impaired waterbody (Tables 2 and 3). In 1996, the NDDoH assessed the reservoir as hypereutrophic due to a rapid loss of dissolved oxygen below the thermocline, a need for aeration to maintain the fishery and a history of significant algal blooms (NDDoH, 1996).

**Table 2. 2004 Section 303(d) TMDL Listing for Dissolved Oxygen.**

| | |
|---|---|
| Identification Number | Assessment Unit (AU) ND-10130103-014-L_00 |
| Description | McDowell Dam |
| Size | 51.1 acres |
| Designated Use | Fish and Other Aquatic Biota |
| Use Support | Not Supporting |
| Impairment | Dissolved Oxygen |
| Priority | 1 (High) |

**Tabl 3. 2004 Section 303(d) TMDL Listing for Nutrients/Eutrophication.**

| | |
|---|---|
| Identification Number | Assessment Unit (AU) ND-10130103-014-L_00 |
| Description | McDowell Dam |
| Size | 51.1 acres |
| Designated Use | Recreation |
| Use Support | Not Supporting |
| Impairment | Nutrient/Eutrophication |
| Priority | 1 (High) |

The reservoir is listed as “not supporting” for aquatic life (i.e., fish and other aquatic biota) and recreation uses because of low dissolved oxygen and nutrient/eutrophication, respectively. McDowell Dam is classified as a Class 3 warm water fisheries lake, defined as capable of supporting growth and propagation of nonsalmonid fishes and associated aquatic biota. The fishery that was initially established within the reservoir consisted of bluegill, largemouth bass, smallmouth bass and rainbow trout. As the reservoir has aged it has experienced repeated late summer fish kills. These repeated die offs were caused by a eutrophic condition and subsequent anoxia below the thermocline.

## 1.2 Topography

The contributing watershed for McDowell Dam covers approximately 3,759 acres or 5.9 square miles and is located within the Missouri Coteau. The Missouri Coteau is characterized by gently rolling uplands with moderate slopes. The maximum relief is approximately 100 feet. Soils in this region are formed from rocky, gravelly and sandy glacial till and are moderately to well-drained. The McDowell Dam watershed is composed of five subwatersheds with subwatersheds 3, 4 and 5 contributing flow to the reservoir (Table 4, Figure 1). Subwatersheds 1 and 2 are considered part of the McDowell Dam watershed, however under normal runoff conditions a small upstream dam prevents these waters from flowing into the reservoir.

**Table 4. Subwatersheds of McDowell Dam and Hydrologic Characteristics.**

| Subwatershed | Drainage Area (acres) | Drainage Area ($mi^2$) | Hydrologic Characteristics |
|---|---|---|---|
| 1 | 360 | 0.56 | Contributes water to an upper watershed dam |
| 2 | 1,285 | 2.01 | Contributes water to an upper watershed dam |
| 3 | 1,050 | 1.64 | Contributes water to the reservoir |
| 4 | 584 | 0.91 | Contributes water to the reservoir |
| 5 | 480 | 0.75 | Contributes water to the reservoir |
| ***Total*** | *3,759* | *5.87* | |

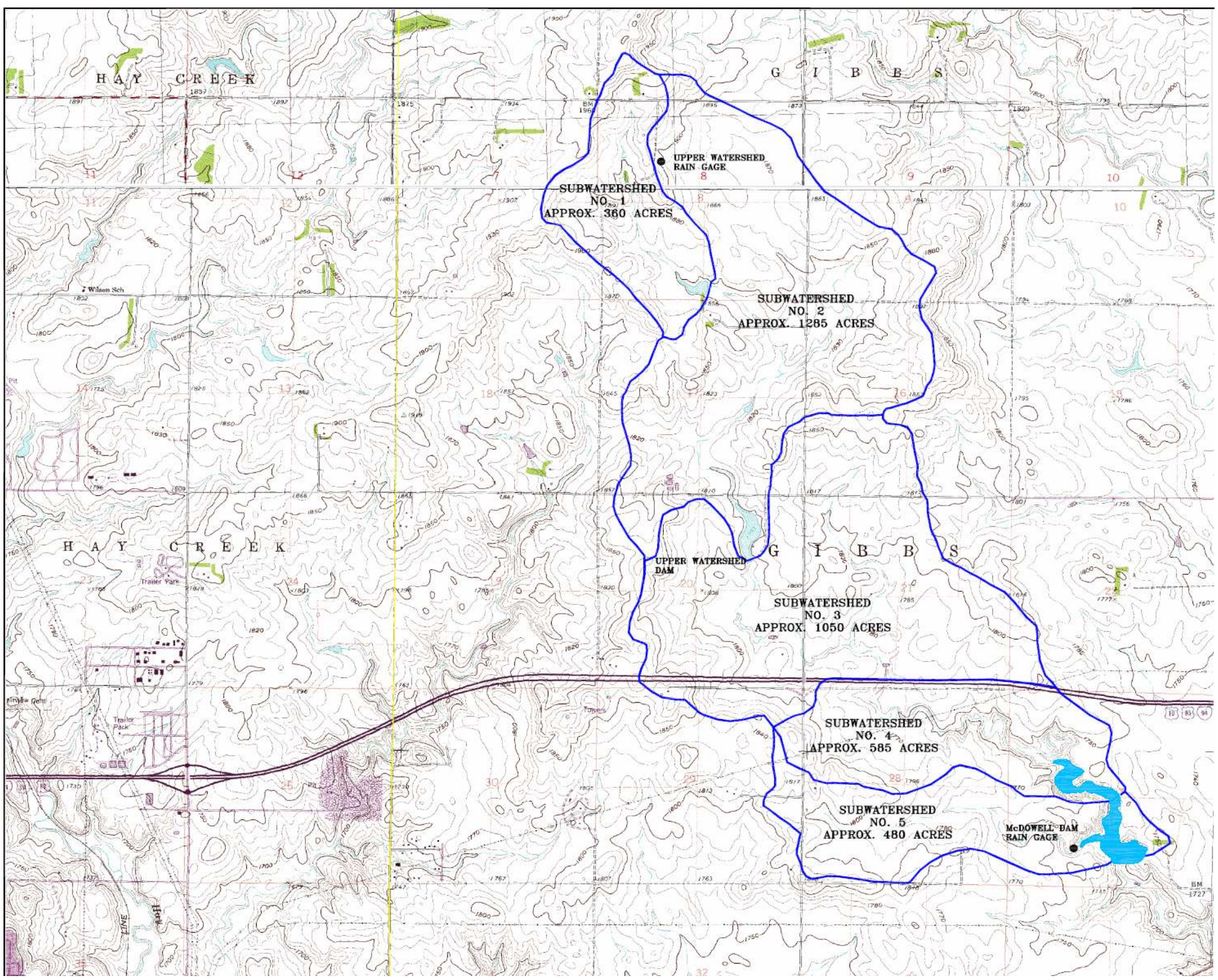


**Figure 1. McDowell Dam and Subwatersheds**.

## 1.3 Land Use/Land Cover in the Watershed

Primary land use is agriculture, with 2,650 acres or 71% in cultivation. The remaining land uses include non-cultivated acres (i.e., pasture) (23%), rural residential developments (5%) and roads (1%) (Figure 2).

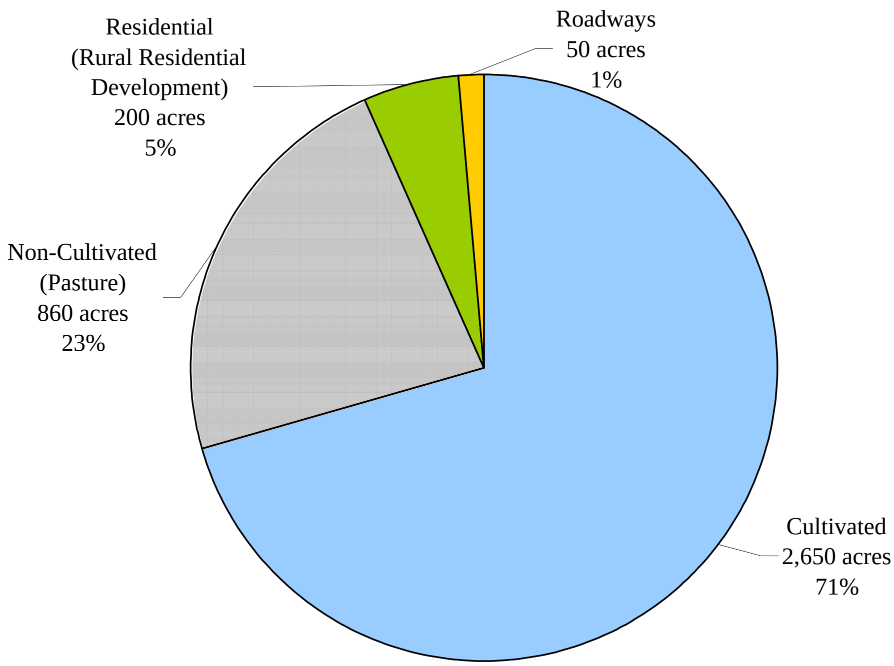


**Figure 2. Land Use Summary for the McDowell Dam Watershed.**

## 1.4 Climate and Precipitation

McDowell Dam and its watershed lie within the south central climate division of North Dakota. South central North Dakota has a typical continental climate characterized by large annual, daily, and day-to-day temperature changes, light to moderate precipitation, and nearly continuous air movement. The average air temperature in January is 9.18˚F, while the average air temperature in July is 70.57˚F (HPRCC, 2007). Over the last twenty years the average annual temperature and precipitation recorded in nearby Bismarck, North Dakota, is 41.88° F and 16.33 inches, respectively. Average monthly precipitation totals are shown in Figure 3 (HPRCC, 2007). June is the wettest month of the year with average precipitation of 2.97 inches. Precipitation events tend to be brief and intense and occur mainly during the months of May through August, with little precipitation from November through March.

Further discussion of the climate and precipitation data is included in the *McDowell Dam Water Quality Assessment Report* (Appendix A).

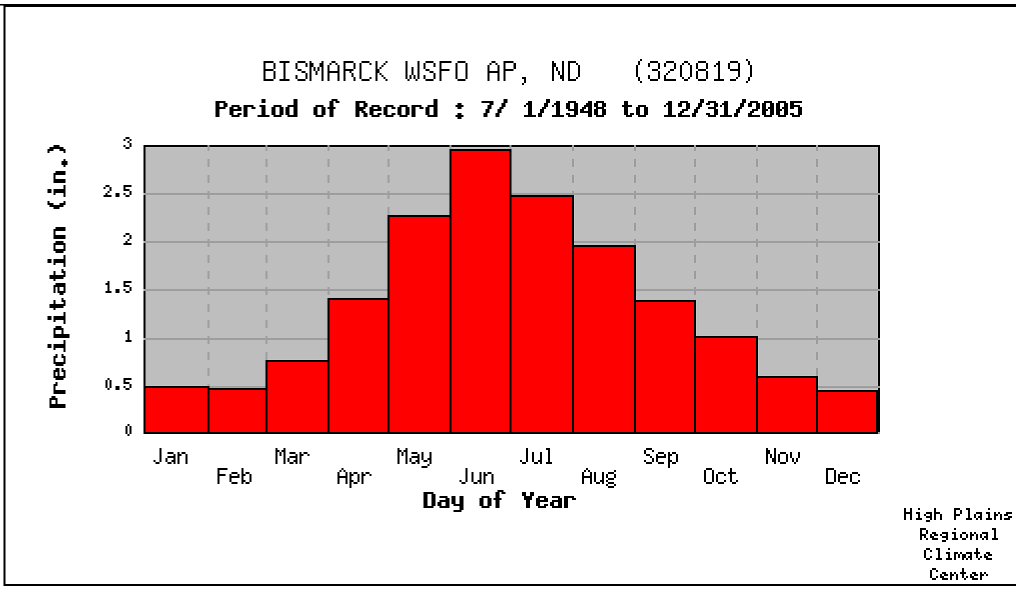


**Figure 3. Average Total Monthly Precipitation.**

## 1.5 Available Water Quality and Hydrology Data

The NDDoH collected water quality samples in 1994 and 1995 from the reservoir using the methodology described in the *Lake Water Quality Assessment Atlas, Volume II* (NDDoH, 1996). Parameters analyzed included phosphorus, nitrogen, dissolved oxygen, water temperature, Secchi disk transparency, lake bed sediments, aquatic vegetation and phytoplankton. Data were summarized and reported in the *North Dakota Lake Assessment Atlas, Volume II* (NDDOH, 1996).

American Engineering, P.C. completed an evaluation of the annual and summer runoff yields and a simulation of historic water levels within the reservoir. The data are summarized in the *McDowell Dam Recreation Area: A Supplemental Water Supply Evaluation – Annual Runoff Review, Reservoir Simulation and Benefit/Cost Analysis* (American Engineering, 1995). Information used in the evaluation included an analysis of runoff yields, precipitation and evaporation records, embankment seepage rates, and physical features of the reservoir's recreational area and watershed.

There were three water quality sampling sites selected for the TMDL study (Table 5, Figure 3). The upstream site was located near the intersection of the walking trail and the creek on the northwest side of the reservoir. The downstream site was located at the outlet to the reservoir. The in-lake site was located in the deepest part of the reservoir at the south end near the intake structure. Most of the monitoring activities occurred between May and October 2003 with one additional sampling event in November 2002.

**Table 5. Location of water sampling sites for McDowell Dam.**

| Sampling Site | Site ID | Latitude (approx.) | Longitude (approx.) |
|---|---|---|---|
| In-lake | 380815 | 46N 49'33" | 100W 38' 3" |
| Upstream | 385275 | 46N 49' 59" | 100W 38' 43" |
| Downstream | 385274 | 36" RCP outlet at the base of the dam discharging into the plunge pool | |

1.5.1 Upstream Monitoring

Surface water grab samples were collected from the upstream site on three dates at mid-depth of the flow in the creek. Samples were collected in accordance with accepted Standard Operating Procedures (SOPs) [see *Quality Assurance Project Plan for the McDowell Dam TMDL.*, (Houston Engineering, 2002)].

1.5.2 Downstream Monitoring

The downstream sampling site measured only seepage discharges through the earthen embankment. There was one sample collected during the study period. Historic seepage outflow data were obtained from the NRCS (Wiedenmeyer, 2004).

1.5.3 In-Lake Monitoring

In-lake water quality samples were collected at 3 predetermined depths for the lab analyzed parameters and throughout the water column at one meter intervals for the field measured parameters. Table 6 identifies the frequency of sampling and the analysis for each sample. Samples were collected in accordance with accepted SOPs [see *Quality Assurance Project Plan for the McDowell Dam TMDL*. (Houston Engineering, 2002)].


**Figure 4. McDowell Dam Sampling Locations.**

**Table 6. Samples Collected from McDowell Dam and the Parameters Analyzed for the TMDL Study.**

| Parameter | Field/Lab Analysis[1] | Sampling Frequency[2] | | Sample Depth[3] |
|---|---|---|---|---|
| | | Nov 2002 - April 2003 | May 2003 - October 2003 | |
| Water level (Stage) | Daily average from May – Oct 2003 | | | |
| Temperature | F | M | B | d |
| Dissolved oxygen | F | M | B | d |
| Total Kjeldahl nitrogen | L | M | B | a,b,c |
| Ammonia nitrogen | L | M | B | a,b,c |
| Nitrite plus nitrate nitrogen | L | M | B | a,b,c |
| Total nitrogen | L | M | B | a,b,c |
| Dissolved phosphorus | L | M | B | a,b,c |
| Total phosphorus | L | M | B | a,b,c |
| Total suspended solids | L | M | B | a,b,c |
| Total dissolved solids | L | M | B | a,b,c |
| Turbidity | F | M | B | e |
| pH | F/L | M | B | d/a,b,c |
| Total alkalinity | L | M | B | a,b,c |
| Specific conductance | F/L | M | B | d/a,b,c |
| Chlorophyll-a | L | M | B | a,b,c |
| Chlorophyll-b | L | M | B | a,b,c |
| Fecal coliform bacteria | L | ---- | Q | a |
| Phytoplankton enumeration and biovolume | L | M (Nov 2002) | B (May – Aug 2003) | a |

[1] Field/Lab Analysis: F = Field, L = Laboratory
[2] Sampling Frequency: B = Bimonthly, M = Monthly, Q = Quarterly, D = Daily
[3] Sample Depth: a = surface, b = mid-depth, c = bottom depth, d = 1-m increments from surface to bottom, e = depth as necessary

## 2.0 WATER QUALITY STANDARDS

McDowell Dam is a Class 3 waterbody which carries the following definition:

- W*arm water fishery. Waters capable of supporting growth and propagation of nonsalmonid fishes and associated aquatic biota.*

### 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, 2001).

- 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, 2001).

### 2.2 Numeric Water Quality Standards

*Standards of Quality for Waters of the State* (North Dakota Century Code 33-16) establishes numeric standards for dissolved oxygen and total phosphorus (Table 7). The numeric standards for Class I streams include all classified lakes. The standard for dissolved oxygen is a concentration not less than 5.0 mg/L. The standard for total phosphorus is 0.1 mg/L. In addition, guidelines for nitrates as N and phosphates as P have been established for use as goals in lake improvement and maintenance programs. The guideline for phosphates as P is 0.02 mg/L and 0.25 mg/L for nitrates as N.

**Table 7. Numeric Standards Applicable for North Dakota Lakes and Reservoirs (NDDoH, 2001).**

| Parameter | Guidelines | Limit |
|---|---|---|
| Guidelines for Classified Lakes | | |
| Nitrates (dissolved) | 1.0 mg/L | Maximum allowed |
| Phosphorus (total) | 0.1 mg/L | Maximum allowed |
| Dissolved Oxygen | 5 mg/L | Not less than |
| Guidelines for Goals in a lake improvement or maintenance program | | |
| $NO_3$ as N | 0.25 mg/L | Goal |
| $PO_4$ as P | 0.02 mg/L | Goal |

## 3.0 TMDL TARGETS

The Clean Water Act requires that Total Maximum Daily Loads (TMDLs) be developed for all 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 cause of impairment (e.g., nutrients, organic enrichment).

A TMDL target is the value that is measured to judge the success of the TMDL effort. TMDL targets must be based on state water quality standards, but can also include site-specific values when no numeric criteria are specified in a state's water quality standards. It is the goal of the Burleigh County Park Board and Water Resource Boards to keep the McDowell Dam a primary focus of recreation for the nearby city of Bismarck and other county residents. This means keeping McDowell Dam aesthetically pleasing and available for swimming while maintaining a viable fishery.

### 3.1 Nutrient TMDL Target

The McDowell Dam reservoir is classified as a Class III warmwater fishery. However, the primary use of the reservoir is for swimming (i.e., full body contact recreation). Therefore, rather than solely using the average annual or growing season total phosphorus concentration as the lake water quality goal, the use of water clarity (expressed as Secchi disk transparency), algal concentration (expressed as chlorophyll-a concentration) and algal bloom frequency are recommended for the nutrient TMDL targets. It is anticipated that by using these targets, current water quality standards will be achieved.

A reduction in algal bloom frequency is the primary method for establishing the nutrient TMDL target because it directly relates to recreational use. Algal bloom nuisance conditions, defined as chlorophyll-a concentration exceeding 30 ug/L, are predicted to be reduced from the current 36.4% to 24.5% of the time with a 30% reduction in the surface inflow and internal cycling total phosphorus load. During May, June, July and August (123 days total) this means 30 days compared to 45 days classified as "nuisance conditions" because of algae bloom conditions.

A secondary nutrient TMDL target for McDowell Dam is represented by trophic condition. The reservoir's trophic status can be described by the total phosphorus concentration, chlorophyll-a concentration or Secchi disk transparency**.** The term trophic state refers to the level of productivity in a lake and can be quantified using the Carlson's Trophic State Index (TSI). McDowell Dam is classified as hypereutrophic based on the total phosphorus concentration (TSI = 79). Based on a 30% reduction in the annual average total phosphorus loading from all sources, annual average total phosphorus concentrations will be reduced from 174.6 ug/L to 150.3 ug/L. Based on the predicted annual average total phosphorus concentration of 150.3 ug/L a TSI target of 76 has been chosen as a secondary target for this TMDL.

### 3.2 Dissolved Oxygen TMDL Target

The Water Quality Standard for the McDowell Dam is a dissolved oxygen level of "not less than 5 mg/L" (*Standards of Quality for Waters of the State*, North Dakota Century Code 33-16).

## 4.0 SIGNIFICANT SOURCES

### 4.1 Point Sources

There are no point sources in the McDowell Dam watershed.

### 4.2 Nonpoint Sources

Nonpoint source pollution accounts for 100 percent of the nutrient loading to McDowell Dam (NDDoH, 1996). Approximately 71% of the land upstream of the reservoir is farmed with an additional 23% used for pasture or with permanent cover. Currently, there are few developed areas in the watershed.

According to the Burleigh County Soil Conservation District, the majority (95%) of the cultivated lands and all other lands (100%) are adequately treated to prevent soil loss (NDDoH, 1996). "Adequately treated" is defined as the amount of land treatment necessary to achieve the soil loss tolerance value (T). The average T value for the McDowell Dam watershed is between 3 and 5 tons per acre. The P8 model predicts that during "normal" precipitation years a total of 19,873.3 lbs (9,033.3 kg) of total suspended solids, 421.1 lbs (191.4kg) of total phosphorus and 1322.2 lbs (601.0 kg) of total nitrogen (Table 8) are delivered to the McDowell Dam reservoir annually.

## 5.0 TECHNICAL ANALYSIS

Establishing a relationship between in-lake TMDL water quality targets and pollutant 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 necessary to meet water quality standards.

Nutrients are the driving influence on the water quality in terms of both algal response and dissolved oxygen concentration in the reservoir. The estimated values of the load and concentration for sediment, total nitrogen, total phosphorus, chlorophyll-a and Secchi disk transparency were calculated using the P8 and BATHTUB models. A complete discussion of the models used in the assessment is available in the *McDowell Dam Water Quality Assessment Report* (Appendix A).

### 5.1 P8 Model Estimated Annual Loads

The P8 model provided an estimate of the annual average tributary loads (lbs) and concentrations (ppm) for total suspended solids (TSS), total phosphorus, total kjeldahl nitrogen (TKN), ammonia ($NH_3$) and nitrate plus nitrite ($NO_2 + NO_3$) (Table 8). The tributary loads are estimated for 2001 (normal runoff year) and 2003 and correspond to the lake and rainfall monitoring period in 2003.

**Table 8. Estimated Tributary Loads and Average Concentrations Generated by the P8 Watershed Runoff Model for 2003 and a Normal Precipitation Year (2001).**

| **Variable**[1] | **Load (lbs)** | | **Concentration** | |
|---|---|---|---|---|
| | *2003* | *Normal Year* | *2003* | *Normal Year* |
| Total Suspended Solids | 3,183.28 | 19,875.3 | 22.1 mg/L | 18.6 |
| Total Phosphorus | 59.60 | 421.1 | 413.5 ug/L | 394.7 |
| Total Kjeldahl Nitrogen (TKN) | 159.24 | 1131.3 | 1104.8 | 1060.3 |
| $NH_3$ | 18.27 | 127.3 | 126.7 | 119.3 |
| $NO_2 + NO_3$ | 27.40 | 190.9 | 190.1 ppb | 179.0 ppb |

[1]TKN = organic nitrogen + $NH_3$; Total Nitrogen = ($NO_3 + NO_2$) + TKN. Surface runoff volume estimated is 53.03 Acre-feet for 2003 and 329.5 acre-feet for a normal precipitation year (2001).

The results show that the nutrient loads from surface runoff are estimated to increase by a factor of seven during “normal” conditions when compared to those observed during 2003. A “normal” precipitation year was developed using data from the North Dakota Agricultural weather network for the Mandan Station. The normal precipitation year was operationally defined as an annual precipitation depth with a 50 percent probability of occurrence (median value) for the period of record. By examining the historic precipitation record, the median annual precipitation depth was found to occur during 2001. The total rainfall depth for the period from May 4, 2001 through October 21, 2001 was then used in the P8 model to develop the “normal precipitation year” hydrologic cycle. The net groundwater inflow/outflow was assumed equal to zero.

Phosphorus and sediment yields for surface runoff were estimated for the sub-watersheds 3,4 and 5 using the P8 model (Table 9). The phosphorus and sediment yields for the watershed in 2003 are 0.009 tons/mi$^2$ and 0.48 tons/mi$^2$, respectively.

**Table 9. Phosphorus (Total) and Sediment Loads for Sub-watersheds 3, 4 and 5 as Estimated by the P8 Model for the McDowell Dam Watershed in 2003.**

| Drainage Area (acre) | Drainage Area (mi$^2$) | Phosphorus Load (tons) | Phosphorus Yield (tons/mi$^2$) | Sediment Load (tons) | Sediment Yield (tons/mi$^2$) |
|---|---|---|---|---|---|
| 2,114 | 3.3 | 0.0298 | 0.009 | 1.59 | 0.48 |

Runoff from subwatersheds 1 & 2 were detained by an upstream dam and did not flow into McDowell Dam Reservoir during 2003.

For a complete description of the P8 watershed runoff model please refer to Section 4.2.2 of the McDowell Dam Water Quality Assessment Report (Appendix A).

## 5.2 BATHTUB Model and In-Reservoir Trophic Response

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

Input for the BATHTUB model included information about the in-reservoir water quality data from the 2003 monitoring season for calibrating the model, reservoir geometry, the hydrologic budget and the nutrient loads. The model was calibrated to the measured 2003 in-reservoir water quality for total phosphorus, total nitrogen, chlorophyll-a and Secchi depth. The model was calibrated by adjusting the sediment term for total phosphorus and total nitrogen.

Two BATHTUB models were developed from the mass balance data (i.e., one for 2001-the normal precipitation year, and a second for 2003–the monitoring year). The mass balances show that the internal total phosphorus load is similar in magnitude for a normal precipitation year, to the load from surface runoff. A large proportion of the load is retained within the reservoir. The importance of this information is that any proposed management strategy should also focus on the internal load if it is to be successful in improving water quality.

For a complete description of the BATHTUB model please refer to Section 4.2.3 of the McDowell Dam Water Quality Assessment Report (Appendix A).

# 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 which 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 margin of safety of 10% of the loading capacity will be used as an explicit margin of safety.

Assuming the combined "normal" year tributary load and internal cycling to McDowell Dam is 403.6 kg of total phosphorus and the goal of a 30% reduction in tributary load and internal cycling has been set as the TMDL, this would result in a target loading capacity of 282.52 kg of total phosphorus per year. A 10 % explicit margin of safety for the TMDL would be 28.25 kg per year.

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

## 6.2 Seasonality

Section 303(d)(1)(C) of the Clean Water Act and the U.S. Environmental Protection Agency (EPA's) regulations require that a TMDL be established with seasonal variations. The McDowell Dam TMDLs address seasonality because the BATHTUB model incorporates season differences in its prediction of annual average total phosphorus concentrations.

# 7.0 TMDL

Table 10 summarizes the nutrient TMDL for McDowell Dam in terms of loading capacity (LC), wasteload allocations (WLA), load allocations (LA), and a margin of safety (MOS). The TMDL can be generically described by the following equation:

TMDL = LC = WLA + LA + MOS

where:

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

WLA = 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 nonpoint sources;
MOS = margin of safety, or an accounting of 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 loading capacity.

### 7.1 Nutrient TMDL

In order to meet the algal bloom frequency and phosphorus TSI nutrient TMDL targets the BATHTUB computer model was used to predict the anticipated improvement in water quality with percentage reductions in the total phosphorus loads from surface water runoff and internal cycling (the average annual). A 30% reduction in total phosphorus loading is predicted to result in a 33% reduction in the number of days with nuisance algal blooms (i.e., chlorophyll-a concentrations greater than 30 ug/L). A 30% reduction in average annual phosphorus loading will result in a decrease in the average in-lake phosphorus concentration from 174.6 ug/L (TSI = 79) to 153.3 ug/L (TSI = 76). For further discussion regarding the nutrient TMDL please see Section 5.2 of the McDowell Dam Water Quality Assessment Report (Appendix A).

**Table 10. Summary of the Nutrient TMDL for McDowell Dam.**

| Category | Total Phosphorus (kg/yr) | Explanation |
|---|---|---|
| **Existing Load (Tributary and Internal Cycling)** | 403.6 | Based on total Phosphorus loads from all sources (see Figure 4-19, Appendix A). |
| **Loading Capacity** | 282.52 | 30 percent reduction based on BATHTUB modeling |
| **Wasteload Allocation** | 0 | No point sources |
| **Load Allocation** | 254.27 | Entire loading capacity minus MOS is allocated to nonpoint sources |
| **MOS** | 28.25 | Explicit ten percent (10%) MOS. |

### 7.2 Dissolved Oxygen TMDL

The modeling done for the McDowell Dam TMDL is not capable of establishing a direct relationship between dissolved oxygen and the total phosphorus load reduction target. A more complex model might have been able to predict dissolved oxygen concentrations under a wide range of loading scenarios. However, research by Dodds (2002) has established a linkage between instream nutrient levels, algae, and dissolved oxygen concentrations by running the QUAL2K model under dry weather, low flow conditions, when elevated nutrient levels exert their largest influence on dissolved oxygen concentrations. As a result of this direct influence it is anticipated that meeting the phosphorus load reduction target in McDowell Dam will address the dissolved oxygen impairment.

BATHTUB and P8 models indicate that excessive nutrient loading is responsible for the low dissolved oxygen levels in McDowell 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 NDDoH’s opinion that decreased nutrient loads at the watershed level will result in improved oxygen levels, the concern is that this process takes a significant amount of time (5-15 years).

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

Nürnberg (1995, 1995a, 1996, 1997) developed a model that quantified duration (days) and extent of lake oxygen depletion, referred to as an anoxic factor (AF). This model showed that AF is positively correlated with average annual total phosphorous (TP) concentrations. The AF may also be used to quantify 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 American lakes. NDDoH has calculated the morphometric parameters such as surface area ($A_o$ = 55.2 acres; 0.22 $km^2$), mean depth (z = 13.8 feet; 4.21 meters), and the ratio of mean depth to the surface area ($z/A_o^{0.5}$ = 8.98) for McDowell Dam which show that these parameters are within the range of lakes used by Nürnberg. Based on this information, NDDoH is confident that Nürnberg’s empirical nutrient-oxygen relationship holds true for North Dakota lakes and reservoirs. NDDoH is also confident that prescribed BMPs will reduce external loading of nutrients to the McDowell Dam which will reduce algae blooms and therefore increase oxygen levels over time.

Best professional judgment concludes that as levels of phosphorus are reduced by the implementation of best management practices, dissolved oxygen levels will improve. This is supported by the research of Thornton, et al. (1990). They state that, “... as organic deposits were exhausted, oxygen conditions improved.”

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

# 8.0 ALLOCATION

Restoration alternatives for reservoirs and lakes can generally be classified as:

- Source controls;
- In-lake controls; and
- Problem treatment.

Source controls are used to modify the quality of water entering a lake or reservoir. Examples of source controls are management within the watershed to reduce erosion (i.e., BMPs), chemical treatment to reduce inflow nutrient concentrations, and point source treatment or diversion. The application of alum, a chemical used to remove phosphorus from the water column, and dredging are examples of in-lake controls. Problem treatment includes weed harvesting, aeration, and chemical treatment to reduce plant growth and the release of nutrients from lake sediments. A variety of methods for improving the water quality of the reservoir are potentially available.

Table 11 presents a list of these methods. No single method by itself is likely to be completely effective in improving the water quality of the reservoir. A combination of methods is generally needed to improve water quality. For example, external load reduction (i.e., source control) combined with in-lake controls (i.e., alum treatment) appears warranted.

## 8.1 Restoration Alternatives

This section presents the specific recommendations for managing the McDowell Dam reservoir to meet the 30% total phosphorus load reduction goal. The recommendations are based upon recreation (e.g., swimming and boating) as the primary use. Specifically:

- Implement a short-term (5-10 year) in-lake nutrient reduction strategy through alum treatment (Note: this strategy was implemented in June 2006).

- Control external nutrient loads from surface water runoff in the watershed by implementing, to the maximum extent possible, conservation management practices (i.e., BMPs on all cropland and pastureland acres).

- Implement a long-term nutrient reduction strategy through the “Dilution with Hypolimnetic Withdrawal” alternative. The “Dilution with Hypolimnetic Withdrawal” alternative is preferred because of its normalized cost, $275 per kg of total phosphorus removed, provided potential downstream water quality issues can be minimized.

**Table 11. Restoration Alternatives for McDowell Dam Reservoir.**

| Method or Technique | Type of Technique | Desired Effect | Anticipated Improvement | Longevity | Positive Factors | Negative Factors | Estimated Cost |
|---|---|---|---|---|---|---|---|
| 1. Agricultural Runoff Treatment | Source Control | Reduction in algae and macrophyte biomass by treating surface runoff. | Not recommended for McDowell Dam reservoir. | Years | Easy to do. | Low return on investment. | None. |
| 2. Dredging | In-Lake | Removal of sediments as a nutrient source and maintain adequate oxygen for sustaining fishery. | 50% reduction in internal load (estimate) | More than 10 years at present solids loading | Technology commonly used and available. | Potential loss of reservoir use for a period of time. May need to repeat on periodic basis. Hydraulic dredging disposal site and permitting. Moderate success for aquatic macrophytes. | Approximately $2.5 - $5.0 per cubic yard excluding haul and disposal costs. |
| 3. No Phosphorus Fertilizer | Source Control | Eliminate or reduce contact between nutrient source and runoff. | Not recommended within an agricultural watershed. Soil testing to determine optimum application rates may be useful. | Years | Easy to do. | Few | None |
| 4. Harvesting Aquatic Plants | Problem Treatment | Reduction in aquatic macrophyte density. | Effect on in-lake phosphorus minimal or some slight increase, good reduction in aquatic plants. Not recommended for McDowell Dam reservoir. | Weeks to Months | Improves aesthetics immediately. Easily implemented and low cost. | Does not address nutrient source. Needs repeating 2-3 times/yr. May remove habitat. Turbidity increases temporarily. May spread aquatic nuisance species. | Commercial: $2.50/acre plus $500 mobilization cost. Total cost of $1500/ treatment. Purchase: $15,000 - $35,000 plus O&M. |
| 5. Dilution with Hypolimnetic withdrawal | In-Lake | Reduction in algae biomass by increasing loss of algae and decreasing residence time. | Considered feasible with an estimated 25% load reduction (internal and surface load). Not quite capable of meeting the in-reservoir water quality goals – 30% load reduction. | Years | Cost | Downstream water quality impacts | Estimated: $305,000 in capital costs and $4,500 of annual operating costs. |

**Table 11 (cont.) Restoration Alternatives for McDowell Dam Reservoir.**

| Method or Technique | Type of Technique | Desired Effect | Anticipated Improvement | Longevity | Positive Factors | Negative Factors | Estimated Cost |
|---|---|---|---|---|---|---|---|
| 6. Nutrient Inactivation – Alum Treatment | In-Lake | Reduction in algae biomass by removing nutrients from the water column and "sealing" sediment. | Substantial because of the reduction in internal loading. Considered 80% effective in controlling internal load for a 5-year period. Estimated 41% reduction in combined internal and surface runoff loads. Capable of meeting in-reservoir water quality goal. | Between 5 and 10 years, with external load reduction. | Effective long-lasting (up to 10 years) when application appropriate. | Fails to treat ultimate nutrient source. Public concern over chemical cost. May need to buffer the lake. | $75,000 per treatment. Estimate excludes mobilization cost. |
| 7. Aeration | Problem Treatment | Maintain oxic conditions at sediment-water interface, reducing nutrient release. Maintain refuge for fish. | 50% reduction in internal load estimate. Capable of meeting in-reservoir water quality goal. | Years | Maintains refuge for fish if winterkill is problem. | Can result in increased mixing and availability of nutrients. Success is varied and uncertainty of success large. | $30,000<br>Excluding Administration and Engineering |
| 8. Food Chain Manipulation | In-Lake | Increase the abundance of large zooplankton thereby increasing grazing on algae | Minor. Not recommended. | Unknown | Theoretically attractive. | Effectiveness difficult to predict. | None. |
| 9. Hypolimnetic Withdrawal | Source Control | Remove nutrient rich water from the lake bottom during stratification and sediment release of nutrients. | Estimated 45% reduction in combined surface runoff and nutrient load. Capable of meeting in-reservoir water quality goal. | Years | Potential to remove large amounts of nutrient. Common sense easy method. | Need area to discharge, possibly wetland treatment system. If system is nitrogen limited expect little improvement. Will affect lake algae. | None |
| 10. Grazing System BMPs (fence cattle away from lake, alternative water supply and lake riparian buffer) | Source Control | Reduce load entering lake. | Minor (~1-2 kg/yr TP plus fences) | Years | Logical | Requires changing habits. | Up to $5,000. |

### 8.1.1 Conservation Management Practices

Conservation management practices primarily consist of altering the current tillage practices for cultivated land within the watershed to reduce the sediment and nutrient load reaching the reservoir. Potential conservation management practices are tillage and residue management options. These options include the use of no-till, ridge till, mulch tillage and leaving various amounts of crop residue.

The use of conservation management practices is encouraged for improving reservoir water quality. Conservation management practices effectively reduce the nutrient load reaching McDowell Dam. Soil nutrients are retained within the cultivated soils and lead to enhanced crop production. Reservoir longevity is enhanced because of the reduction in solids and sediment reaching the reservoir and the loss in storage resulting from accumulation.

Appendix B of the McDowell Dam Water Quality Assessment Report (Appendix A) contains a preliminary analysis and estimate of the total phosphorus annual load reduction in surface runoff load, assuming one-half of the currently cultivated land within the watershed is placed in permanent cover. The analysis presented is only for illustrative purposes – the conservation management practices ultimately implemented will need to be determined through the combined efforts of the landowner and the Burleigh County Soil Conservation District. The analysis is intended to show the magnitude of annual load reduction possible with the implementation of conservation management practices.

The analysis shows that for a normal precipitation year the current estimated total phosphorus load resulting from surface runoff can be reduced from 185 kg per year to 93 kg per year. This annual load reduction corresponds to a 23% reduction (92 kg per year) in the combined internal and surface runoff load. The estimated cost for treating the 1334.4 acres assuming land retirement at a cost of $500 per acre is $667,000. Therefore, the estimated cost for the total phosphorus reduction is $7,250 per kg.
Permanent land retirement is not the recommended alternative. However, every opportunity to reduce the external nutrient load to the reservoir should be pursued as a recommended implementation strategy. Residue management is expected to be the most cost effective method of reducing the external nutrient load.

### 8.1.2 Nutrient Inactivation – Alum Treatment

The salts of iron and aluminum have long been used in advanced wastewater treatment to remove phosphorus. This method consists of the addition of primarily aluminum sulfate (alum) to the lake-surface or injected above the hypolimnion. The effect of the addition is twofold. The precipitate formed within the water column removes phosphorus. The floc once settled on the sediment-surface reduces the cycling of internal nutrients. One side effect of the application of alum is a reduction in pH in low alkalinity waters.

Alum treatment is most effective when internal loading is an important source of nutrients, relative to external sources. Lakes with nutrient rich sediment resulting from historical wastewater discharges often benefit from an alum treatment. The effect of this method is to eliminate the release of nutrients from sediments.

An alum application is generally considered to be up to 80% effective in controlling the internal cycling of nutrients from sediment. The quantity of aluminum required is generally considered to be equal to the product of the internal total phosphorus load and the number of years of control. Up to 15 years of control is possible, but 5 to 7 years is considered typical. The duration of effectiveness is directly tied to the reduction of external nutrient loads.

An alum application will immediately clear the water column and increase light penetration, likely stimulating the growth of rooted aquatic plants. One-half of the reservoir acreage is less than 9 feet in depth, with most of the area in the upper portion of the reservoir. This area is likely to become colonized by rooted aquatic plants following alum application.

The typical cost range per acre treated is $750 per acre. Additional testing is needed prior to application. Therefore the estimated cost is $75,000 which includes mobilization and engineering. The total phosphorus reduction for this method is 164 kg 41% of the combined internal and surface runoff load. The normalized cost is $460 per kg of total phosphorus. McDowell Dam Water Quality Assessment Report (Appendix A).

#### 8.1.3 Dilution with Hypolimnetic Withdrawal

Dilution with hypolimnetic withdrawal has two primary methods of action when considered as a reservoir management tool. The concentration of the limiting nutrient is reduced by the addition of water with a lower nutrient concentration. The additional water added to the reservoir, also decreases the residence time of the lake, flushing algae. The loss rate of algae can exceed the growth rate as a result of flushing. The primary considerations relative to dilution with hypolimnetic withdrawal as a restoration method are the presence of a dependable source of low nutrient water and the present hydraulic residence time of the lake. Dilution with hypolimnetic withdrawal is less effective when the hydraulic residence time is short.

Apple Creek is a potential source of dilution water. Nutrient concentrations within Apple Creek during the spring into July are less than in the reservoir's hypolimnion in late June, July and August (see Appendix F of the McDowell Dam Water Quality Assessment Report (Appendix A)). Flow rates within Apple Creek also are generally large enough to allow for the diversion / pumping of several cfs into the reservoir. By adding water from Apple Creek (3 cfs) and selectively withdrawing water from the reservoir hypolimnion following thermal stratification (3 cfs), an estimated 99 kg of total phosphorus can be removed annually from the reservoir during July and August. The removal of water from the hypolimnion requires restoring the use of the conservation port and possibly operation of the low level drawdown. The load reduction (at a 3 cfs rate) equates to approximately 25% of the combined internal and surface runoff total phosphorus load.

The opinion of probable cost (preliminary) for this method is $305,000. The estimated cost includes a capital cost for the pump system and restoring the use of the conservation port. The administrative costs of acquiring the required permits and easements are not included in the estimate. Assuming a replacement life of 20 years and 4% interest the estimated annual cost of the infrastructure is $22,448. Annual operation assuming a two month pumping period is approximately $4,500. Additional engineering analysis is also needed prior to implementation to evaluate timing and water quality and quantity issues with the removal of waters from Apple Creek. The normalized cost for this method is an estimated $275 per kilogram of total phosphorus removed.

Additional technical analysis is needed to resolve issues associated with this method. A selective withdrawal analysis is recommended to evaluate the specific reservoir zones of withdrawal and whether a retrofit of the outlet is needed. Additional time series analysis of water quality concentrations and flow rates within Apple Creek is recommended. Further analysis of the potential downstream affects of releasing the high nutrient water from the reservoir into Apple Creek, is also required. The construction of a series of drop structures downstream of McDowell Dam may be necessary to reareate the water released from the reservoir.

The combination of these three methods should be effective in reducing the annual total phosphorus load by more than 30%. Table 12 presents the opinion of probable costs for these management methods.

While the primary use of the McDowell Dam reservoir is swimming and body contact recreation, the reservoir has been a viable fishery and fishing remains a secondary use of the reservoir. If the focus of reservoir improvement recommendation is limited to improving the fishery quality of the reservoir, hypolimnetic aeration is a viable method of water quality improvement.

**Table 12. Opinions of Probable Cost of the Recommended Management Methods.**

| Management Method | Implementation Costs | Annual Operating Cost | Estimated Phosphorus Reduction | Normalized Cost ($/kg of phosphorus removed) |
|---|---|---|---|---|
| Implementation of Conservation Management Practices[1] | Widely Variable & Future Development Dependent | | | |
| Alum Treatment | $75,000 per treatment[2] | none | 164 kg | $460 |
| Dilution with Hypolimnetic Withdrawal | $305,000 | $4500 | 99 kg annually | $275 |
| Hypolimnetic Aeration[3] | $30,000 | Minimal | Minimal | --- |

[1] Costs of implementation will vary widely depending on effort. Efforts could range from encouraging producers to implement better residue management practices (minimal costs) to the purchasing of land for permanent retirement of land (significant cost).
[2] Treatment will typically last 5 to 10 years depending on external phosphorus load
[3] Aeration is recommended when the only improvement goal is to improve the fishery quality of the reservoir.

## 9.0 PUBLIC PARTICIPATION

A 30-day public notice, soliciting comment and participation from interested parties was published in Bismarck Tribune on February 26, 2007. In addition, the proposed TMDL was made available in hardcopy, electronic format and via the internet at http://www.health.state.nd.us/wq, from the North Dakota Department of Health.

Copies of the draft TMDL, with cover letter requesting public comment was sent to the following stakeholders:

Bismarck Parks and Recreation Department
Burleigh County Soil Conservation District
Burleigh County Water Resource Board
Burleigh County Park Board
North Dakota Game and Fish Department
US EPA - Region VIII
USDA-NRCS State and Burleigh County Field Offices
US Fish and Wildlife Service, Ecological Services Field Office, Bismarck ND

The 30 day public notice was held from February 26, 2007 to March 30, 2007. Comments were received from the following agencies: North Dakota Game and Fish and the U.S. EPA, Region 8. A letter of support was also received from the Burleigh County water Resource District. Public comments received and the North Dakota Department of Health's response to those comments received are provided in Appendix C.

## 10.0 MONITORING STRATEGY

Depending on the implementation of restoration alternatives, future monitoring will be conducted in accordance with an approved Quality Assurance Project Plan(s) for McDowell Dam.

Specifically, monitoring will be conducted for all variables that are currently causing impairments to the beneficial uses of the waterbody. These include, but are not limited to nutrients (i.e., nitrogen and phosphorus) and dissolved oxygen. Monitoring will be conducted in the lake beginning two years after implementation and extending 5 years after the implementation project is complete.

In response to the alum treatment that occurred on May 10, 2006, McDowell Dam has (and will be) monitored in accordance with the Quality Assurance Project Plan for the McDowell Dam Alum Treatment (Houston Engineering, 2006).

## 11.0 RESTORATION STRATEGY

Local sponsors have expressed interest in implementing best management practices to help restore the beneficial uses of McDowell Dam.

In the event a Watershed Restoration Project is undertaken, monitoring will be a required component of the project. As a part of the watershed project, data are collected to monitor and track the effects of BMP implementation as well as to judge overall project success. A Quality Assurance Project Plan will be developed as part of the project that details the strategy of how, when and where monitoring will be conducted to gather the data needed to document success in meeting the TMDL implementation goal(s). As data are gathered and analyzed, watershed restoration tasks will be adapted, if necessary, to place BMPs where they will have the greatest benefit to water quality and in meeting the TMDL goal(s).

## 12.0 ENDANGERED SPECIES

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

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

## 13.0 REFERENCES

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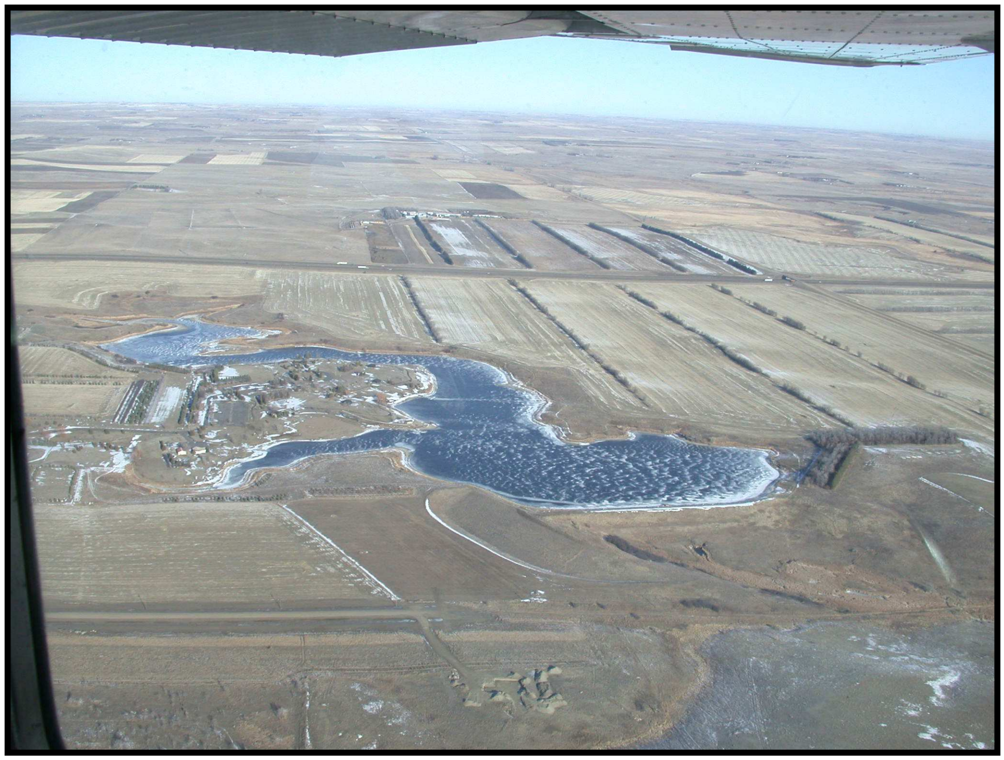
# APPENDIX A

**McDowell Dam Water Quality Assessment Report**

# MCDOWELL DAM
# WATER QUALITY ASSESSMENT REPORT
## BURLEIGH COUNTY
## WATER RESOURCE DISTRICT
### SEPTEMBER 2004




| | | |
|---|---|---|
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# 1.0 GENERAL INFORMATION

| | |
|---|---|
| ***Applicant Information*** | |
| Name of Organization | Burleigh County Water Resource District (BCWRD) |
| Type of Organization | Water Resource District |
| Project Manager | Mr. Michael Ell<br>North Dakota Department of Health (NDDH)<br>Surface Water Quality Management Program<br>1200 Missouri Avenue Bismarck, ND 58506<br>701-328-5210 |
| Principle Investigator | Mr. Michael Gunsch, PE<br>Houston Engineering, Inc.<br>304 East Rosser Avenue, Bismarck, ND 58501-4012<br>701-323-0200 |
| ***Project Information*** | |
| Project Name | McDowell Dam Water Quality Improvement Project |
| Impaired Use | Aquatic Life |
| Impairment Cause | Nutrient enrichment and low dissolved oxygen |
| Funding | \$20,000 EPA/NDDH - TMDL Program<br>\$22,688 EPA/NDDH – Section 319 Non-Point Source Pollution Control Program<br>\$3,285 In-Kind – Bismarck Parks & Recreation<br>\$7,135 In-Kind – North Dakota Game and Fish funding from the North Dakota Save Our Lake Program<br>\$4,911 In-Kind – BCWRD **Total = \$58,019** |
| Project Dates | June 2002 – June 2004 |
| Project Summary | The goal of this project is to determine the nutrient load reductions for McDowell Dam which, if implemented, will improve the lake's trophic status, thereby improving its beneficial uses for recreation, fishing, and public water supply. This goal will be accomplished by: 1) determining hydrologic and nutrient budgets for the lake; 2) by identifying the primary causes and sources of nutrients in the watershed and delivered to McDowell Dam; and 3) examining and making recommendations for lake restoration and/or watershed BMPs which can be implemented to reduce nutrient loading to the lake. |

# 2.0 PROJECT BACKGROUND

McDowell Dam is located in Burleigh County, North Dakota, approximately four miles east of Bismarck in the central portion of the state **(Figure 2-1)**. The McDowell Dam Reservoir (the reservoir) formed by the dam, is identified on the North Dakota 2002 303(d) List as a priority waterbody for TMDL development. The North Dakota Department of Health (NDDH) and Burleigh County Water Resource District (BCWRD) pursued funding to develop data to ultimately complete a Total Maximum Daily Load (TMDL) analysis for this reservoir.

This study is intended to provide information necessary for the development of a future TMDL. The goal is to develop load reduction recommendations for the reservoir which, if implemented, will improve the lake's trophic status, thereby improving beneficial uses for recreation, fishing, and public water supply. This goal will be accomplished by: 1) determining hydrologic and nutrient budgets for the lake; 2) by identifying the primary causes and sources of nutrients in the watershed and delivered to the reservoir; and 3) examining and making recommendations for restoration and/or watershed BMPs which can be implemented to reduce nutrient loadings.

## 2.1 Description of the Problem

The Clean Water Act requires the development of TMDLs for all waters on a state's Section 303(d) List. One part of the TMDL is the allocation of allowable loads. A load allocation is the sum of the allowable loads of a single pollutant from all contributing point and nonpoint sources, which a waterbody can receive, and still meet water quality standards. Development of a TMDL must take into consideration the seasonal variation in water quality and a margin of safety that addresses uncertainties in the analysis. Separate TMDLs are required to address each cause of impairment (i.e., nutrients, sediments, etc). This report will address the nutrient impairment in the McDowell Dam Reservoir.

Section 303(d) of the Clean Water Act (CWA) requires each state to identify waterbodies which are considered water quality limited and require load allocations, waste load allocations and Total Maximum Daily Loads (TMDLs). The North Dakota

Insert Figure 2-1 Location of McDowell Dam Reservoir

Department of Health (NDDH) has identified McDowell Dam as an impaired waterbody **(Table 2-1).** In 1996, the NDDH identified the reservoir as hypereutrophic because of a rapid loss of dissolved oxygen below the thermocline, a need for aeration to maintain the fishery, and a history of significant algal blooms (NDDH, 1996).

**Table 2-1 The Section 303(d) TMDL listing for McDowell Dam (NDDH, 2004).**

| | |
|---|---|
| Identification Number | Assessment Unit (AU) ND-10130103-014-L_00 |
| Description | McDowell Dam |
| Size | 56.5 acres |
| Designated Use | Fish and Other Aquatic Biota |
| Use Support | Not Supporting |
| Impairment | Dissolved Oxygen |
| Priority | 1 (High) |

The reservoir is listed as "not supporting" for fish and other aquatic biota because of low dissolved oxygen. McDowell Dam is classified as a Class 3 warm water fisheries lake, defined as capable of supporting growth and propagation of nonsalmonid fishes and associated aquatic biota (NDDH, 2001). The fishery established initially within the reservoir consisted of bluegill, largemouth and smallmouth bass, and rainbow trout. The reservoir has experienced repeated late summer fish kills. These die offs were caused by a eutrophic condition and subsequent anoxia below the thermocline.

## 2.2 History of the Watershed and McDowell Dam

The McDowell Dam Recreation Area was opened in June 1980 by the Burleigh County Water Resource District (BCWRD). The facility was designed by the Natural Resources Conservation Service with funding assistance from the BCWRD and the Lewis and Clark Regional Development Council. The BCWRD holds the title to the property and contracts with the Bismarck Parks and Recreation Department to operate and manage the facility.

The McDowell Dam Recreational Area includes a swimming beach, boat ramp and dock, boat and canoe rentals, walking trails, picnic shelters, playground equipment and a seasonal concessionaire. The facility covers 151 acres within the Missouri Coteau. The area is characterized by gently rolling uplands with moderate slopes. The maximum relief is approximately 100 feet. Soils are formed from rocky, gravelly and sandy glacial till and are moderately to well drained.

The reservoir was created in 1976 by damming a small tributary to Apple Creek, which is a tributary to the Missouri River. It covers 56.5 acres and has a mean depth of 14 feet and a maximum depth of 43 feet **(Figure 2-2)**. **Table 2-2** summarizes general characteristics of McDowell Dam and the watershed.

The McDowell Dam outlet structure consists of a concrete drop inlet with a conservation port and a low level drawdown. The principal spillway is a 36-inch Reinforced Concrete Pipe (RCP) that exits to a rock riprap plunge pool. The weir elevation of the concrete drop inlet structure was originally 1723.5 msl (as-built measurement on 11/17/75). Redwood flashboards were installed in May 1980 that effectively raised the weir elevation to 1724.56 msl. The design discharge capacity is 214 cfs.

The principal spillway structure has a low-level drawdown system to assist in maintaining reservoir water quality. The system was designed to allow initial reservoir outflows from the lower pool elevations, which contain waters with higher nutrient levels that can cause water quality problems within the reservoir. The low level drawdown structure is a 16-inch Asbestos Cement Pipe (ACP) that is controlled by a waterman gate. The inlet of the drawdown pipe is at 1684.36 msl. The waterman gate stem was broken in March 1995 and subsequently repaired but has not been operated since. The emergency spillway is a grassed waterway at elevation 1729.5 msl and a maximum design capacity of 703 cfs.

Insert Figure 2-2 McDowell Dam Recreation Area

**Table 2-2 General characteristics of McDowell Dam and the watershed**

| **Waterbody Name** | **McDowell Dam** |
|---|---|
| 8-Digit HUC | 10130103 |
| Waterbody Type | Constructed reservoir |
| Location | Township 139 North, Range 79 West, Section 27 |
| County Location | Burleigh County, ND |
| Nearest City | Bismarck, ND |
| Physiographic Region | Missouri Coteau |
| Major Drainage Basin | Tributary of Apple Creek |
| Watershed Area | 3,959 acres |
| Surface Area of Reservoir | 56.5 acres |
| Volume | 779 acre-feet |
| Mean Depth | 13.8 feet |
| Maximum Depth | 43 feet |
| Dam Type | Constructed earthen embankment |
| Outlet Type | None |
| Principal Spillway Elevation | 1724.0 msl |
| Tropic Status | Hypereutrophic |
| Fishery Type | Warm water fishery – stocked with bluegill, largemouth bass and trout |

## 2.3 Land Uses in the Watershed

The contributing watershed for McDowell Dam covers approximately 3,759 acres or 5.9 square miles **(Figure 2-3)** and **(Table 2-3)**. The watershed is composed of five subwatersheds with subwatersheds 3, 4 and 5 contributing flow to the reservoir. Subwatersheds 1 and 2 contribute water to the tributary, however under normal runoff conditions a small upstream dam prevents these waters from flowing into the reservoir at McDowell Dam Recreational Area.

Insert Figure 2-3 McDowell Dam Watershed

Primary land use is agriculture, with 2,650 acres or 71% in cultivation. The remaining land uses include non-cultivated acres (23%), rural residential developments (5%) and roads (1%) **(Figure 2-4)**.

**Table 2-3 The contributing subwatersheds for McDowell Dam.**

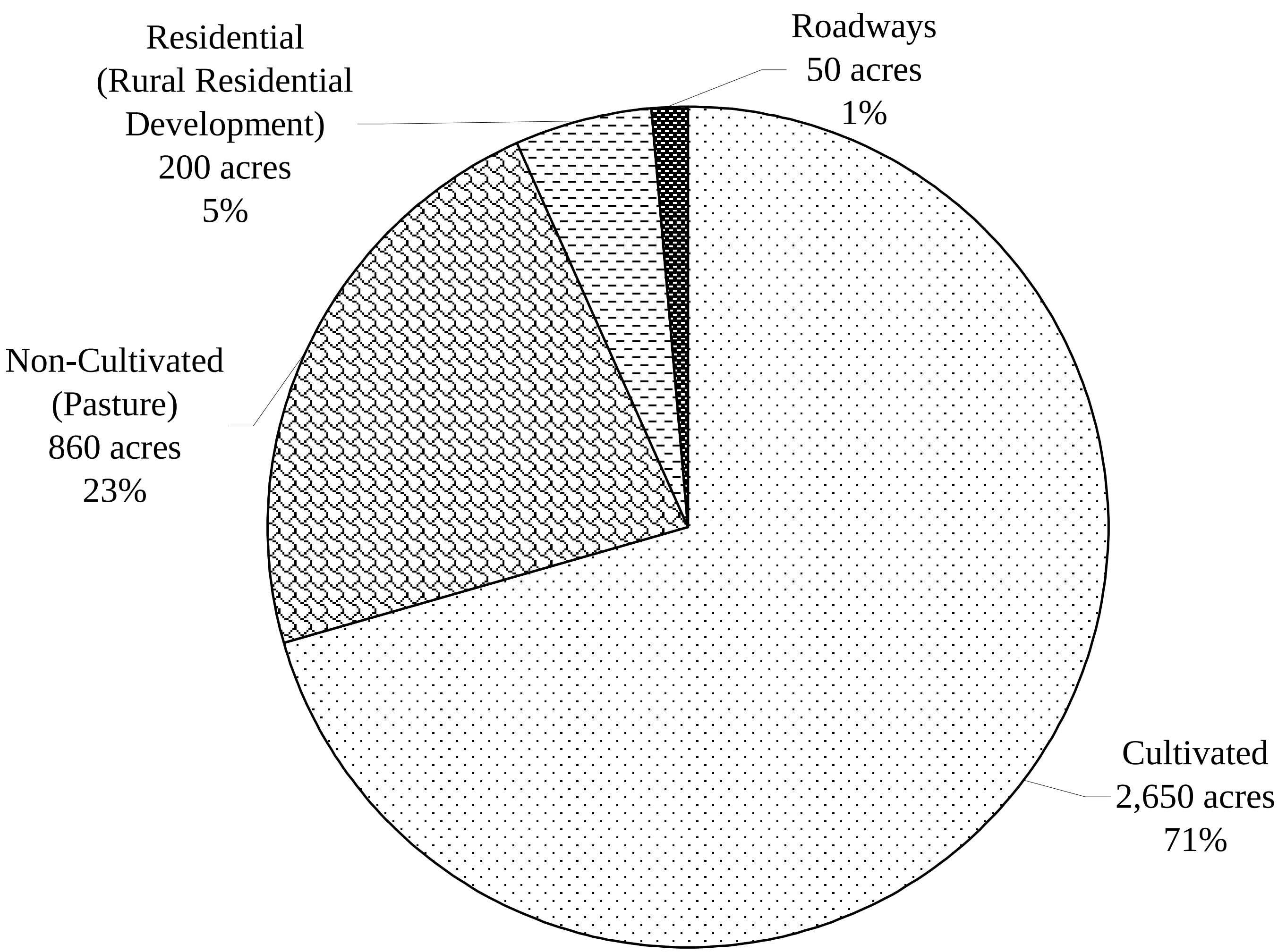
| Subwatershed | Drainage Area (acres) | Drainage Area ($mi^2$) | Comments |
|---|---|---|---|
| 1 | 360 | 0.56 | Contributes water to an upper watershed dam |
| 2 | 1,285 | 2.01 | Contributes water to an upper watershed dam |
| 3 | 1,050 | 1.64 | Contributes water to the reservoir |
| 4 | 584 | 0.91 | Contributes water to the reservoir |
| 5 | 480 | 0.75 | Contributes water to the reservoir |
| ***Total*** | *3,759* | *5.87* | |

### 2.4 Previous Data Collection

The NDDH collected water quality samples in 1994 and 1995 from the reservoir using the methodology described in the *Lake Water Quality Assessment Atlas, Volume II* (NDDH, 1996). Parameters analyzed included phosphorus, nitrogen, dissolved oxygen, water temperature, trophic status, lake bed sediments, aquatic vegetation and phytoplankton. Data were summarized and reported in the *North Dakota Lake Assessment Atlas, Volume II* (NDDH, 1996).

American Engineering, P.C. (1996) completed an evaluation of the annual and summer runoff yields and a simulation of historic water levels within the reservoir. The data is summarized in the *McDowell Dam Recreation Area: A Supplemental Water Supply Evaluation – Annual Runoff Review, Reservoir Simulation and Benefit/Cost Analysis* (American Engineering, 1995). Information used in the evaluation included an analysis of runoff yields, precipitation and evaporation records, embankment seepage rates, and physical features of the Reservoir recreational area and its watershed.

**Figure 2-4. Land Use for the 3,759 acres contributing to McDowell Dam.**



### 2.5 Water Quality Standards

The purpose of the TMDL process is to improve water quality and restore or protect defined beneficial uses of the waterbody. The establishment of water quality targets that can be measured and tracked is necessary to gage document and verify improvement. Numeric criteria, established as a water quality standard, can serve as these targets.

*Standards of Quality for Waters of the State* (North Dakota Century Code 33-16) establishes numeric standards for dissolved oxygen and total phosphorus **(Table 2-4)**. The numeric standards for Class I Streams include all classified lakes. The standard for dissolved oxygen is a value not less than 5.0 mg/l and for total phosphorus, a value of 0.1 mg/l. In addition, nutrient guidelines have been established for use as goals in lake improvement and maintenance programs at 0.02 mg/l for phosphorus ($PO_4$ as P).

**Table 2-4. Numeric Standards from the *Standards of Quality for Waters of the State* (North Dakota Century Code 33-16).**

| Parameter | | Guidelines | Limit |
|---|---|---|---|
| Guidelines for Classified Lakes | | | |
| | Nitrates (dissolved) | 1.0 mg/l | Maximum allowed |
| | Phosphorus (total) | 0.1 mg/l | Maximum allowed |
| | Dissolved Oxygen | 5 mg/l | Not less than |
| Guidelines for Goals in a lake improvement or maintenance program | | | |
| | $NO_3$ as N | 0.25 mg/l | Goal |
| | $PO_4$ as P | 0.02 mg/l | Goal |

## 3.0 STUDY METHODS

The purpose for the monitoring activities was to obtain representative hydrologic and water quality data to characterize the lake water quality, reservoir quality and to have the data needed to estimate nutrient loads. Most of the monitoring activities occurred between May and October 2003 with one additional sampling event in November 2002. This section of the report summarizes the methods used.

## 3.1 Water Quality Monitoring

There were three water quality sampling sites selected for the study **(Table 3-1; Figure 3-1)**. The upstream site was located near the intersection of the walking trail and the creek on the northwest side of the reservoir. The downstream site was located at the outlet to the reservoir. The in-lake site was located in the deepest part of the reservoir at the south end near the intake structure.

**Table 3-1 Location of water sampling sites for McDowell Dam.**

| Sampling Site | Site ID | Latitude (approx.) | Longitude (approx.) |
|---|---|---|---|
| In-lake | 380815 | 46N 49’33” | 100W 38’ 3” |
| Upstream | 385275 | 46N 49’ 59” | 100W 38’ 43” |
| Downstream | 385274 | 36” RCP outlet at the base of the dam discharging into the plunge pool | |

### 3.1.1 Upstream Monitoring

Surface water grab samples were collected from the upstream site on three dates, at mid-depth of the flow in the creek. Samples were collected in accordance with accepted Standard Operating Procedures (SOPs) (see *Quality Assurance Project Plan for the McDowell Dam TMDL*, 2002).

### 3.1.2 Downstream Monitoring

The downstream sampling site measured only seepage discharges through the earthen embankment. There was one sampling date during the study period. The historic seepage outflow data was obtained from the NRCS (Wiedenmeyer, 2004).

Insert Figure 3.1 Location of Sampling sites

### 3.1.3 In-Lake Monitoring

In-lake water quality samples were collected at 3 predetermined depths for the lab analyzed parameters and through the water column at 1-m increments for the field measured parameters. **Table 3-2** identifies the frequency of sampling and the analysis for each sample. Samples were collected in accordance with accepted SOPs (see *Quality Assurance Project Plan for the McDowell Dam TMDL*, 2002).

### 3.1.4 Ground Water

There were no wells or piezometers installed as part of this project.

## 3.2 Precipitation

Precipitation data was collected using two continuous recording rain gages. The gages recorded precipitation depth electronically in 0.01-inch increments. The upper watershed rain gage was located in the S½, SE¼, Sec. 8, T139N, R79W (approx: Lat 46N 52’ 27” Long 100W 40’ 50”). The McDowell Dam rain gage was located in the NE ¼ , SW¼, SW¼, Sec. 27, T139N, R79W (approx: Lat 46N 49’ 38” Long 100W 38’ 28”). There was no flow past the upper watershed dam during the study period; therefore the McDowell Dam rain gage was used for the precipitation data for the study.

**Table 3-2 Water samples collected from the McDowell Dam reservoir and the parameters analyzed for the TMDL study.**

| Parameter | Field/Lab Analysis[1] | Sampling Frequency[2] | | Sample Depth[3] |
|---|---|---|---|---|
| | | Nov 2002 - April 2003 | May 2003 - October 2003 | |
| Water level (Stage) | Daily average from May – Oct 2003 | | | |
| Temperature | F | M | B | d |
| Dissolved oxygen | F | M | B | d |
| Total Kjeldahl nitrogen | L | M | B | a,b,c |
| Ammonia nitrogen | L | M | B | a,b,c |
| Nitrite plus nitrate nitrogen | L | M | B | a,b,c |
| Total nitrogen | L | M | B | a,b,c |
| Dissolved phosphorus | L | M | B | a,b,c |
| Total phosphorus | L | M | B | a,b,c |
| Total suspended solids | L | M | B | a,b,c |
| Total dissolved solids | L | M | B | a,b,c |
| Turbidity | F | M | B | e |
| pH | F/L | M | B | d/a,b,c |
| Total alkalinity | L | M | B | a,b,c |
| Specific conductance | F/L | M | B | d/a,b,c |
| Chlorophyll-a | L | M | B | a,b,c |
| Chlorophyll-b | L | M | B | a,b,c |
| Fecal coliform bacteria | L | ---- | Q | a |
| Phytoplankton enumeration and biovolume | L | M (Nov 2002) | B (May – Aug 2003) | a |

[1] Field/Lab Analysis: F = Field, L = Laboratory

[2] Sampling Frequency: B = Bimonthly, M = Monthly, Q = Quarterly, D = Daily

[3] Sample Depth: a = surface, b = mid-depth, c = bottom depth, d = 1-m increments from surface to bottom, e = depth as necessary

### 3.3 Evaporation

Potential evapotranspiration was calculated using five different methodologies with daily observation data obtained from the *North Dakota Agricultural Weather Network (NDAWNs)* (http://ndawn.ndsu.nodak.edu) for the Mandan station (latitude46.767, longitude 100.917). Data was obtained for the period from May 7, 2003 to October 21, 2003.

The five methods were the Penman equation, Lake Hefner #1 equation, Lake Hefner #2 equation, Meyer 1915 equation and the results from the Penman PET located at the Mandan NDAWNS station. The meteorological data required for the methods included average air temperature, minimum relative humidity, ratio of actual to maximum possible sunshine hours, and average wind speed. The value used as the evaporation rate for modeling and determining the hydrologic balance for the monitoring period is the average of the five methods (**Table 3-3**).

**Table 3-3 Evaporation calculation methods.**

| Evaporation Calculation Methods | Calculated Evaporation for the Monitoring Period 5/7/03 through 10/21/03 (Inches) |
|---|---|
| Penman equation | 51.25 |
| Lake Hefner #1 equation | 27.46 |
| Lake Hefner #2 equation | 33.51 |
| Meyer 1915 equation | 36.81 |
| Penman PET | 43.04 |
| Average | 38.42 |

### 3.4 Water Level (Stage)

An electronic continuous stage recorder was used to obtain daily stage levels within the reservoir. Continuous stage readings every one hour were averaged to determine the daily average stage. Reservoir levels were also measured once per month using a staff gage or measurement at the outfall structure.

### 3.5 Vegetation

A survey of the macrophyte community was conducted on McDowell Dam in 1993 (NDDH, 1996). Six emergent and five submergent plant species were identified that are tolerant of fresh and alkaline waters. Plant coverage was limited due to the steep gradient of the shoreline. Actual coverage was between 10 to 20 percent of the lake surface.

### 3.6 Modeling of Hydrology, Nutrient Loads and Reservoir Response

Instrumentation placed in the field is normally used to quantify the various terms comprising the hydrologic budget. By combining these terms and the quality of runoff, an annual nutrient load is developed. Because of the dry conditions, little runoff into the reservoir occurred during the study period, therefore an alternative method needed to be developed. The method selected consisted of the application of the P8 Urban Catchment Model (http://wwwalker.net/p8/). This model was used simulate watershed hydrology and nutrient loads into the reservoir.

P8 is a water quality model used for predicting the generation and transport of stormwater runoff pollutants in urban watersheds. The P8 model has also successfully been applied to rural watersheds for the purpose of estimating loads. The loads from the P8 model were then used to evaluate reservoir response, using the BATHTUB model.

#### 3.6.1 P8 Model

Continuous water-balance and mass-balance calculations are performed on a user-defined system consisting of the following elements: watersheds (non-point source areas) including curve number, length of travel across the landscape; devices (runoff storage/treatment areas or BMPs); particle classes; type of channel or pond; and water quality components (NURP water quality data). The simulations are driven by continuous hourly rainfall and daily air temperature time series. The model was adjusted to generate the average water quality for Apple Creek (USGS, 2001), because of a lack of measured runoff quality from the reservoir tributary.

The hydrologic results obtained from the P8 model were qualitatively compared to a HEC-1 model for the same period. Peak runoff and volume were compared to ensure reasonable behavior of the P8 model. The runoff volume and loads from the P8 model were then used within the BATHTUB model to predict the in-reservoir response.

Developing an implementation strategy based on hydrologic conditions for a dry climatic period occurred during 2003 may be misleading. Therefore, models were needed to assess the response of the reservoir to load reductions for more "normal" hydrologic conditions. Because of the small amount of runoff and number of samples collected, during the 2003 monitoring period rainfall data from 2001 (NDAWNs), a "normal" annual precipitation year, were used to run the P8 model and generate loads to the reservoir. These loads were generated for the period from early May through the end of October.

Normally, a water quality runoff model is "calibrated" or adjusted to achieve a measured average runoff concentration. The average runoff concentration used is the measured or monitored surface runoff quality. Because of the low number of runoff samples collected from the tributary to McDowell Dam, an alternative method to adjust the P8 model was needed. The P8 model results were "adjusted" to predict the average runoff quality from Apple Creek. These data came from monitoring completed by the USGS between 1/28/1975 and 12/19/1984 (USGS).

### 3.6.2 BATHTUB Model

The BATHTUB model applies a series of empirical eutrophication equations to morphologically complex lakes and reservoirs. The program performs steady-state water and nutrient balance calculations in a spatially segmented hydraulic network that accounts for advective and diffusive transport and nutrient sedimentation. Eutrophication-related water quality conditions (Total P, Total N, chlorophyll-a, transparency and hypolimnetic oxygen depletion) are predicted using empirical relationships derived from reservoir data. The BATHTUB outputs include tabular and/or graphic displays of segment hydraulics, water and nutrient balances, predictions of nutrient concentrations, transparency, chlorophyll-a concentrations, and oxygen depletion for observed and predicted values.

The BATHTUB model was calibrated to the 2003 reservoir water quality data. A second model was then developed for a normal precipitation year (2001) and also calibrated to the 2003 reservoir water quality data. Internal loading from anoxic sediments was computed using the reservoir water quality data (as described below).

The BATHTUB Model included an explicit term for the internal total phosphorus load from sediments. Using the change in total phosphorus concentration within the hypolimnion during the period of thermal stratification (approximately May 5, 2003 to August 20, 2003), the increase in total phosphorus mass was an estimated 205.4 kg. The estimate is based upon an average summer elevation for the upper limit of the hypolimnion at elevation 1721.4 (derived from the temperature profiles), which corresponds to a hypolimnion volume of 200 acre-feet. The change in total phosphorus concentration within the hypolimnion from the onset of thermal stratification until just prior to turnover was 830 ppb. The internal load was assumed constant between years for the purposes of modeling.

# 4.0 STUDY RESULTS

This section discusses the results of the reservoir monitoring, tributary and seepage outflow monitoring. Because of the dry conditions, only 1-3 samples were collected at the upstream and downstream locations, so the data could not be interpreted. Therefore, only the reservoir monitoring results are presented.

## 4.1 Reservoir Monitoring Results

The temperature during the winter 2002-2003 was generally warmer than average **(Table 4-1)**. The spring and early summer were generally cool with below average precipitation. May 2003 was a wetter than normal month with precipitation 2.27 inches above average. Summer months were warmer than average with precipitation below average.

**Table 4-1 Monthly mean temperature and difference from the mean for the Mandan, North Dakota Station for November 2002 through November 2003. The mean precipitation data was obtained from the on-site rain gage at McDowell Dam.**

| Month | Mean Air Temp (F) (2002-2003) | Mean Air Temp (F) (1999-current) | Difference | Mean Precip (in) (2002-2003) | Mean Precip (in) (1999-current) | Difference |
|---|---|---|---|---|---|---|
| Nov/02 | 31.0 | 28.0 | 3.0 | No data | No data | No data |
| Dec /02 | 24.0 | 15.0 | 9.0 | No data | No data | No data |
| Jan/03 | 14.0 | 10.0 | 4.0 | No data | No data | No data |
| Feb/03 | 11.4 | 17.0 | -5.6 | No data | No data | No data |
| Mar/03 | 24.6 | 29.0 | -4.4 | No data | No data | No data |
| Apr/03 | 46.6 | 43.0 | 3.6 | No data | No data | No data |
| May/03 | 53.2 | 56.0 | -2.8 | 4.24 | 1.97 | 2.27 |
| Jun/03 | 62.1 | 65.0 | -2.9 | 1.99 | 3.94 | -1.95 |
| Jul/03 | 71.0 | 70.0 | 1.0 | 0.96 | 2.19 | -1.23 |
| Aug/03 | 74.1 | 69.0 | 5.1 | 0.26 | 1.73 | -1.47 |
| Sep/03 | 58.6 | 57.0 | 1.6 | 1.92 | 1.19 | 0.73 |
| Oct/03 | 49.5 | 45.0 | 4.5 | 0.17 | 0.85 | -0.68 |
| Nov/03 | 20.9 | 28.0 | -7.1 | No data | No data | No data |
| Year 2003 | 41.6 | 41.0 | 0.6 | No data | No data | No data |

The reservoir data collected during this period is used to diagnose the extent of the water quality problems within McDowell Dam. This data was also used to calibrate the BATHTUB model.

### 4.1.1 Temperature, Dissolved Oxygen, pH, Transparency and Specific Conductance

The mixing dynamics of the reservoir influence its chemical and biological characteristics and are a function of the temperature profile, the amount of solar radiation and wind energy striking the water surface. **Figure 4-1** shows the temperature profile of the reservoir from November 2002 through October 2003. The reservoir was stratified from mid-June through September 2003. The thermocline reached an estimated depth of 16 to 26 feet at the base of the epilimnion and top of the hypolimnion, respectively.

The dissolved oxygen (DO) concentration below the thermocline is less than 5 mg/l throughout the summer months **(Figure 4-2)**. The NDDH (1996) report on McDowell Dam cited low DO as a problem below the thermocline. Typical concentrations necessary to maintain aquatic life are 4-5 mg/l, depending on water temperature. Adequate DO concentrations were available above the thermocline to sustain aquatic life. Anoxic conditions were usually reached within 3 feet below the thermocline which agrees with the NDDH results obtained in 1996.

As the DO concentrations decrease the pH also decreases across the profile **(Figure 4-3)**. Measurements ranged from a pH of 9.2 at the surface to a pH of 7.1 at the bottom depth. The range of pH values across the profile varies on a seasonal basis dependent on the stratification of the reservoir. When the lake is non-stratified, the pH was uniform throughout the profile. During stratification, the pH generally varies 1 unit from the surface to the bottom of the profile.

Water transparency was measured with the secchi disk, which roughly corresponds to the depth of light penetration necessary for plant growth. Clarity of the reservoir varies seasonally depending upon algal blooms and/or suspended sediments. **Figure 4-4** shows that the secchi depth in early spring prior to stratification ranged from 1.4 feet to 9.6 feet. After the reservoir stratifies, the secchi depth ranged from 2.5 feet to 4.7 feet. Wind mixing is likely a contributing factor to the degree of water clarity in this reservoir.

**Figure 4-1. McDowell Dam Temperature (degree C)**

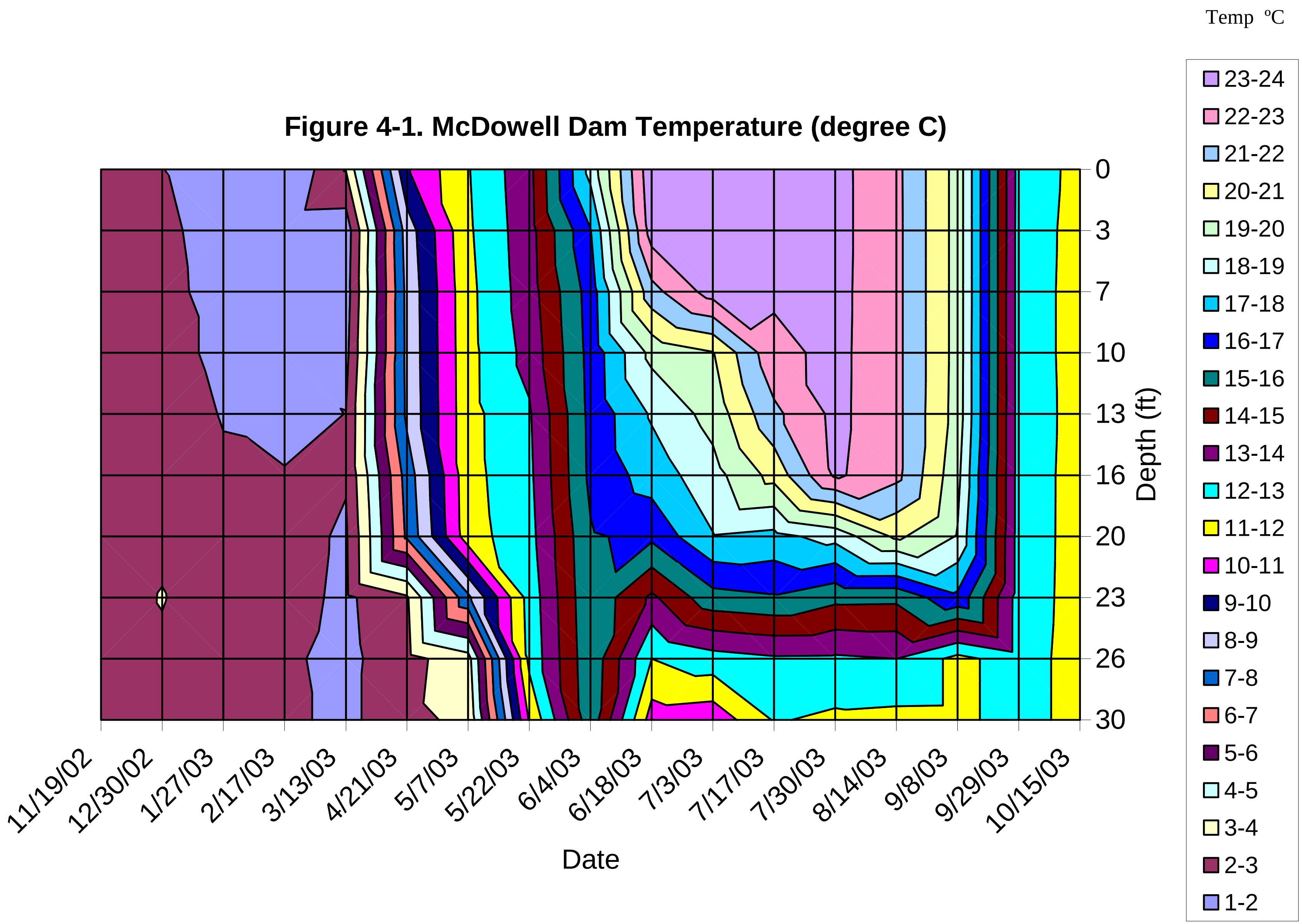


**Figure 4-2. McDowell Dam Dissolved Oxygen (mg/l)**

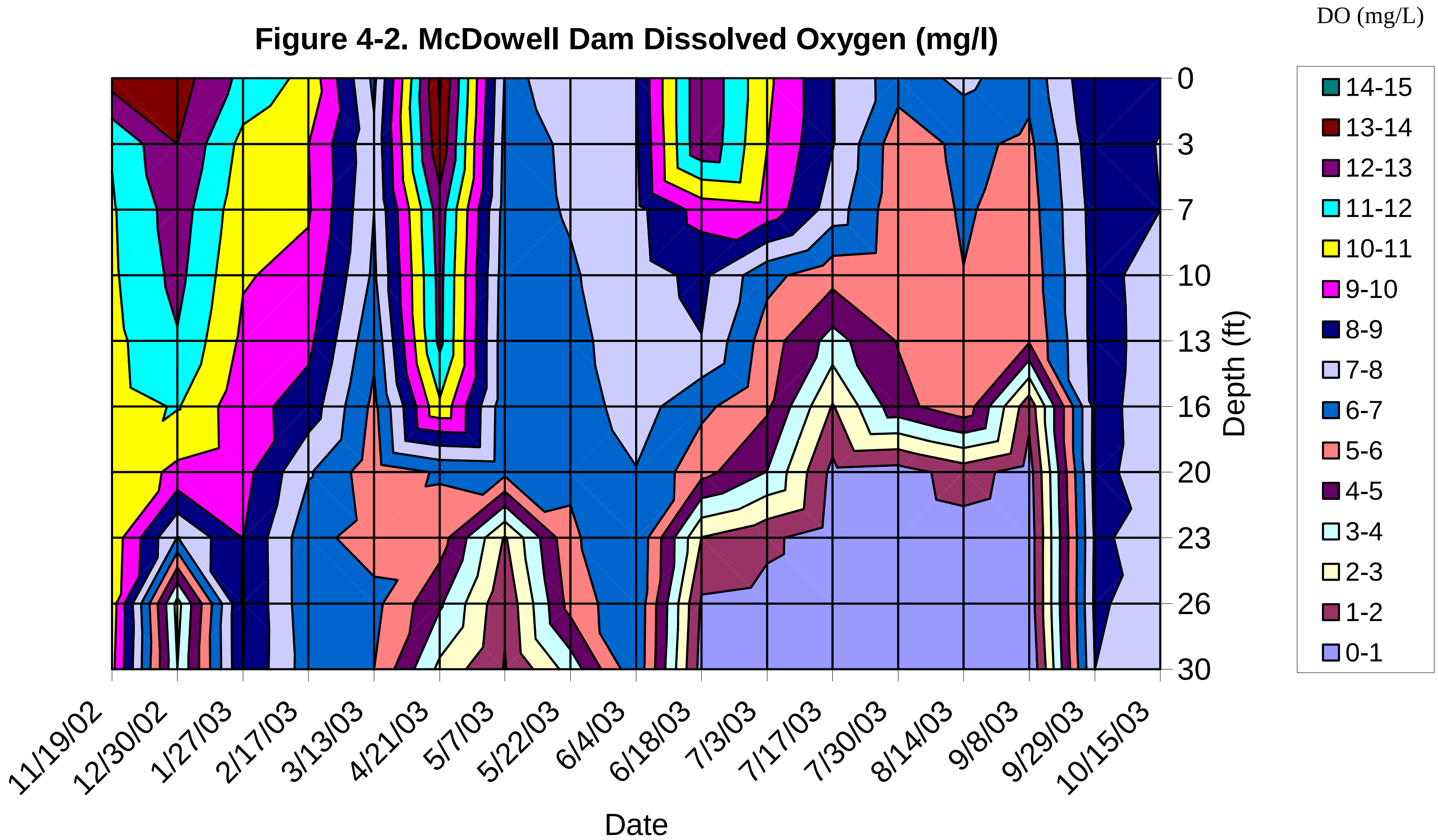


**Figure 4-3. McDowell Dam pH Profile**

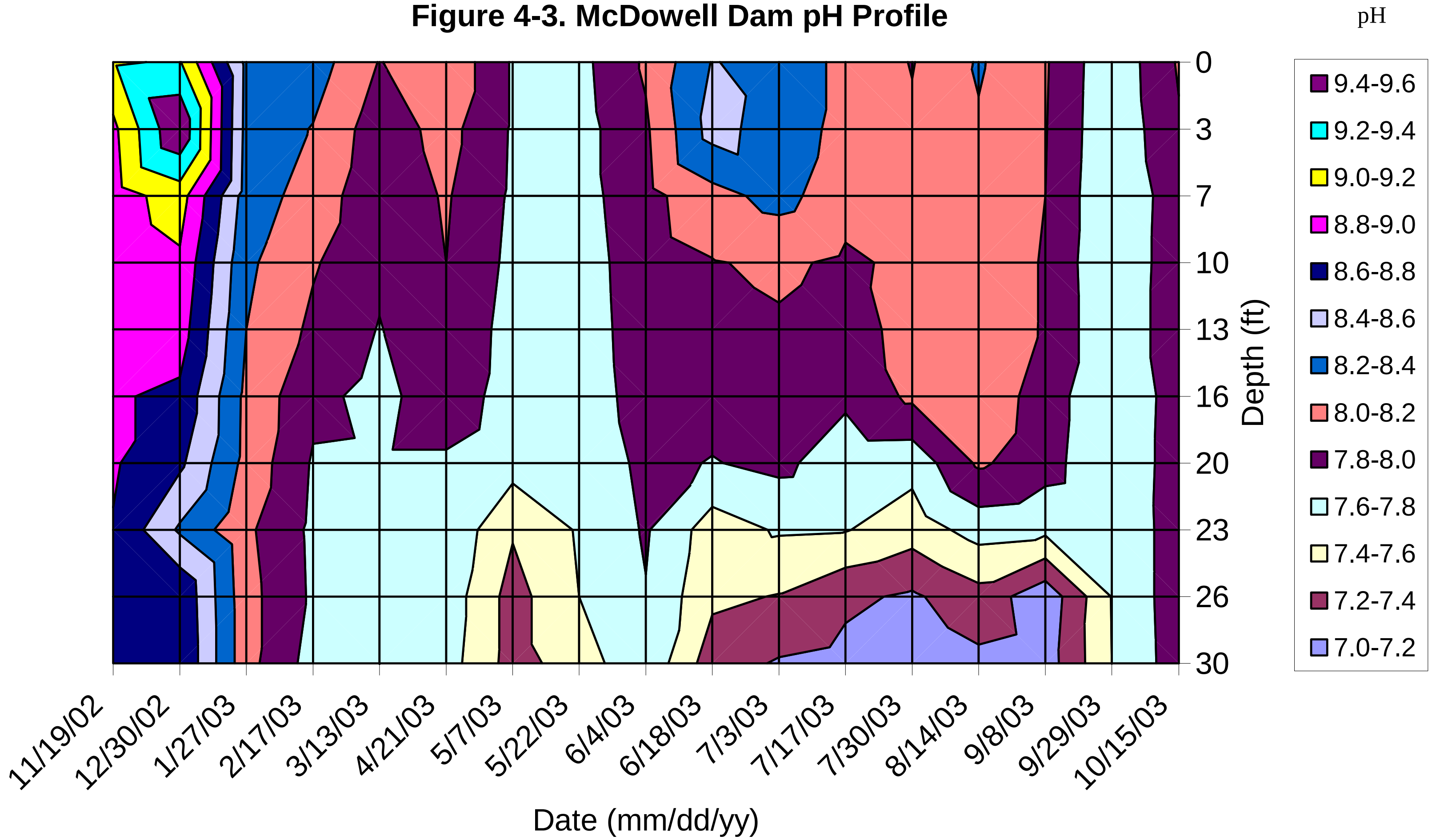
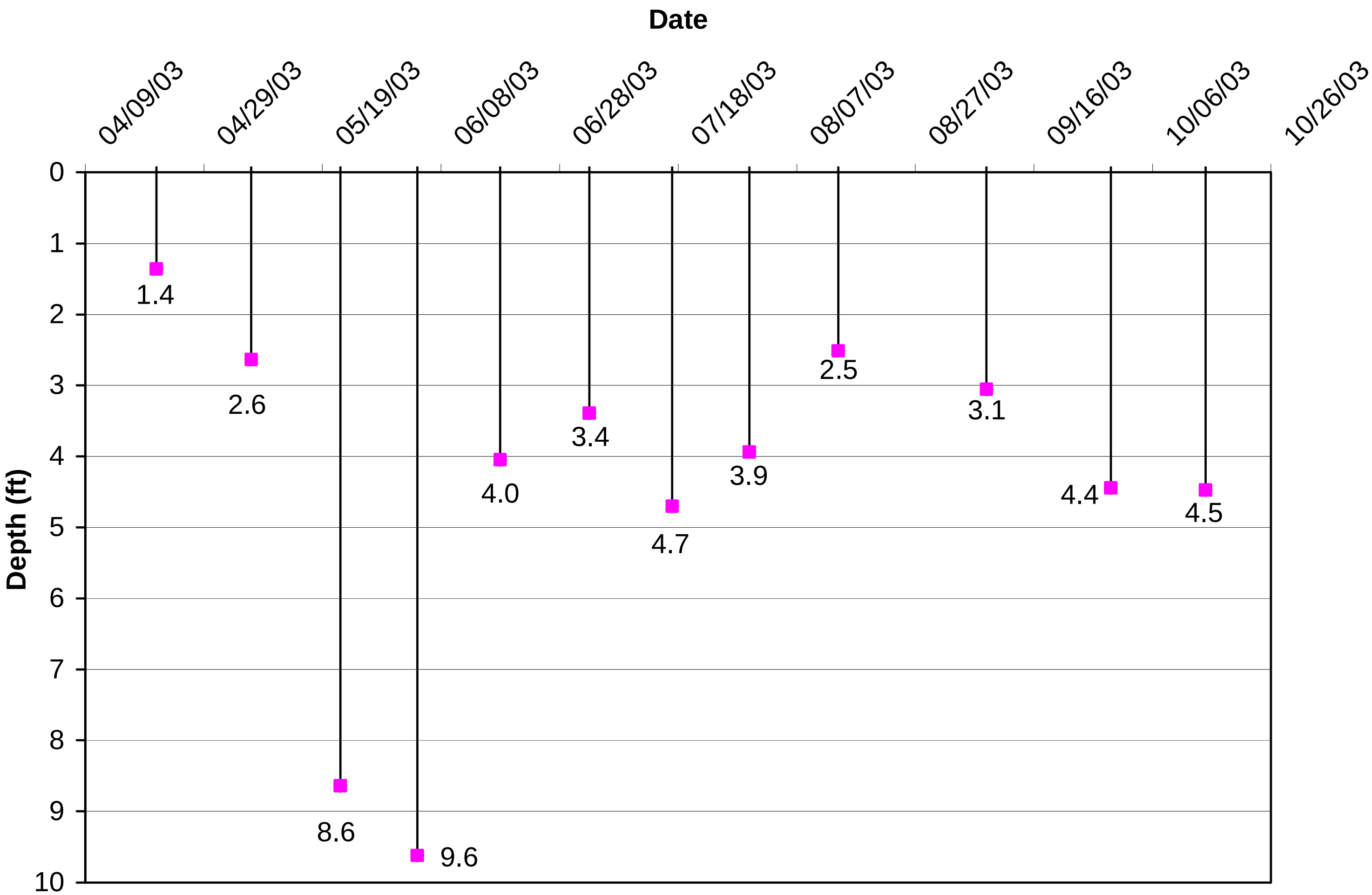


**Figure 4-4. McDowell Dam Secchi Depth (ft) Visibility**



Specific conductance within the surface mixed layer (0-6 feet) ranged from 2280 to 2860 umhos/cm **(Figure 4-5)**. Within the entire profile, the specific conductance ranged from 2270 to 2910 umhos/cm. The NDDH report (1996) calculated an average volume-weighted mean conductivity for McDowell Dam of 839 umhos/cm. The average (not volume-weighted) for 2002-2003 across the profile was 2566 umhos/cm. In 2002-2003, the reservoir had low stage levels which increase the conductance of the water. As a result, the conductivity levels are likely elevated as compared to the 1996 results. However, a comparison with 1996 is difficult since the McDowell Dam stage levels were not reported in the 1996 report.

#### 4.1.2 Nutrients and Chlorophyll-a

The reservoir's trophic state can be described by the total phosphorus concentration, chlorophyll-a concentration and secchi depth **(Table 4-2)**. The term trophic state refers to the level of productivity in a lake and can be quantified using the Carlson's Trophic State Index (TSI). McDowell Dam is classified as hypereutrophic based on the total phosphorus concentration (TSI = 79). Based on chlorophyll-a (TSI = 64) and secchi depth (TSI = 56), the trophic state of McDowell Dam is classified as eutrophic. This suggests that some factor other than total phosphorus limits algae growth in the reservoir and drives water clarity. Based on the secchi disk depth during the summer, light penetration may limit algal growth.

The total phosphorus average value over the sampling period was 0.17 mg/l across all depths, which is 0.07 mg/l above the North Dakota total phosphorus guideline. The 0.1 mg/l guideline was exceeded beginning at the deeper sampling depths in April 2003 **(Figure 4-6)**. The average value for total phosphorus across all depths was exceeded beginning in June 2003 **(Figure 4-7)**. The high total phosphorus within the hypolimnion indicates sediments releasing phosphorus during periods of low DO. By July 2003, the standard was exceeded at all depths. The ratio of dissolved phosphorus to total phosphorus can be used to determine if the origin is organic (dissolved) or associated with sediments. The concentration of total and dissolved phosphorus through time follows the same trend **(Figure 4-8)**.

**Table 4-2 Carlson's Trophic State Index.**

| Trophic State Index (TSI) Scale | Total Phosphorus Concentration (µg/l)[1] | Chlorophyll-a Concentration (µg/l)[2] | Secchi Depth (m)[3] | Lake Classification[4] |
|---|---|---|---|---|
| 0 | 0.75 | 0.04 | 64 | Oligotrophic |
| 10 | 1.5 | 0.12 | 32 | Oligotrophic |
| 20 | 3 | 0.34 | 16 | Oligotrophic |
| 30 | 6 | 0.94 | 8 | Oligotrophic |
| 40 | 12 | 2.61 | 5 | Mesotrophic |
| 50 | 24 | 7.23 | 2 | Eutrophic |
| 60 | 48 | 20 | 1 | Eutrophic |
| 70 | 96 | 55.5 | 0.5 | Hypereutrophic |
| 80 | 192 | 154 | 1.25 | Hypereutrophic |
| 90 | 384 | 426 | 1.025 | Hypereutrophic |
| 100 | 768 | 1180 | 0.0625 | Hypereutrophic |

[1] TSI = (14.42*[ln (Total Phosphorus average)]) + 4.15

[2] TSI = (9.81*[ln (Chlorophyll-a average)]) + 30.6

[3] TSI = 60 - (14.41*[ln (Secchi average)])

[4] Lakes can generally be classified in order of increasing productivity and decreasing water quality as oligotrophic (TSI = 0-40), mesotrophic (TSI = 40-50), eutrophic (TSI = 50-70) or hypereutrophic (TSI = 70-100).

Figure 4-5. Specific Conductance (umhos/cm) within the Mixed Surface Layer

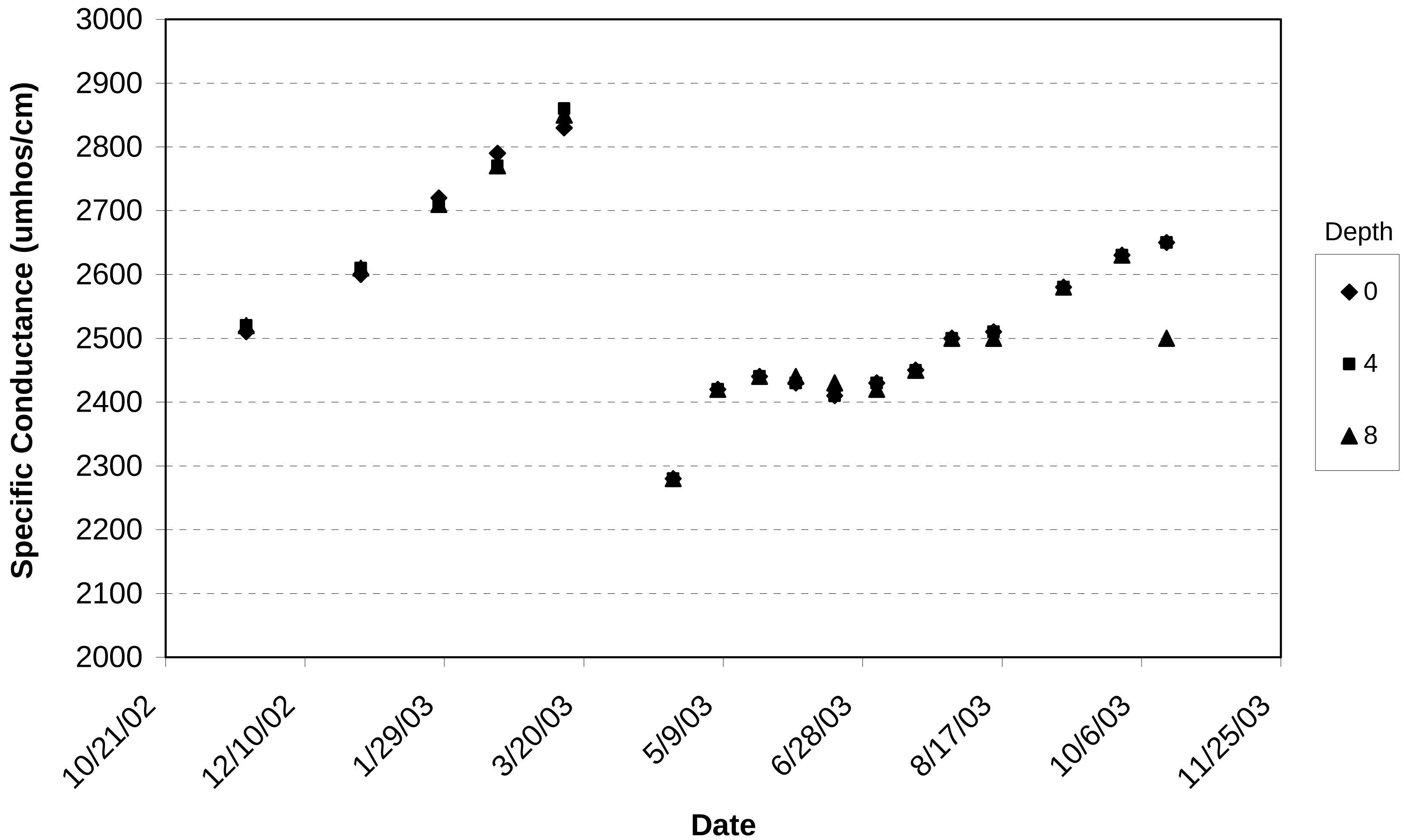


**Figure 4-6. Total Phosphorus Concentration (mg/l)**

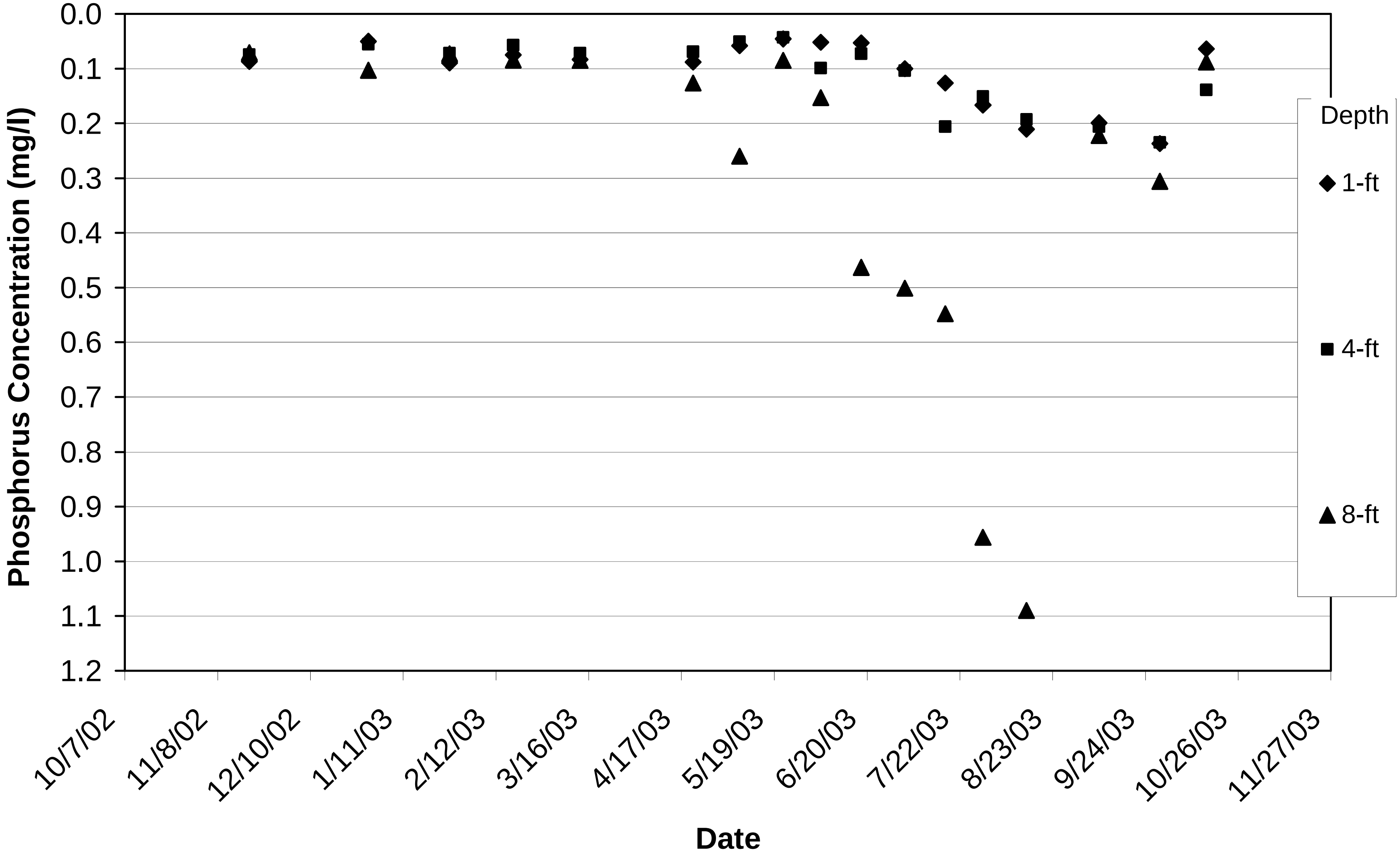


**Figure 4-7. Depth Averaged Total Phosphorus Concentration (mg/l)**

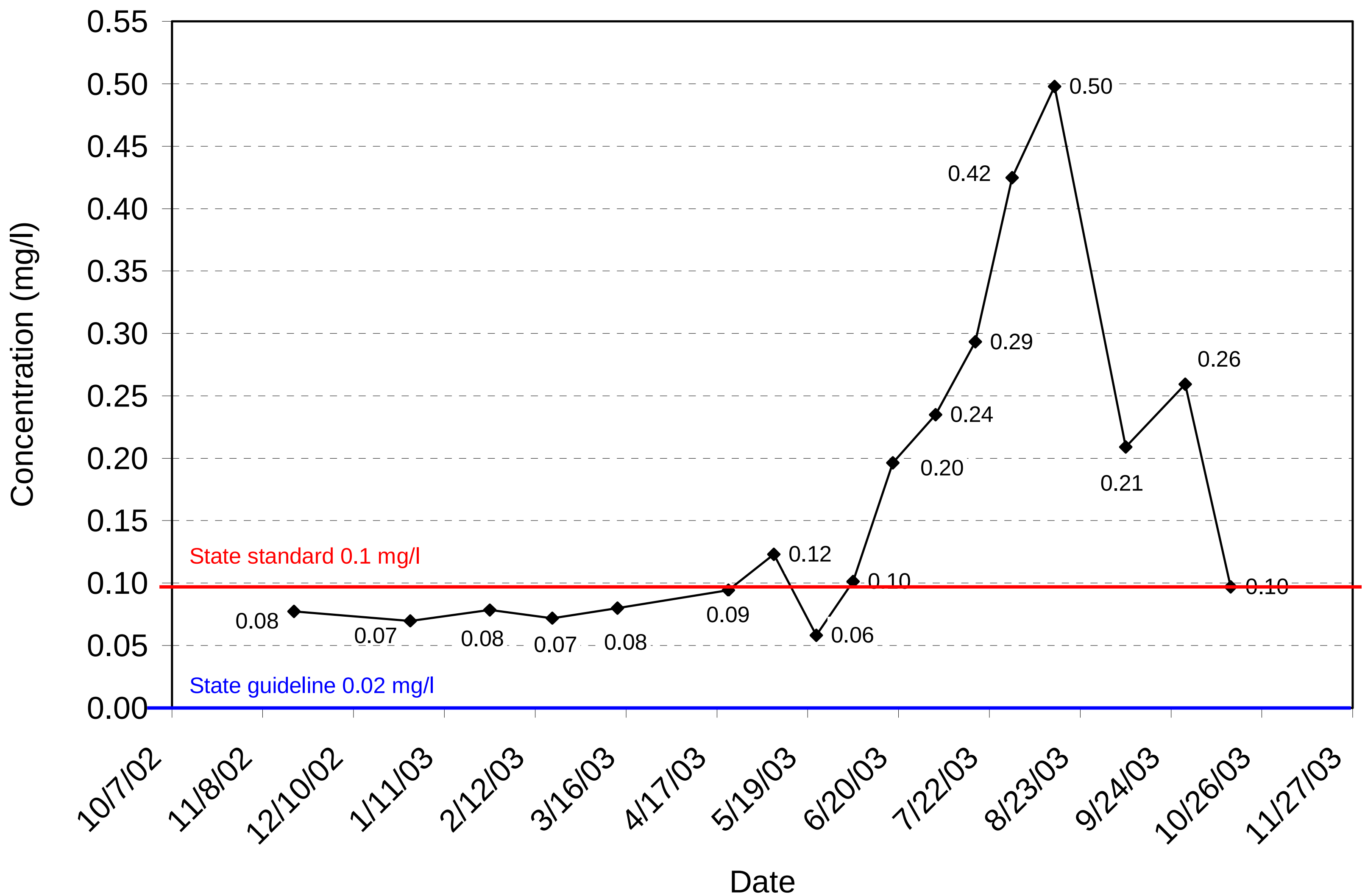
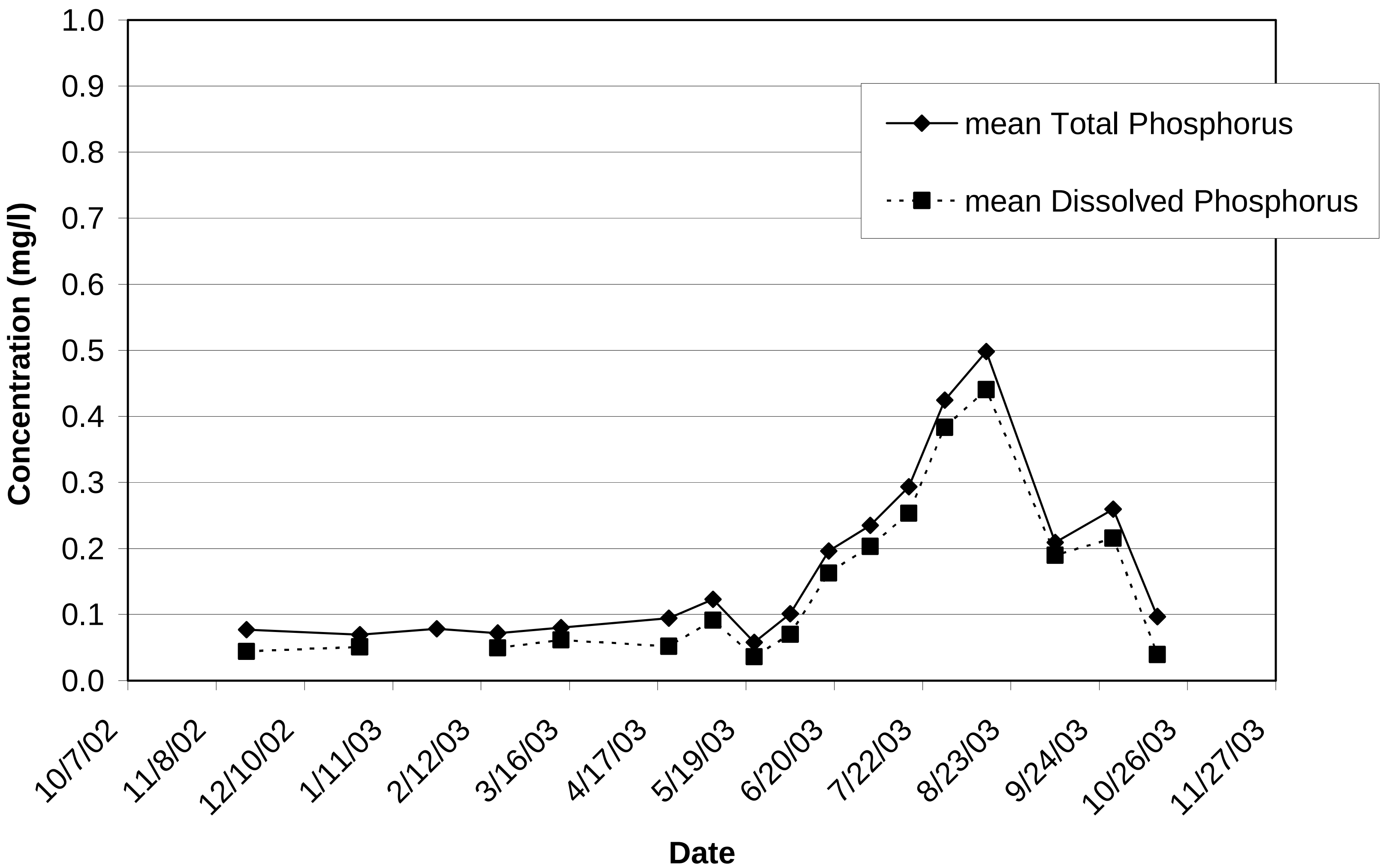


**Figure 4- 8. Mean Dissolved Phosphorus and Total Phosphorus Concentrations (mg/l)**



Nitrogen to phosphorus ratios are shown in **Figure 4-9**. The total nitrogen to total phosphorus ratio (TN:TP) ranged from 37.5:1 for a mid-lake sample in June 2003 to 1.7:1 to for a surface sample in November 2003. The depth averaged ratio was 14.8:1. Prior to July 2003, the ratio indicated that the limiting nutrient for phytoplankton growth was phosphorus. After July 2003, nitrogen became the limiting nutrient.

Lake sediment has a role in the phosphorus cycle within the reservoir. There are elevated concentrations of total phosphorus within the hypolimnion in late July/early August 2003 **(Figure 4-6)**. As the bottom sediments become anoxic, phosphorus is mobilized or released from the sediments. The period of sediment release typically corresponds with stratification and low DO concentrations.

Chlorophyll-a concentrations were measured at the surface of the reservoir. The highest value occurred (62 mg/l) when the total phosphorus was readily available in September 2003 **(Figure 4-10; Figure 4-6)**. High chlorophyll-concentrations are typically associated with algal blooms, which are common in the reservoir.

### 4.1.3 Phytoplankton Abundance

Phytoplankton is a collective term for microscopic aquatic plants and plant-like animals. The phytoplankton, primarily, algae, form the base of the aquatic food chain. In a highly productive lake (hypereutrophic), excessive algal growth creates scums or algae blooms. Algae blooms are usually the most obvious evidence of water quality problems.

Typical algae types include green, brown, red and blue-green. Green and brown algae are generally abundant in a lake. Blue-green algae are considered undesirable and may lead to algae blooms which have an odor during decay. Algae abundance can be expressed by either concentration or biovolume. Brown algae (diatoms), red algae (dinoflagellates) and blue-green algae were the most common phytoplankton within the reservoir on a biovolume basis **(Figure 4-11)**. Diatoms (brown algae) dominated in November 2002 and May, mid-June and July 2003 **(Figure 4-12)**. Dinoflagellates (red algae) dominated in early June, late June and July 2003. Blue-green algae biovolumes started to increase in mid-July in the reservoir.

**Figure 4-9. Ratio of Total Nitrogen to Total Phosphorus**

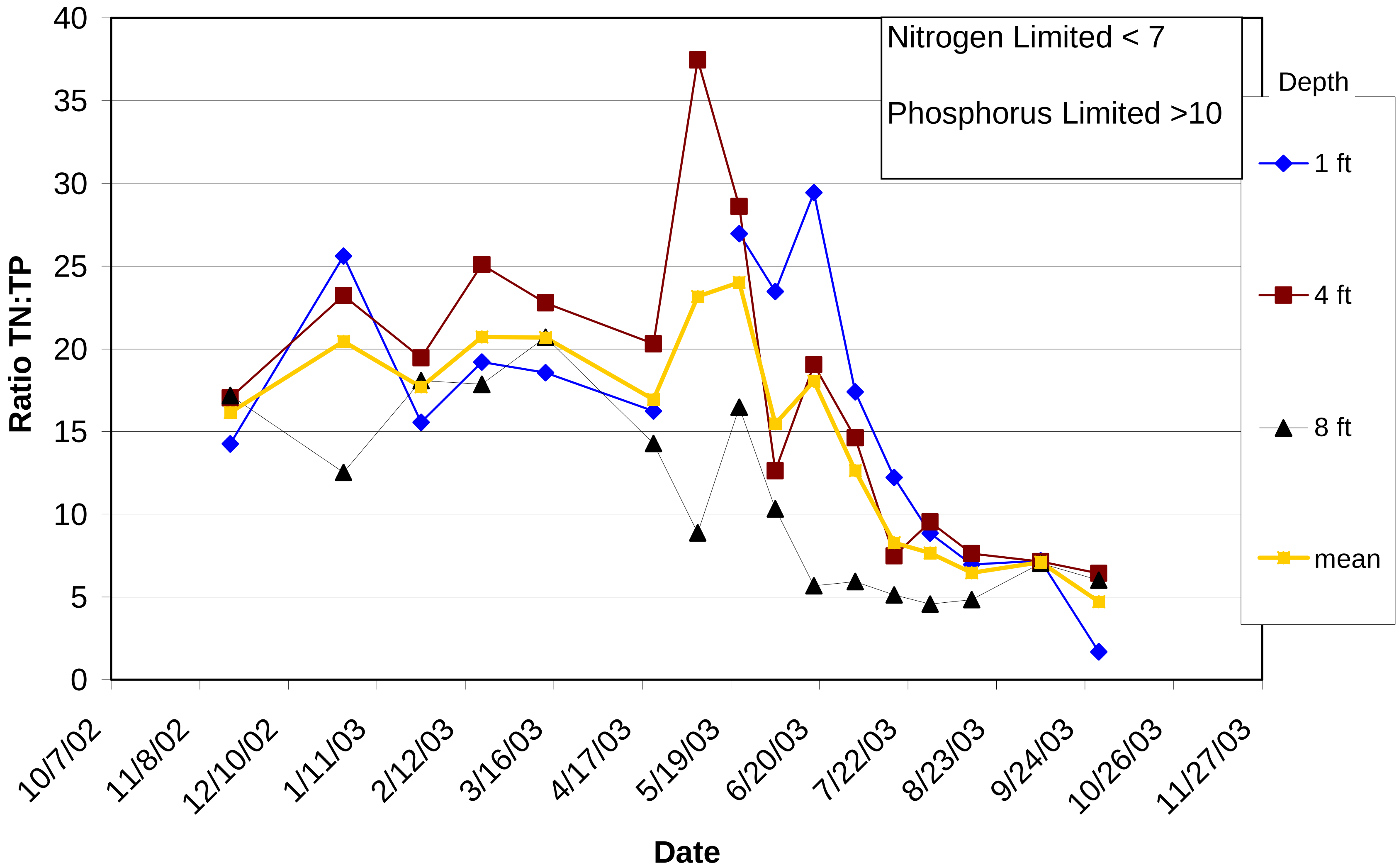


Figure 4-10. Chlorophyll Concentrations (ug/l)

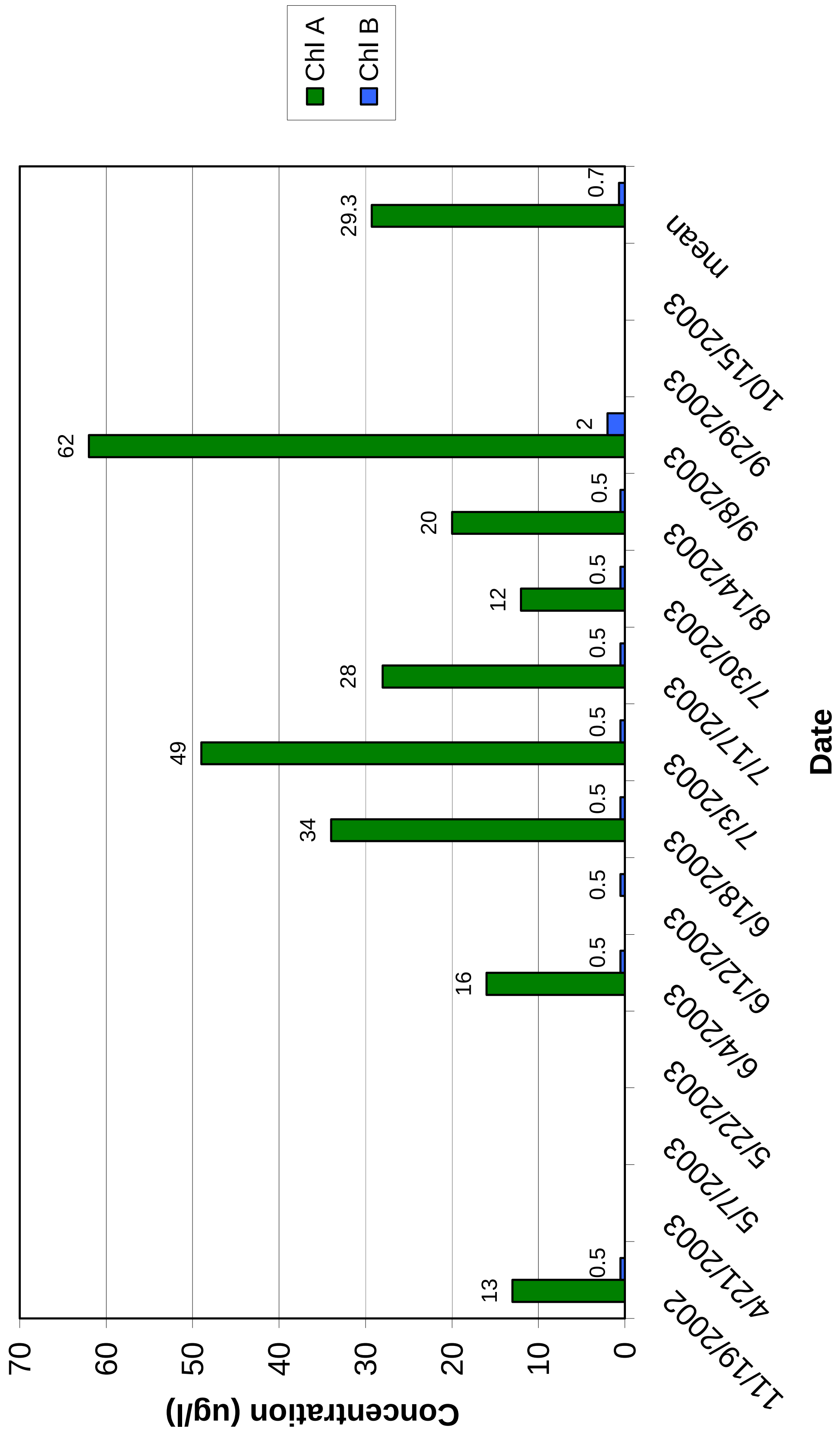


**Figure 4-11. Mean Phytoplankton Biovolume by Class**

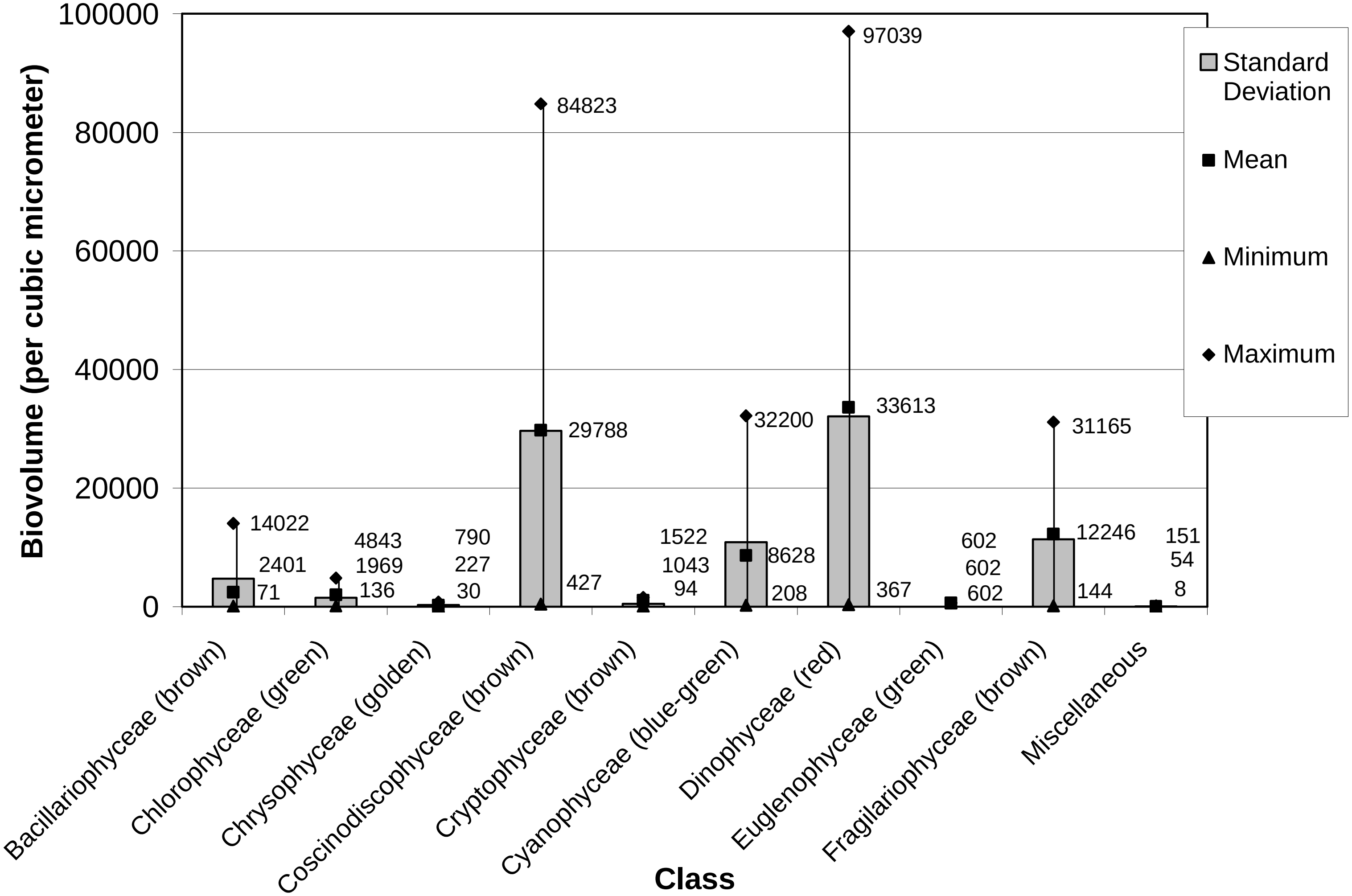
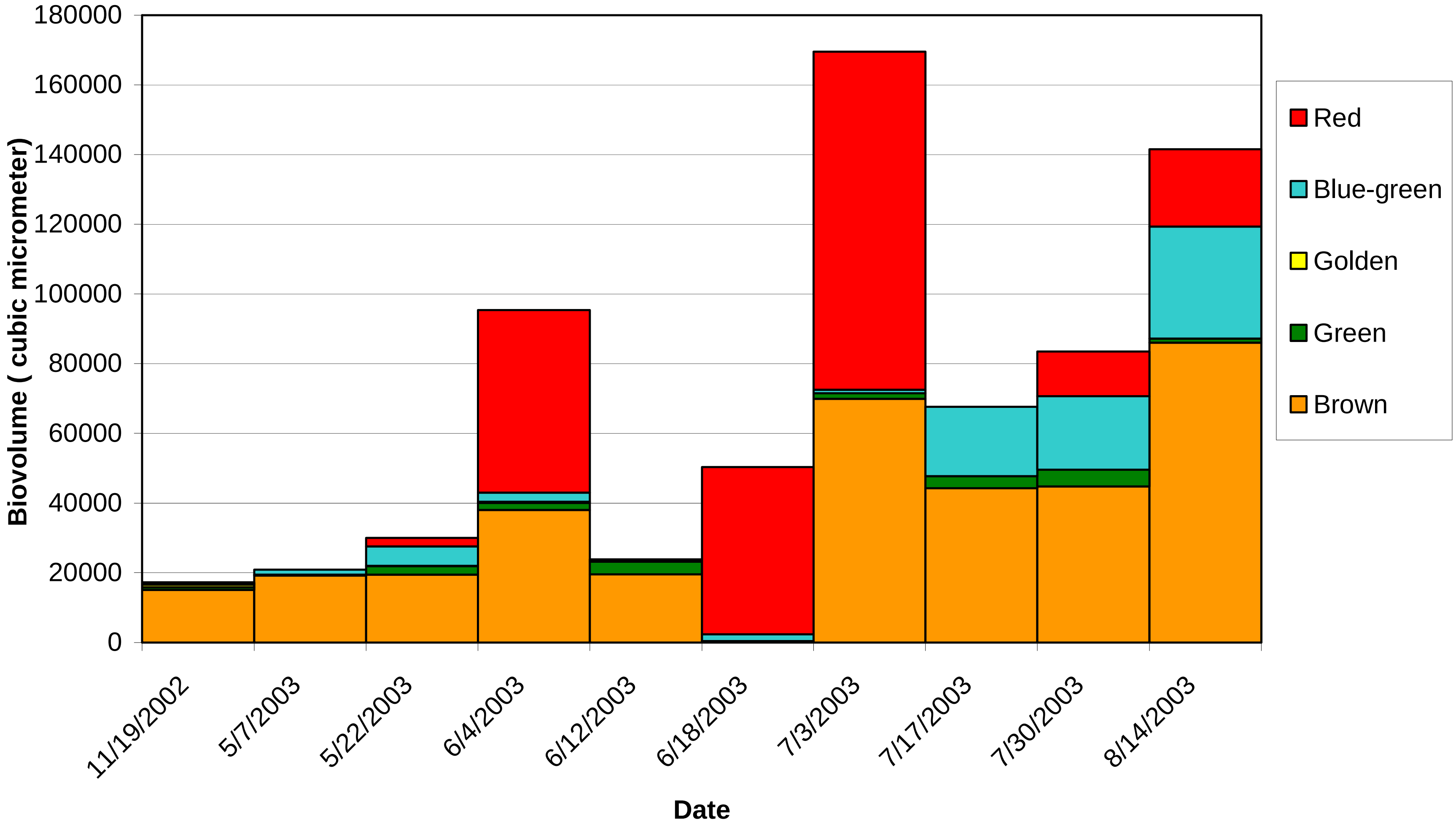


**Figure 4-12. Phytoplankton Biovolume by Sampling Date (May - August 2003)**



### 4.2 Modeling Results

Nutrients influence the water quality of the reservoir. The estimated values of the load and concentration for sediment, total nitrogen, total phosphorus, chlorophyll-a and secchi depth were calculated using the P8 and BATHTUB models. The following discussion focuses primarily on reservoir hydrology, nutrient loads and reservoir response to a reduced nutrient load.

#### 4.2.1 Hydrology

Climatic factors influence the amount of runoff reaching McDowell Dam. There was measured surface runoff to the reservoir, from May through July 2003. However, no surface runoff occurred for the remainder of the monitoring period **(Figure 4-13)**. The reservoir level declined 2.32 feet from May through October 2003. The change in stage is equivalent to a volume of water equaling 116.7 acre-feet or approximately 14% of the volume of the reservoir **(Figure 4-14)**. The reservoir reached a maximum stage during May/June 2003 (~1722.26 msl) and a minimum stage at the end of the study (~ 1719.94 msl).

A hydrologic balance was developed using the measured 2003 data. Seepage through the dam was estimated using records and regression curves provided by the NRCS. Evaporation loss was computed using the average of five methods as described in Section 3.3. The depth of rainfall to the lake surface came from the McDowell Dam rainfall gage. Surface runoff was computed using a rating curve developed from the inflow channel and measured channel stage. Net ground water inflow and outflow was assumed to be negligible.

The hydrologic balance equation is:

$$\text{Storage End} - \text{Storage Begin} = \text{Surface Runoff} + \text{Ground Water Inflow} + \text{Precipitation to Lake Surface} - \text{Evaporation} - \text{Ground Water Outflow} - \text{Dam Seepage} \pm \text{Error}$$

Direct rainfall and surface runoff contributed 94.6 acre-feet of water to the reservoir during the 2003 monitoring period **(Figure 4-15)**. Evaporation and seepage accounted for 100% of the water loss. There was no surface outflow from the reservoir. There was a total volume loss of 98.2 acre-feet during the monitoring period, which resulted in a stage decrease of 2.32 ft.

## Figure 4-13. McDowell Dam Rainfall, Runoff, and Lake Level, 2003

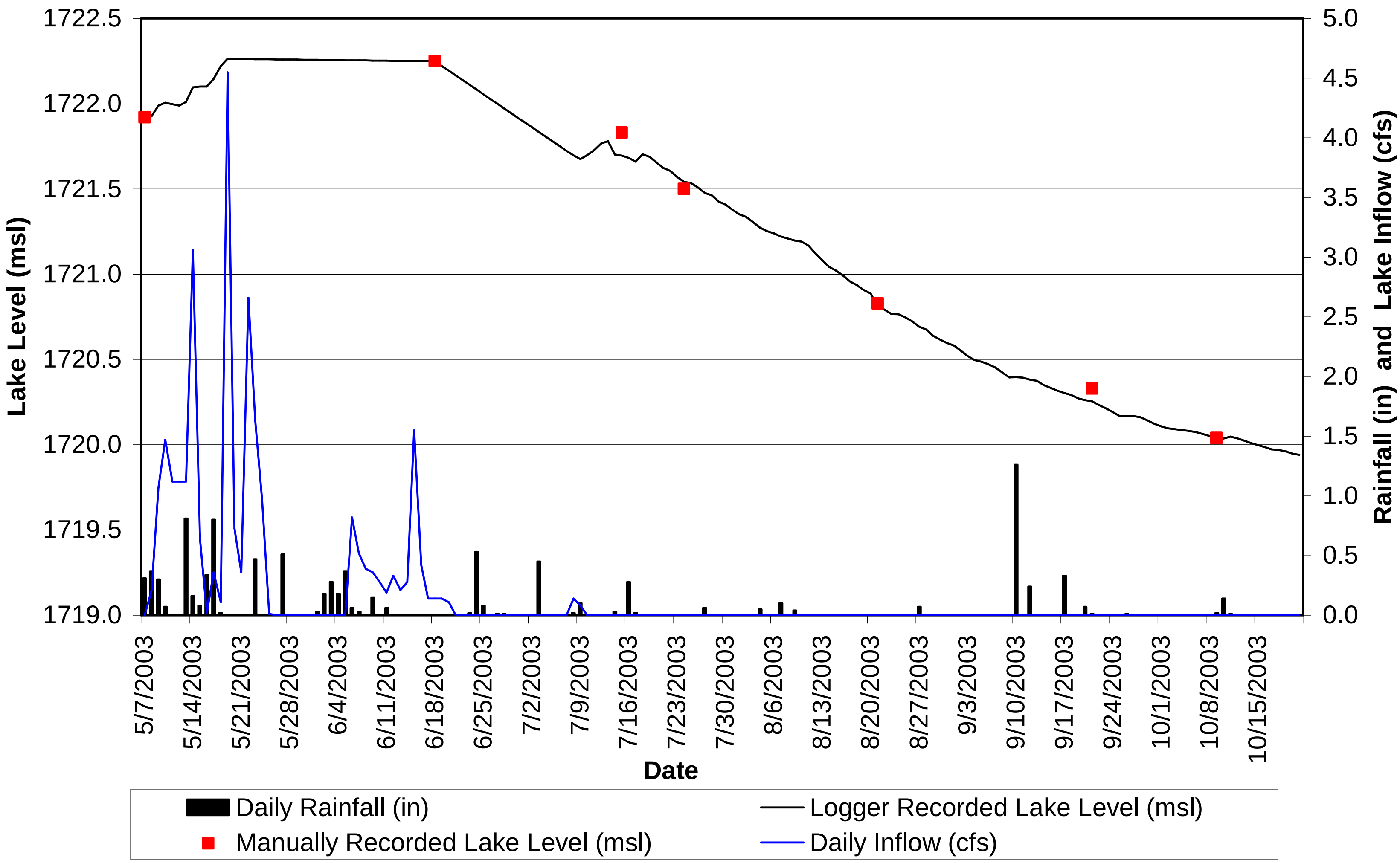


**Figure 4-14. Elevation vs Storage Capacity and Surface Area for McDowell Dam.**

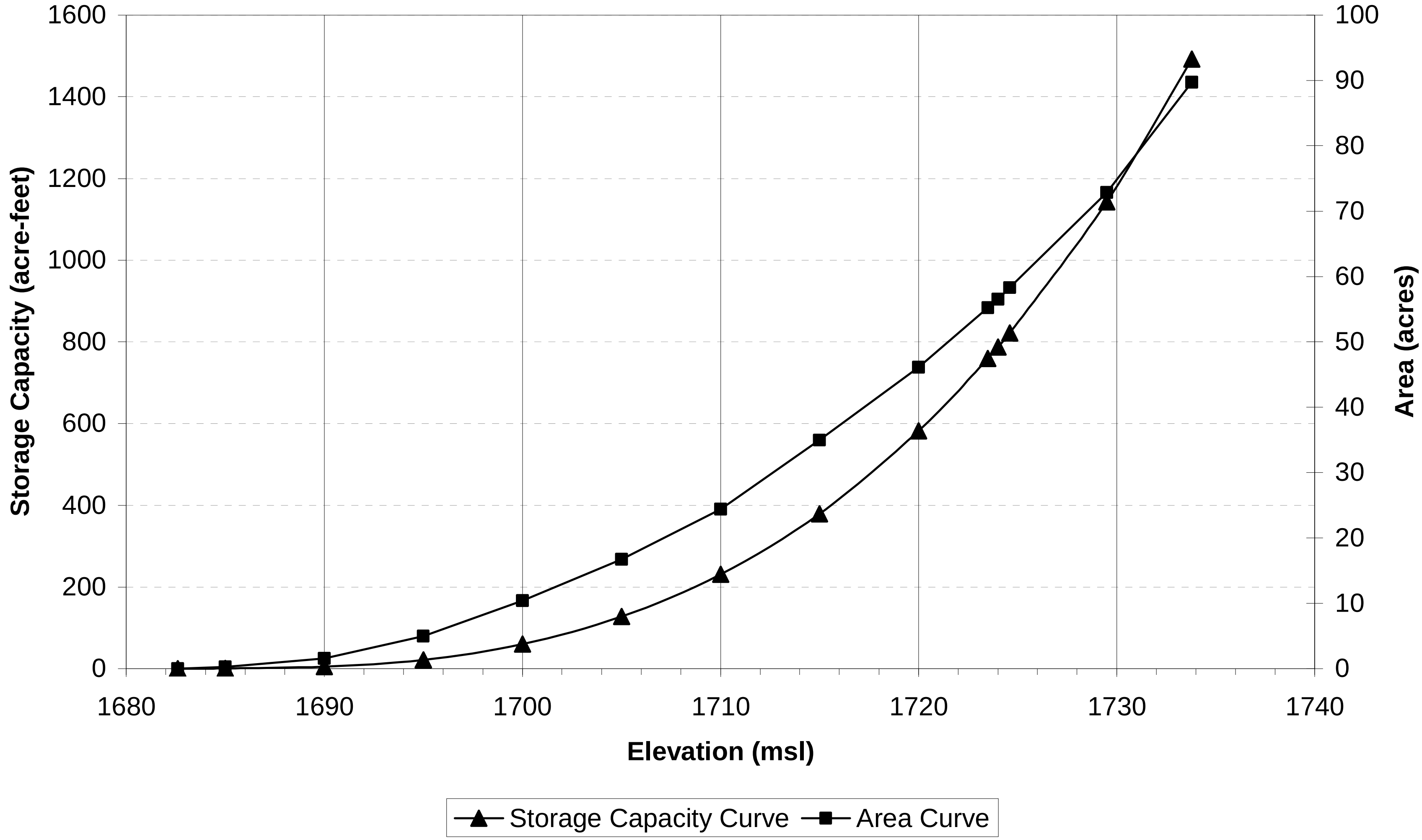
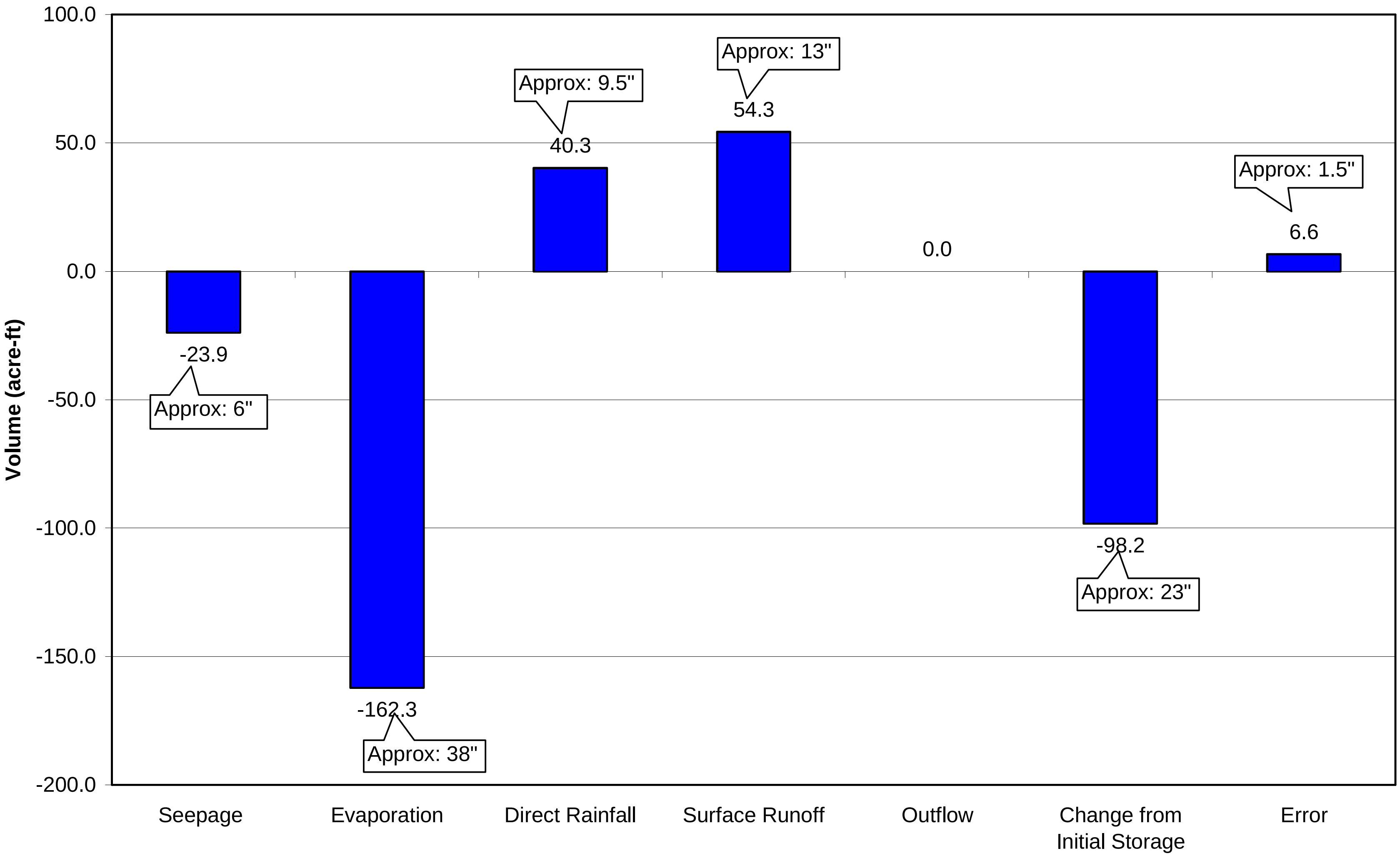


**Figure 4-15. McDowell Dam Reservoir (2003) Hydrologic Budget**



The P8 model was also used to develop the surface runoff term of the hydrologic budget for a “normal” precipitation year using precipitation data from the North Dakota Agricultural weather network for the Mandan Station (see page 17). The normal precipitation year was operationally defined as an annual precipitation depth with a 50% probability of occurrence (median value) for the period of record. The total rainfall depth for the period from May 4, 2001 through October 21, 2001 was then used in the P8 model to develop the “normal precipitation year” hydrologic balance. The net groundwater inflow / outflow was assumed equal to zero.

Based upon the P8 model, an estimated 85% of the total inflow volume to the reservoir is derived from surface runoff during a normal precipitation year **(Figure 4-16)**. Discharge through the reservoir outlet and evaporation are approximately equal in magnitude. The hydraulic residence time is estimated at 2.7 years, compared to a nearly infinite residence time when no surface outflow occurs during dry conditions like 2003.

### 4.2.2 P8 Model Estimated Annual Loads

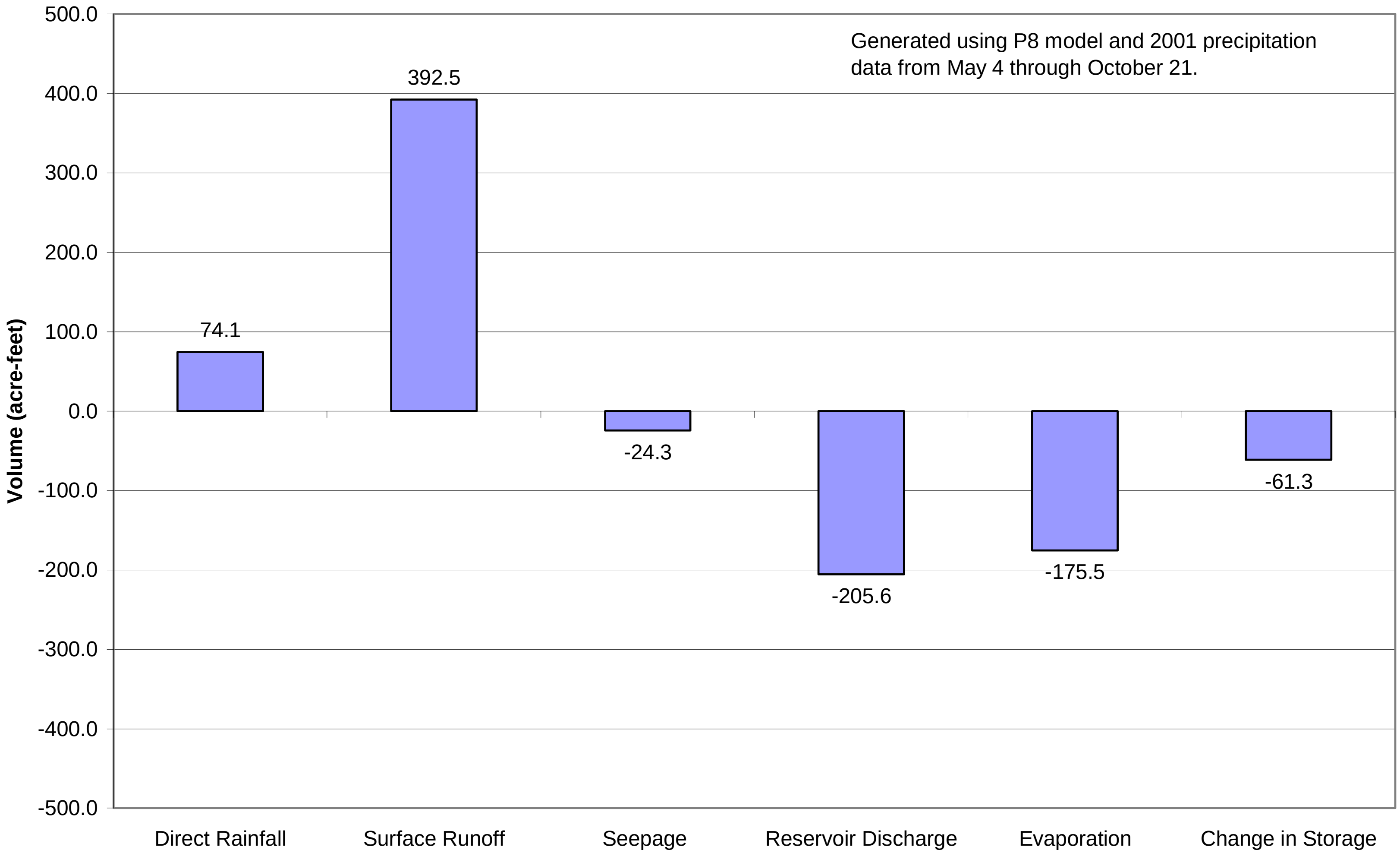
The P8 model estimated the load (lbs) and concentrations (ppm) for Total Suspended Sediments (TSS), Total Phosphorus, Total Kjedahl Nitrogen, $NH_3$ and $NO_2$ + $NO_3$. **Table 4-3** shows the P8 model generated loads and average concentrations within surface runoff. The loads are for the period of May through the end of October and correspond to the lake level and rainfall monitoring period.

**Table 4-3 Estimated loads and average concentrations generated by the P8 model for 2003 and a normal precipitation year (2001).**

| **Variable**[1] | **Load (lbs)** | | **Concentration** | |
|---|---|---|---|---|
| | *2003* | *Normal Year* | *2003* | *Normal Year* |
| Total Suspended Solids | 3,183.28 | 19,875.3 | 22.1 ppm | 18.6 ppm |
| Total Phosphorus | 59.60 | 421.1 | 413.5 ppb | 394.7 ppb |
| Total Kjeldahl Nitrogen (TKN) | 159.24 | 1131.3 | 1104.8 ppb | 1060.3 ppb |
| $NH_3$ | 18.27 | 127.3 | 126.7 ppb | 119.3 ppb |
| $NO_2$ + $NO_3$ | 27.40 | 190.9 | 190.1 ppb | 179.0 ppb |

[1]TKN = organic nitrogen + $NH_3$; Total Nitrogen = ($NO_3$ + $NO_2$) + TKN. Surface runoff volume estimated is 53.03 Acre-feet for 2003 and 329.5 acre-feet for a normal precipitation year (2001).

**Figure 4-16. McDowell Dam Reservoir Hydrologic Budget for "Normal" Precipitation Year**



The results show that the nutrient loads from surface runoff are estimated to increase by a factor of seven during “normal” conditions, compared to those observed during 2003.

The phosphorus and sediment yields for surface runoff can be calculated for the watershed using the P8 model **(Table 4-4)**. The phosphorus and sediment yields for the watershed in 2003 are 0.009 tons/mi$^2$ and 0.48 tons/mi$^2$, respectively.

**Table 4-4 Phosphorus (Total) and sediment loads for subwatersheds 3, 4 and 5 as estimated by the P8 model for the McDowell Dam watershed in 2003.**

| Drainage Area (acre) | Drainage Area (mi$^2$) | Phosphorus Load (tons) | Phosphorus Yield (tons/mi$^2$) | Sediment Load (tons) | Sediment Yield (tons/mi$^2$) |
|---|---|---|---|---|---|
| 2,114 | 3.3 | 0.0298 | 0.009 | 1.59 | 0.48 |

Runoff from subwatersheds 1 & 2 were detained by an upstream dam and did not flow into McDowell Dam Reservoir during 2003.

There was no outflow in 2003 so the entire load (100%) collected in the reservoir.

### 4.2.3 BATHTUB Model and In-Reservoir Response

Input for the BATHTUB model included information about the in-reservoir water quality data from the 2003 monitoring season for calibrating the model, reservoir geometry, the hydrologic budget and the nutrient loads. The model was calibrated to the measured 2003 in-reservoir water quality for total phosphorus, total nitrogen, chlorophyll-a and secchi depth. The model was calibrated by adjusting the sediment term for total phosphorus and total nitrogen.

Two BATHTUB models were developed from the mass balance data: i.e., one for 2001 (the normal precipitation year) and a second for 2003, **(Figures 4-17** and **4-18)**. The mass balances show that the internal total phosphorus load is similar in magnitude for a normal precipitation year, to the load from surface runoff. A large proportion of the load is retained within the reservoir. The importance of this information is that any proposed management strategy should also focus on the internal load if it is to be successful in improving water quality.

**Figure 4-17. McDowell Dam Reservoir Total Phosphorus Mass Balance for 2003**

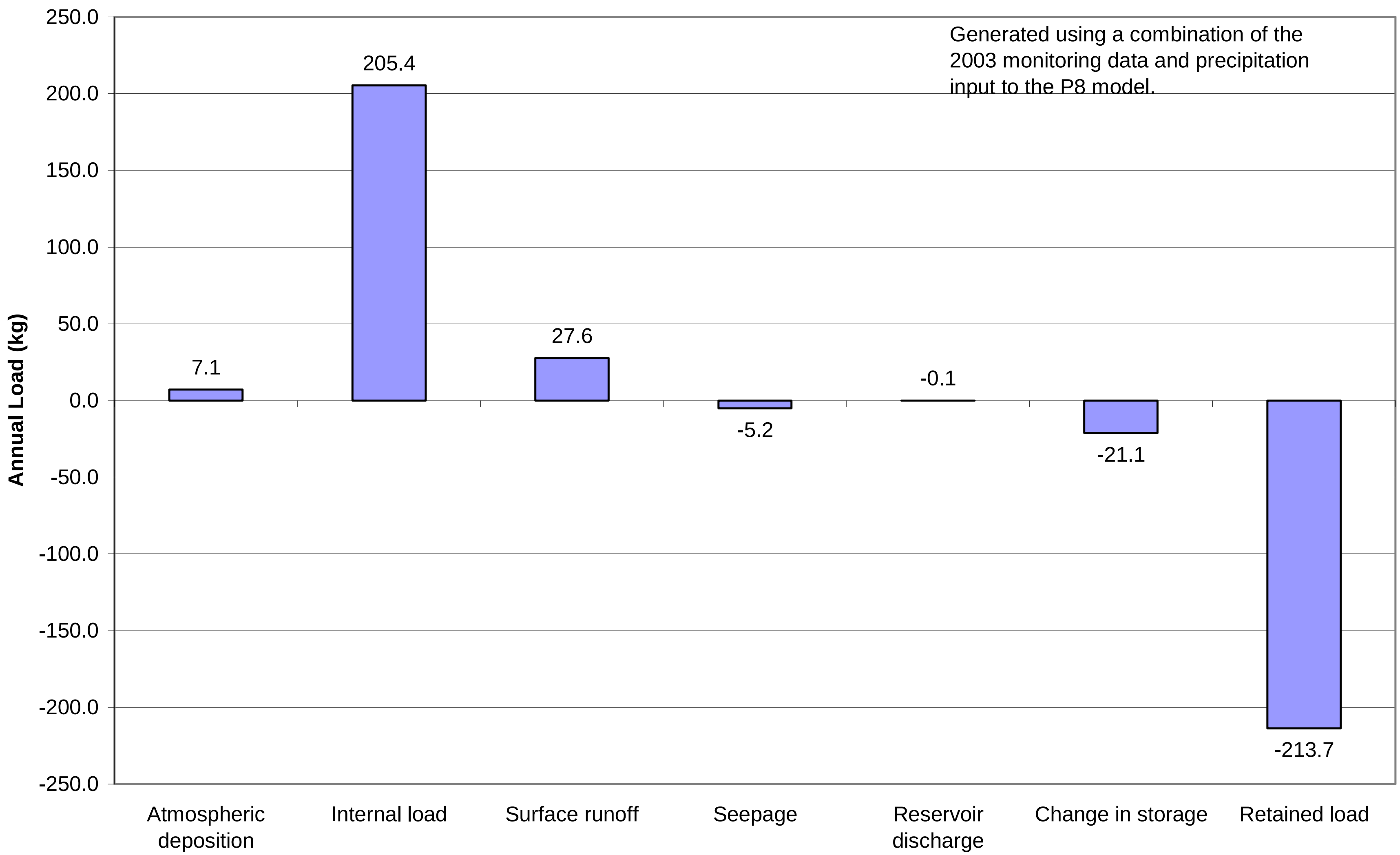
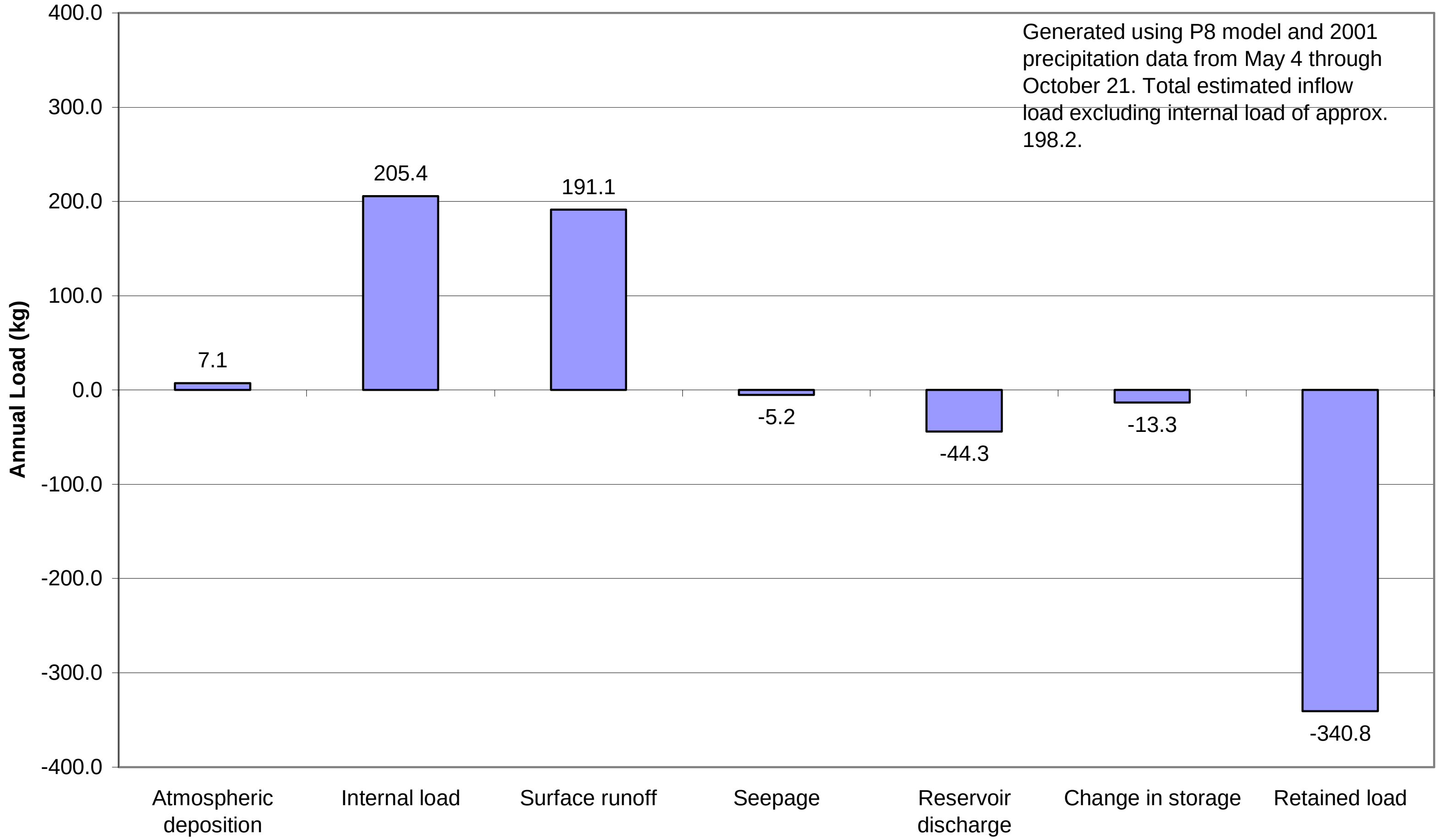


**Figure 4-18. McDowell Dam Reservoir Total Phosphorus Mass Balance for Normal Precipition Year**



Understanding the in-reservoir response to the reduction in the tributary and internal nutrient loads is useful in establishing nutrient load reduction goals for the McDowell Dam Reservoir. **Figures 4-19 through 4-21** show the in-reservoir response for total phosphorus and chlorophyll-a concentrations, and secchi visibility for various *percentage reductions in tributary and internal loads* for both the monitored and normal precipitation years. The in-reservoir reduction in average total phosphorus concentration ranges from 14% to 19% with a 40 percent nutrient load reduction **(Figure 4-19)**. Because of the in-reservoir decline in total phosphorus, the average chlorophyll-a concentration decreases in excess 20% **(Figure 4-20)** with improved water clarity **(Figure 4-21)**.

Nuisance algal blooms periodically prevent the use of the reservoir. As the algal concentration reaches and exceeds some threshold value, the reservoir becomes less desirable for swimming and use ceases. Load reduction goals based on the frequency of anticipated algal blooms are most directly related to recreational use. **Figure 4-22** shows the relationship between algal concentrations (expressed as chlorophyll-a concentration) and the percentage tributary and internal load reduction for a normal precipitation year.

The frequency analysis is based upon reservoir data within the BATHTUB model. Assuming 30 ppb chlorophyll-a is established an the nuisance threshold, a 30% nutrient load reduction decreases the frequency of time above this value from the current 36.4% of the time to 24.5% of the time. This means a potential increase in reservoir use of approximately 12% of the time.

**Figure 4-19. Annual Average Reservoir Total Phosphorus Concentrations Corresponding with Percentage Tributary and Internal Load Reductions**

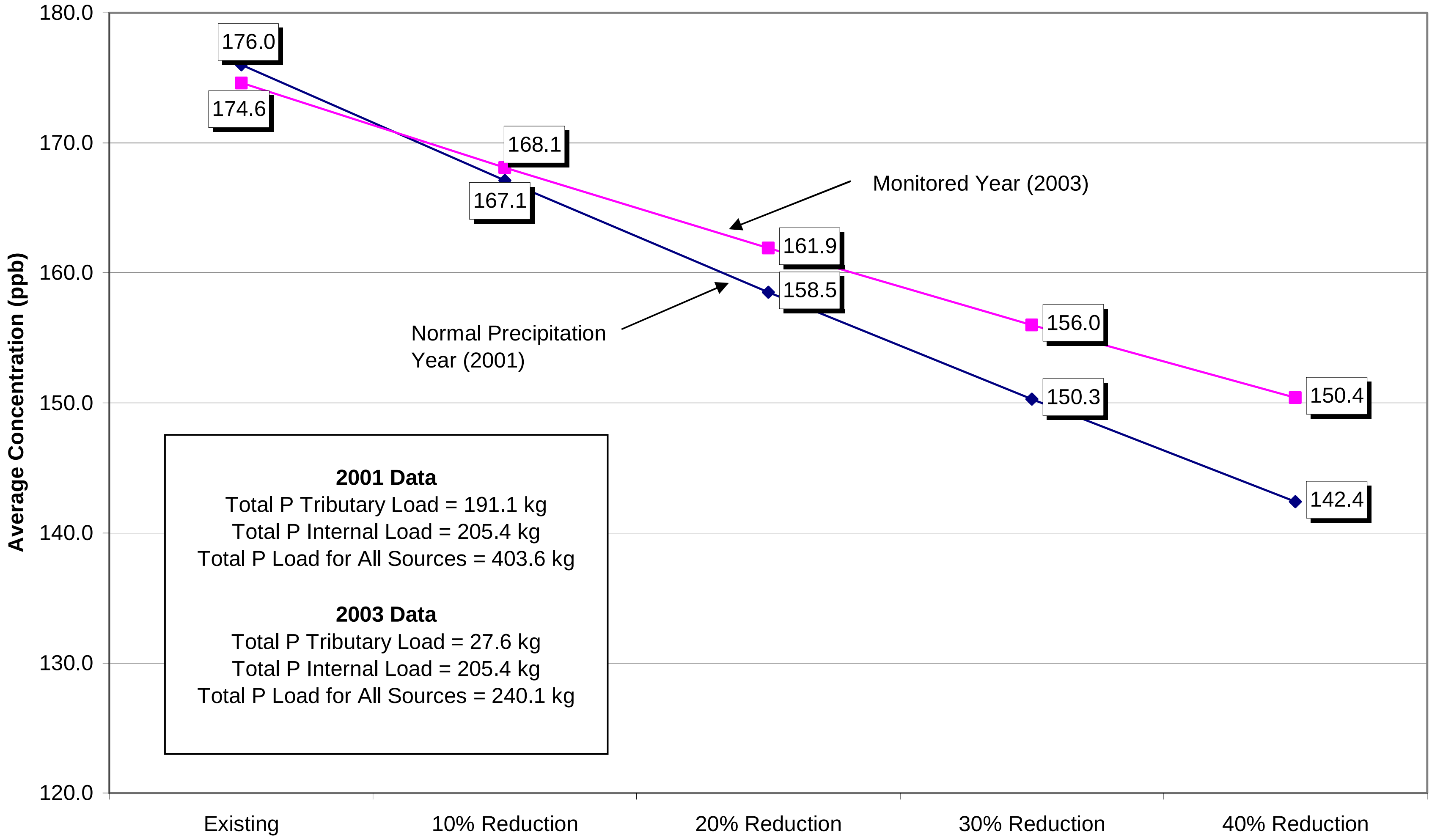


**Figure 4-20. Annual Average Reservoir Chlorophyll-a Concentrations Corresponding with Percentage Tributary and Internal Load Reductions**

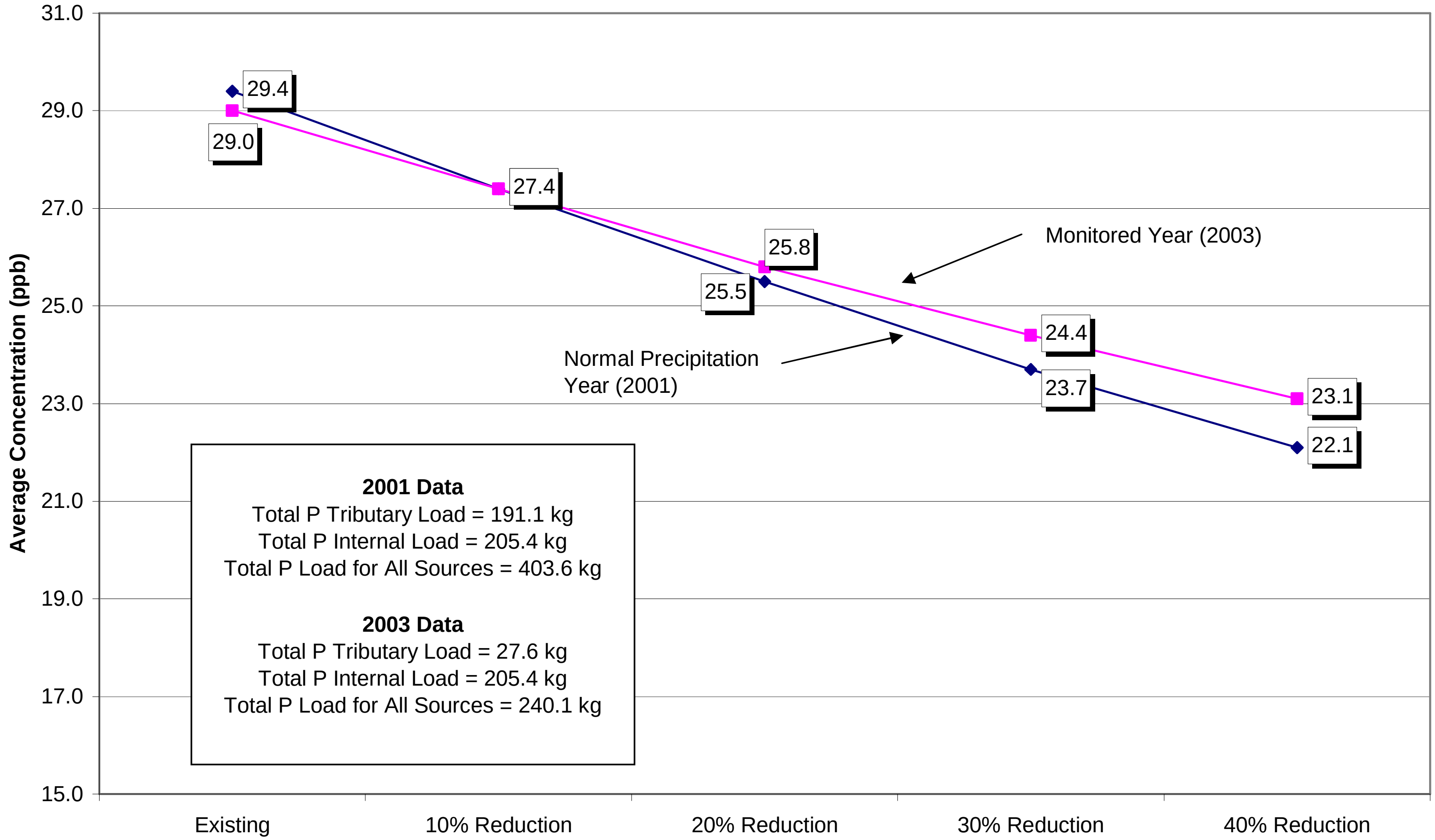


**Figure 4-21. Annual Average Reservoir Sechi Depth Corresponding with Percentage Tributary and Internal Load Reductions for Normal Precipitation Year (2001) and Monitored Year (2003)**

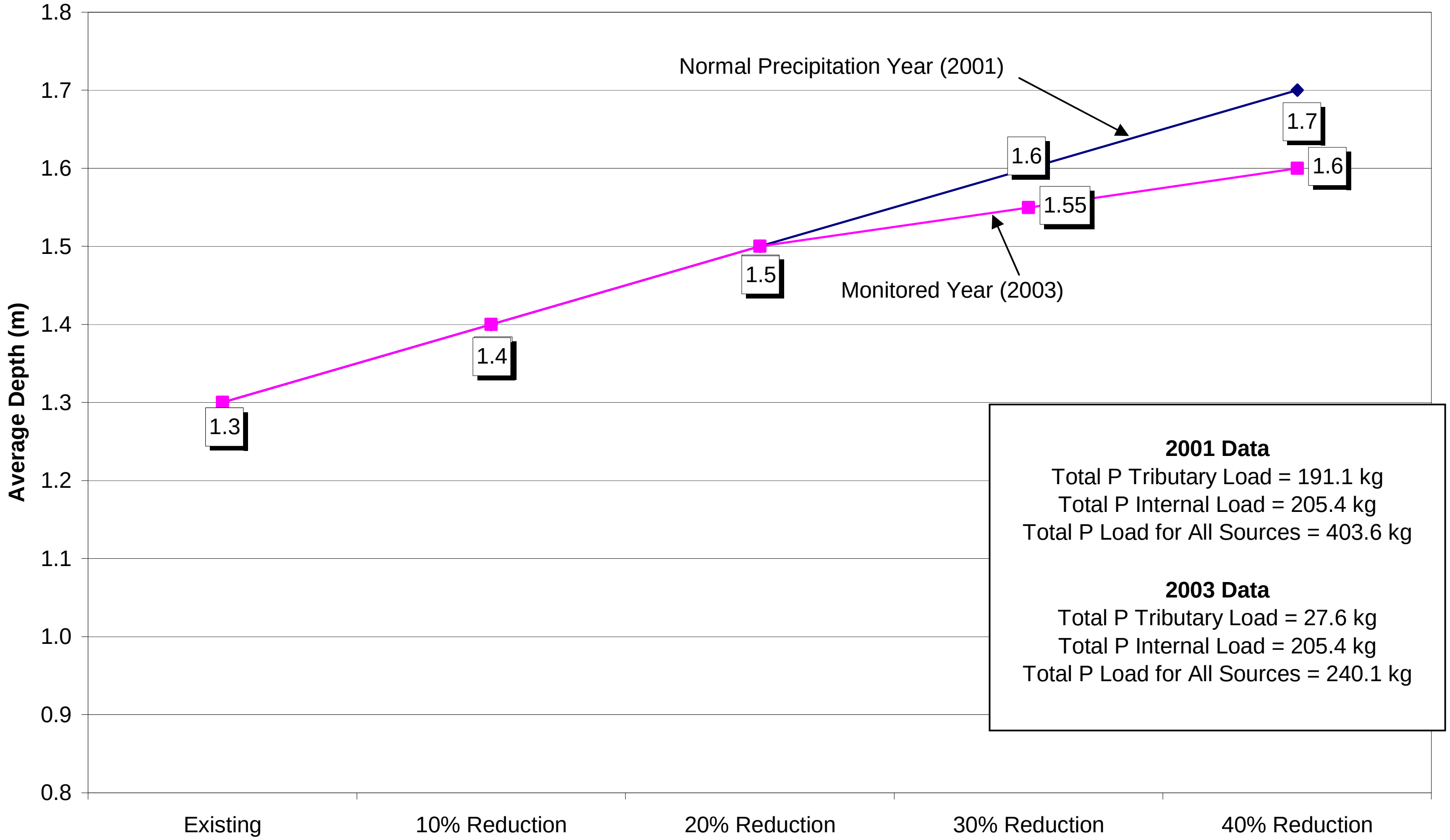
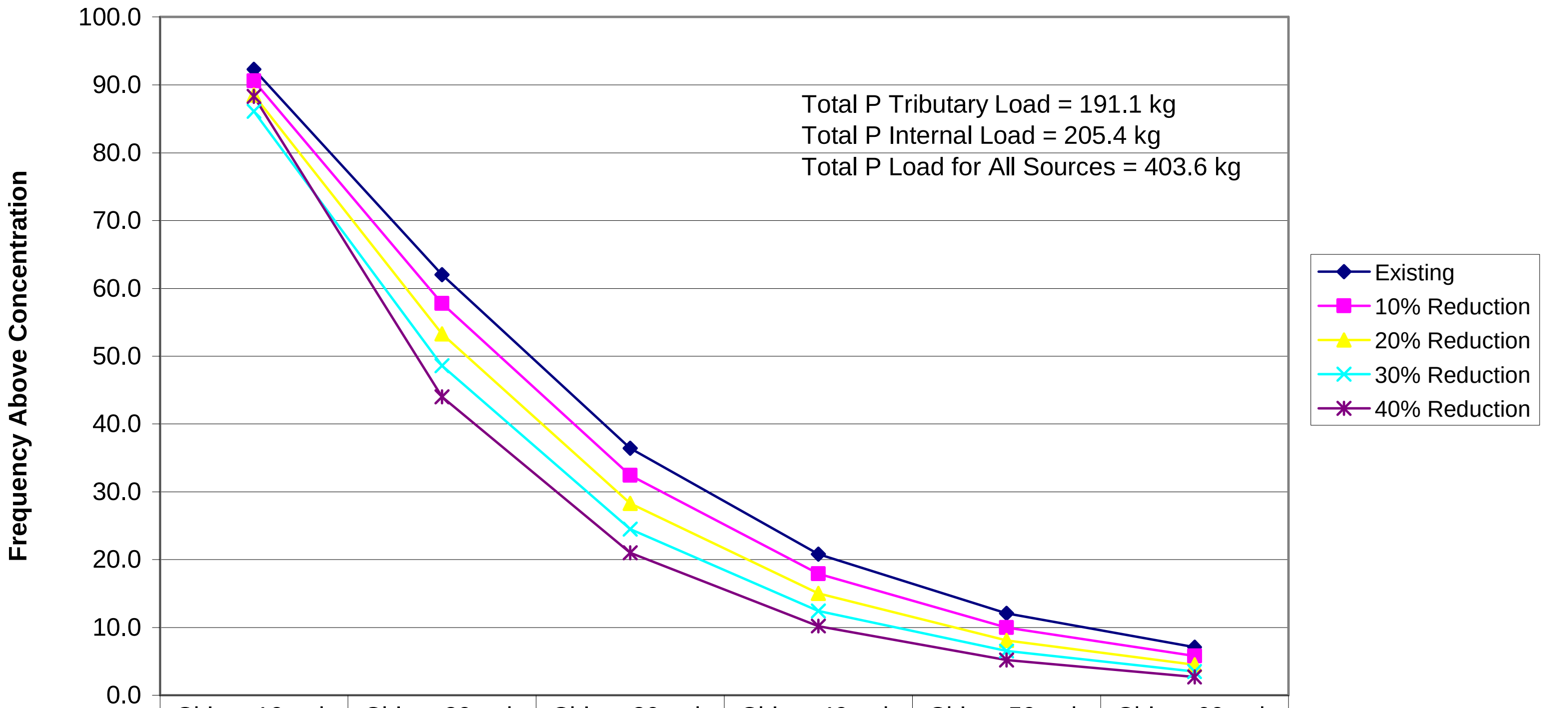


**Figure 4-22. McDowell Dam Reservoir
Frequency Analysis of Chlorphyll-a Concentrations with Tributary and Internal Percentage
Load Reduction for Normal Precipitation Year (2001)**




| | Chla > 10 ppb | Chla > 20 ppb | Chla > 30 ppb | Chla > 40 ppb | Chla > 50 ppb | Chla > 60 ppb |
|---|---|---|---|---|---|---|
| Existing | 92.3 | 62.0 | 36.4 | 20.8 | 12.1 | 7.1 |
| 10% Reduction | 90.6 | 57.8 | 32.4 | 17.9 | 10.0 | 5.8 |
| 20% Reduction | 88.5 | 53.3 | 28.3 | 15.0 | 8.1 | 4.5 |
| 30% Reduction | 86.1 | 48.6 | 24.5 | 12.4 | 6.5 | 3.5 |
| 40% Reduction | 88.3 | 44.0 | 21.0 | 10.2 | 5.2 | 2.7 |

# 5.0 FEASIBILITY OF WATER QUALITY MANAGEMENT ALTERNATIVES

## 5.1 Water Quality Exceedences

**Table 5-1** contains a summary of the percentage of the sampling dates that exceeded state water quality standards for total phosphorus, DO and temperature values. The information presented includes samples collected across all depths during the time period of November 2002 through October 2003.

**Table 5-1. Summary of percent exceedences for the time period from November 2002 to October 2003.**

| Parameter | Standard Value (unit) | % Exceedences |
|---|---|---|
| **TOTAL PHOSPHORUS** | > 0.1 mg/l | 43.1 |
| Dissolved Oxygen | < 5 mg/l | 19.5 |
| Temperature | > 29.44 ºC (85 ºF) | 0.0 |

## 5.2 Recommended Water Quality Goals

The water quality goal for McDowell Dam reservoir is focused on nutrients. The U.S. Army Corps of Engineers' BATHTUB computer model was used to predict the anticipated improvement in water quality with percentage reductions in the total phosphorus loads from surface water runoff and internal cycling **(Figures 4-19** through **Figure 4-21)**. The primary use of the McDowell Dam reservoir swimming and body contact recreation therefore, rather than solely using the average annual or growing season total phosphorus concentration as the lake water quality goal, the use of water clarity (expressed as secchi visibility), algal concentration (expressed as chlorophyll-a) and algal bloom frequency is recommended. Algal bloom frequency is perhaps the best method for establishing the goal because it is usually directly related to recreational use.

Algal bloom nuisance conditions, defined as chlorophyll-a concentration exceeding 30 ppb, can be reduced from the current 36.4% to 24.5% of the time with a 30% reduction in the surface inflow and internal cycling total phosphorus load. During May, June, July and August (123 days total) this means 30 days compared to 45 days classified as "nuisance conditions" because of algae bloom conditions. A 30% load reduction is also predicted to decrease the annual average total phosphorus concentration from 176.0 ppb to 150.3 for a normal precipitation year.

## 5.3 Nutrient Sources

### 5.3.1 Point Sources

There are no known point sources upstream of the McDowell Dam Reservoir. Approximately 71% of the land upstream of the reservoir is farmed with an additional 23% used for pasture or with permanent cover. Currently there are few developed areas in the watershed.

### 5.3.2 Non-point Sources

Non-point source pollution accounts for 100 percent of the nutrient and sediment loading to McDowell Dam (NDDH, 1996). According to the Burleigh County Soil Conservation District, the majority (95%) of the cultivated lands and all other lands (100%) are adequately treated to prevent soil loss (NDDH, 1996). "Adequately treated" is defined as the amount of land treatment necessary to achieve the soil loss tolerance (T). The average T value for McDowell is between 3-5 tons per acre. The P8 model predicts that during "normal" precipitation years 9.9 tons of total suspended solids are delivered to the McDowell Dam Reservoir annually.

## 5.4 Feasibility of Water Quality Management Alternatives

Management alternatives for reservoirs and lakes can generally be classified as:

- Source controls;
- In-lake controls; and
- Problem treatment.

Source controls are used to modify the quality of water entering a lake or reservoir. Examples of source controls are management within the watershed to reduce erosion, chemical treatment to reduce inflow nutrient concentrations, and point source treatment or diversion. The application of alum, a chemical used to remove phosphorus from the water column and dredging, are examples of in-lake controls. Problem treatment includes weed harvesting, aeration, and chemical treatment to reduce plant growth and the release of nutrients from lake sediments. A variety of methods for improving the water quality of the reservoir are potentially available.

**Table 5-2** presents a list of these methods. No single method by itself is likely to be completely effective in improving the water quality of the reservoir. A combination of methods is generally needed to improve water quality. For example, external load reduction (i.e., source control) combined with in-lake controls appears warranted.

This section presents the evaluation of various methods for improving the water quality of the McDowell Dam Reservoir. Preliminary opinions of probable cost for these management alternatives are also provided. A specific water quality goal is essential in developing a water quality management plan. The preliminary goal established for the purposes of evaluating the alternatives corresponds to a 30% reduction in internal and surface runoff total phosphorus loads.

### 5.4.1 Surface Runoff Treatment

This concept consists of treating surface runoff to reduce the nutrient load, prior to reaching the reservoir and can be accomplished by constructing additional upstream sedimentation basins or physically treating the runoff (with alum much like a wastewater plant) to reduce nutrients. One sedimentation basin is currently located upstream from the reservoir. The opportunity to add an additional sedimentation basin is limited and may subsequently affect water quality inflows. Because during a normal precipitation period the internal load exceeds the load from surface runoff, reducing the load from surface runoff alone is unlikely to achieve the intended reservoir water quality goals. Therefore, this alternative was eliminated from additional consideration.

### 5.4.2 Conservation Management Practices

Conservation management practices primarily consist of altering the current tillage practices for cultivated land within the watershed to reduce the sediment and nutrient load reaching the reservoir. Potential conservation management practices are tillage and residue management options. These options include the use of no-till, ridge till, mulch tillage and leaving various amounts of crop residue.

The use of conservation management practices is encouraged for improving reservoir water quality. Conservation management practices effectively reduce the nutrient load reaching McDowell Dam Reservoir. Soil nutrients are retained within the cultivated soils and lead to enhanced crop production. Reservoir longevity is enhanced because of the reduction in solids and sediment reaching the reservoir and the loss in storage resulting from accumulation.

Appendix B contains a preliminary analysis and estimate of the total phosphorus annual load reduction in surface runoff load, assuming one-half of the currently cultivated land within the watershed is placed in permanent cover. The analysis presented is only for illustrative purposes – the conservation management practices ultimately implemented will need to be determined through the combined efforts of the landowner and the Burleigh County Soil Conservation District. The analysis is intended to show the magnitude of annual load reduction possible with the implementation of conservation management practices.

The analysis shows that for a normal precipitation year the current estimated total phosphorus load resulting from surface runoff can be reduced from 185 kg per year to 93 kg per year. This annual load reduction corresponds to a 23% reduction (92 kg per year) in the combined internal and surface runoff load. The estimated cost for treating the 1334.4 acres assuming land retirement at a cost of $500 per acre is $667,000. Therefore, the estimated cost for the total phosphorus reduction is $7,250 per kg.

Permanent land retirement is not the recommended alternative. However, every opportunity to reduce the external nutrient load to the reservoir should be pursued as a recommended implementation strategy. Residue management is expected to be the most cost effective method of reducing the external nutrient load.

# Table 5-2

## Restoration Alternatives for McDowell Dam Reservoir

| Method or Technique | Type of Technique | Desired Effect | Anticipated Improvement | Longevity | Positive Factors | Negative Factors | Estimated Cost |
|---|---|---|---|---|---|---|---|
| 1. Agricultural Runoff Treatment | Source Control | Reduction in algae and macrophyte biomass by treating surface runoff. | Not recommended for McDowell Dam reservoir. | Years | Easy to do. | Low return on investment. | None. |
| 2. Dredging | In-Lake | Removal of sediments as a nutrient source and maintain adequate oxygen for sustaining fishery. | 50% reduction in internal load (estimate) | More than 10 years at present solids loading | Technology commonly used and available. | Potential loss of reservoir use for a period of time. May need to repeat on periodic basis. Hydraulic dredging disposal site and permitting. Moderate success for aquatic macrophytes. | Approximately $2.5 - $5.0 per cubic yard excluding haul and disposal costs. |
| 3. No Phosphorus Fertilizer | Source Control | Eliminate or reduce contact between nutrient source and runoff. | Not recommended within an agricultural watershed. Soil testing to determine optimum application rates may be useful. | Years | Easy to do. | Few | None |
| 4. Harvesting Aquatic Plants | Problem Treatment | Reduction in aquatic macrophyte density. | Effect on in-lake phosphorus minimal or some slight increase, good reduction in aquatic plants.<br><br>Not recommended for McDowell Dam reservoir. | Weeks to Months | Improves aesthetics immediately. Easily implemented and low cost. | Does not address nutrient source. Needs repeating 2-3 times/yr. May remove habitat. Turbidity increases temporarily. May spread Eurasian Water Milfoil if present. | Commercial: $2.50/acre plus $500 mobilization cost. Total cost of $1500/ treatment. Purchase: $15,000 - $35,000 plus O&M. |
| 5. Dilution with Hypolimnetic withdrawal | In-Lake | Reduction in algae biomass by increasing loss of algae and decreasing residence time. | Considered feasible with an estimated 25% load reduction (internal and surface load). Not quite capable of meeting the in-reservoir water quality goals – 30% load reduction. | Years | Cost | Downstream water quality impacts | Estimated:<br>$305,000 in capital costs and $4,500 of annual operating costs. |

## Table 5-2 (cont.)

## Restoration Alternatives for McDowell Dam Reservoir

| Method or Technique | Type of Technique | Desired Effect | Anticipated Improvement | Longevity | Positive Factors | Negative Factors | Estimated Cost |
|---|---|---|---|---|---|---|---|
| 6. Nutrient Inactivation – Alum Treatment | In-Lake | Reduction in algae biomass by removing nutrients from the water column and "sealing" sediment. | Substantial because of the reduction in internal loading. Considered 80% effective in controlling internal load for a 5-year period. Estimated 41% reduction in combined internal and surface runoff loads. Capable of meeting in-reservoir water quality goal. | Between 5 and 10 years, with external load reduction. | Effective long-lasting (up to 10 years) when application appropriate. | Fails to treat ultimate nutrient source. Public concern over chemical cost. May need to buffer the lake. | $75,000 per treatment. Estimate excludes mobilization cost. |
| 7. Aeration | Problem Treatment | Maintain oxic conditions at sediment-water interface, reducing nutrient release. Maintain refuge for fish. | 50% reduction in internal load estimate. Capable of meeting in-reservoir water quality goal. | Years | Maintains refuge for fish if winterkill is problem. | Can result in increased mixing and availability of nutrients. Success is varied and uncertainty of success large. | $30,000<br>Excluding Administration and Engineering |
| 8. Food Chain Manipulation | In-Lake | Increase the abundance of large zooplankton thereby increasing grazing on algae | Minor. Not recommended. | Unknown | Theoretically attractive. | Effectiveness difficult to predict. | None. |
| 9. Hypolimnetic Withdrawal | Source Control | Remove nutrient rich water from the lake bottom during stratification and sediment release of nutrients. | Estimated 45% reduction in combined surface runoff and nutrient load. Capable of meeting in-reservoir water quality goal. | Years | Potential to remove large amounts of nutrient. Common sense easy method. | Need area to discharge, possibly wetland treatment system. If system is nitrogen limited expect little improvement. Will affect lake algae. | None |
| 10. Grazing System BMPs (fence cattle away from lake, alternative water supply and lake parian buffer) | Source Control | Reduce load entering lake. | Minor (~1-2 kg/yr TP plus fences) | Years | Logical | Requires changing habits. | Up to $5,000. |

### 5.4.3 Dredging

Dredging as a reservoir management tool has met with varied success. Sediment removal usually includes one or more of the following objectives (Peterson, 1981).

- Deepening to improve boating, fishing, water-skiing or other uses impaired by shoaling;
- Preventing or reducing the internal cycling of nutrients by removing the sediment source;
- Removing of toxic sediments; and
- The reduction in nuisance aquatic macrophyte growth.

The primary disadvantages of dredging are the resuspension of lake sediment during dredging, the potential liberation of toxic material if present, the disruption of the benthic community and finding a suitable disposal location. Dredging fails to treat the excessive nutrient problem, if the source is external to the lake and not from accumulated sediment. Dredging fails to treat the source nutrient loads and must generally be implemented with source controls to be effective.

With regard to the McDowell Dam reservoir, dredging could be used to remove organic rich sediment from the bottom, to enhance water column oxygen concentrations and reduce internal nutrient cycling. The question of whether to use dredging to address these problems is one of cost and the likelihood of success.

Dredging the McDowell Dam reservoir should be successful in removing nutrients accumulated in the sediment, but there is no technically defensible method to quantify the anticipated in-reservoir improvement. It seems reasonable to expect a 50% reduction in internal loading by sediment removal. Dredging will need to be repeated at some future date, unless the external surface runoff load is also reduced.

A preliminary cost estimate was developed assuming the removal of sediment 3 feet in depth from an area equal to the reservoir surface area (i.e., 56.5 acres). A sediment depth of 3 feet across the reservoir surface area equates to an in-place sediment volume of 273,460 cubic yards (wet weight). Typical hydraulic dredge costs, excluding disposal, range from $2.5 to $5.0 per cubic yard. Therefore, the anticipated cost for dredging would likely exceed $500,000, excluding contract administration and engineering costs. If the internal loading is reduced by 50% annually (102.5 kg) the removal cost, excluding contract administration and engineering, is an estimated $4,878 per kilogram of total phosphorus.

Based upon the P8 modeling, the total suspended solids (not sediment) load during a normal precipitation year, is 9,034 kg per year. Assuming a specific gravity of 190 lbs per cubic yard, this equates to an estimated 105 cubic yards annually, accumulating within the reservoir. This implies the need for additional dredging in the near future is unlikely. Should dredging be pursued, sediment retention in the existing upstream basin should be evaluated to ensure maximum removal.

Dredging is not recommended if the problem is low dissolved oxygen during winter. A more cost effective method of enhancing oxygen concentrations during the winter is the removal of snow from ice. Winterkill tends to occur during periods of heavy snow-cover, when light fails to penetrate the ice. Snow removal in strips over areas less than 7 feet in depth, allows light penetration and the production of oxygen by rooted aquatic plants.

#### 5.4.4 Dilution with Hypolimnetic Withdrawal

Dilution with hypolimnetic withdrawal has two primary methods of action when considered as a reservoir management tool. The concentration of the limiting nutrient is reduced by the addition of water with a lower nutrient concentration. The additional water added to the reservoir, also decreases the residence time of the lake, flushing algae. The loss rate of algae can exceed the growth rate as a result of flushing. The primary considerations relative to dilution with hypolimnetic withdrawal as a restoration method are the presence of a dependable source of low nutrient water and the present hydraulic residence time of the lake. Dilution with hypolimnetic withdrawal is less effective when the hydraulic residence time is short.

Apple Creek is a potential source of dilution water. Nutrient concentrations within Apple Creek during the spring into July are less than in the reservoir's hypolimnion in late June, July and August (see Appendix F). Flow rates within Apple Creek also are generally large enough to allow for the diversion / pumping of several cfs into the reservoir. By adding water from Apple Creek (3 cfs) and selectively withdrawing water from the reservoir hypolimnion following thermal stratification (3 cfs), an estimated 99 kg of total phosphorus can be removed annually from the reservoir during July and

August. The removal of water from the hypolimnion requires restoring the use of the conservation port and possibly operation of the low level drawdown. The load reduction (at a 3 cfs rate) equates to approximately 25% of the combined internal and surface runoff total phosphorus load.

The opinion of probable cost (preliminary) for this method is $305,000. The estimated cost includes a capital cost for the pump system and restoring the use of the conservation port. The administrative costs of acquiring the required permits and easements are not included in the estimate. Assuming a replacement life of 20 years and 4% interest the estimated annual cost of the infrastructure is $22,448. Annual operation assuming a two month pumping period is approximately $4,500. Additional engineering analysis is also needed prior to implementation to evaluate timing and water quality and quantity issues with the removal of waters from Apple Creek. The normalized cost for this method is an estimated $275 per kilogram of total phosphorus removed.

Additional technical analysis is needed to resolve issues associated with this method. A selective withdrawal analysis is recommended to evaluate the specific reservoir zones of withdrawal and whether a retrofit of the outlet is needed. Additional time series analysis of water quality concentrations and flow rates within Apple Creek is recommended. Further analysis of the potential downstream affects of releasing the high nutrient water from the reservoir into Apple Creek, is also required. The construction of a series of drop structures downstream of McDowell Dam may be necessary to reareate the water released from the reservoir.

#### 5.4.5 Hypolimnetic Withdrawal Only

Hypolimnetic withdrawal is a method for exporting nutrients, which accumulate within the hypolimnion during stratification. The result is a shorter detention time within the hypolimnion and presumably the likelihood of developing anaerobic conditions is decreased. The technique is most applicable only to stably stratified lakes and reservoirs (like McDowell). The primary concern with hypolimnetic withdrawal is the potential to destratify a lake. Destratification can result if sufficient cold water is removed from the hypolimnion. Some consideration in the potential change in lake-elevation is also needed and due to water quantity issues associated with the reservoir an alternative source may be required.

The potential improvement in lake water quality associated with hypolimnetic withdrawal was evaluated. The release of water from the hypolimnion was assumed to occur at a rate of 3 cfs during the months of July and August. An estimated total phosphorus load reduction of 180 kg during July and August (~45% of the annual load) can be realized with hypolimnetic withdrawal.

This analysis assumes no adverse hydrologic impacts and no additional load from ground water because of hypolimnetic withdrawal.

The use of this method is limited to surplus water years during the summer without an alternate source. Releasing a constant 3 cfs during July and August equals 357 acre-feet or 6 feet of water from the reservoir surface. Without the addition of water to offset this loss this method is infeasible.

#### 5.4.6 Nutrient Inactivation – Alum Treatment

The salts of iron and aluminum have long been used in advanced wastewater treatment to remove phosphorus. This method consists of the addition of primarily aluminum sulfate to the lake-surface or injected above the hypolimnion. The effect of the addition is twofold. The precipitate formed within the water column removes phosphorus. The floc once settled on the sediment-surface reduces the cycling of internal nutrients. One side effect of the application of aluminum sulfate is a reduction in pH in low alkalinity waters. Hypolimnetic application of liquid alum is the preferred method.

Alum treatment is most effective when internal loading is an important source of nutrients, relative to external sources. Lakes with nutrient rich sediment resulting from historical wastewater discharges often benefit from an alum treatment. The effect of this method is to eliminate the release of nutrients from sediments.

An alum application is generally considered up to 80% effective in controlling the internal cycling of nutrients from sediment. The quantity of aluminum required is generally considered to be equal to the product of the internal total phosphorus load and the number of years of control. Up to 15 years of control is possible, but 5 to 7 years is considered typical. The duration of effectiveness is directly tied to the reduction of external nutrient loads.

An alum application will immediately clear the water column and increase light penetration, likely stimulating the growth of rooted aquatic plants. One-half of the reservoir acreage is less than 9 feet in depth, with most of the area in the upper portion of the reservoir. This area is likely to become colonized by rooted aquatic plants following alum application.

The typical cost range per acre treated is $750 per acre. Additional testing is needed prior to application. Therefore the estimated cost is $75,000 which includes mobilization and engineering. The total phosphorus reduction for this method is 164 kg 41% of the combined internal and surface runoff load. The normalized cost is $460 per kg of total phosphorus.

#### 5.4.7 Hypolimnentic Aeration

Low dissolved oxygen levels are typically observed in eutrophic lakes because the decomposition of organic matter consumes oxygen, which is not replaced by photo-synthesis or diffusion from the atmosphere. As a result, available fish habitat in the lake is decreased, noxious odors are produced and conditions are created which favor the release of nutrients (phosphorus) held in the sediments. Several projects have studied the use of artificial aeration equipment to improve dissolved oxygen in the lake. In one approach, air is injected into the lake near the bottom through a bubblier device, such as a perforated hose. As the bubbles rise, water is carried to the surface and the lake is mixed. Another approach avoids mixing the lake by pumping old, oxygen-deficient water from the hypolimnion to the surface or on shore and returning the same water after aeration to the lake, thereby maintaining the stratified nature of the lake. Recent design work done by the University of Minnesota allows the suspension of an aeration system some distance (about 1 meter) above the lake sediment. Air injected into the system effectively blankets the region above the lake bottom, reducing nutrient release from the sediments.

A preliminary analysis to determine the approximate size for an aeration system was completed, for the purpose of providing an opinion of probable cost. An aeration system could be used and sized to maintain a dissolved oxygen concentration of 4 mg/l or more within the upper portion of the hypolimnion. Based upon the 2003 field data, the upper portion of the hypolimnion is located between 16 (~ 1710 msl) and 20 feet (~ 1706 msl) below the normal pool elevation. The water volume within the upper portion of the hypolimnion is an estimated 30 acre-feet during the period of thermal stratification. The dissolved oxygen concentration within the upper hypolimnion declines from approximately 7.5 mg.l to 2.5 mg/l from early June through the end of August. To maintain the concentration at or above 4.0 mg/l, an additional 1 mg/l of dissolved oxygen must be added, which equates to a minimum of 6.1 lbs of $O_2$ per day (2.8 kg $0_2$ per day) during July and August. The estimate of 6.1 lbs of $O_2$ per day must be further adjusted for efficiency and peak requirements. The estimated airflow rate necessary for the system is 3.8 cfs. Further analysis of the actual diffuser is needed for proper sizing. The estimated cost to install a basic aeration system for the size and shape of the McDowell Dam reservoir is $30,000, excluding contract administration and engineering. Assuming a replacement life of 25 years and 4% interest, the estimated annual cost of the aeration system is approximately $1950.

Sizing an aeration system for a hypereutrophic system like the McDowell Dam reservoir is challenging. Aeration systems have traditionally been undersized and success has been varied. Therefore, installation of an aeration system is not recommended, unless the primary purpose is to create and maintain a refuge for fish to avoid summer or winterkill. The system should then be installed within the deepest part of the reservoir, upstream from the embankment.

### 5.5 Management Alternatives Summary

This section presents the specific recommendations for managing the McDowell Dam reservoir to meet the 30% total phosphorus load reduction goal. The recommendations are based upon swimming and body contact recreation as the primary use. Specifically:

- External nutrient loads from surface water runoff should be controlled to the maximum extent possible, through the implementation of conservation management practices;

- The conservation management practices should be combined with the "Dilution with Hypolimnetic Withdrawal" method or the "Nutrient Inactivation-Alum Treatment" method. The "Dilution with Hypolimnetic Withdrawal" method is preferred because of normalized cost, $275 per kg of total phosphorus removed, provided potential downstream water quality issues can be minimized.

The combination of these two methods should be effective in reducing the annual total phosphorus load by more than 30%. **Table 5-3** presents the opinion of probable costs for these management methods.

While the primary use of the McDowell Dam reservoir is swimming and body contact recreation, the reservoir has been a viable fishery and fishing remains a secondary use of the reservoir. If the focus of reservoir improvement recommendation is limited to improving the fishery quality of the reservoir, hypolimnetic aeration is a viable method of water quality improvement.

**Table 5.3 Opinions of Probable Cost of the Recommended Management Methods**

| Management Method | Implementation Costs | Annual Operating Cost | Estimated Phosphorus Reduction | Normalized Cost ($/kg of phosphorus removed) |
|---|---|---|---|---|
| Implementation of Conservation Management Practices[1] | Widely Variable & Future Development Dependent | | | |
| Alum Treatment | $75,000 per treatment[2] | none | 164 kg | $460 |
| Dilution with Hypolimnetic Withdrawal | $305,000 | $4500 | 99 kg annually | $275 |
| Hypolimnetic Aeration[3] | $30,000 | Minimal | Minimal | --- |

[1] Costs of implementation will vary widely depending on effort. Efforts could range from encouraging producers to implement better residue management practices (minimal costs) to the purchasing of land for permanent land retirement of land (significant cost).
[2] Treatment will typically last 5 to 10 years depending on external phosphorus load
[3] Aeration is recommended when the only improvement goal is to improve the fishery quality of the reservoir.

# APPENDIX A

## References

## References

*Lake Water Quality Assessment Atlas, Volume II* (NDDH, 1996) page 9

*North Dakota Lake Assessment Atlas, Volume II*. (NDDH 1996) page 9

*McDowell Dam Recreation Area: A Supplemental Water Supply Evaluation – Annual Runoff Review, Reservoir Simulation and Benefit/Cost Analysis,* American Engineering, (1995) page 9

*Standards of Quality for Waters of the State* (North Dakota Century Code 33-16) page 11

*Quality Assurance Project Plan for the McDowell Dam TMDL*, 2002 page 14

*North Dakota Agricultural Weather Network* (NDAWNs) http://ndawn.ndsu.nodak.edu page 16

P8 Urban Catchment Model http://wwwalker.net/p8/ page 17

USGS, 2001, National Water Information System (NWISWeb) data available on the World Wide Web at URL http://nwisdata.usgs.gov/nwis/qw

# APPENDIX B

# Estimate Nutrient Load Reduction Resulting from Conservation Tillage Practices on Agricultural Land

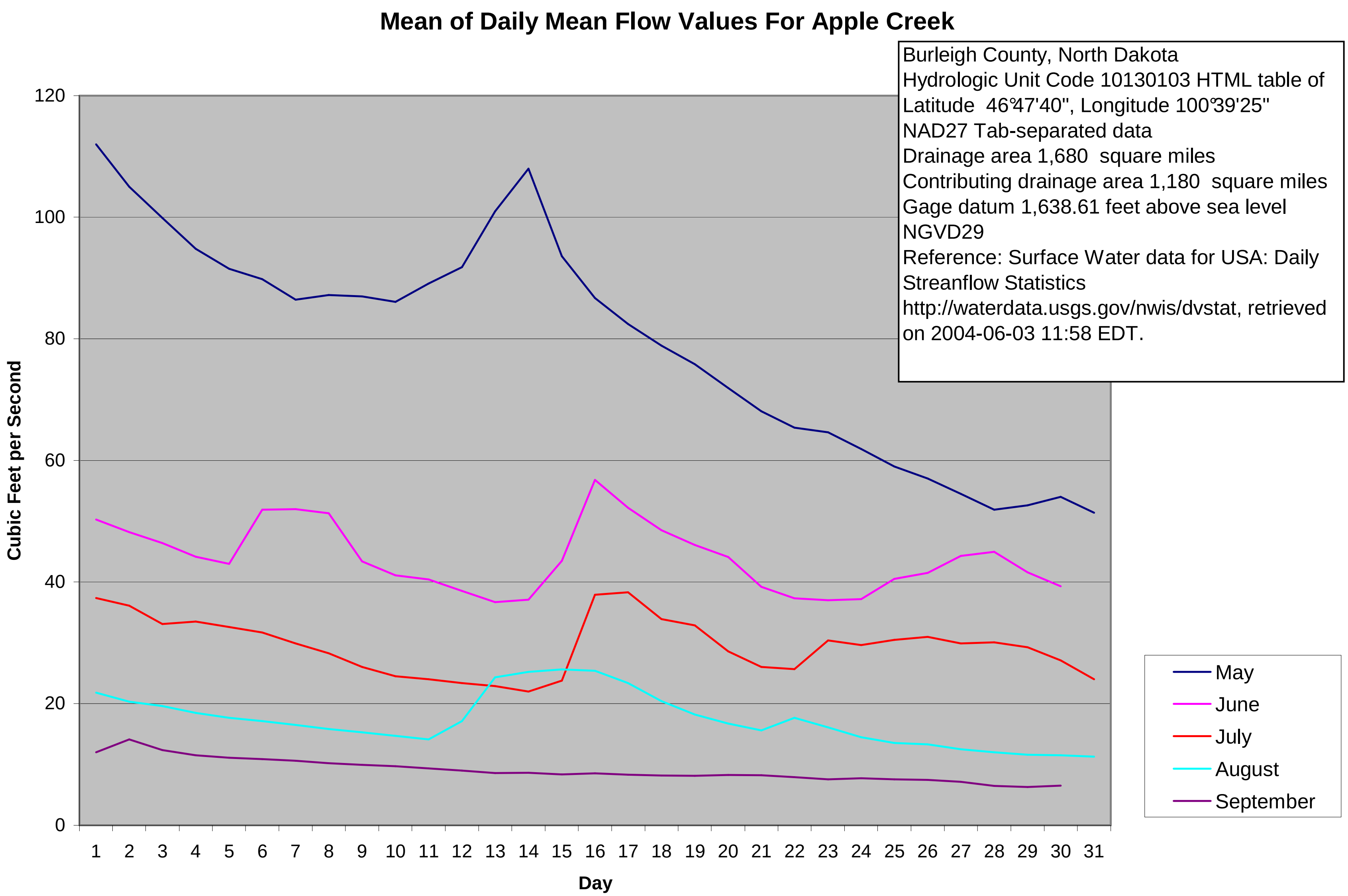
# APPENDIX C

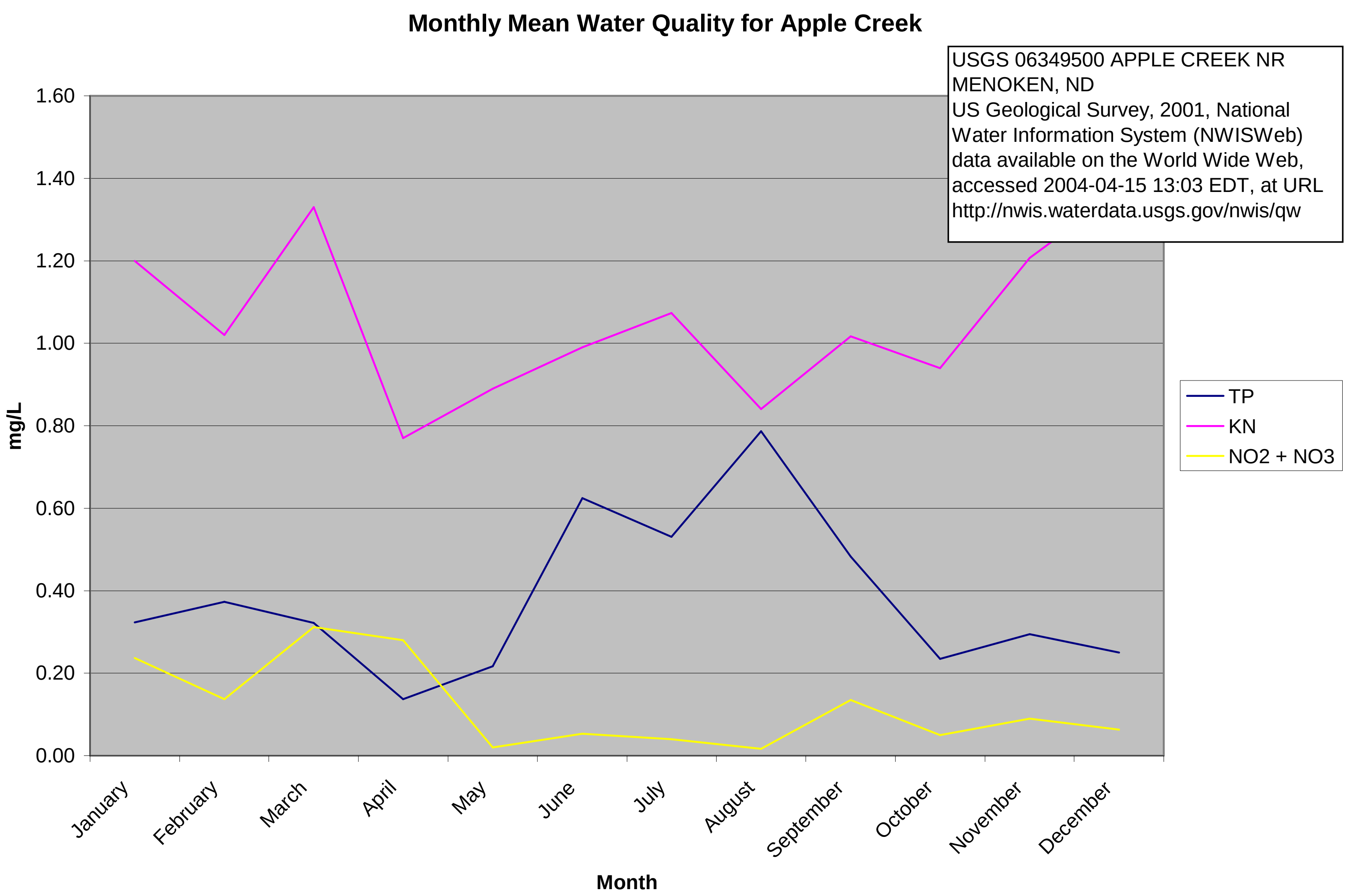
## Detailed Monitoring Plan (QAPP)

**Available upon request from Houston Engineering, Inc.**

# APPENDIX D

## Monitoring Data from USGS for Apple Creek


Mean of Daily Mean Flow Values For Apple Creek
Burleigh County, North Dakota
Hydrologic Unit Code 10130103 HTML table of
Latitude 46°47'40", Longitude 100°39'25"
NAD27 Tab-separated data
Drainage area 1,680 square miles
Contributing drainage area 1,180 square miles
Gage datum 1,638.61 feet above sea level
NGVD29
Reference: Surface Water data for USA: Daily
Streanflow Statistics
http://waterdata.usgs.gov/nwis/dvstat, retrieved
on 2004-06-03 11:58 EDT.
Cubic Feet per Second
120
100
80
60
40
20
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Day
May
June
July
August
September


Monthly Mean Water Quality for Apple Creek
USGS 06349500 APPLE CREEK NR MENOKEN, ND
US Geological Survey, 2001, National Water Information System (NWISWeb) data available on the World Wide Web, accessed 2004-04-15 13:03 EDT, at URL http://nwis.waterdata.usgs.gov/nwis/qw
mg/L
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
January
February
March
April
May
June
July
August
September
October
November
December
Month
TP
KN
NO2 + NO3

# APPENDIX E

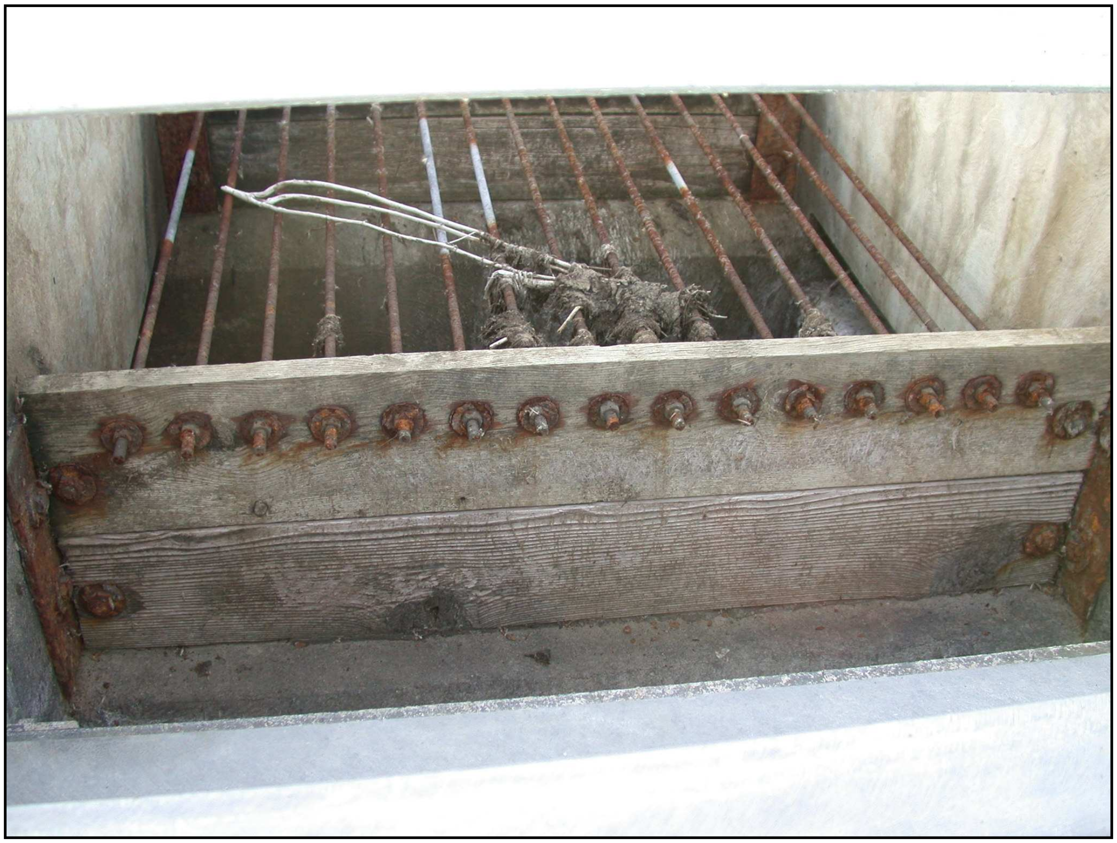
# Photos

**Upper watershed Dam #1 – Facing North**

**Upper Watershed Dam outlet**

**Upper Watershed Dam #2 facing south towards embankment**

**McDowell Dam outfall structure #1**



**Redwood flashboards installed in 1980 to raise the effective outfall elevation of McDowell Dam from 1723.5 to 1724.56.**

**McDowell Dam outfall structure #2**

**Low Level drawdown gate**

**In-Lake stage recorder**

# APPENDIX B

**County Occurrence of Endangered, Threatened and Candidate Species and Designated Critical Habitat in North Dakota**

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

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

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

**County Occurrence of Endangered, Threatened and Candidate Species and Designated Critical Habitat in North Dakota**

**March 2006**

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

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

# Appendix C

**Public Comments on the Draft McDowell Dam Nutrient and Dissolved Oxygen TMDL Report and the North Dakota Department of Health's Response to Comments**

During the 30-day public notice soliciting comment on the draft report entitled "Nutrient and Dissolved Oxygen TMDLs for McDowell Cam in Burleigh County, North Dakota", the NDDoH received comments from Scott Elstad with the North Dakota Game and Fish Department, Vern Berry with the US EPA Region 8 and Ken Royse with the Burleigh County Water Resource District (attached letter). Mr. Elstad's comments were submitted as hand written comments submitted in the margins of the draft report. Mr. Berry's comments were submitted to the NDDoH via email dated March 30, 2007. The following are their comments and the NDDoH's reponse to those comments.

**NDGF Comment:** In Section 1.0, Table 1, page 1 "The Fishery Type should be the same as that named under the Classified Beneficial Uses and rainbow trout should be added under Fishery Type"?

**NDDoH Response:** Yes, the table was changed to be consistent and rainbow trout was added.

**NDGF Comment:** In Section 1.1, Tables 2 and 3 "The size of the waterbody should be consistent with that listed in Table 1".

**NDDoH Response:** Suggested change was made.

**NDGF Comment:** In Section 8.1, Table 11, page 17, "Under Negative Factors for Harvesting Aquatic Plants, Eurasion Water Milfoil be changed to Aquatic Nuisance Species".

**NDDoH Response:** Suggested change was made.

**EPA Region 8 Comment:** In Section 7.1, Table 10, The "existing load" for total phosphorous shown in Table 10 (p 14) is said to be based on the "normal" year model results. This does not match the normal year total phosphorous load shown in Table 8 (TMDL) or Table 4-3 (Appendix A). Please double check the existing load figure in Table 10. If that number is changed to match the numbers shown in Tables 8 and 4-3, then the LC, LA and MOS loads in Table 10 and in some of the text (e.g., Section 6.1 MOS discussion) would also need to change.

**NDDoH Response:** The reason for the different values reflected in the tables is that the TMDL is written based on the total phosphorus load from all sources (tributary and internal cycling). That loading estimate is provided in Figure 4 -19 of Appendix A. The P8 model was used to determine the tributary load. It is the tributary load that is reflected in Table 4-3, Section 5.1. Section 5.1 will be more clearly titled and the explanation of the "Existing Load" in Table 10 will be clarified.

**EPA Region 8 Comment:** The Table 9 units for the second column (Drainage Area) should be expressed as miles squared.

**NDDoH Response:** Suggested change was made.

BURLEIGH COUNTY Water Resource DISTRICT

# Burleigh County Water Resource District

City/County Office Building - 221 North 5th Street
Bismarck, North Dakota 58501


RECEIVED MAR 16 2007 DIV. OF WATER QUALITY

March 14, 2007

Michael J. Ell
Division of Water Quality
ND Department of Health
918 E Divide Ave., 4th Floor
Bismarck, ND 58501-1947

RE: McDowell Dam Nutrient and Dissolved Oxygen Total Maximum Daily Loads

Dear Mike:

Thank you for the opportunity to review the draft copy of the McDowell Dam Nutrient and Dissolved Oxygen Total Maximum Daily Loads (TMDL). As the local project sponsor and owner of the facility, we understand the importance of continuing efforts to improve and protect the quality of water stored in the reservoir.

As you are aware, we completed an alum treatment of the reservoir this past summer with grant assistance provided through the Section 319 program. We are currently continuing with the water quality monitoring program as outlined in the Quality Assurance Project Plan. We are also working with the USGS to conduct additional sampling from Apple Creek this spring and summer, to better assess the quality and compatibility of this potential supplemental water source. Therefore, we support the establishment of effective TMDL's, and the recommendations of the draft report.

Throughout our efforts to improve the recreational resources associated with McDowell Dam and Reservoir, we have received outstanding cooperation from the ND Department of Health as well as other state and federal agencies. We appreciate all your assistance and we look forward to working with you and your department in continuing efforts to improve the quality of water stored behind McDowell Dam.

Sincerely,

Ken Royse

Ken Royse, Chairman
Burleigh County Water Resource District

C: Michael Gunsch, Houston Engineering, Inc.