Lake Water Quality Assessment for Pipestem Reservoir Stutsman County, North Dakota

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List of Tables

List of Figures

SUMMARY

Pipestem Reservoir is an 885-acre impoundment on Pipestem Creek in Stutsman County, North Dakota. The dam was constructed in 1973 by the U.S. Army Corps of Engineers for flood control, recreation and fish and wildlife enhancement (Figure 1). As constructed, the dam had a maximum depth of 42 feet with a multi-purpose storage of 9,870 acre-feet. The maximum flood control depth is 96 feet, with a hydraulic storage of 146,880 acre-feet.

The reservoir's watershed covers approximately 400 square miles of primarily agricultural lands in Wells, Foster and Stutsman counties. The entire watershed lies within the Glaciated Plains Ecoregion of North Dakota. The watershed is characterized by rolling and hilly glaciated plains with many small and large pothole wetlands. Pipestem Creek is the largest tributary to the James River in North Dakota.

Public facilities include two boat ramps equipped with courtesy docks and associated parking, two picnic areas and one unimproved access point along the southwest shore. The public facilities are maintained by the Corps. Access to Pipestem Reservoir is excellent from paved roads during all seasons.

Pipestem Reservoir's fishery is managed by the North Dakota Game and Fish Department (NDGF). Management practices include tracking fish recruitment and survival, stocking species of both game and forage fish and placement of artificial habitat. In general, the fishery is good to excellent, with the largest variables affecting the fishery being water level fluctuations and out-migration.

Primary fish species managed in the Pipestem Reservoir include northern pike, walleye, perch and crappie. Additionally, there is an abundant carp, black bullhead and white sucker population in the reservoir. Historical records show that the NDGF stocked tiger muskie, bluegill and small-mouthed bass, and it is reasonable to assume there are still possibly remnant populations of the bluegill and small-mouthed bass.

WATER QUALITY

Lake water quality assessment data was collected on the Pipestem Reservoir during the summer of 1998 and winter of 1999. Water quality samples were collected from the reservoir five times at three separate locations. Locations were near the dam, at mid-lake and the inlet area. Sampling occurred on May 13, July 21, August 13, October 13, 1998 and February 17, 1999.

All samples independent of location were collected over the thalway. The dam site was sampled at three depths (1 meter below the surface, mid-depth and ½ meter off the bottom); the mid-lake site was sampled at two depths (1 meter below the surface and ½ meter off the bottom); and the inlet site was sampled at one depth (½ the total depth).

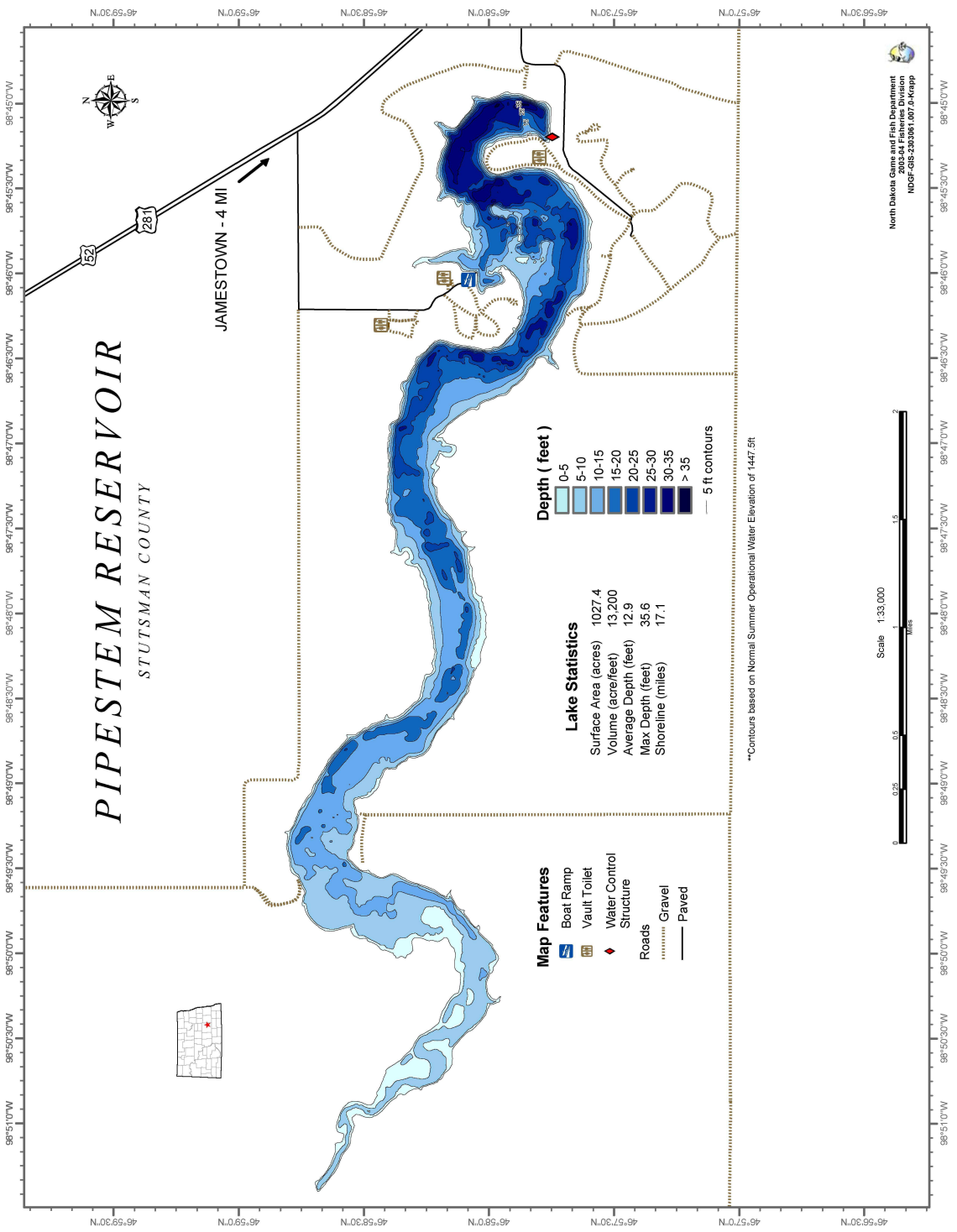

Figure 1. Map of Pipestem Reservoir

Physical, chemical and biological data were collected on each sample date and at each site and depth. Physical data included temperature and dissolved oxygen profiles, secchi disk depth transparency and current weather conditions. Chemistry data analyzed for each sample included a complete suite of nutrients, major cations and anions and trace metals. Biological data included phytoplankton and chlorophyll-a.

Temperature and dissolved oxygen profiles were collected to determine if thermal stratification was occurring and the amount of dissolved oxygen present within discrete depth levels. Thermal stratification was only documented on May 13, 1998 at the near-dam site between 5 and 6 meters (Figures 2, 4 and 6).

Dissolved oxygen concentrations were usually above the state's standard of 5 milligrams per liter (mg/L) with the exception of the near-dam location on August 18, 1998 (Figures 3, 7 and 9). On August 18, 1998, dissolved oxygen concentrations at the dam site ranged from a high of 3.34 mg/L at ½ meter below the surface to a low of 1.69 mg/L at ½ meter off the bottom. Field notes taken August 8, 1998 at the dam site indicate the water was visually unpleasant, and secchi disk readings were shallow at 0.6 meters. However, water quality data collected at the same time does not show a significant increase in nutrients, anions or biomass.

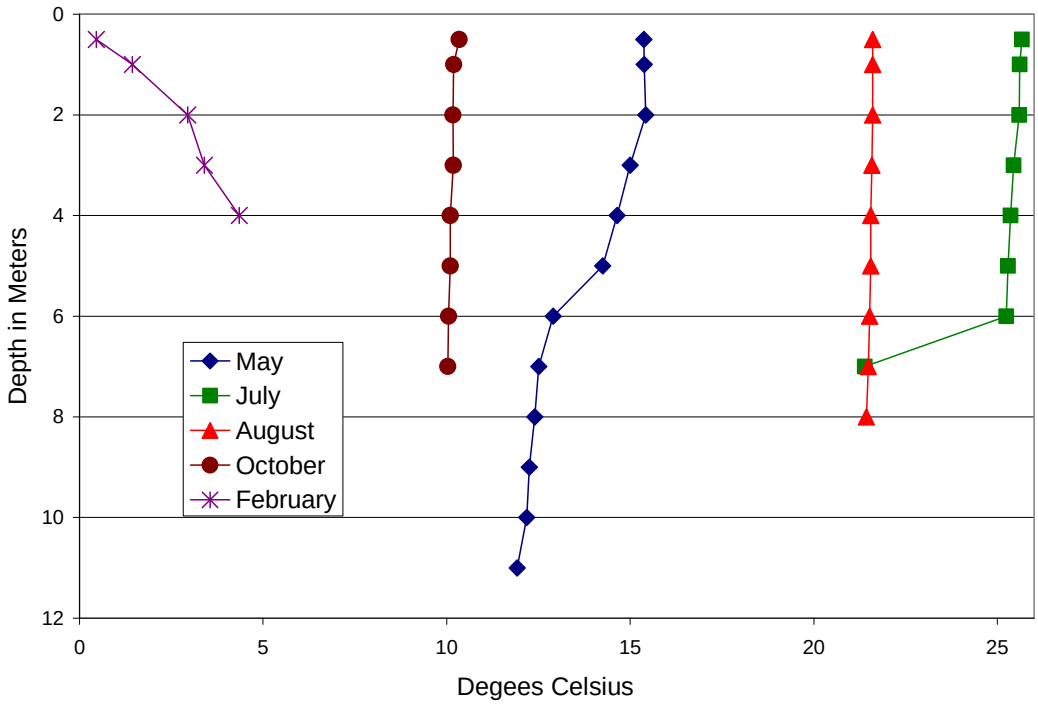

Figure 2. Pipestem Reservoir Temperature Profiles Near Dam 1998-1999

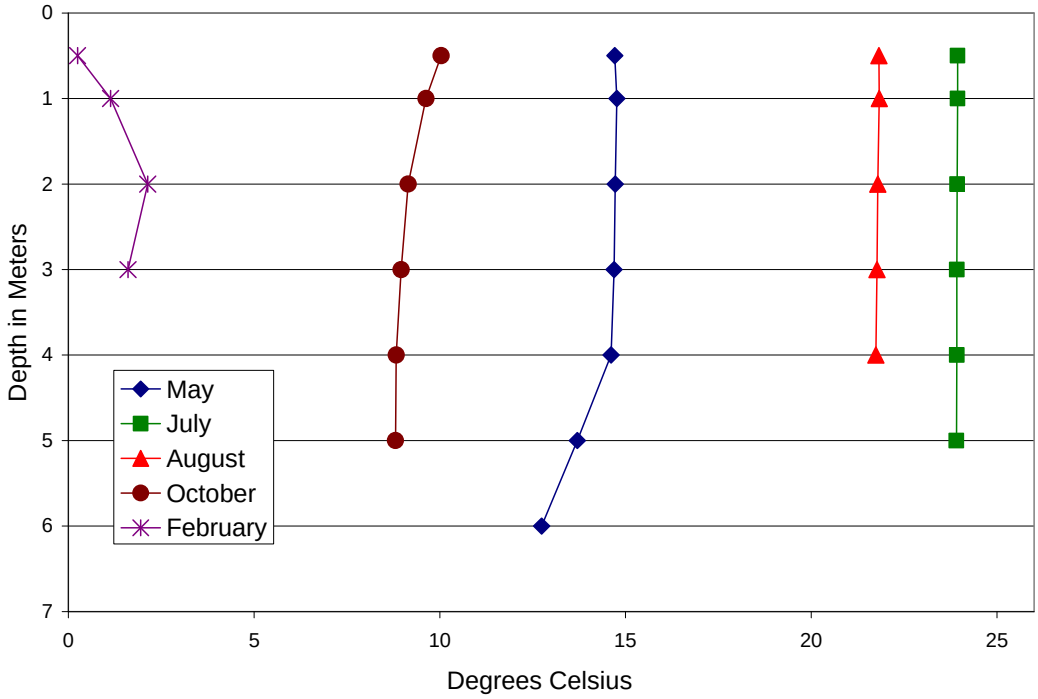

Figure 3. Pipestem Reservoir Temperature Profiles Mid-Lake 1998-1999

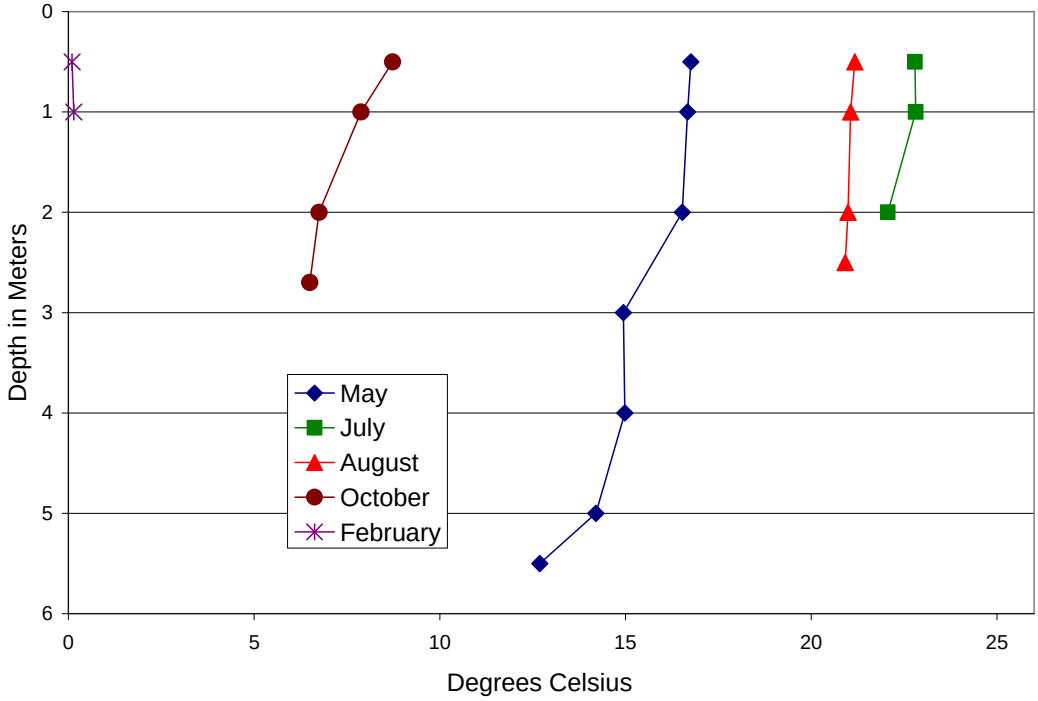

Figure 4. Pipestem Reservoir Temperature Profiles Near Inlet 1998-1999

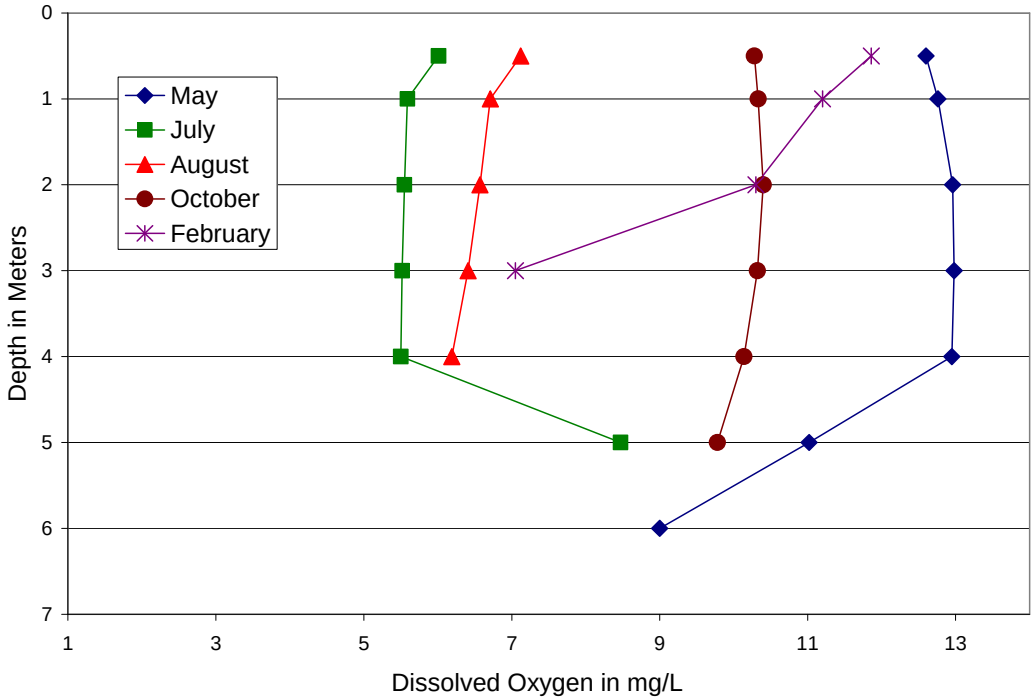

Figure 5. Pipestem Reservoir Dissolved Oxygen Profiles Near Dam 1998-1999

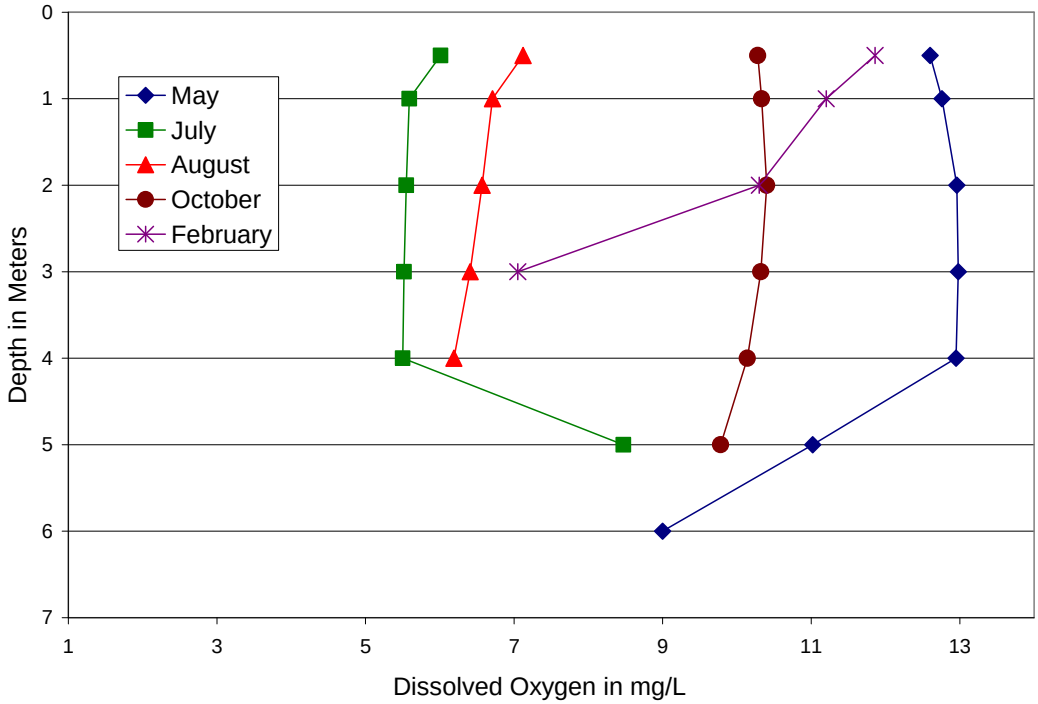

Figure 6. Pipestem Reservoir Dissolved Oxyegn Profiles Mid-Lake 1998-1999

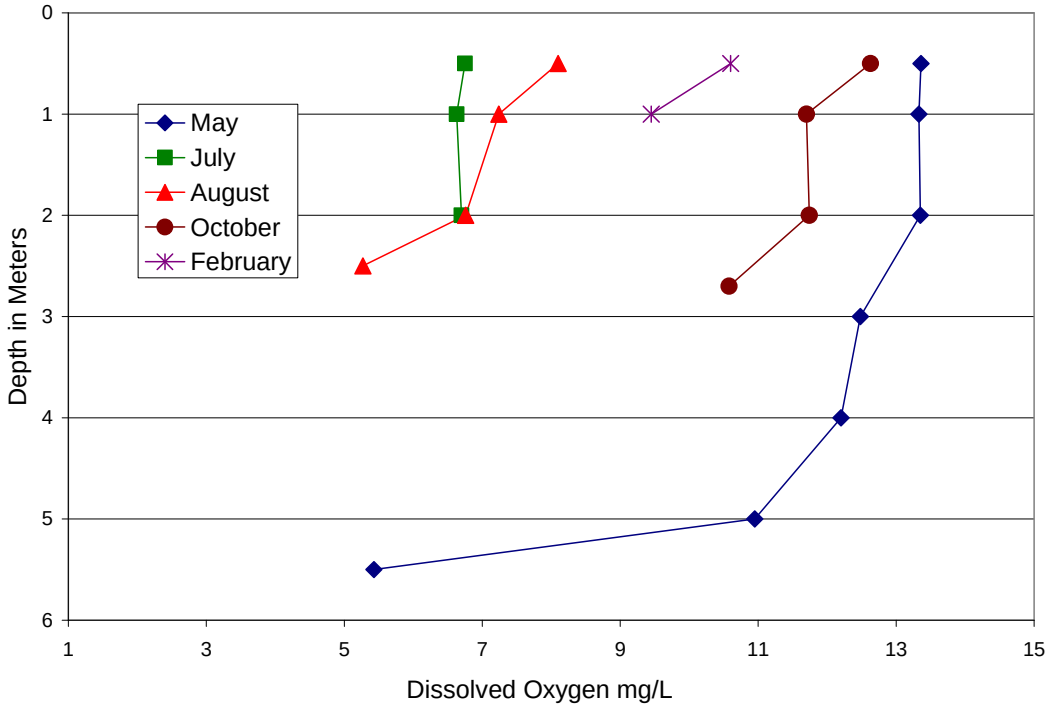

Figure 7. Pipestem Reservoir Dissolved Oxygen Profiles Near Inlet 1998-1999

Water quality samples collected in 1998-1999 described Pipestem Reservoir as a well-buffered reservoir that ranged from hypereutrophic at the inlet and mid-lake areas to eutrophic at the dam. Total alkalinity as calcium ranged from170 mg/L to 350 mg/L with a volume-weighted mean at the dam of 248 mg/L.

Nitrate + nitrite as nitrogen and total phosphorus as phosphate concentrations ranged from non-detectable to 0.230 mg/L and 0.073 mg/L to 0.635 mg/L, respectively, with volume-weighted mean concentrations near the dam of 0.081 mg/L and 0.227 mg/L.

The dominant anions within the water column are bicarbonates and sulfates. Bicarbonates ranged from 157 mg/L to 427 mg/L with a volume-weighted mean at the dam of 285 mg/L. Sulfates ranged from 131 mg/L to 322 mg/L with a volume-weighted mean of 199 mg/L at the dam. Tables 1, 2 and 3 contain the volume-weighted means for selected parameters at all three sampling locations and the arithmetic mean of all lakes and reservoirs sampled by the state between 1995 and 2001.

Table 1. Pipestem Reservoir Near Dam - Volume-Weighted Mean Concentrations for Select Water Quality Parameters and the North Dakota Arithmetic Mean for all Lakes Sampled between 1995 and 2001

Parameter	Near-Dam Site	1995-2002 Mean	Unit
Total Dissolved Solids	531	1545	mg/L
Hardness as Calcium	329	474	mg/L
Sulfate as SO_4	199	785	mg/L
Chlorides	11	64	mg/L
Total Alkalinity as Calcium	248	229	mg/L
Bicarbonate as HCO_3	285	274	mg/L
Conductivity	835	1984	omhos/cm
Total Phosphorus as Phosphate	0.227	0.152	mg/L
Nitrate + Nitrite as Nitrogen	0.081	0.117	mg/L
Total Ammonia as Nitrogen	0.321	0.272	mg/L
Total Kjeldahl Nitrogen	1.083	1.775	mg/L

Table 2. Pipestem Reservoir Mid-Lake - Volume-Weighted Mean Concentrations for Select Water Quality Parameters and the North Dakota Arithmetic Mean for all Lakes Sampled between 1995 and 2001

Parameter	Mid-Lake Site	1995-2002 Mean	Unit
Total Dissolved Solids	580	1545	mg/L
Hardness as Calcium	361	474	mg/L
Sulfate as SO_4	219	785	mg/L
Chlorides	11	64	mg/L
Total Alkalinity as Calcium	270	229	mg/L
Bicarbonate as HCO_3	310	274	mg/L
Conductivity	914	1984	omhos/cm
Total Phosphorus as Phosphate	0.328	0.152	mg/L
Nitrate + Nitrite as Nitrogen	0.089	0.117	mg/L
Total Ammonia as Nitrogen	0.300	0.272	mg/L
Total Kjeldahl Nitrogen	1.376	1.775	mg/L

Table 3. Pipestem Reservoir's Inlet Site Volume-Weighted Mean Concentrations for Select Water Quality Parameters and the North Dakota Arithmetic Mean for all Lakes Sampled between 1995 and 2001

Parameter	Inlet Site	1995-2002 Mean	Unit
Total Dissolved Solids	615	1545	mg/L
Hardness as Calcium	377	474	mg/L
Sulfate as SO_4	230	785	mg/L
Chlorides	12	64	mg/L
Total Alkalinity as Calcium	288	229	mg/L
Bicarbonate as HCO_3	324	274	mg/L
Conductivity	966	1984	omhos/cm
Total Phosphorus as Phosphate	0.458	0.152	mg/L
Nitrate + Nitrite as Nitrogen	0.098	0.117	mg/L
Total Ammonia as Nitrogen	0.248	0.272	mg/L
Total Kjeldahl Nitrogen	1.463	1.775	mg/L

LIMITING NUTRIENT

Ratios of total nitrogen to total phosphorus ranged from 3.76 to 12.38 indicating that the Pipestem Reservoir is nitrogen limited (Figure 8). For purposes of this assessment, the waterbody is assumed to be in nutrient equilibrium with a ratio of total nitrogen to total phosphorus of 15:1. When a lake's total nitrogen to total phosphorus ratio is less than 15:1, nitrogen is probably the controlling nutrient; when it exceeds 15 the controlling nutrient is probably phosphorus. When nitrogen becomes the limiting nutrient, primary production is usually not limited but altered. The altered condition favors certain species of primary producers that are either able to affix nitrogen, utilize organic nitrogen or are tolerant of low-nitrogen conditions.

TROPHIC STATUS

During the 1998-1999 investigation, Pipestem Reservoir's trophic status was assessed as hypereutrophic in the upper reaches of reservoir and eutrophic in the lower reaches. Trophic status is an estimation of a lake's or reservoir's productivity. In general, as a lake ages it becomes more productive. When this maturing process reaches an advanced stage (hypereutrophic), it is usually identified by loss of lake depth through sedimentation and a decline in aesthetics due to frequent algal blooms. When a lake is hypereutrophic, it also usually gives off an odor, suffers frequent fish kills and experiences rapid oxygen depletion during thermal stratification and under ice-cover conditions. Reservoirs which inundate large areas of deep fertile soils are especially susceptible to rapid eutrophication and often begin in an over-productive condition.

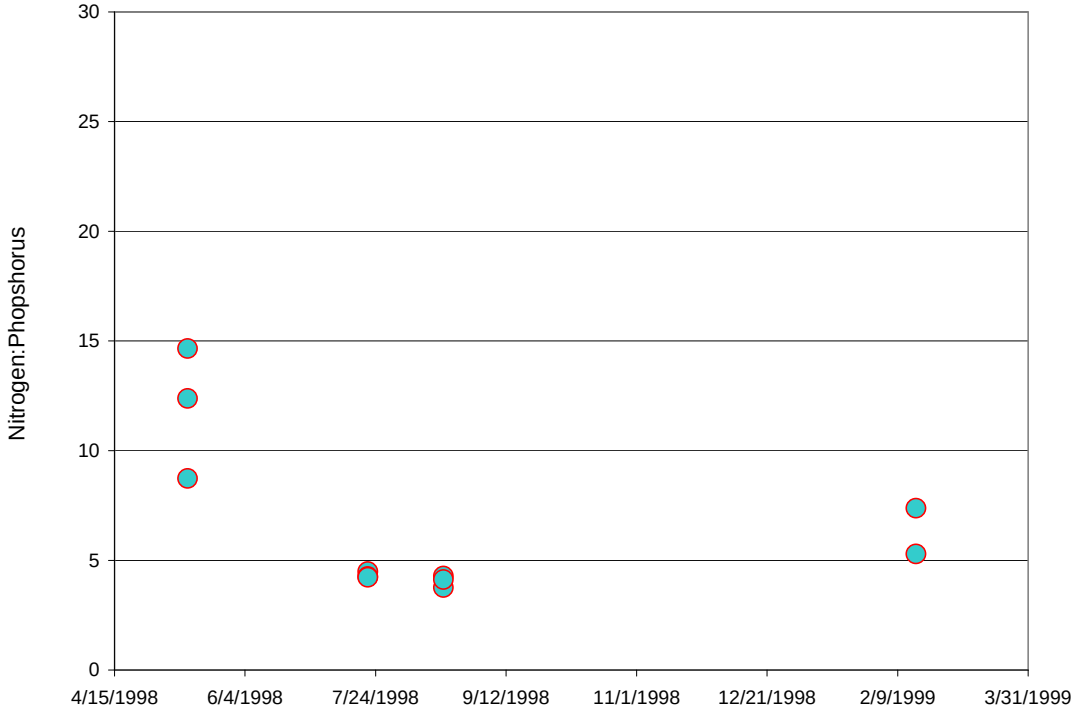

Figure 1. Total Nitrogen to Total Phosphorus Ratios

For purposes of this project, trophic status is measured using Carlson's Trophic Status Index (TSI) (Carlson 1977). Carlson's TSI was selected because of its common use among limnologists and because it was developed for lakes in Minnesota, a state close to North Dakota geographically. Carlson's TSI uses a mathematical relationship based on secchi disk depth transparency, concentrations of total phosphorus at the surface and chlorophyll-a concentrations. This numerical value then corresponds to a trophic condition ranging from 0 to 100 with increasing values indicating a more eutrophic condition (Figure 9). Trophic Status Index scores for the Pipestem Reservoir ranged from a low of 47 at the dam to a high of 79 at the inlet. Mean TSI scores for the three areas sampled were 60.5 at the dam, 78 at mid- lake and 78.5 at the inlet.

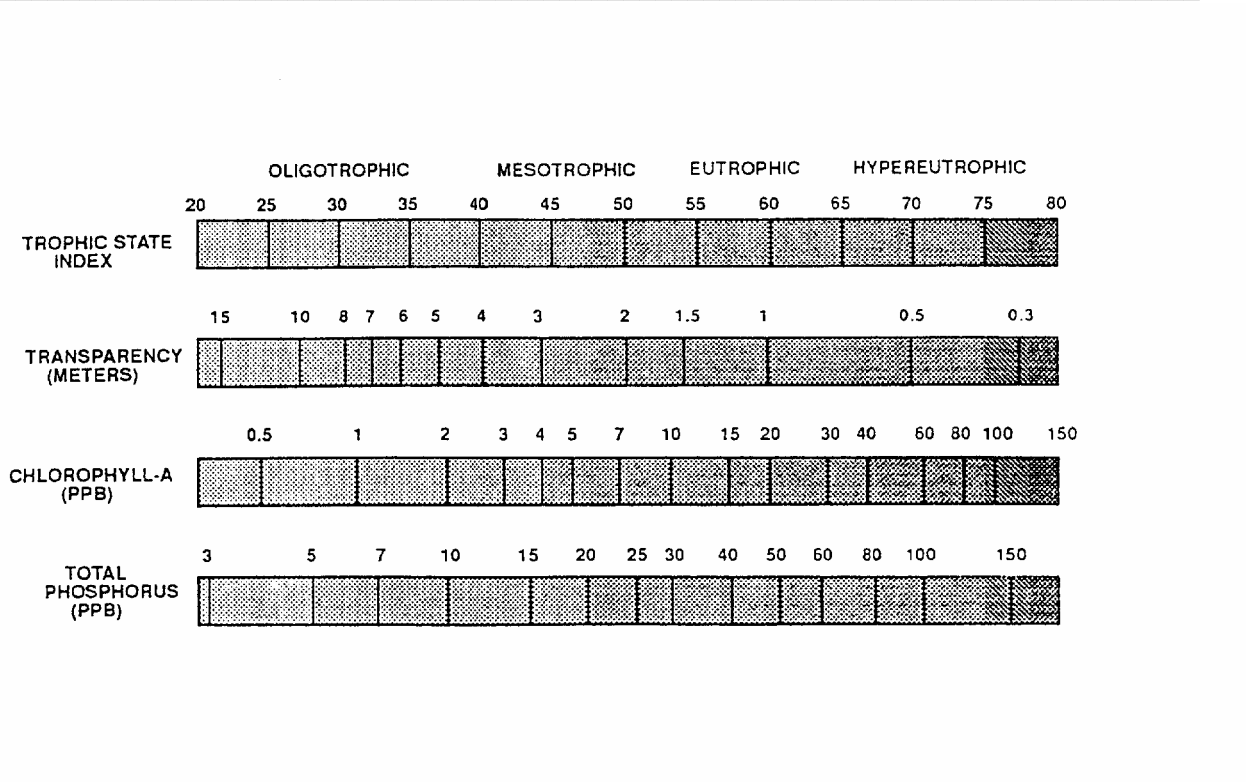

Figure 9. Graphic Depiction of Carlson's Trophic Status Index

PHYTOPLANKTON

Pipestem Reservoir's phytoplankton community was sampled four times and at three locations during the summer of 1998. Sampling date were May 13, July 22, August 18 and October 14, and sampling sites were located at the inlet, at mid-lake and near the dam.

Samples collected in 1998 show that Pipestem Reservoirs phytoplankton community is large and diverse with representation from seven orders and 148 genera. Densities ranged from 21,770 to 135,526 cells per milliliter, and volumes ranged from 2,686,414 to 39,802,372 cubic micrometers per milliliter.

The phytoplankton population was most densely populated by the division Cyanophyta (between 76 and 88 percent of the population in all samples collected). The next most populous division was Bacillariophyta which occupied between 8 and 12 percent of the population. Other divisions in descending order of occurrence were Chlorophyta, Cryptophyta, Cryptophyta, Euglenophyta and Chrysophyta.

The phytoplankton population enumerations by volume were very different than by density. The large organisms in the division Bacillariophyta displaced the greatest volume, ranging from 62 to 75 percent of the entire population volume. The remaining divisions in descending order of volume are Cyanophyta, Pyrrophyta, Euglenophyta, Chlororphyta, Cryptophyta and Chrysophyta.