SECTION 319 NONPOINT SOURCE POLLUTION CONTROL PROGRAM ASSESSMENT/PLANNING PROJECT FINAL REPORT

Cresbard Lake
Faulk County, SD

By

Aaron Larson, Environmental Project Scientist
and
Andrew Repsys, Environmental Project Scientist

Sponsor

Dakota Central Conservation Association, Inc.

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This project was conducted in cooperation with the State of South Dakota and the United States Environmental Protection Agency, Region 8.

Grant # C9998185-00

Executive Summary

PROJECT TITLE: Dakota Central Watershed Assessment

PROJECT START DATE: 4/14/00 PROJECT COMPLETION DATE: 4/14/02

FUNDING: TOTAL BUDGET: $87,200.00

TOTAL EPA GRANT:	$52,320.00	
TOTAL EXPENDITURES OF EPA FUNDS:	$49,273.99	
EXPENDITURES OF NATURAL RESOURCE FEE FUNDS:		$24,150.00
OTHER SECTION 319 MATCH ACCRUED:		$11,115.21
TOTAL SECTION 319 MATCH ACCRUED:	$35,265.21	
BUDGET REVISIONS:	None	
TOTAL EXPENDITURES:	$84,539.20	

FUNDING SUMMARY:

The above budget represents funding sources and expenditures for the Dakota Central Watershed Assessment project (grant # C9998185-00). The EPA section 319 grant provided the majority of funding for the project. Dakota Central Conservation Association, Inc. contributed the local match for the project. This grant funded an assessment of two lakes, Cresbard Lake and Loyalton Dam. Expenditures for each lake assessment were not tracked separately. This report, however, addresses only the assessment of Cresbard Lake and its watershed.

SUMMARY OF ACCOMPLISHMENTS:

The primary objectives of this effort were to (1) assess current physical, chemical, and biological condition of Cresbard Lake and its tributaries, (2) determine non-point source critical areas within the Cresbard Lake watershed, and (3) define management prescriptions for identified non-point source critical areas.

Cresbard Lake was included in the 1998 South Dakota 303(d) list as an impaired TMDL waterbody (SDDENR, 1998). Information supporting this listing was derived from statewide lake assessment data (Stueven and Stewart, 1996), the 1996 305(b) report (SDDENR, 1996), and the evidence of a fish kill. According to the 1996 305(b) report, causes for impaired uses include noxious aquatic plants and two agricultural nonpoint source pollutants - nutrients and silt. The 2000 305(b) report lists the same agricultural sources of impairment, but algal growth and chlorophyll *a* concentrations replaced noxious aquatic plants as causes of impairment (SDDENR, 2000). No additional impairment sources were documented. Cresbard Lake is also listed in *Ecoregion Targeting for Impaired Lakes in South Dakota* (Stueven et al., 2000b) as not supporting its beneficial uses. In this document, the assessed lakes in each ecoregion are ranked by mean trophic state index (TSI) values. The TSI provides a means of evaluating the productivity of algae in a waterbody using measures of Secchi depth, phosphorus concentrations, and chlorophyll concentrations. Cresbard Lake ranks as 15th of the 19 assessed lakes in the Northern Glaciated Plains ecoregion, in order of increasing productivity (eutrophication). In other words, only four of the assessed lakes in the Northern Glaciated Plains ecoregion were considered to have poorer water quality than Cresbard Lake in terms of TSI values.

Two lake sites and four tributary sites were sampled monthly from June 2000 to June 2001. Tributary samples were also collected after major rain events. Continuous stage data was collected from the tributary sites throughout the project period in order to determine sediment and nutrient loading.

Most of the assessed parameters fell within state water quality standards. However, high concentrations of nutrients were observed in both lake and tributary samples. Average stream total nitrogen concentration was 4.17 mg/L, and average stream total phosphorus concentration was 1.70 mg/L. Maximum inlake total nitrogen concentration was 2.63 mg/L, and maximum inlake total phosphorus concentration was 1.06 mg/L. Fecal coliform bacteria were present at elevated concentrations on two sampling dates. Approximately 6% of inlake fecal bacteria samples exceeded the South Dakota single-sample water quality standard.

Non-point source critical areas within the study watershed were identified using the AGNPS loading model. AGNPS nutrient output indicates that the study watershed has a total nitrogen (soluble + sediment bound) delivery rate of 0.52 lbs/acre/year (10.6 tons/year) and a total phosphorus (soluble + sediment bound) delivery rate of 0.14 lbs/acre/year (2.9 tons/year). AGNPS estimated sediment delivery rate was 0.02 tons/acre/year (815 tons/year). Most of the high erosion areas occur on slopes of greater than 3% and in locations where conventional tillage is practiced.

A variety of BMPs were modeled using AGNPS to estimate percent reductions in nutrient and sediment load. By practicing conservation tillage, reducing fertilizer applications, and installing grassed waterways, a 40% reduction in phosphorus load can be achieved.

A 95% percent reduction in total phosphorus load would be required to meet ecoregion-based beneficial use criteria. The ecoregion-based criteria do not appear to be suitable for Cresbard Lake, as demonstrated by the large reduction in total phosphorus needed to meet current ecoregion criteria. Economic and technical limitations prohibit this level of nutrient load reduction. Nutrient reductions of this magnitude would require severe land use alterations and possibly the elimination of agriculture in the watershed. Therefore, the TMDL was developed based on realistic criteria using watershed-specific, attainable BMP reductions.

The TMDL goal has been established as an annual total phosphorus load of 2,785 kg or a mean in-lake TSI of 74. A 40% reduction in total phosphorus load can be achieved in this watershed to meet the TMDL goal. Reductions beyond 40% would severely alter most agricultural practices in the watershed and would be cost prohibitive on a percent reduction basis. The recommended reduction in phosphorus load from the Cresbard Lake watershed will improve compliance with South Dakota's narrative criteria as well as watershed-specific criteria.

Management practices recommended in this report will improve the water quality of Cresbard Lake and its watershed. Long-term monitoring is recommended following implementation to evaluate the effects of management activities.

Acknowledgements

The cooperation of the following organizations is gratefully appreciated. The assessment of Cresbard Lake and its watershed could not have been completed without their assistance.

Dakota Central Conservation Association

Faulk County Conservation District

Natural Resource Conservation Service – Faulk County

South Dakota Department of Health

South Dakota Department of Environment and Natural Resources – Water Resource Assistance Program

South Dakota Department of Environment and Natural Resources – Water Rights

United States Environmental Protection Agency – Non-Point Source Program

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Introduction

The purpose of the Dakota Central Watershed Assessment was to determine the sources of impairment for two small reservoirs, Cresbard Lake and Loyalton Dam, as well as the associated inlet and outlet tributaries. This report discusses the current condition, possible restoration alternatives, and a TMDL summary for only the Cresbard Lake watershed.

Watershed Description

Cresbard Lake watershed is located in northwest Faulk County and southwest Edmunds County (Figure 1). Average annual precipitation is approximately 32 inches. Approximately 73% of the precipitation occurs during the months of April through September. In the summer, the average temperature is about 70 degrees F. During the winter, the average temperature is about 18 degrees F. Average monthly precipitation data for the project period is shown in Figure 2 for the weather station located in Faulkton, SD (source: http://abe.sdstate.edu/weather/weather.htm). Faulkton is located less than ten miles south of the Cresbard Lake watershed and was the closest weather station available.

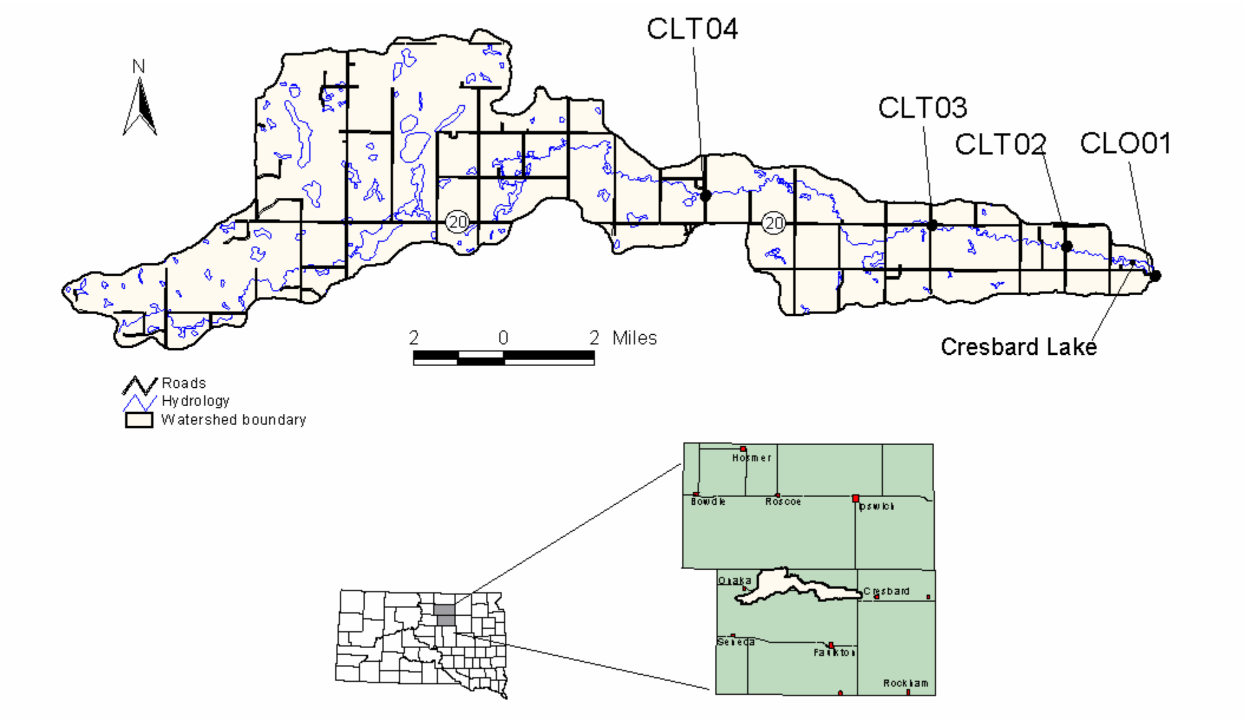

Figure 1. Cresbard Lake watershed with location of tributary sites, Faulk and Edmunds Counties, SD.

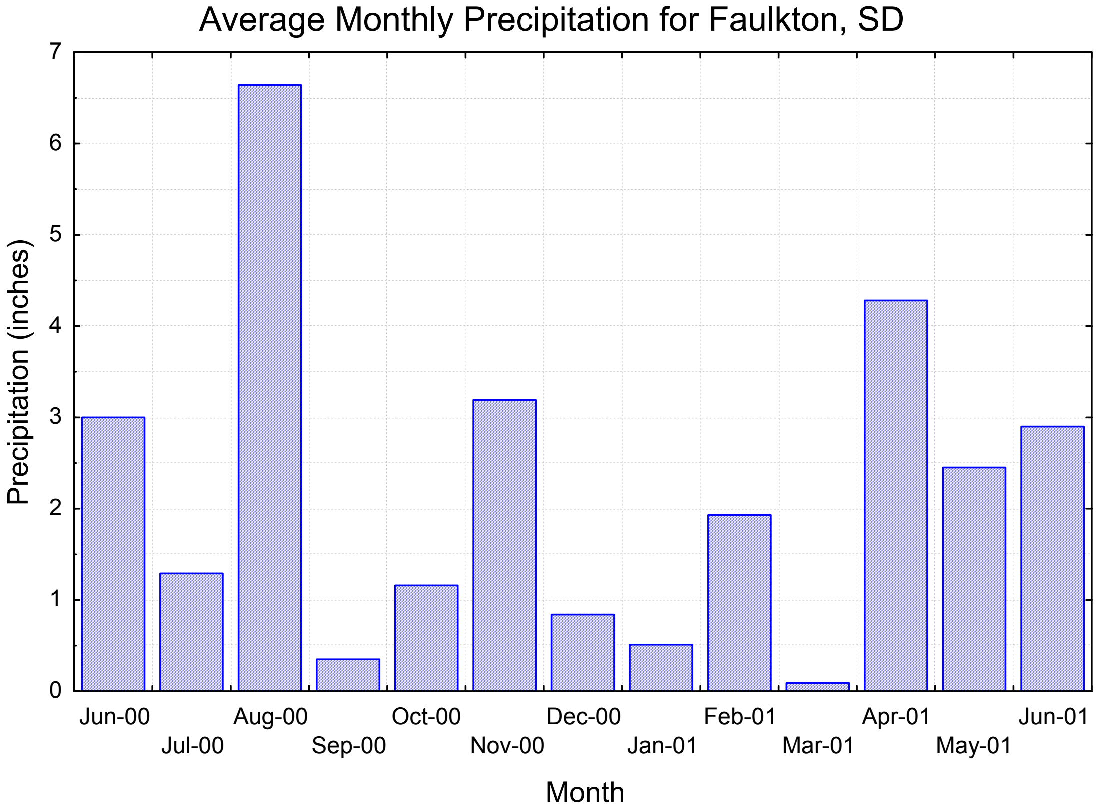

Figure 2. Average monthly precipitation for Faulkton, SD for the project period. This weather station is located less than ten miles south of the Cresbard Lake watershed.

Landuse in the watershed is primarily agricultural, with both crop and grazing acres. The streams in this watershed drain predominantly agricultural land and receive runoff from agricultural operations. Wheat, row crops and hay are the dominant crops on cultivated lands. Some winter animal feeding areas are located in the watershed. The major soil association found in the Cresbard Lake watershed is Williams-Bowbells.

The inlet of Cresbard Lake (an unnamed tributary) drains approximately 40,858 acres. North Fork of Snake Creek drains portions of Faulk County in South Dakota and is the outlet of Cresbard Lake. The small towns of Wecota and Norbeck are located in the Cresbard Lake watershed. The estimated population within a 65-mile radius of Cresbard Lake is 76,839.

Beneficial Use Assignment and Water Quality Standards

Each waterbody within South Dakota is assigned beneficial uses. All waters (both lakes and streams) are designated with the uses of fish and wildlife propagation, recreation, and stock watering. Additional uses are assigned by the state based on a beneficial use analysis of each waterbody. Water quality standards have been defined in South Dakota state statutes in support of these uses. These standards consist of suites of criteria that provide physical and chemical benchmarks from which management decisions can be developed.

Cresbard Lake has been assigned the following beneficial uses: (1) warmwater semipermanent fish propagation, (2) immersion recreation, (3) limited contact recreation, and (4) wildlife propagation, recreation, and stock watering.

Table 1 lists the criteria that must be met to maintain the above beneficial uses. When multiple standards exist for a particular parameter, the most stringent standard is used.

Table 1. State surface water quality standards for Cresbard Lake.

Parameter	Standard *	Use requiring standard
Nitrate – N	≤ 88 mg/L	Wildlife propagation, recreation, and stock watering
Unionized Ammonia	≤ 0.04 mg/L	Warmwater semipermanent fish propagation
Undissociated Hydrogen Sulfide	≤ 0.002 mg/L	Warmwater semipermanent fish propagation
Alkalinity ($CaCO_3$)	≤ 1313 mg/L	Wildlife propagation, recreation, and stock watering
pH	6.5 – 9.0	Warmwater semipermanent fish propagation
Conductivity	≤ 7,000 umhos/cm	Wildlife propagation, recreation, and stock watering
Total Dissolved Solids	≤ 4,375 mg/L	Wildlife propagation, recreation, and stock watering
Total Suspended Solids	≤ 158 mg/L	Warmwater semipermanent fish propagation
Temperature	≤ 90 º F (32.2 º C)	Warmwater semipermanent fish propagation
Dissolved Oxygen	≥ 5.0 mg/L	Warmwater semipermanent fish propagation
Fecal Coliform Bacteria	≤ 400 colonies/100mL	Immersion recreation

* These values reflect daily maximum concentrations (criteria are also established for 30-day averages).

All South Dakota streams are assigned the beneficial uses of irrigation, fish and wildlife propagation, recreation, and stock watering. No additional beneficial uses have been assigned to streams in the Cresbard Lake watershed. Table 2 lists the criteria that must be met to maintain the above beneficial uses.

Table 2. State surface water quality standards for stream sites.

Parameter	Standard *	Use requiring standard
Alkalinity ($CaCO_3$)	≤ 1313 mg/L	Wildlife propagation, recreation, and stock watering
pH	6.0 – 9.5	Wildlife propagation, recreation, and stock watering
Conductivity	≤ 4,375 umhos/cm	Irrigation
Total Dissolved Solids	≤ 4,375 mg/L	Wildlife propagation, recreation, and stock watering
Nitrate-N	≤ 88 mg/L	Wildlife propagation, recreation, and stock watering

* These values reflect daily maximum concentrations (criteria are also established for 30-day averages).

Threatened and Endangered Species

No threatened or endangered species have been documented in the Cresbard Lake watershed. The U.S. Fish and Wildlife Service lists the whooping crane, bald eagle, and western prairie fringed orchid as species that could potentially be found in the area.

According to the South Dakota Department of Game, Fish, and Parks, whooping cranes are likely to occur as migrants in this area. However, these birds are very rare and should not be encountered regularly in the watershed. Bald eagles are likely to occur in migration and may nest in the watershed. Bald eagle nests are appearing all over South Dakota, and the chances of bald eagles nesting in the Cresbard Lake watershed are fairly high. Western prairie fringed orchids have not been documented in South Dakota since 1916. Only two historic collections are known.

None of the above species were encountered during this study. However, care should be taken when considering management activities in the watershed.

Project Goals, Objectives, and Activities

The primary goals of this assessment project were to determine and document sources of impairment to Cresbard Lake and to develop feasible restoration alternatives.

Objectives and Tasks

Objective 1: Lake Sampling

The first objective was to determine the current condition of Cresbard Lake and calculate the trophic state. This information was used to determine the total amount of nutrienttrapping that is occurring in the lake and the reduction of nutrients required to improve the trophic condition of Cresbard Lake.

Water quality samples and field measurements were collected at two in-lake sites on Cresbard Lake. In-lake samples were tested to assess ambient nutrient concentrations in the lake and identify trophic state. The South Dakota State Health Laboratory analyzed all water chemistry samples and fecal coliform samples. Staff from the Water Resource Assistance Program analyzed phytoplankton samples in the Matthew Training Center Laboratory, Pierre, SD.

Objective 2: Tributary Sampling

Sediment and nutrient loadings from tributaries in the Cresbard Lake watershed were estimated through hydrologic and chemical monitoring. The information was used to locate critical areas in the watershed to be targeted for implementation.

Water quality samples and field measurements were collected from four tributary sites. Samples were collected during spring runoff, storm events, and monthly base flows. Water level recorders were installed at sites to maintain a continuous stage record for the project period. Discrete discharge measurements were taken on a regular schedule and following major rain events. Discharge measurements and water level data were used to calculate a hydrologic budget for the creek systems. Discharge measurements and concentrations of sediment and nutrients were used to calculate loadings from the watershed.

Objective 3: Quality Assurance/Quality Control (QA/QC)

Approved quality assurance/quality control (QA/QC) procedures were utilized to ensure the collection of accurate and defendable data. QA/QC samples consisted of field blanks and field replicate samples. Replicate and blank samples were analyzed for at least 10% of the total number of collected water samples. All QA/QC activities were conducted in accordance with the EPA approved Quality Assurance Project Plan for the Water Resource Assistance Program. The activities involved with QA/QC procedures and the results of QA/QC monitoring are reported in a subsequent section of this report.

Objective 4: Watershed Modeling

Watershed impacts on water quality were assessed for the Cresbard Lake watershed using the Agricultural Nonpoint Source (AGNPS) model. AGNPS is a comprehensive land use model that estimates soil loss and delivery of sediment and nutrients from a watershed. This model was used to identify critical areas of nonpoint source pollution in the watershed to target for management. Contributions of nutrients and sediment to surface water in the Cresbard Lake watershed were quantified.

Objective 5: Public Participation

Informational meetings were held to inform the involved parties and the general public of progress on the study. These meetings provided an avenue for input from the residents in the area. News releases were also made available to local news media.

Objective 6: Development of Restoration Alternatives

The results of AGNPS modeling were used in conjunction with the nutrient and hydrologic budget to determine critical areas in the watershed. Feasible watershed restoration alternatives and recommendations for the Cresbard Lake watershed are documented in this report. This effort will provide data for the development of an implementation project for the Cresbard Lake watershed.

Methods

Tributary Assessment Methods

Four stream sites were selected for chemical and hydrologic monitoring. All stream samples and measurements were collected using methods described in *Standard Operating Procedures for Field Samplers* for the South Dakota Water Resources Assistance Program (Stueven et al., 2000a). At each site visit, water samples were collected mid-stream at the same location using the same collection method. After the water sample was collected, water and air temperature, pH, and dissolved oxygen measurements were taken using a YSI meter. Table 3 lists all parameters assessed at stream sites.

Table 3. Parameters measured at stream sites.

Physical	Chemical	Biological
Air temperature	Dissolved oxygen	Fecal coliform bacteria
Water temperature	Ammonia	
Discharge	Unionized ammonia	
Depth	Nitrate/nitrite	
Visual observations	TKN	
Water level	Total phosphorus	
Total solids	Total dissolved phosphorus	
Total dissolved solids	Field pH	
Total suspended solids		

Water level recorders were installed at sites to maintain a continuous stage record for the project period. An ISCO model 4230 bubbler stage recorder was installed at sites CLT02, CLT03, and CLT04. A Stevens Type F stage recorder was installed at the outlet site (CLO01). Daily stage averages were calculated for all sites. Instantaneous discharge measurements were taken with a hand-held current velocity meter. A regression equation was developed from the relationship between discharge and stage data to estimate hydrologic load for the drainage system. Watershed loads were calculated from discharge measurements and sample concentrations of sediment and nutrients. FLUX, a eutrophication model developed by the Army Corps of Engineers (US ACOE, 1999), was used to estimate nutrient and sediment loading.

Lake Assessment Methods

Physical, chemical, and biological parameters were examined for Cresbard Lake on a monthly basis and during rain events from June 2000 to June 2001, excluding the months November 2000 and February 2001. Samples were collected from surface and bottom depths at two sites (
Figure 3). Water temperature, dissolved oxygen, conductivity, field pH, and water depth were measured using a YSI multi-probe meter. As with tributary sampling, all samples and measurements were collected using methods described in *Standard Operating Procedures for Field Samplers* for the South Dakota Water Resources Assistance Program (Stueven et al., 2000a). Table 4 lists all parameters measured for Cresbard Lake.

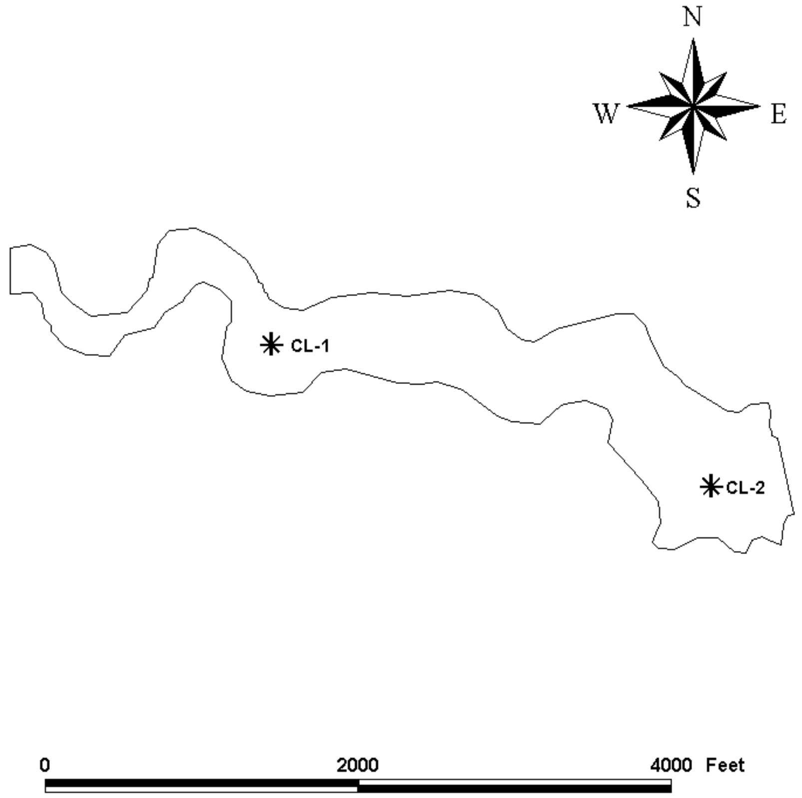

Figure 3. Location of inlake sampling sites for Cresbard Lake, Faulk County, SD.

Table 4. Parameters measured at lake sites.

Physical	Chemical	Biological
Air temperature	Total alkalinity	Fecal coliform bacteria
Water temperature	Unionized ammonia	Algae
Secchi transparency	Total Kjeldahl Nitrogen	Chlorophyll *a*
Visual observations	Nitrate/nitrite	Macrophytes
Total solids	Total phosphorus	
Total dissolved solids	Total dissolved phosphorus	
Total suspended solids	Dissolved oxygen	
Depth	Conductivity	
	Field pH	

Results

Tributary Physical and Chemical Parameters

Annual Loading

Sample data and instantaneous flow measurements were used to estimate loads using the FLUX model. Hydrologic load was calculated using FLUX in order to develop a water budget for Cresbard Lake. Approximately 4.2 billion liters (3,416 acre-ft) of water flowed into Cresbard Lake from the gauged watershed during the project period. The amount of water delivered per acre for the gauged watershed was 103,162 liters. Total flow volume and mean flow rate for each site are listed in Table 5. As expected, total flow volume and flow rate increased in an upstream to downstream direction. The outlet (site CLO01) had a slightly higher flow volume and flow rate than the inlet (Table 5), which is presumably due to groundwater effects or flow from the ungauged portion of the watershed. Approximately 600 of the 40,858 watershed acres (1.5%) were not gauged.

Table 5. Hydrologic loads delivered from the Cresbard Lake watershed. Sites are listed in upstream order with site CLT04 being furthest upstream. CLTO01 is the outlet site and CLT02 is the inlet site.

Site	Flow Duration (project period)	Total Flow Volume During Project Period (hm^3)	Mean Flow Rate (hm^3/yr)	Mean Flow Rate (cfs)
CLO01	426 days (1.166 years)	4.284	3.674	0.136
CLT02	426 days (1.166 years)	4.215	3.614	0.134
CLT03	426 days (1.166 years)	2.759	2.365	0.087
CLT04	426 days (1.166 years)	1.385	1.187	0.044

Note: 1 hm^3 = 1,000,000 m^3 and $1m^3 \approx 35.3$ ft^3

Seasonal and annual loads for each measured parameter (nutrients and solids) were also calculated using FLUX (

Table 6). Highest loads occurred during the spring due to spring snowmelt runoff and rain events. Summer and fall months contributed a relatively small amount of load. No loading occurred during winter months as measured by the gauging stations.

Table 6. Seasonal and annual loads (kg) delivered from the Cresbard Lake watershed.

Parameter	Spring (kg)	Summer (kg)	Fall (kg)	Annual (kg)
Total Nitrogen	14,784	476	203	15,463
Ammonia	2,127	68	29	2,224
Nitrate	4,002	129	55	4,186
Total Kjeldahl Nitrogen	10,782	347	148	11,276
Organic Nitrogen	8,655	279	119	9,052
Total Phosphorus	4,438	143	61	4,641
Total Dissolved Phosphorus	3,364	108	46	3,519
Alkalinity	410,110	13,195	5,621	428,926
Total Solids	1,938,405	62,367	26,566	2,027,337
Total Dissolved Solids	1,587,126	51,065	21,751	1,659,942
Total Suspended Solids	351,279	11,302	4,814	367,396
Volatile Suspended Solids	45,914	1,477	629	48,020

Water Temperature

Environmental variables in aquatic systems are extremely interconnected. Water temperature is an influential variable in biological, chemical, and physical processes. Temperature can influence metabolic rates of aquatic organisms, toxicity of pollutants, and levels of dissolved oxygen. The greatest source of heat in freshwaters is solar radiation, especially waterbodies that are directly exposed to the sun (Hauer and Lamberti, 1996). Elevated water temperatures are common in midwestern streams with little canopy cover.

As can be expected in lotic (flowing water) systems, water temperatures were highly variable. Greatest variability was observed at the inlet site (CLT02) (Figure 4). Average temperature at the inlet site was 7.63 degrees Celsius, while average temperature at the outlet site (CLO01) was 3.71 degrees Celsius. Maximum water temperature (17.24 degrees Celsius) was recorded at site CLT03 (

Table 7). Stream temperature data was limited. 85% of the temperature measurements were collected during either March or April, explaining the relatively low water temperatures. Increased temperature variability is typical of intermittent streams. Seasonal or monthly tributary temperatures are not reported due to limited data.

Table 7. Descriptive statistics of water temperature (degrees Celsius) for tributary sites.

Site	Number of Measurements	Mean	Median	Minimum	Maximum	Standard Deviation
CLO01	2	3.71	3.71	3.68	3.74	0.04
CLT02	4	7.63	6.20	2.19	15.94	5.85
CLT03	5	7.45	5.42	2.54	17.24	5.68
CLT04	2	3.72	3.72	3.20	4.24	0.74

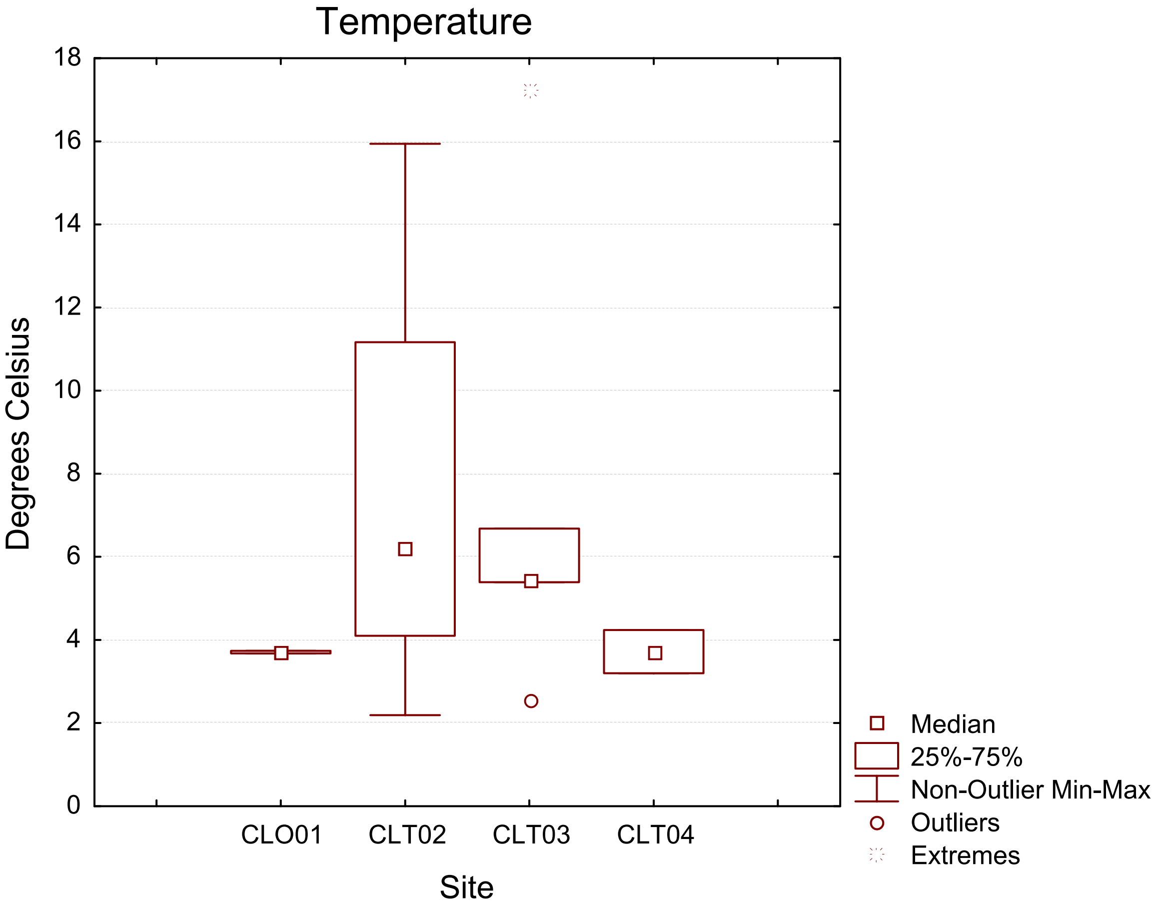

Figure 4. Box plot of temperature by site for tributary sites. This box plot demonstrates medians, quartiles (25th and 75th percentiles), and non-outlier minima and maxima (see legend).

Dissolved Oxygen

Dissolved oxygen (DO) greatly affects aquatic life, since the metabolism of all aerobic aquatic organisms requires dissolved oxygen. For this reason, it is important to monitor DO in aquatic systems.

Concentrations of DO often vary both spatially and temporally. Seasonal loadings of organic matter greatly influence DO concentrations (Wetzel, 2001). Physical factors, such as temperature and pressure, also influence concentrations of DO. Atmospheric oxygen solubility is most affected by temperature. A waterbody's capacity for DO increases considerably with colder water temperatures.

Highest average DO concentration (17.66 mg/L) was observed at site CLT04. Average DO concentration at the inlet site was 14.73 mg/L, while average DO concentration was 11.08 mg/L at the outlet (Table 8). Lower DO concentrations at the outlet are probably due to respiration occurring in the lake. Similar to temperature data, large variability in the DO measurements (Figure 5) suggests no significant difference between the sites. As stated before, seasonal or monthly concentrations are not reported due to limited data.

Table 8. Descriptive statistics of dissolved oxygen (mg/L) for tributary sites.

Site	Number of Measurements	Mean	Median	Minimum	Maximum	Standard Deviation
CLO01	2	11.08	11.08	10.59	11.57	0.69
CLT02	4	14.73	11.60	8.47	27.26	8.48
CLT03	5	10.07	9.19	4.19	15.39	4.23
CLT04	2	17.66	17.66	5.67	29.65	16.96

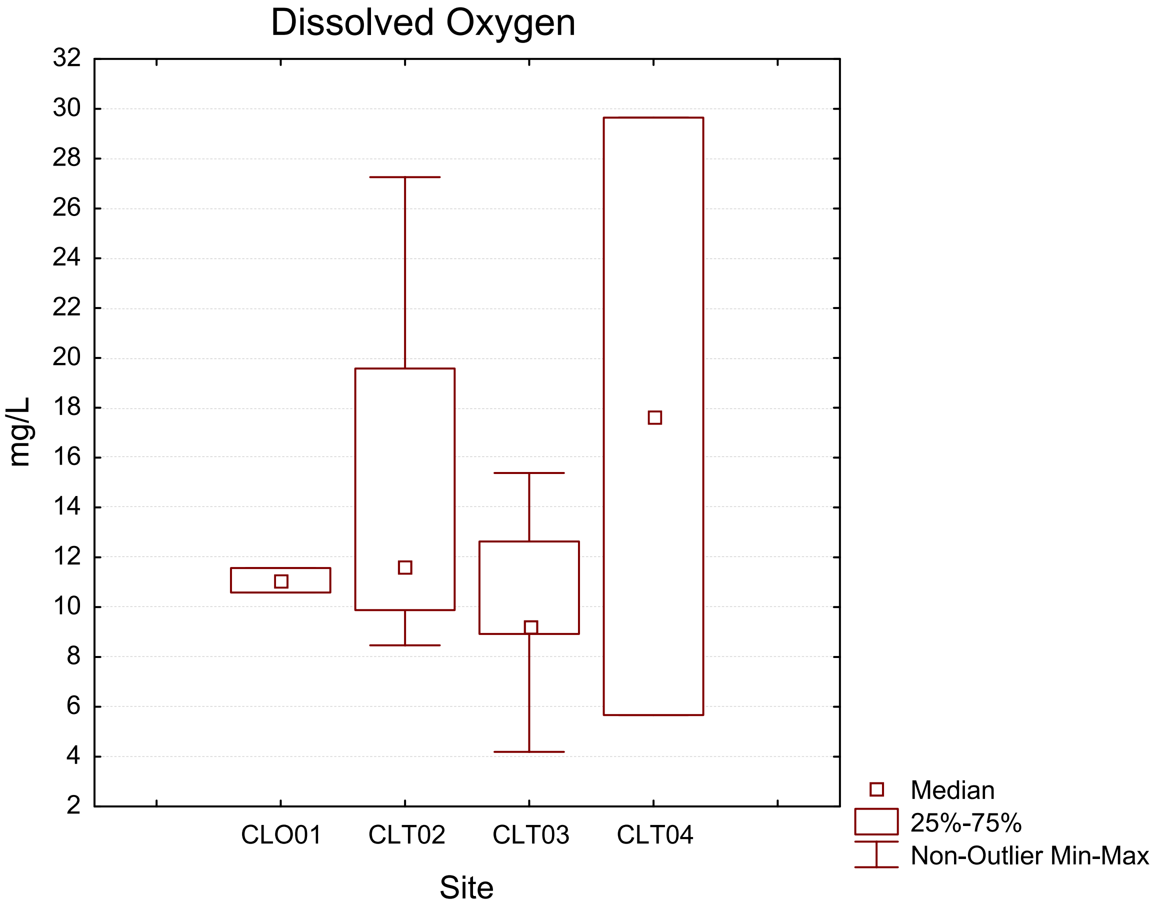

Figure 5. Box plot of dissolved oxygen by site for tributary sites.

Acidification and Alkalinity

The primary measurements of acidification are alkalinity and pH. The pH scale ranges from 0 to 14, with 7 being neutral. Water with pH < 7 is considered acidic, while water with pH > 7 is considered basic. The pH of water is regulated mostly by the interaction of hydrogen ions. Natural waters exhibit wide variations in acidity and alkalinity. The pH of natural waters ranges between the extremes of 2 and 12 (Wetzel, 2001), yet most forms of aquatic life require an environment with a pH of 6.5 to 9.0.

Field pH for the tributary sites ranged from 7.25 to 8.07. Average field pH at the inlet site was 7.76, while average pH at the outlet site was 7.85. Mean pH appeared to increase in a downstream direction (Table 9). Field pH measurements above the impoundment were more variable than below (Figure 6).

Table 9. Descriptive statistics of field pH (standard units) for tributary sites.

Site	Number of Measurements	Mean	Median	Minimum	Maximum	Standard Deviation
CLO01	2	7.85	7.85	7.71	7.98	0.19
CLT02	4	7.76	7.83	7.32	8.07	0.32
CLT03	5	7.65	7.60	7.25	8.03	0.31
CLT04	2	7.44	7.44	7.44	7.44	0.00

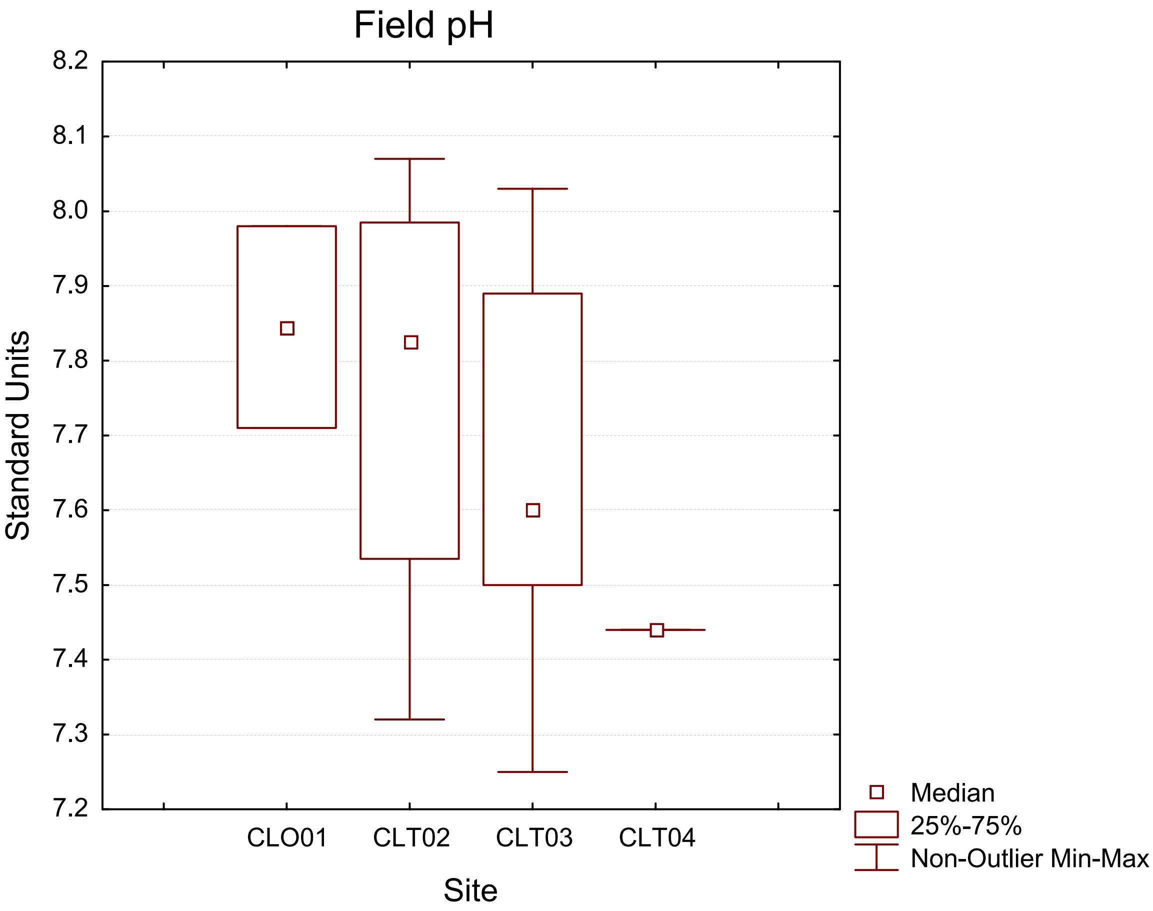

Figure 6. Box plot of field pH by site for tributary sites.

Alkalinity is a term that refers to the buffering ability of the carbonate system in water. The term is also used interchangeably with ‘acid neutralizing capacity’ (ANC), which is the capacity to neutralize strong inorganic acids (Wetzel, 2001). Alkalinity is a product of geological setting. Soils rich in carbonate rock, such as limestone, provide a source of high alkalinity (Monson, 2000). In general, increased alkalinity inhibits drastic pH changes. Alkalinity typically ranges from 20 to 200 mg/L in natural environments (Lind, 1985).

Average alkalinity concentrations from inlet and outlet samples were similar, although somewhat higher at the outlet site (Table 10). Greater variability in alkalinity concentrations was observed above the impoundment (Figure 7). The alkalinity standard of ≤1313 mg/L was not exceeded.

Table 10. Descriptive statistics of alkalinity (mg/L) for tributary samples.

Site	Number of Measurements	Mean	Median	Minimum	Maximum	Standard Deviation
CLO01	8	165	168	60	335	84
CLT02	10	171	114	60	316	104
CLT03	11	156	105	20	282	102
CLT04	11	157	143	50	279	89

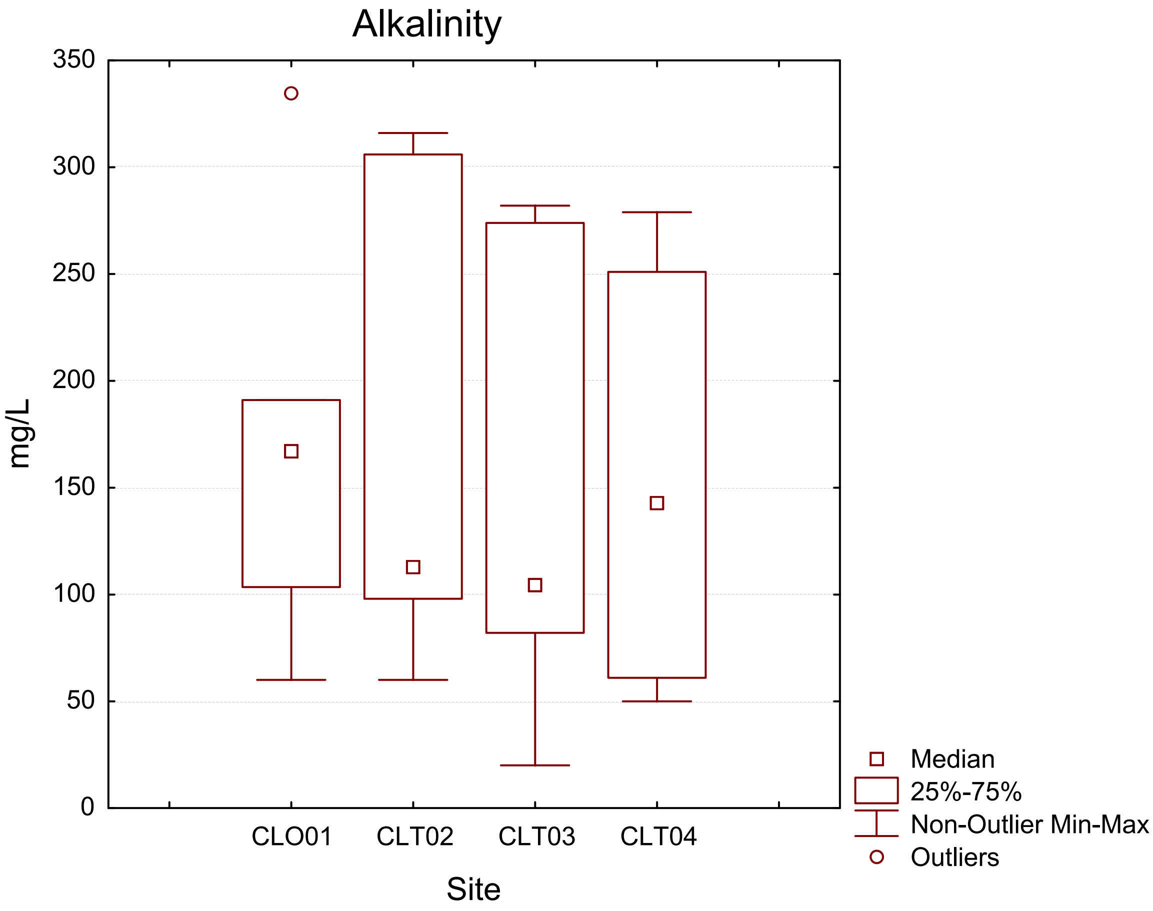

Figure 7. Box plot of alkalinity by site for tributary sites.

Solids

"Solids" is a general term that refers to suspended or dissolved materials that are present in the waterbody. Four solids parameters were examined in this assessment: total solids, total suspended solids, total dissolved solids, and total volatile suspended solids. Total solids include the sum of dissolved and suspended material. Dissolved solids are those materials small enough to pass through a 2.0 µm filter. Suspended solids consist of larger materials that do not pass through the filter; this material is also referred to as the residue. The suspended materials include both organic and inorganic forms. Organic solids (total volatile suspended solids) are determined by combustion of the filtered residue.

Concentrations of total solids were comparable at the inlet and outlet sites (Figure 8). Inlet sample concentrations ranged from 266 to 1,008 mg/L (mean = 588). Outlet sample concentrations ranged from 243 to 1,028 mg/L (mean = 548) (Table 11). FLUX estimated an annual load of 2,027,337 kg (2,235 tons) of total solids was delivered to Cresbard Lake from the watershed. This equates to an average of approximately 50 kg per watershed acre.

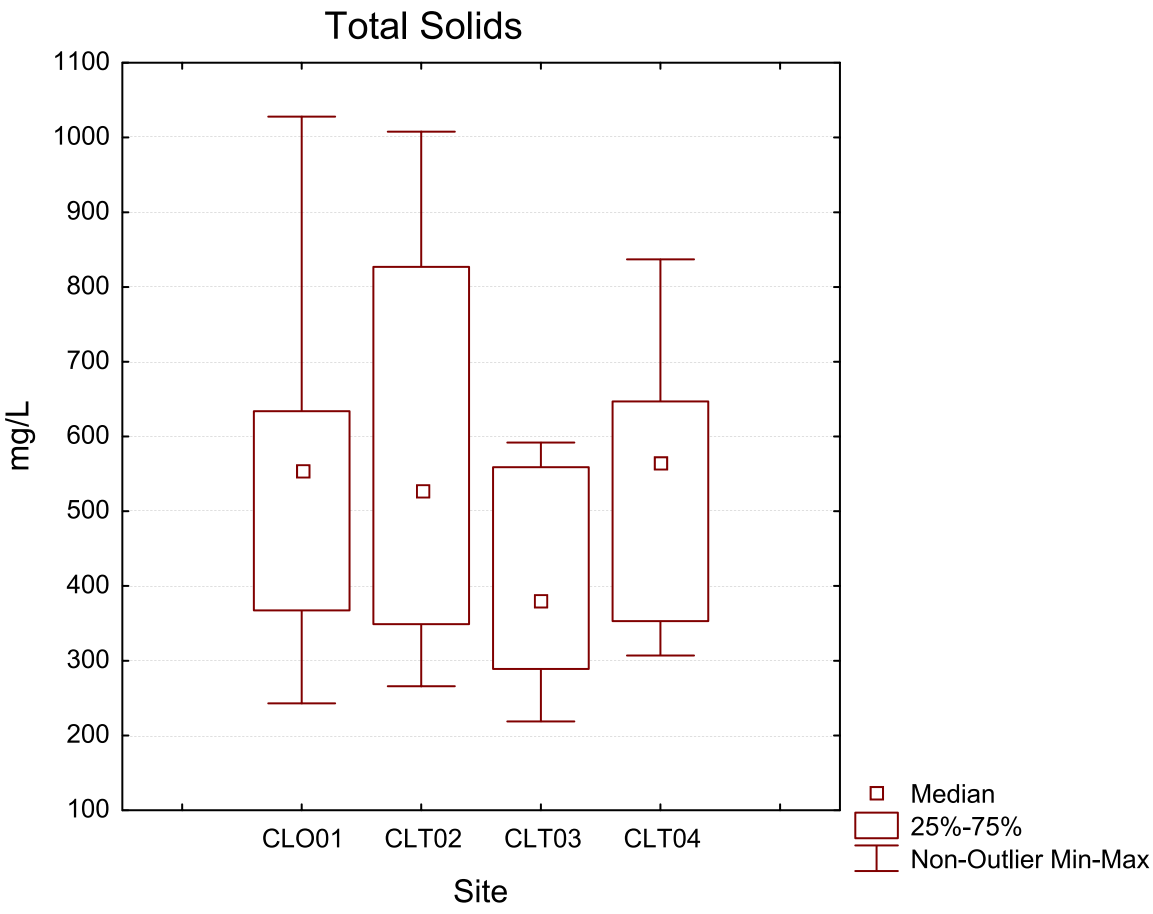

Figure 8. Box plot of total solids by site for tributary sites.

Table 11. Descriptive statistics of total solids (mg/L) for tributary samples.

Site	Number of Measurements	Mean	Median	Minimum	Maximum	Standard Deviation
CLO01	8	548	554	243	1028	241
CLT02	10	588	528	266	1008	273
CLT03	11	406	381	219	592	136
CLT04	11	525	565	307	837	168

Typically, impoundments along the course of a stream allow large amounts of suspended solids to settle out before the water is discharged from the lake or dam. This phenomenon was observed in Cresbard Lake. Concentrations of suspended solids at the inlet ranged from 6 to 324 mg/L (mean = 57), while concentrations at the outlet ranged from 1 to 98 mg/L (mean = 31).
Median concentrations of total suspended solids (TSS) were similar across all sites, but elevated concentrations were observed in samples from the inlet site. In Figure 9, note the two maximum sample concentrations (extremes) collected at the inlet. Average TSS concentration across all sample dates was also highest at the inlet, site CLT02 (Table 12).

The volatile (organic) portion of suspended solids, however, was higher at the outlet. Approximately 19% of the suspended solids load at the inlet was organic, while approximately 51% of the suspended solids load at the outlet was organic. This is due to biological activity occurring in the reservoir. Algae growth can contribute significant amounts of organic suspended solids to the total suspended solids load.

FLUX estimated an annual load of 367,396 kg (405 tons) of total suspended solids was delivered to Cresbard Lake from the watershed, or 9 kg per watershed acre.

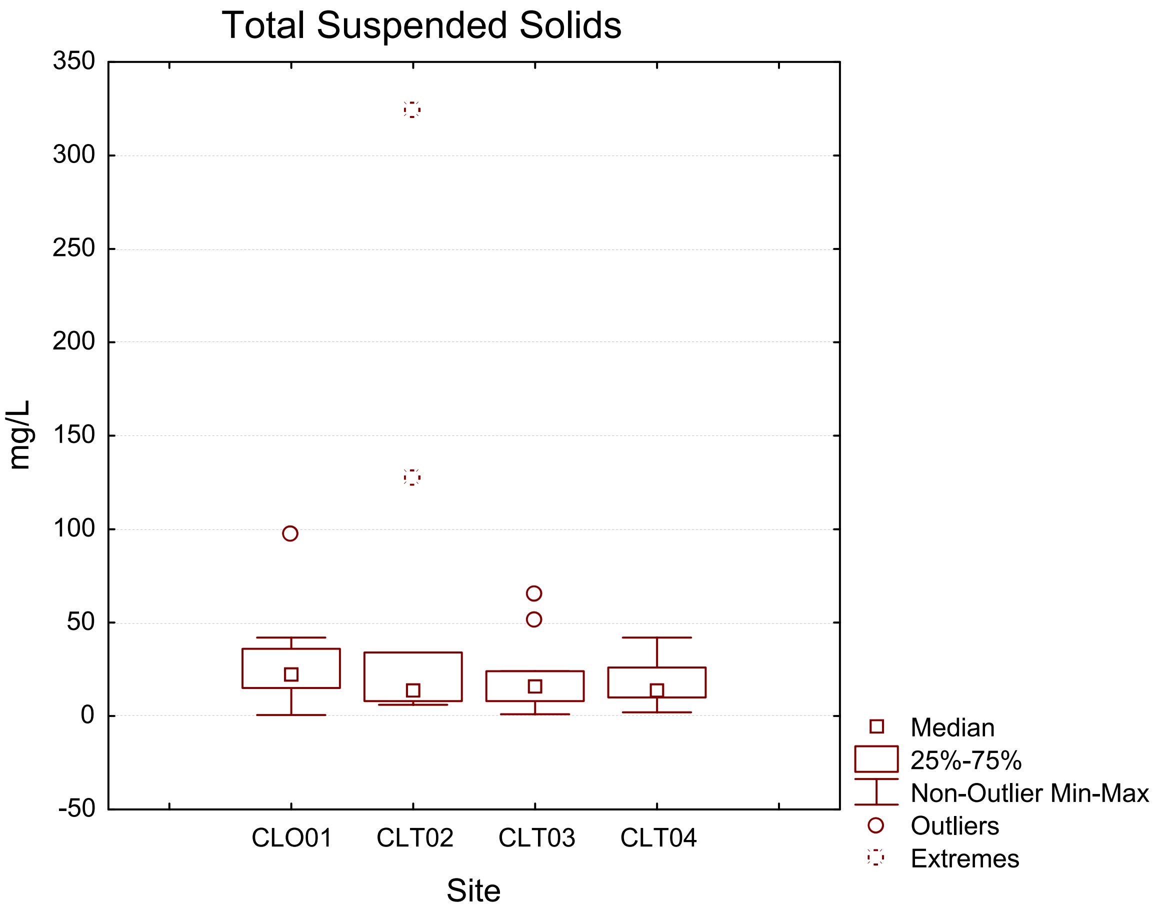

Figure 9. Box plot of total suspended solids (TSS) by site for tributary sites.

Table 12. Descriptive statistics of suspended solids (mg/L) for tributary samples.

Site	Number of Measurements	Mean	Median	Minimum	Maximum	Standard Deviation
CLO01	8	31	23	1	98	30
CLT02	10	57	14	6	324	101
CLT03	11	22	16	1	66	20
CLT04	11	18	14	2	42	12

Nitrogen

Three types of nitrogen were assessed in tributary samples: (1) nitrate/nitrite, (2) ammonia, and (3) Total Kjeldahl Nitrogen (TKN). With these three parameters, relative concentrations of organic and inorganic nitrogen can be determined, as well as total nitrogen concentrations.

Average total nitrogen concentration for inlet samples was 3.35 mg/L. Outlet average concentration was 2.75 mg/L (Table 13). Total nitrogen concentrations of CLT04 samples were much more variable than other sites (Figure 10). Site CLT04 also experienced higher concentrations of inorganic nitrogen, which was probably due to runoff from fertilized croplands. However, livestock wastes could be another potential source of nitrogen at this site. Highest concentrations of fecal coliform bacteria (associated with warm-blooded animal waste) were also observed at this site.

Annual loads for all assessed forms of nitrogen are listed in Table 6. FLUX model output indicated total nitrogen concentration at the inlet was 3.61 mg/L. Estimated total nitrogen annual load was 15,463 kg (17 tons), which is equivalent to 0.38 kg per watershed acre.

Table 13. Descriptive statistics of total nitrogen (mg/L) for tributary samples.

Site	Number of Measurements	Mean	Median	Minimum	Maximum	Standard Deviation
CLO01	8	2.75	2.39	1.47	5.41	1.39
CLT02	10	3.35	2.73	1.58	9.13	2.22
CLT03	11	2.01	1.88	1.46	2.97	0.52
CLT04	11	8.12	3.52	2.28	20.70	7.08

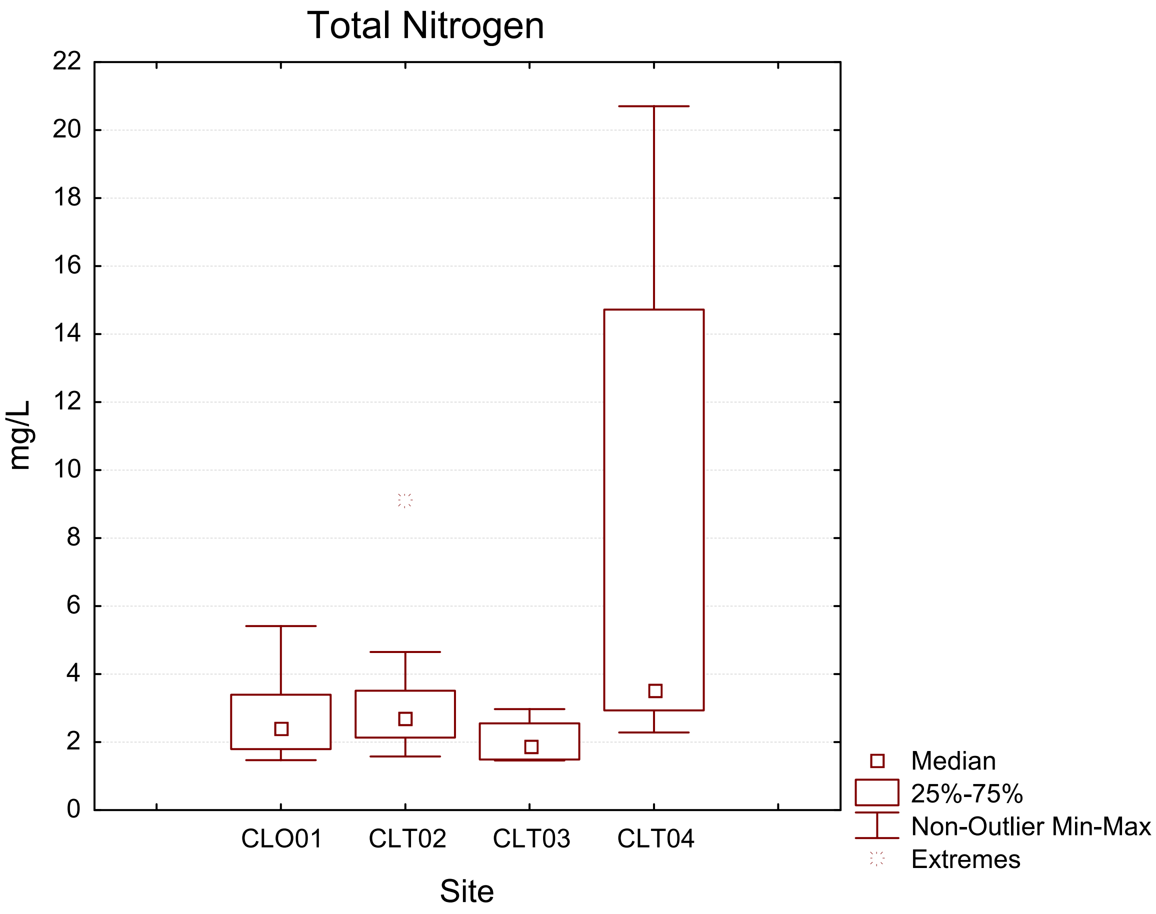

Figure 10. Box plot of total nitrogen by site for tributary sites.

In general, concentrations of organic nitrogen exceeded concentrations of inorganic nitrogen (Figure 11). However, site CLT04 was an exception with an average inorganic nitrogen concentration of 4.50 mg/L and an average organic nitrogen concentration of 3.61 mg/L (Table 14 and Table 15). Possible sources of organic nitrogen in stream samples may include vegetation from the watershed, algae growth, and animal waste.

Table 14. Descriptive statistics of inorganic nitrogen (mg/L) for tributary samples.

	Number of Measurements	Mean	Median	Minimum	Maximum	Standard Deviation
CLO01	8	0.69	0.71	0.06	1.42	0.47
CLT02	10	1.23	0.97	0.10	3.56	1.16
CLT03	11	0.42	0.06	0.06	1.75	0.58
CLT04	11	4.50	0.64	0.11	16.60	5.55

Table 15. Descriptive statistics of organic nitrogen (mg/L) for tributary samples.

	Number of Measurements	Mean	Median	Minimum	Maximum	Standard Deviation
CLO01	8	2.06	1.47	0.92	4.66	1.33
CLT02	10	2.12	1.74	1.23	5.57	1.27
CLT03	11	1.59	1.65	0.93	2.63	0.51
CLT04	11	3.61	2.82	2.17	11.72	2.74

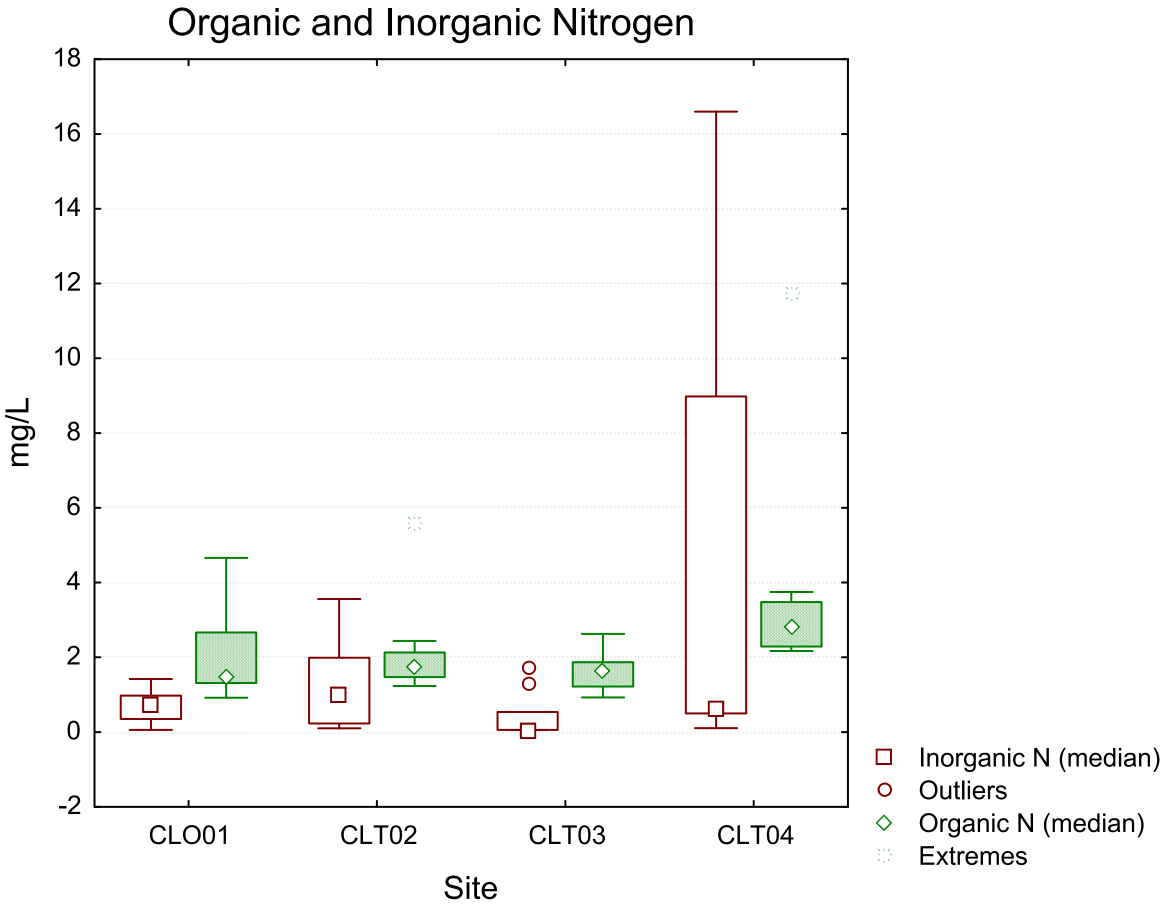

Figure 11. Box plot of organic and inorganic nitrogen concentrations by site for tributary sites.

Average nitrate concentration for inlet samples was 0.87 mg/L. Average sample concentration for the outlet was 0.40 mg/L (Table 16). FLUX output indicated nitrate concentration at the inlet was 0.99 mg/L, and FLUX modeled outlet concentration was 0.42 mg/L (flow-weighted concentration). The nitrate standard for all streams is ≤88 mg/L, much higher than the modeled and observed concentrations.

Table 16. Descriptive statistics of nitrate (mg/L) for tributary samples.

Site	Number of Measurements	Mean	Median	Minimum	Maximum	Standard Deviation
CLO01	8	0.40	0.35	0.05	1.00	0.34
CLT02	10	0.87	0.55	0.05	2.50	0.87
CLT03	11	0.25	0.05	0.05	1.00	0.32
CLT04	11	2.85	0.10	0.05	16.50	5.36

Phosphorus

Phosphorus is present in all aquatic systems. Its natural sources include the leaching of phosphate-bearing rocks and organic matter decomposition. Other potential sources of phosphorus include manmade fertilizers and domestic animal waste. Primary sources of phosphorus in this watershed are agricultural (SDDENR, 2000).

Effects of the dam are apparent when comparing inlet and outlet phosphorus concentrations (Figure 12). Total phosphorus concentrations at the inlet ranged from 0.462 to 3.230 mg/L (mean = 1.654), while concentrations at the outlet ranged from 0.214 to 1.120 mg/L (mean = 0.662) (Table 17). It is expected that much of the phosphorus load entering the lake is either incorporated into aquatic plant and algal biomass or attached to suspended solids that eventually settle to the bottom of the lake. FLUX model output indicated total phosphorus concentration at the inlet was 1.068 mg/L and at the outlet was 0.701 mg/L. FLUX estimated total phosphorus annual load was 4,641 kg (5.1 tons), which is equivalent to 0.11 kg per watershed acre.

Above the impoundment, average concentrations of total phosphorus at sampled sites increased in an upstream direction. Highest concentrations were observed at site CLT04. Watershed areas above site CLT04 should be considered as high priority areas for installation of Best Management Practices. More specific phosphorus critical watershed areas are identified in the AGNPS model section of this report and Appendix F.

Table 17. Descriptive statistics of total phosphorus (mg/L) for tributary samples.

Site	Number of Measurements	Mean	Median	Minimum	Maximum	Standard Deviation
CLO01	8	0.662	0.562	0.214	1.120	0.308
CLT02	10	1.654	1.136	0.462	3.230	1.049
CLT03	11	1.683	0.757	0.375	5.120	1.730
CLT04	11	2.521	2.250	0.531	5.330	1.563

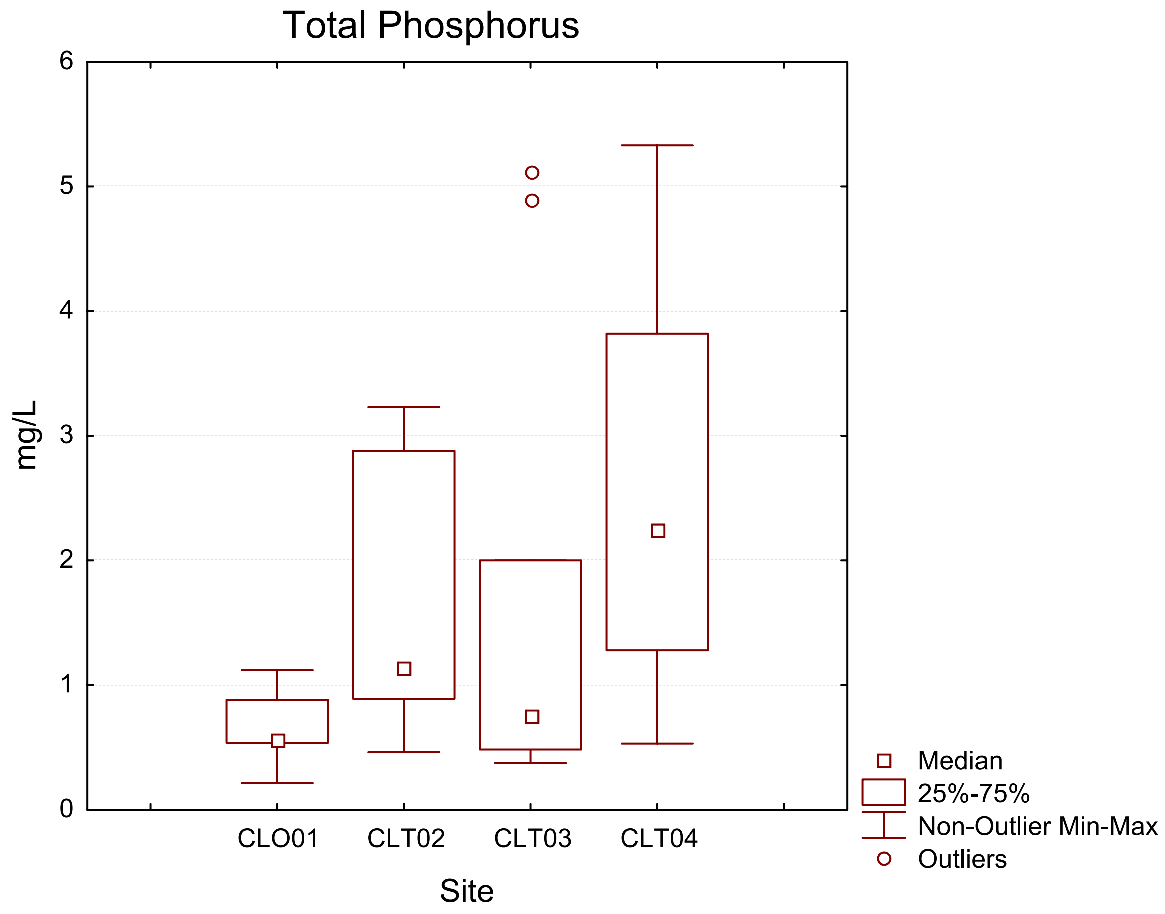

Figure 12. Box plot of total phosphorus by site for tributary sites.

Total dissolved phosphorus (TDP) concentrations at the inlet (CLT02) ranged from 0.312 to 2.850 mg/L (mean = 1.426), while concentrations at the outlet ranged from 0.102 to 0.747 mg/L (mean = 0.484) (Table 18). Similar to all nutrient parameters, TDP concentrations at the inlet were more variable than the outlet (Figure 13). FLUX model output indicated TDP concentration at the inlet was 0.806 mg/L. FLUX estimated TDP annual load was 3,519 kg (3.9 tons), which is equivalent to 0.09 kg per watershed acre.

Table 18. Descriptive statistics of total dissolved phosphorus (mg/L) for tributary samples.

Site	Number of Measurements	Mean	Median	Minimum	Maximum	Standard Deviation
CLO01	8	0.484	0.472	0.102	0.747	0.210
CLT02	10	1.426	0.948	0.312	2.850	0.992
CLT03	11	1.126	0.570	0.314	2.680	0.886
CLT04	11	2.197	2.240	0.379	4.640	1.491

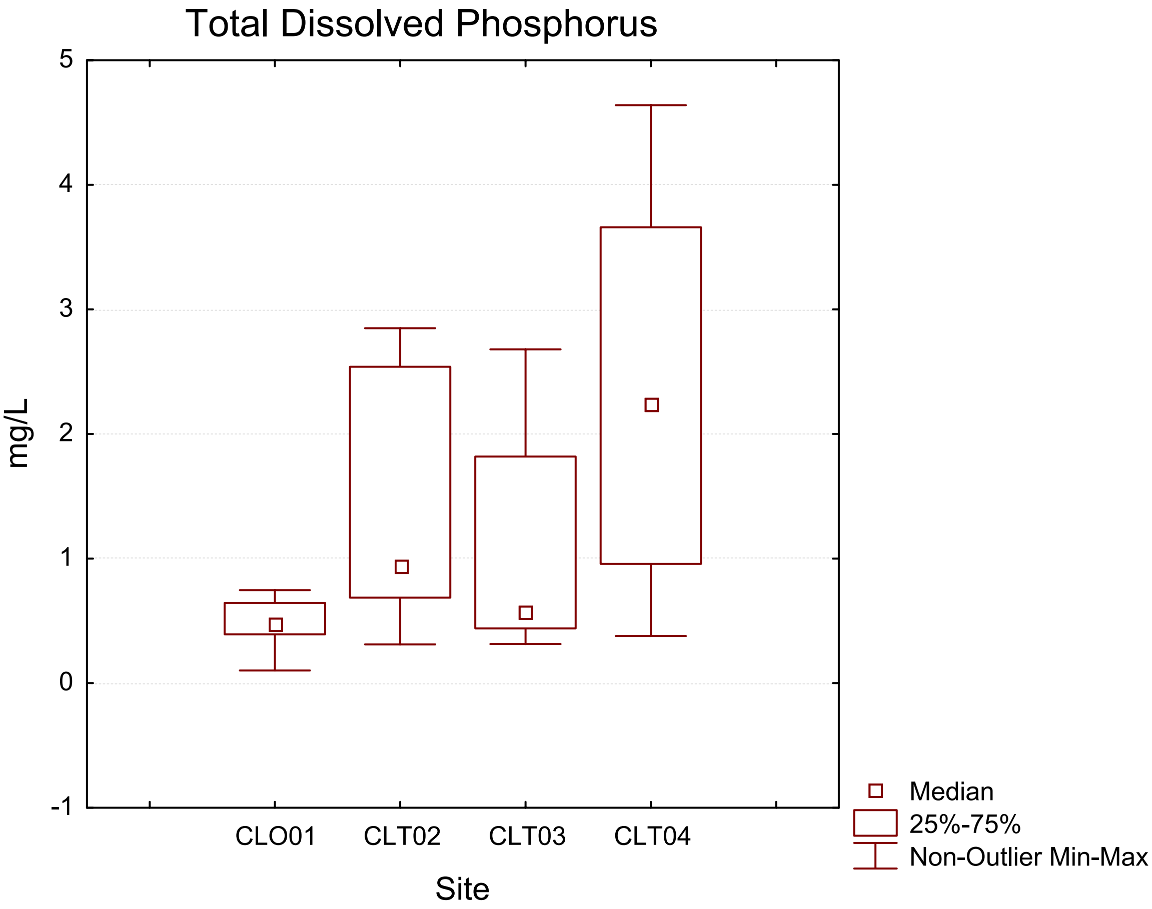

Figure 13. Box plot of total dissolved phosphorus by site for tributary sites.

Tributary Biological Parameters

Fecal Coliform Bacteria

Fecal coliform bacteria are found in the intestinal tract of all warm-blooded animals. Although these organisms are not usually disease-causing organisms themselves, their presence indicates fecal contamination and a higher probability of infectious, water-borne disease.

Fecal bacteria concentrations are often highly variable. Environmental factors (e.g. sunlight exposure, water temperature, etc.) can affect concentrations of fecal bacteria in a waterbody. The life span of fecal bacteria is relatively short compared to the associated animal waste, so the absence of fecal bacteria does not necessarily equate to the absence of animal waste.

Fecal bacteria concentrations at the inlet ranged from 50 to 2,000 bacteria colonies per 100 ml of sample (mean = 640). Concentrations at the outlet ranged from <10 to 700 colonies per 100 ml (mean = 268). The variability of this data is evident in the high standard deviations (Table 19).

Similar to nitrogen and phosphorus parameters, maximum concentrations of fecal coliform bacteria were found at site CLT04. This may indicate that animal waste is a significant source of the nutrient (nitrogen and phosphorus) load. No fecal coliform bacteria standard exists for streams in this watershed.

Table 19. Descriptive statistics of fecal coliform bacteria (number of colonies per 100 ml) for tributary samples.

	Number of Measurements	Mean	Median	Minimum	Maximum	Standard Deviation
CLO01	8	268	235	5	700	244
CLT02	8	640	560	50	2,000	635
CLT03	9	37	30	5	80	24
CLT04	9	44,932	360	5	400,000	133,153

Lake Physical and Chemical Parameters

Water Temperature

Water temperature in Cresbard Lake ranged from 0.16 to 22.73 (mean = 10.49) degrees Celsius (Figure 14). State standards require water temperatures to be maintained below 32.2 degrees Celsius to support the beneficial use of warmwater semipermanent fish propagation. Maximum temperature was reached in July; however, this measurement did not exceed the standard.

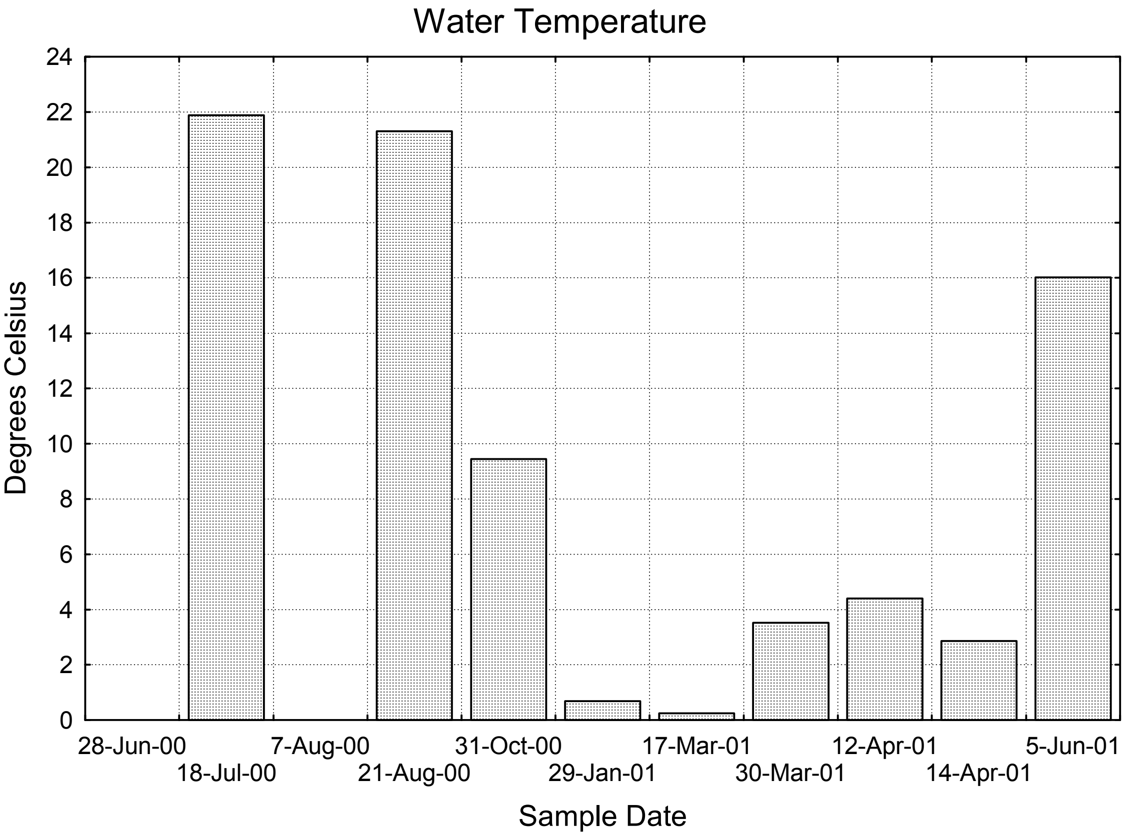

Figure 14. Average water temperature for Cresbard Lake by sample date. This is an average of both sites and all measured depths. NOTE: data were not collected on two sampling dates: 28-Jun-00 and 7-Aug-00.

Dissolved Oxygen

Dissolved oxygen (DO) is made available by photosynthetic inputs from algae/aquatic plants and through diffusion from the atmosphere. Conversely, microbial degradation of dead algae and aquatic plants consumes oxygen. In eutrophic (productive) lakes, a high rate of production and subsequent decomposition of organic matter can result in low or no oxygen in the hypolimnion (Monson, 2000). This trend was observed during the summer months in Cresbard Lake.

DO values ranged from 1.99 to 26.70 mg/L (mean = 7.37). Lowest oxygen values were observed in August (Figure 15). A DO criterion of 5.0 mg/L is required to support both warmwater semipermanent fish propagation and immersion recreation. Approximately 39% of the DO measurements fell below state standard.

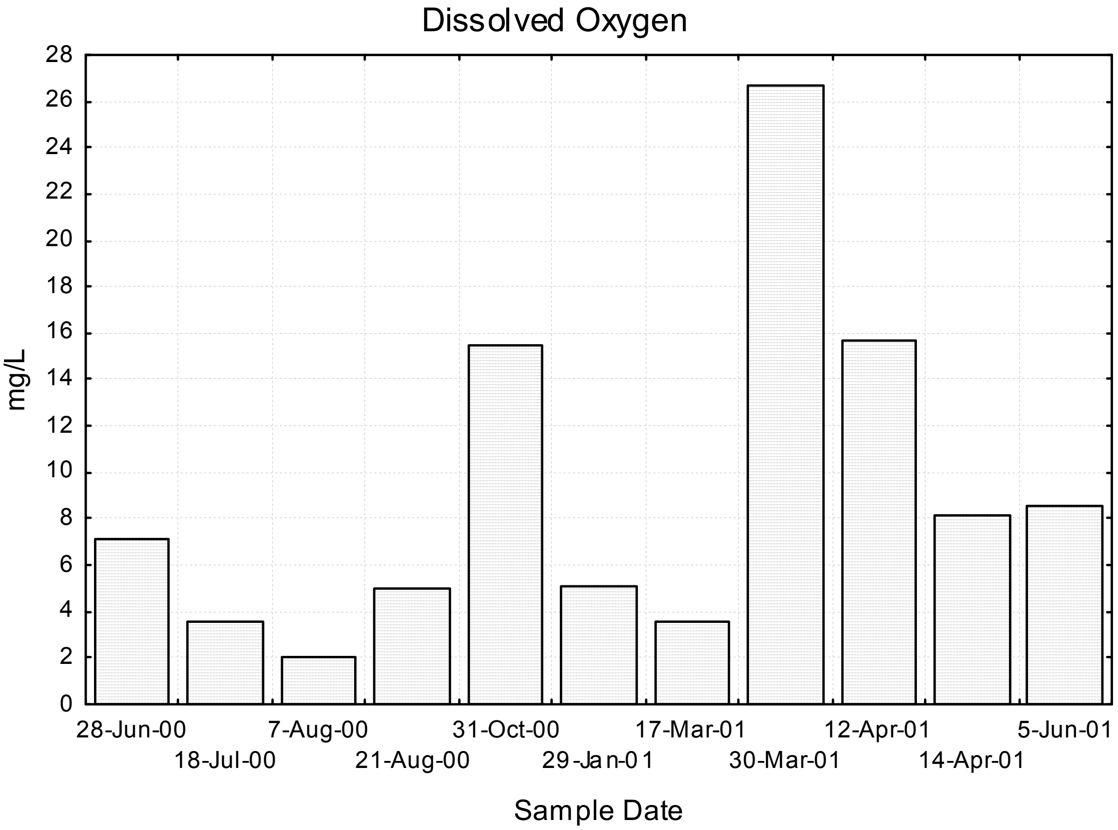

Figure 15. Average dissolved oxygen concentrations for Cresbard Lake by sample date.

Conductivity

Conductivity is a measure of the ability of water to conduct an electric current. This characteristic varies with water temperature and the quantity of dissolved ions present. Conductivity can be correlated to system productivity, since high nutrient waters have high conductivity. However, other factors including non-nutrient salts also influence conductivity. Thus, conductivity is often used as a surrogate measure of salinity. As conductivity/salinity increases, there is a general decrease in aquatic animal diversity. This is due to the tolerance limits of organisms to salinity and to lower levels of dissolved oxygen. The solubility of oxygen decreases with increased salinity (Dodds, 2002).

Conductivity values in Cresbard Lake ranged from 379 to 868 umhos (mean = 584). Highest values were observed in March 2001 (Figure 17). The conductivity standard for Cresbard Lake is ≤7,000 umhos/cm. This criterion was established for the beneficial use of fish and wildlife propogation, recreation, and stock watering. Measurements collected in Cresbard Lake did not exceed this standard.

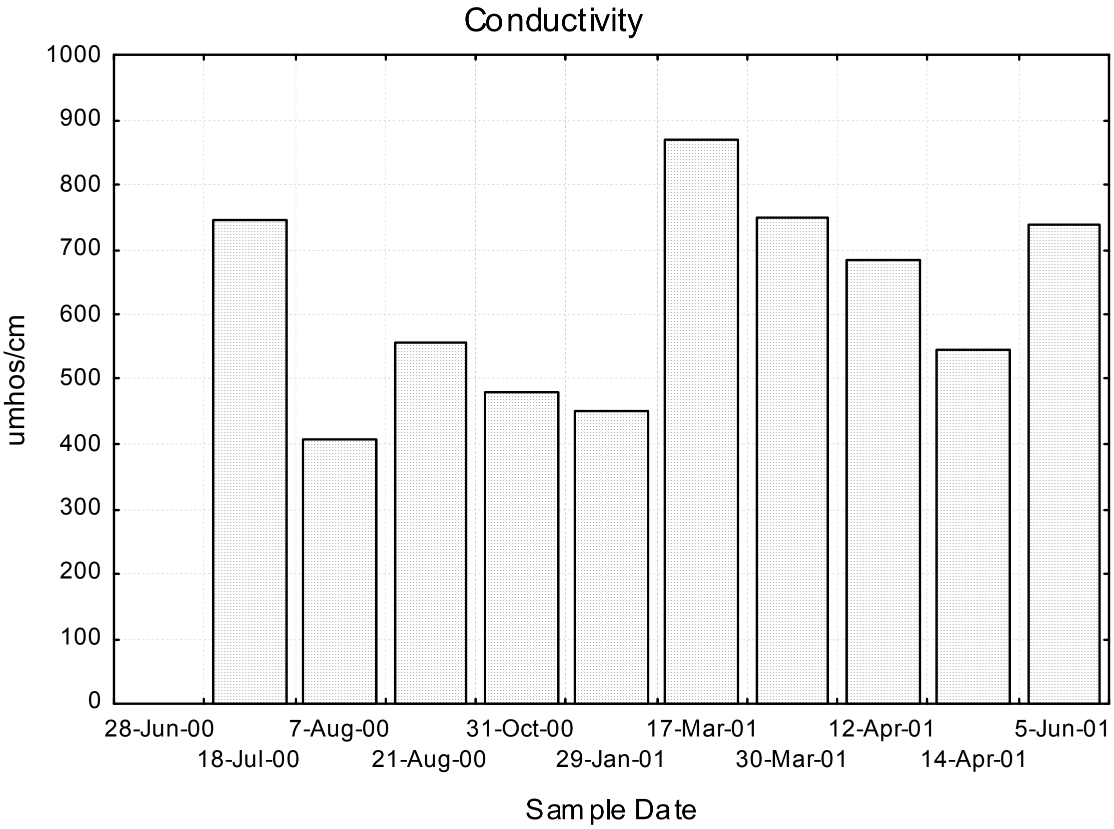

Figure 16. Average conductance by sampling date for Cresbard Lake. NOTE: no measurement was taken on 28-Jun-00.

Acidification and Alkalinity

As previously stated, the primary measurements of acidification are alkalinity and pH. In Cresbard Lake, pH values ranged from 6.90 to 8.78 (mean = 8.16). None of these measurements exceeded state standard, which requires values within a range of 6.5 to 9.0 (Figure 17).

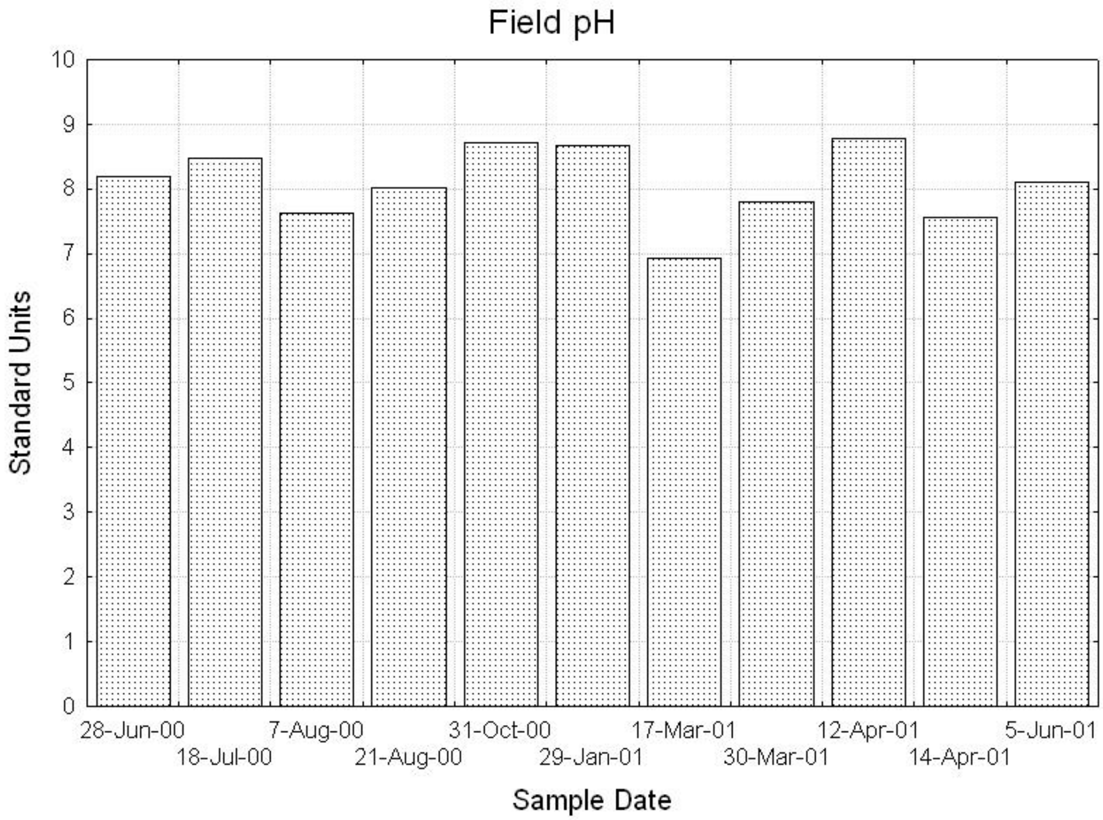

Figure 17. Average pH by sampling date for Cresbard Lake.

Alkalinity is a measure of the buffering capacity of a waterbody. Alkalinity measurements in Cresbard Lake were highly variable throughout the sampling period, ranging from 9 to 235 mg/L (mean = 166). Large rain events in August 2000 and April 2001 (Figure 1) most likely caused the dramatic decreases in alkalinity concentrations due to a dilution effect. The alkalinity standard for Cresbard Lake is ≤1313 mg/L (Figure 18). No samples exceeded the state standard.

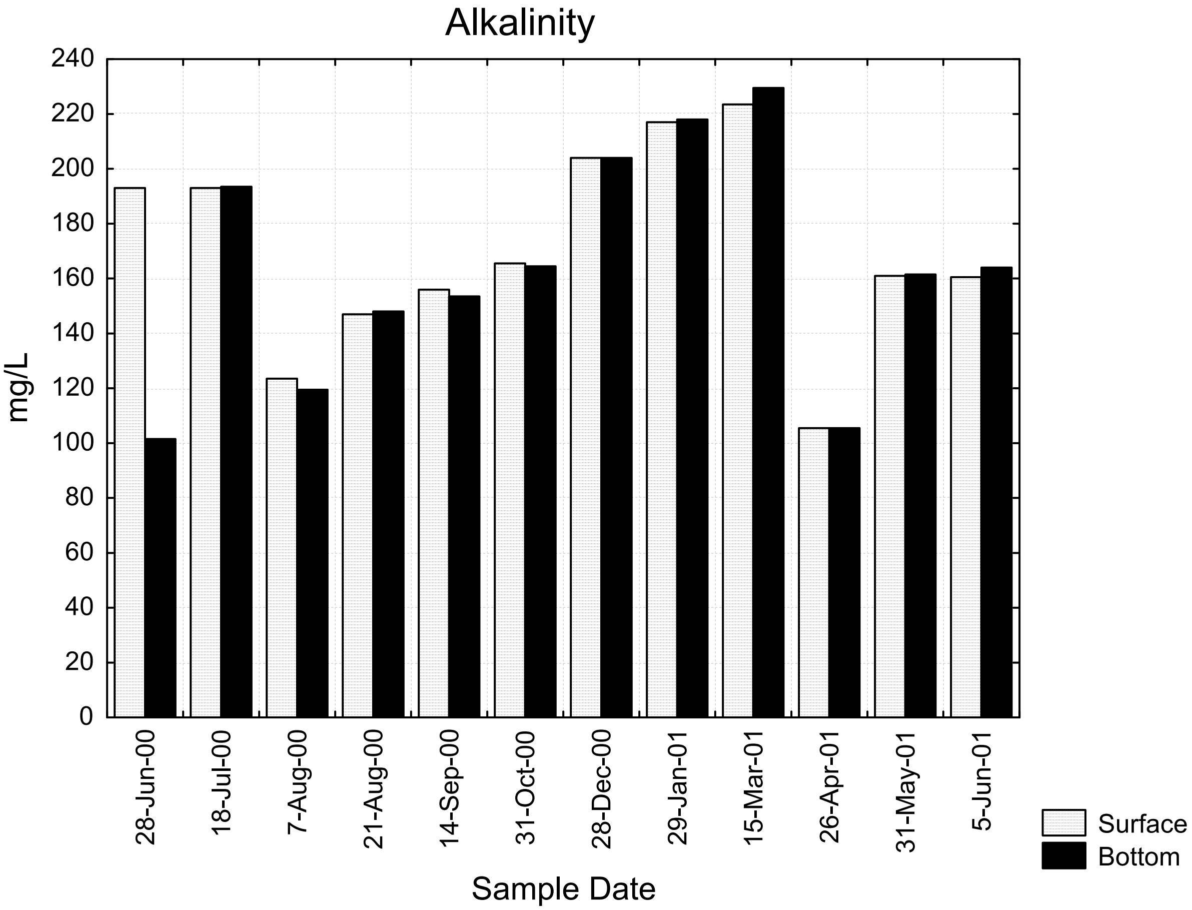

Figure 18. Average alkalinity of surface and bottom samples by sampling date for Cresbard Lake.

Solids

Total solids (suspended and dissolved) in Cresbard Lake ranged from 318 to 686 mg/L (mean = 538). Similar to alkalinity concentrations, total solids concentrations also displayed significant variation throughout the sampling period and dramatic decreases in August 2000 and April 2001 (Figure 19). These months experienced highest monthly precipitation averages (Figure 2). Thus, the low solids concentrations for these months may be due to a dilution effect.

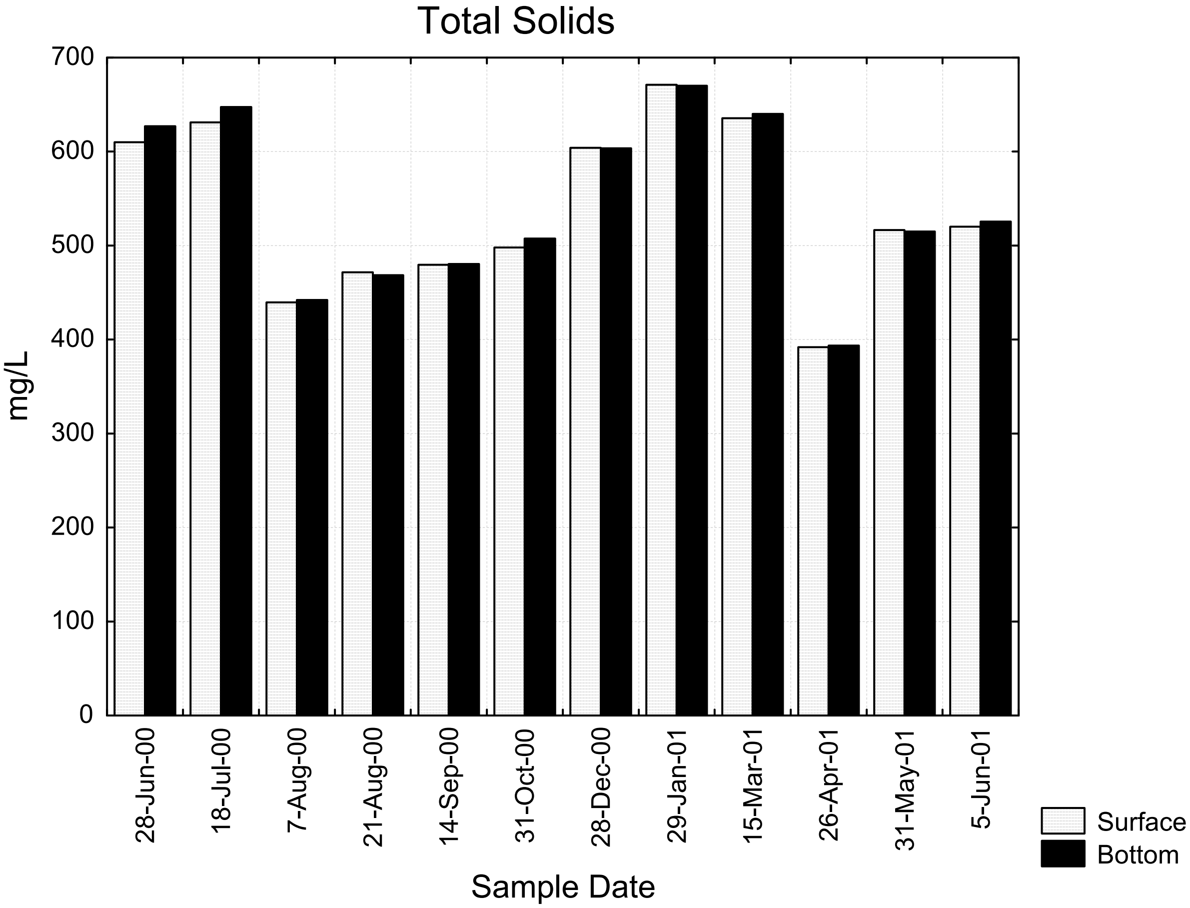

Figure 19. Average surface and bottom concentrations of total solids by sample date for Cresbard Lake.

Typical of most waterbodies, total solids were mostly comprised of dissolved solids. Dissolved solids consist of salts and compounds that increase alkalinity. This direct relationship was observed in Cresbard Lake. As total dissolved solids (TDS) increased, alkalinity increased (Figure 20). TDS ranged from 306 to 641 mg/L (mean = 522). The TDS standard for Cresbard Lake is ≤ 4,375 mg/L.

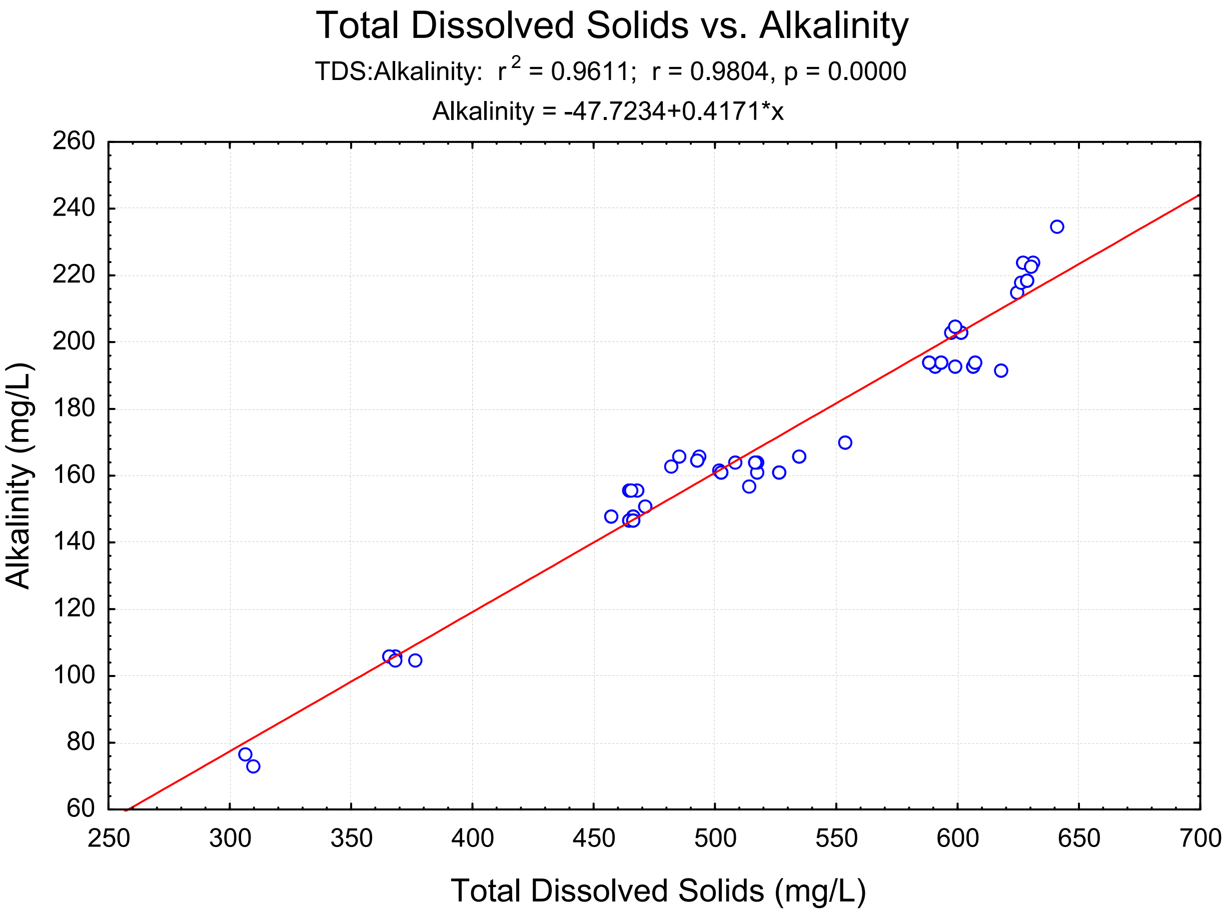

Figure 20. Scatter plot of total dissolved solids versus alkalinity with regression line. One outlier was removed from this plot.

Total suspended solids (TSS) ranged from 2 to 70 mg/L (mean = 16) (Figure 21). TSS concentrations should be maintained below 158 mg/L in Cresbard Lake to support its fishery. This standard was not exceeded.

Relative concentrations of organic (volatile) and inorganic forms of suspended solids were comparable within samples. On average, volatile suspended solids comprised 44% of TSS. As expected, percent of volatile suspended solids was higher for surface samples than for bottom samples. Approximately 46% of TSS from surface samples was organic, while 39% of TSS from bottom samples was organic. The slightly higher proportion of organic suspended solids in the surface samples are likely the result of algae growth.

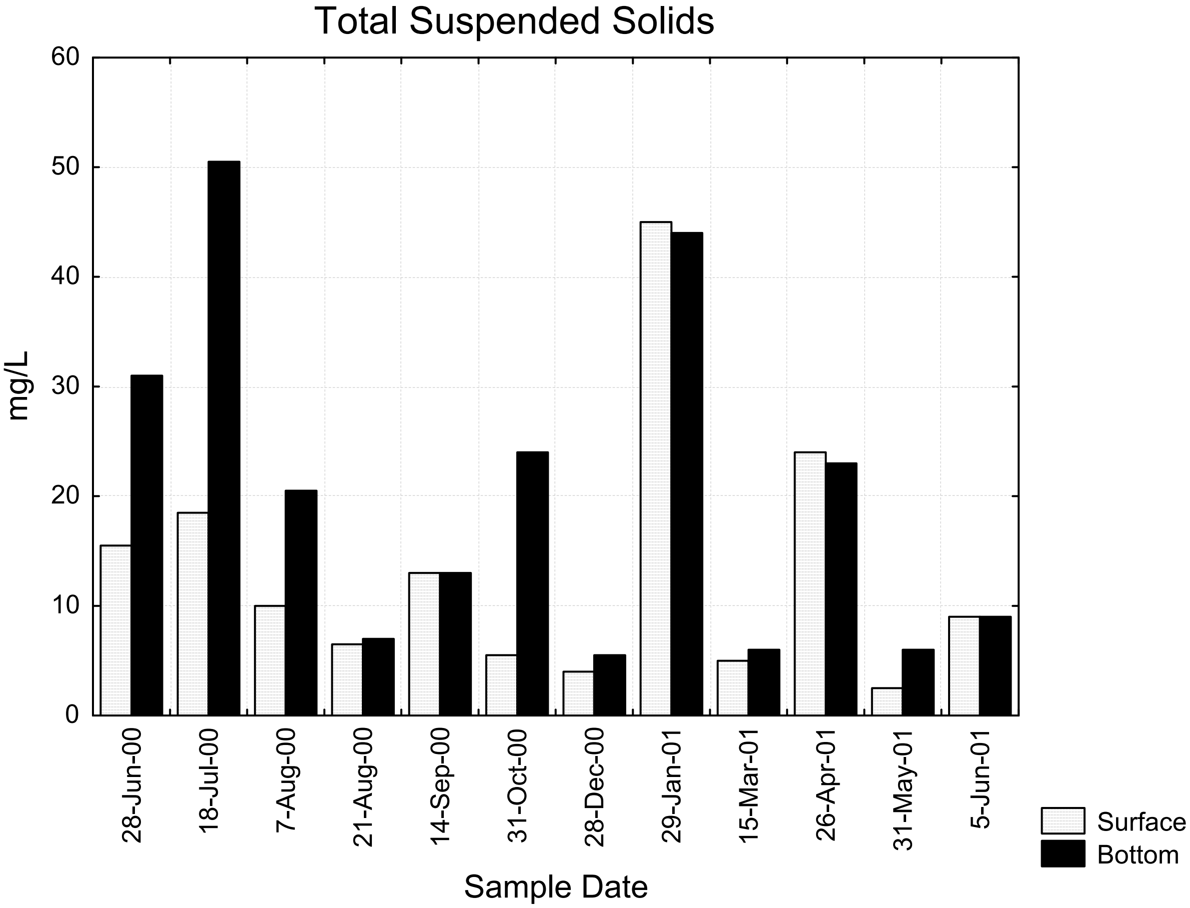

Figure 21. Average surface and bottom concentrations of total suspended solids by sample date for Cresbard Lake.

Nitrogen

Several forms of nitrogen can be found in a waterbody. Natural sources of nitrogen include precipitation, biological processes (i.e. nitrogen fixation), and surface and groundwater drainage. Anthropogenic nitrogen sources include sewage inputs of organic nitrogen and agricultural fertilizer applications.

Total Kjeldahl Nitrogen (TKN) is a measure of organic nitrogen plus ammonia. Therefore, organic nitrogen can be calculated by subtracting ammonia from TKN. In Cresbard Lake, the amount of organic nitrogen far exceeded inorganic forms. Average organic nitrogen concentration was 1.45 mg/L. Average inorganic nitrogen (ammonia and nitrate/nitrite) concentration was 0.21 mg/L.

Ammonia is the nitrogen end product of bacterial decomposition of organic matter. This form of nitrogen is most readily available to algae and aquatic plants for uptake and growth. Sources of ammonia may include animal wastes, decayed organic matter, or bacterial conversion of other nitrogen compounds. Ammonia is present in water primarily in two forms: NH_4^+ (ionized form) and NH_4OH (unionized form). The unionized or "undissociated" form is highly toxic to many organisms, especially fish (Wetzel, 2001). For this reason, the state standard for ammonia is limited specifically to unionized ammonia.

When samples are analyzed for ammonia, 0.02 mg/L is designated as the detection limit. In other words, a concentration of ammonia below 0.02 mg/L is considered undetectable. Ammonia levels were below the detection limit in 38% of the samples collected in Cresbard Lake. These samples were assigned values of half of the detection limit (0.01), assuming that a trace amount was present. Ammonia concentrations ranged from <0.02 to 0.54 mg/L (mean = 0.10) (Figure 22). Several samples displayed elevated ammonia concentrations, however, concentrations dropped to below the detection limit in samples taken one month later. Inorganic forms of nitrogen, including ammonia and nitrate, are quickly consumed by aquatic plants and algae and can become the limiting factor for growth.

Corrected for pH and temperature, unionized ammonia ranged from 0.0002 to 0.0184 mg/L (mean = 0.0037). None of the unionized ammonia values were in violation of state standard.

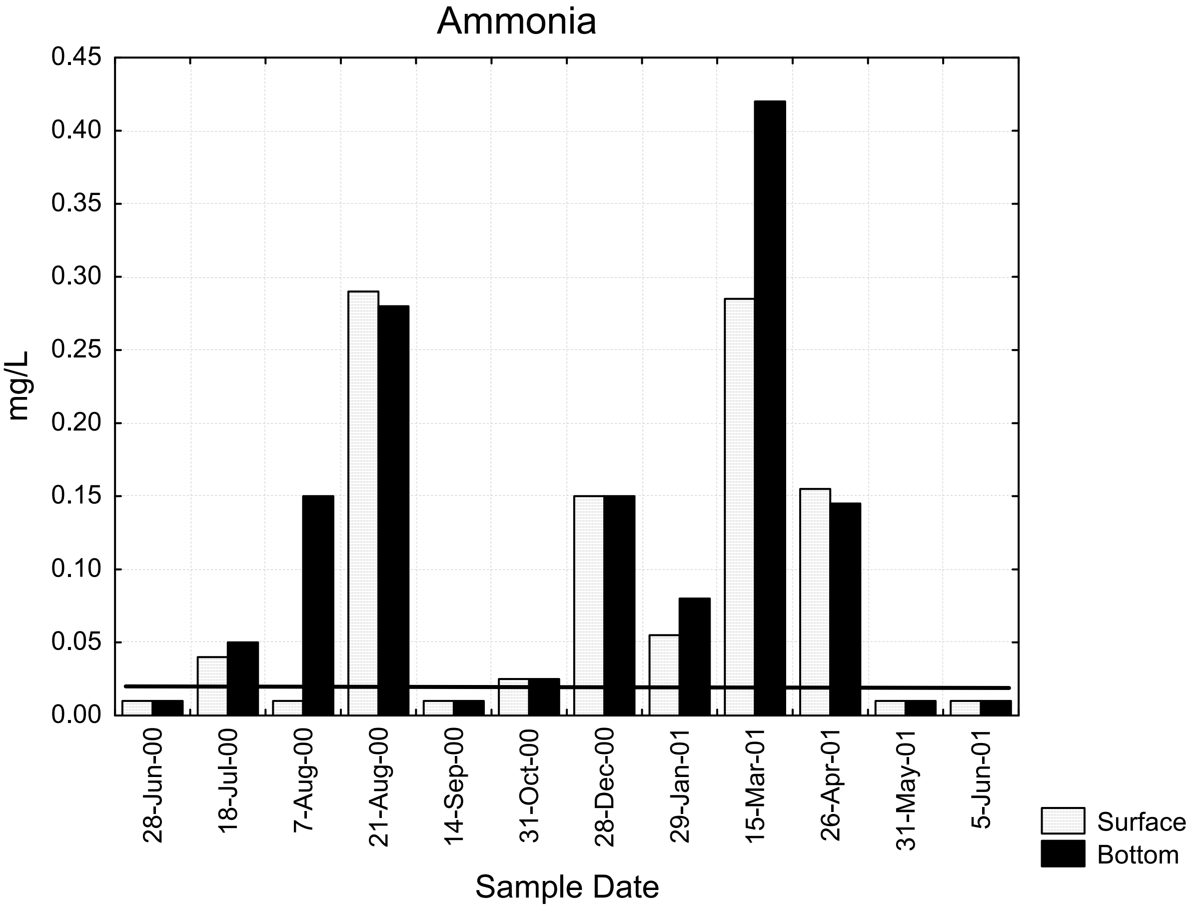

Figure 22. Average surface and bottom concentrations of total ammonia by sample date for Cresbard Lake. Line is detection limit (0.02 mg/L).

Nitrate is usually present in low concentrations in natural waters, yet it is often the most abundant inorganic form of nitrogen. Natural concentrations rarely exceed 10 mg/L and are normally less than 1 mg/L (Lind, 1985).

For nitrate analysis, 0.1 mg/L is designated as the detection limit. Nitrate levels were recorded below the detection limit in 81% of the samples collected in Cresbard Lake. These samples were assigned values of half of the detection limit (0.05). Nitrate concentrations in Cresbard Lake ranged from < 0.10 to 0.50 mg/L (mean = 0.11) (Figure 23). No samples exceeded the nitrate standard (≤ 88 mg/L).

Similar to concentrations of ammonia, maximum nitrate concentrations were observed in samples collected on August 7, 2000 and April 26, 2001 following major rain events.

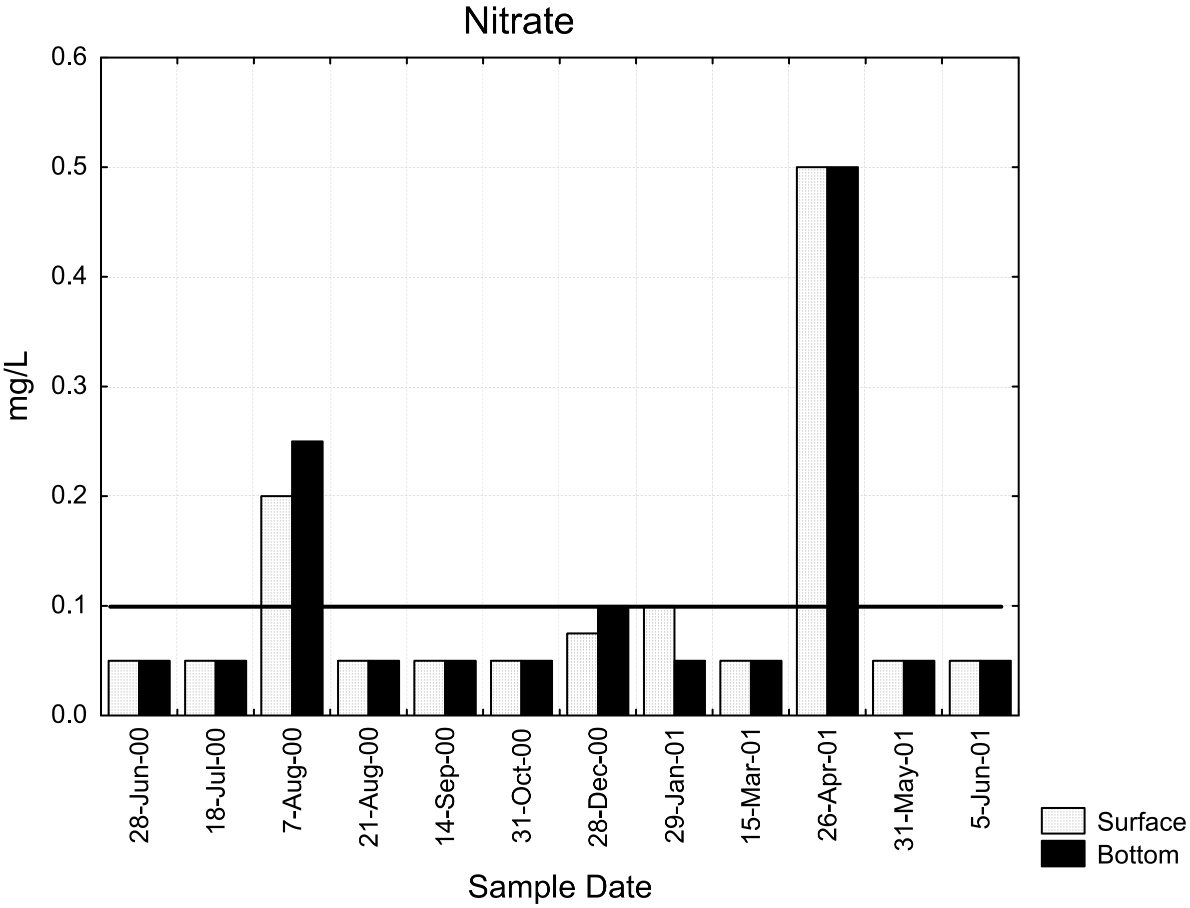

Figure 23. Average surface and bottom concentrations of nitrate by sample date for Cresbard Lake. Line is detection limit (0.1 mg/L).

Total nitrogen can be calculated by adding TKN and nitrate/nitrite concentrations. Total nitrogen values were used to determine whether nitrogen is a limiting nutrient in Cresbard Lake (see limiting nutrient section). Total nitrogen in Cresbard Lake ranged from 1.04 to 2.63 mg/L (mean = 1.66) (Figure 24).

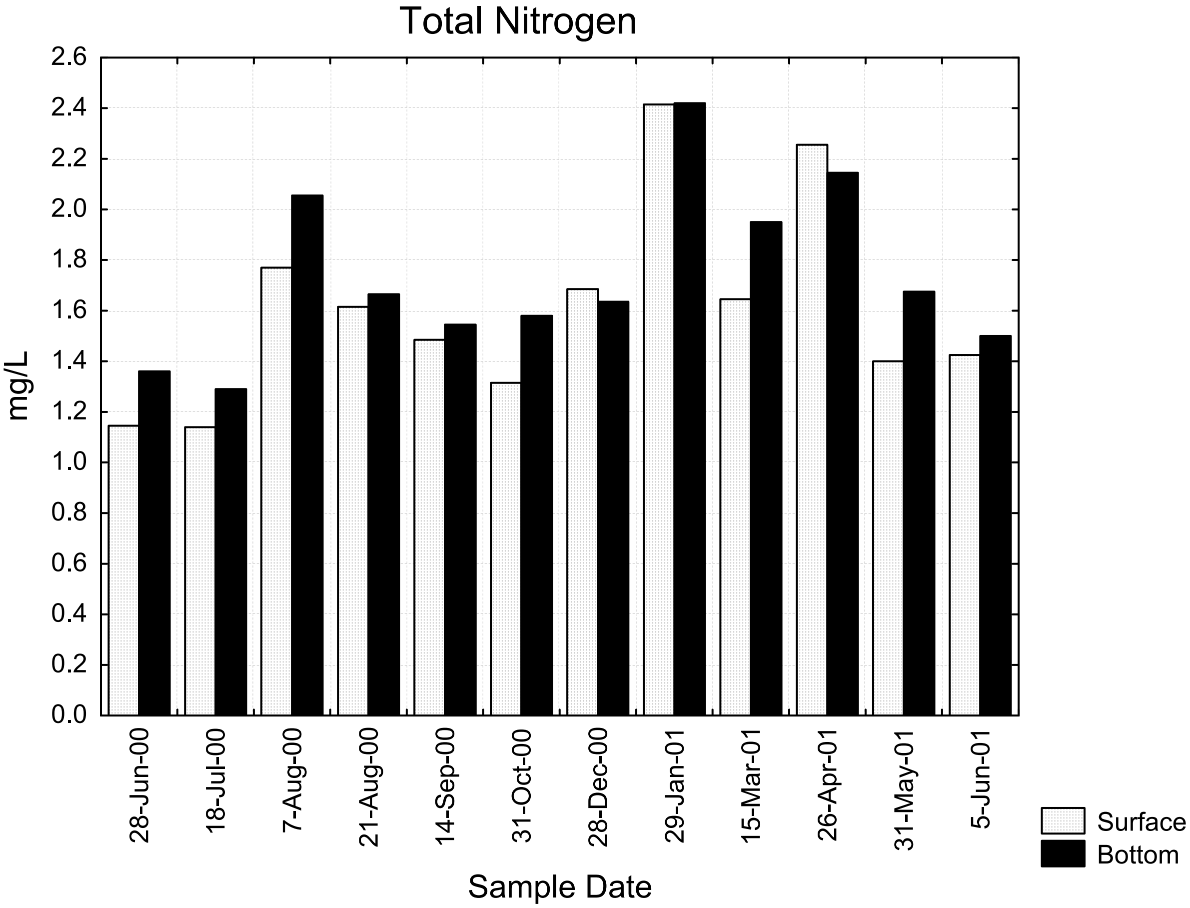

Figure 24. Average surface and bottom concentrations of total nitrogen by sample date for Cresbard Lake.

Phosphorus

Like nitrogen, phosphorus is a biologically active element. It cycles through different states in the aquatic environment, and its concentration in any one state depends on the degree of biological assimilation or decomposition occurring in that system. The predominant inorganic form of phosphorus in lake systems is orthophosphate. Concentrations of orthophosphate were measured as total dissolved phosphorus (TDP) in this study.

Total phosphorus concentrations of non-polluted waters are usually less than 0.1 mg/L (Lind, 1985). Total phosphorus values in Cresbard Lake ranged from 0.172 to 1.060 mg/L (mean = 0.577). Maximum concentrations of phosphorus were observed in August, following a large rain event (Figure 25).

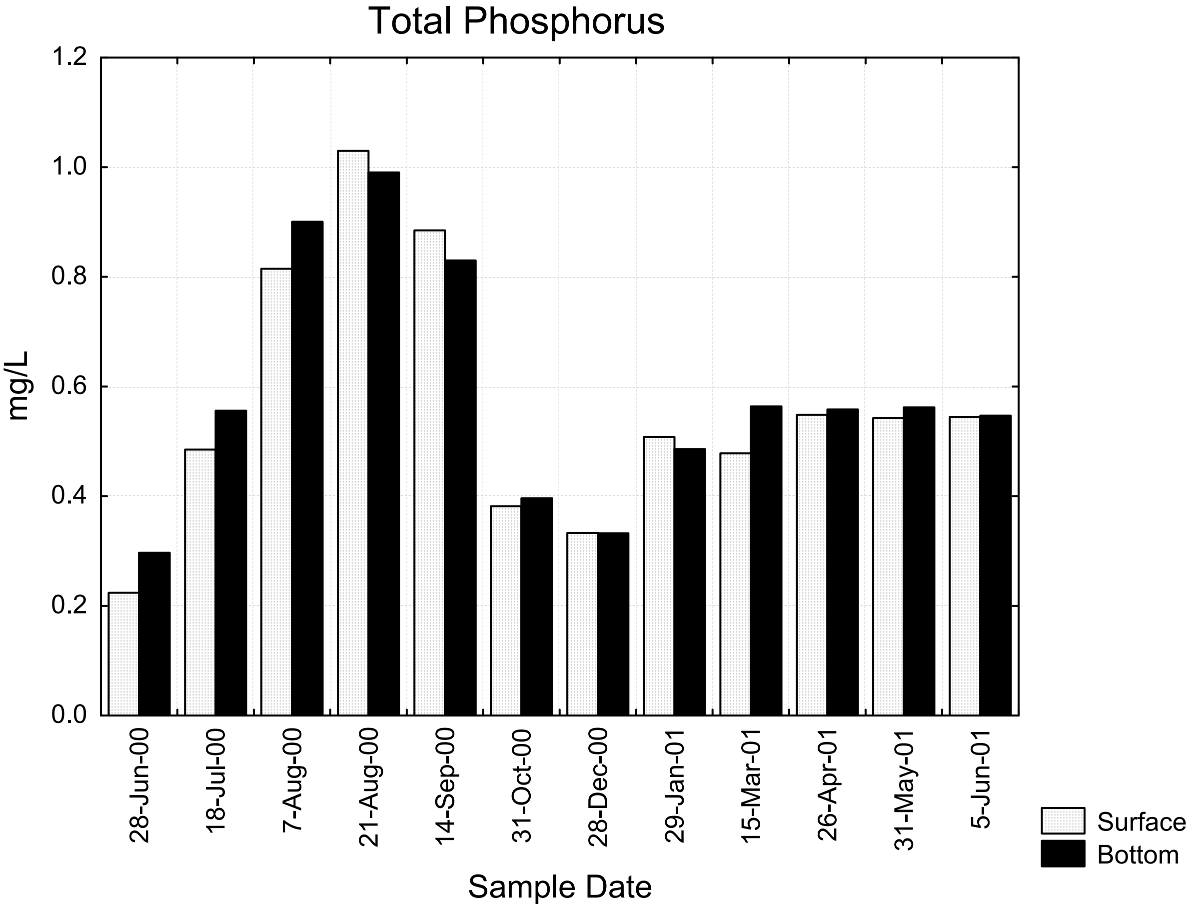

Figure 25. Average surface and bottom concentrations of total phosphorus by sample date for Cresbard Lake.

Phosphorus is often a limiting nutrient to algae and macrophyte production within many aquatic systems. Loading of this nutrient allows for increased eutrophication (primary production). TDP is the portion of total phosphorus that is readily available for aquatic plant or algae utilization. TDP concentrations of non-polluted waters are usually less than 0.01 mg/L (Lind, 1985). TDP concentrations in Cresbard Lake ranged from 0.128 to 1.060 mg/L (mean = 0.485). Concentrations were well above the minimum amount for rapid algal growth, which requires only 0.02 mg/L (Figure 26).

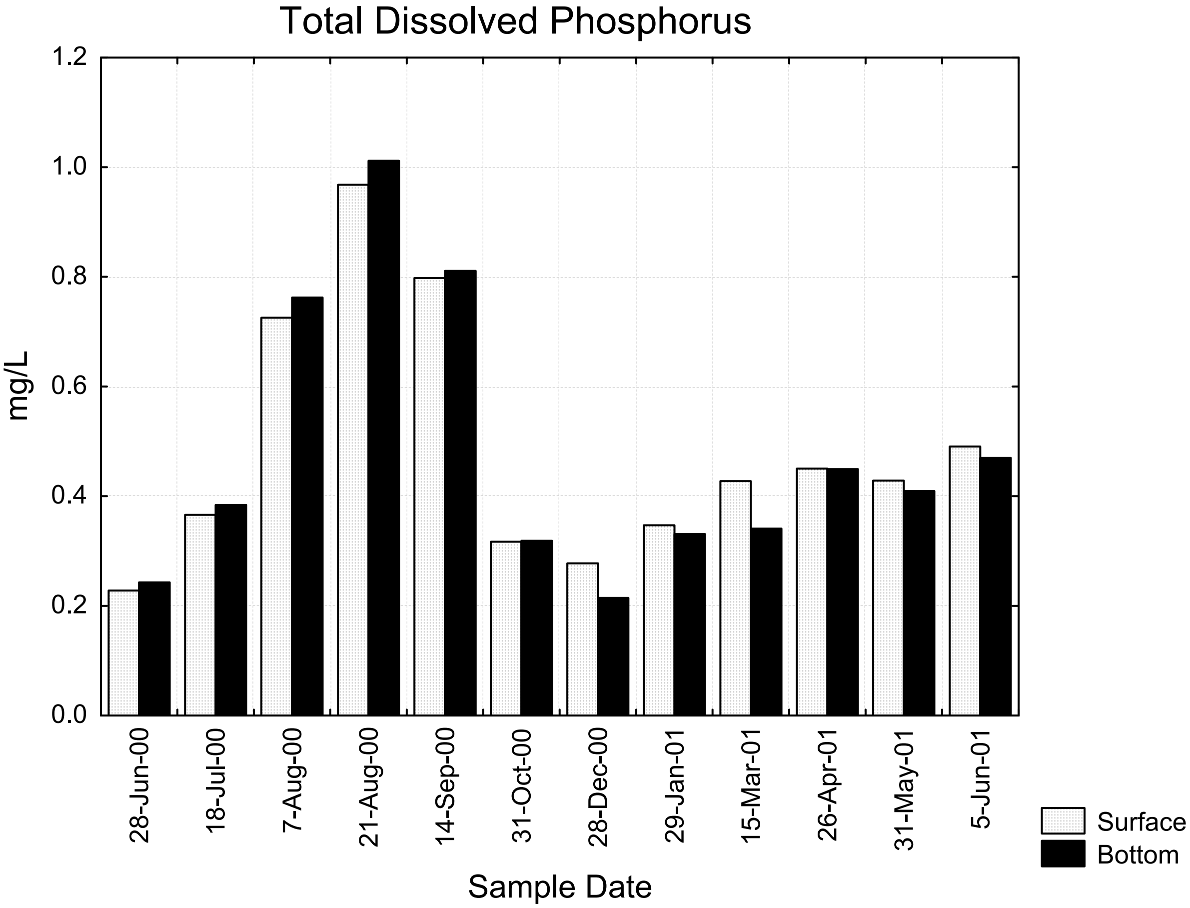

Figure 26. Average surface and bottom concentrations of total dissolved phosphorus by sample date for Cresbard Lake.

Limiting Nutrients

Eutrophication is a term used to describe increased biological production (especially algae and aquatic plants) in lakes due to human impacts (Wetzel, 2001). Great emphasis is placed on regulating nutrient loading to waterbodies to control aquatic productivity. In aquatic systems, the most significant nutrient factors causing the shift from a lesser to a more productive state are phosphorus and nitrogen. Nitrogen is difficult to control because of its highly soluble nature. From a management perspective, phosphorus is easier to manipulate. Consequently, it is most often the nutrient targeted for reduction when attempting to control lake eutrophication.

When either nitrogen or phosphorus reduces the potential for algal growth and reproduction, it is considered the limiting nutrient. Optimal nitrogen and phosphorus concentrations for aquatic plant growth occur at a ratio of 10:1 (N:P ratio). N:P ratios greater than 10:1 indicate a phosphorus-limited system, while N:P ratios less than 10:1 indicate a nitrogen-limited system (USEPA, 1990).

All samples collected in Cresbard Lake were nitrogen-limited. N:P ratios for Cresbard Lake ranged from 1.5:1 to 7.3:1 (Figure 27). The average ratio across all sample dates was 3.3:1.

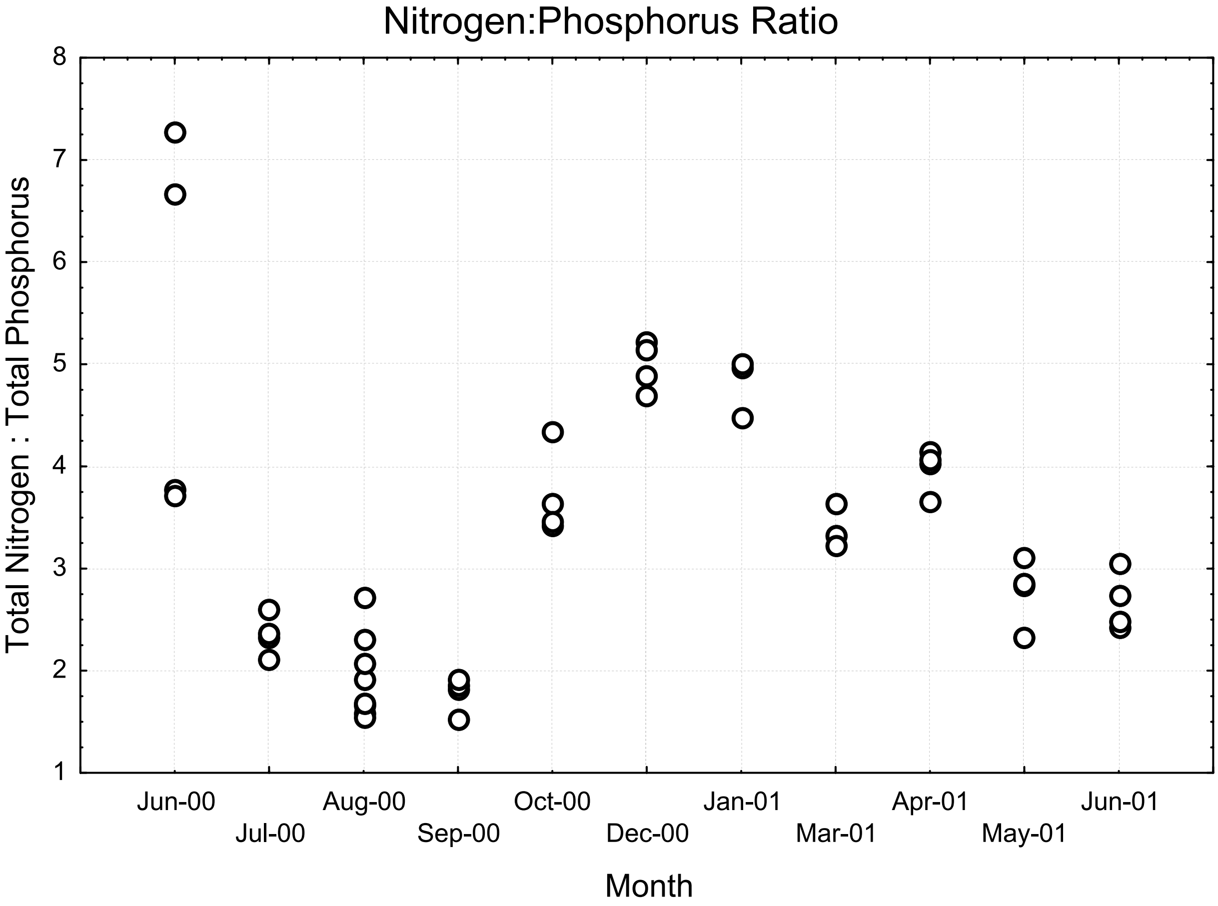

Figure 27. Nitrogen:phosphorus ratios for Cresbard Lake. All samples were nitrogen-limited.

Trophic State

Wetzel (2001) defines 'trophy' of a lake as "the rate at which organic matter is supplied by or to a lake per unit time." Trophic state is often measured as the amount of algal production in a lake, which is one source of organic material. Determinations of trophic state can be made from several different measures including oxygen levels, species composition of lake biota, concentrations of nutrients, and various measures of biomass or production. An index incorporating several of these parameters is best suited to determine trophic state.

The Trophic State Index (TSI) was used to determine the approximate trophic state of Cresbard Lake (Carlson, 1977). This index incorporates measures of Secchi disk transparency, chlorophyll *a*, and total phosphorus into scores ranging from 0 to 100 with each 10-unit increase representing a doubling in algal biomass. Four ranges of index values define Carlson's trophic levels, which include oligotrophic, mesotrophic, eutrophic, and hyper-eutrophic. These levels and their numeric ranges are listed in Table 20 in order of increasing productivity.

Table 20. Carlson's trophic levels and index ranges for each level.

Trophic Level	TSI Range
Oligotrophic	0 - 35
Mesotrophic	36 - 50
Eutrophic	51 - 65
Hyper-eutrophic	66 - 100

TSI values were calculated for each of the three index parameters separately. Chlorophyll TSI values ranged from 55 to 86 (mean = 71), phosphorus TSI values ranged from 78 to 105 (mean = 95), and Secchi depth TSI values ranged from 55 to 79 (mean = 66) (Figure 28). These values were averaged to obtain an overall TSI value or "mean TSI." Only seven mean TSI values could be calculated due to limited chlorophyll and Secchi depth data. Despite limited data, mean TSI values indicate trophic levels comparable to individual TSI parameters (Table 21). Mean TSI average was 78, which is considered hyper-eutrophic. Phosphorus TSI values displayed the greatest variability with early summer months being the most variable (Figure 29). Still, all phosphorus TSI values indicate hyper-eutrophic conditions in Cresbard Lake.

Table 21. Descriptive statistics for observed trophic state index (TSI) values calculated from direct measurements and samples collected in Cresbard Lake.

	Phosphorus TSI	Chlorophyll TSI	Secchi TSI	Mean TSI
Number of Measurements	46	14	23	7
Average	94.7045	70.7231	66.4144	78.4863
Minimum	78.4169	55.3753	54.5091	75.7335
Maximum	104.658	86.177	78.891	81.683
Standard Deviation	6.079	7.689	9.180	2.475

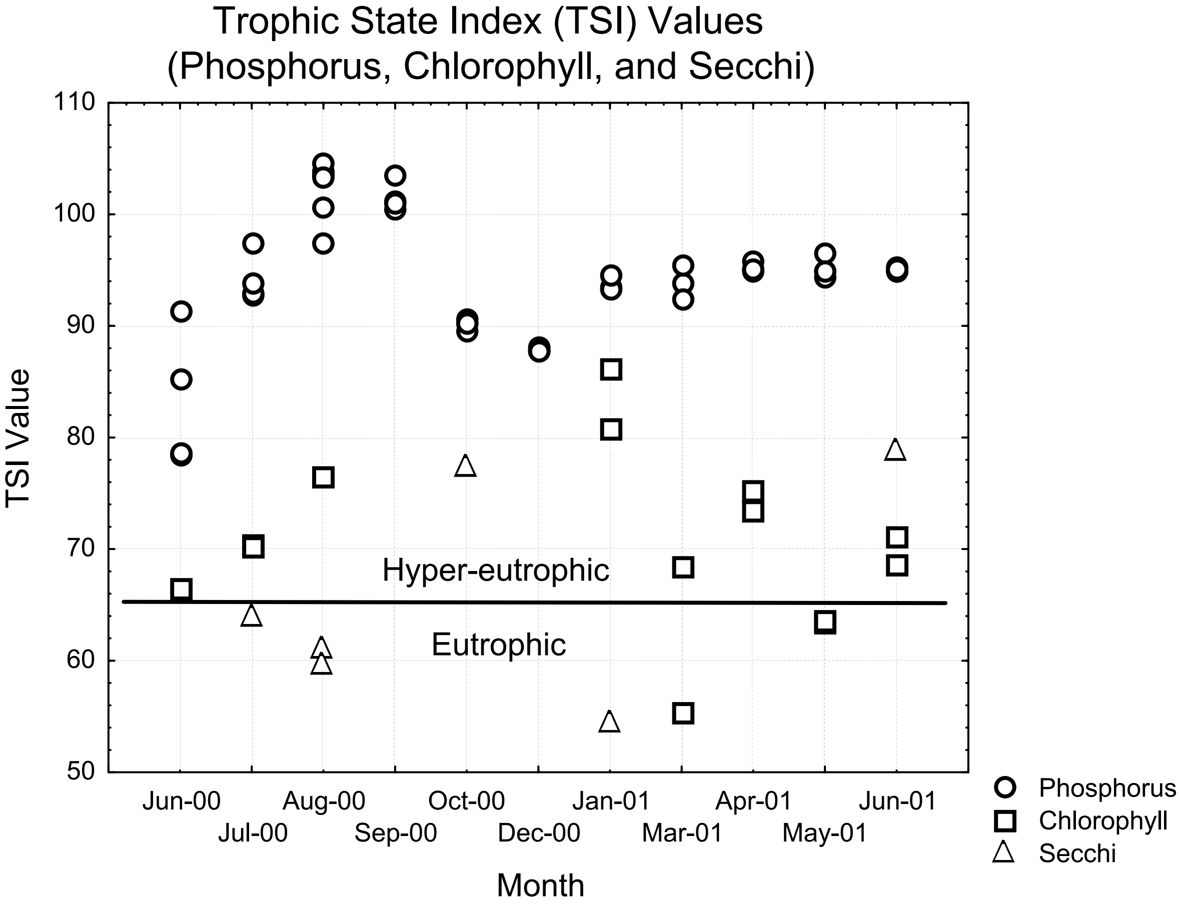

Figure 28. Cresbard Lake observed Secchi depth, phosphorus, and chlorophyll TSI values by month. Lines indicate Carlson's trophic levels.

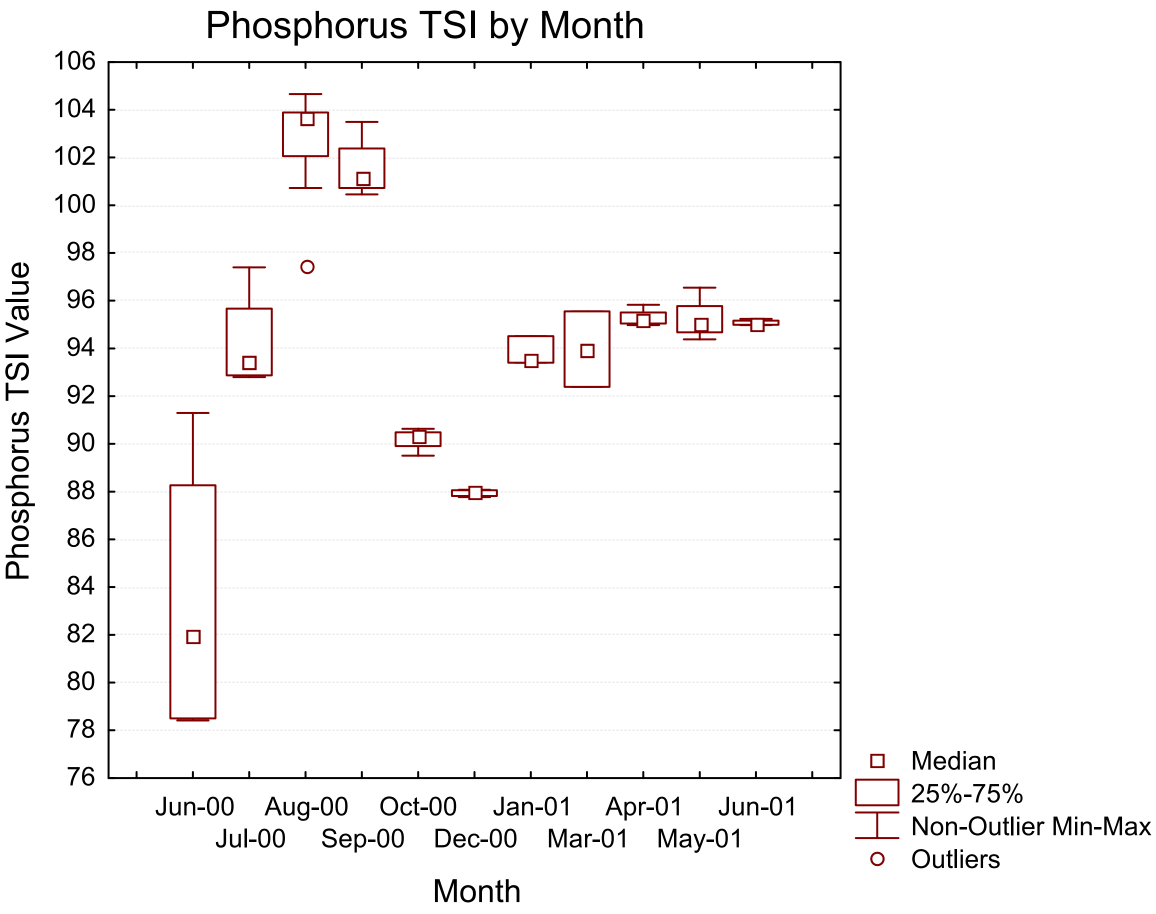

Figure 29. Observed phosphorus TSI by month for Cresbard Lake.

Beneficial use attainment for Cresbard Lake was also assessed using TSI values. USEPA has approved the use of ecoregion specific criteria to evaluate beneficial use attainment. Stueven et al. (2000b) determined TSI criteria for beneficial use classifications that are specific to each South Dakota ecoregion. Cresbard Lake is located in the Northern Glaciated Plains Ecoregion. Numeric TSI criteria of beneficial use categories for the Northern Glaciated Plains Ecoregion are listed in Table 22. TSI values during the study period were plotted in Figure 30 using the ecoregion specific criteria. It is important to note that TSI values span all beneficial use categories throughout the project period. However, phosphorus TSI values are all within the non-supporting range.

Table 22. Beneficial use categories for the Northwestern Glaciated Plains Ecoregion with TSI criteria.

Beneficial Use Category	TSI Criteria
Non-supporting	> 75
Partially Supporting	65 – 75
Fully Supporting	< 65

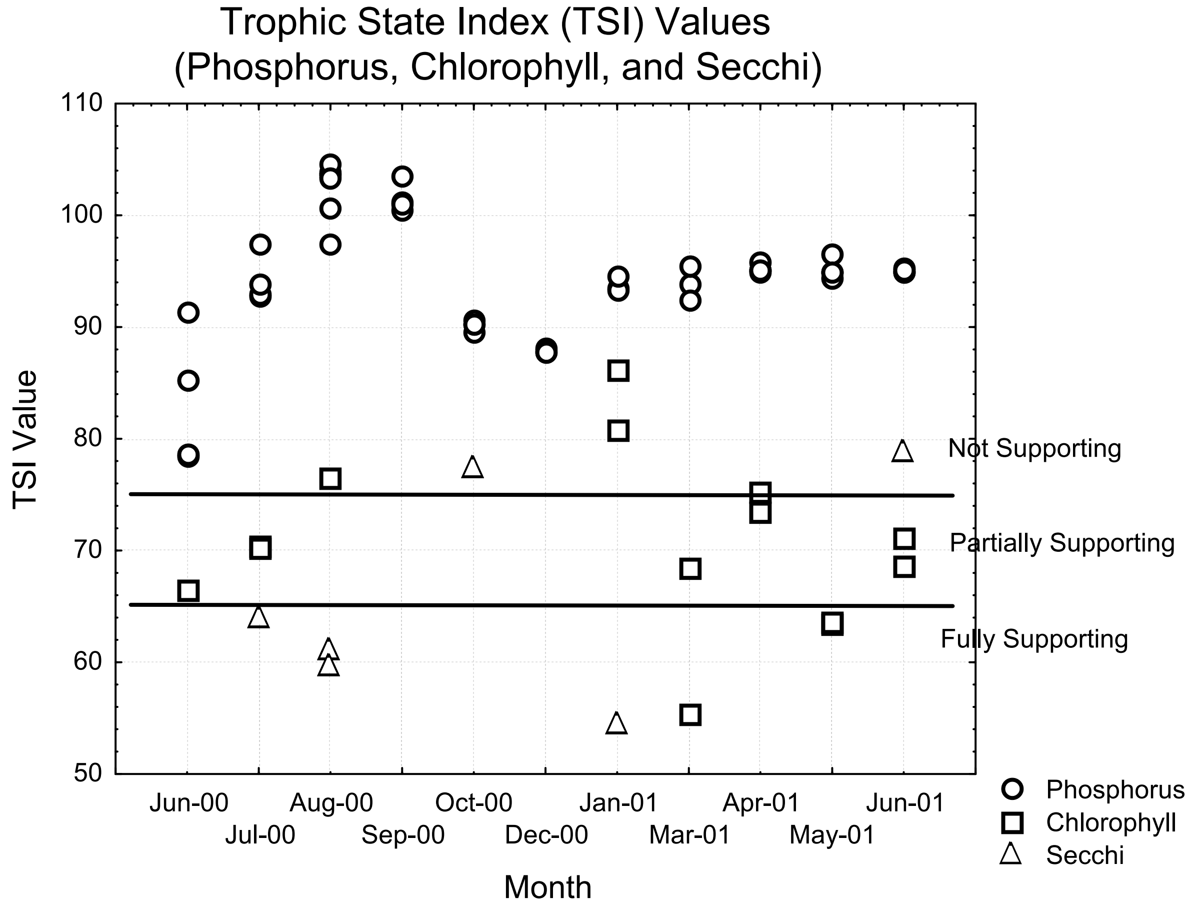

Figure 30. Cresbard Lake Secchi depth, phosphorus, and chlorophyll TSI values by month. Lines indicate beneficial use classifications for the Northern Glaciated Plains Ecoregion.

Reduction Response Model

Inlake reduction response modeling was conducted using BATHTUB, a eutrophication response model designed by the United States Army Corps of Engineers (US ACOE, 1999). The model predicts changes in water quality parameters related to eutrophication (phosphorus, nitrogen, chlorophyll *a*, and transparency) using empirical relationships previously developed and tested for reservoir applications. Lake and tributary sample data were used to calculate existing conditions in Cresbard Lake. Tributary loading data was obtained from the FLUX model output. Inlet phosphorus and nitrogen concentrations were reduced in increments of 10% and modeled to generate an inlake reduction curve.

As anticipated, the predicted inlake concentrations of total nitrogen and phosphorus decreased as modeled tributary loads decreased (Table 23). Individual parameter (phosphorus, chlorophyll, and Secchi) TSI values decreased with the reduction of nitrogen and phosphorus load. Phosphorus TSI values were markedly higher than chlorophyll and secchi TSI values. All predicted phosphorus TSI values with less than an 80% reduction in load were in the non-supporting beneficial use category (Figure 31). Consequently, mean TSI values are amplified due to the high in-lake concentrations of total phosphorus.

Table 23. BATHTUB model-predicted concentrations of total phosphorus and TSI values with successive 10-percent reductions in phosphorus inputs. TSI values are plotted on the following graphs.

Percent Reduction	Total Phosphorus Concentration (ppb)	Predicted TSI value Phosphorus	Predicted TSI value Chlorophyll	Predicted TSI value Secchi Depth	Predicted TSI value Mean
0%	324.9	87.6	71.5	70.9	76.7
10%	306.4	86.7	71.4	70.8	76.3
20%	287.0	85.8	71.3	70.6	75.9
30%	266.3	84.7	71.1	70.5	75.4
40%	244.1	83.4	70.9	70.2	74.8
50%	220.2	81.9	70.6	69.9	74.1
60%	193.6	80.1	70.2	69.5	73.2
70%	163.6	77.7	69.6	68.8	72.0
80%	128.3	74.2	68.5	67.7	70.1
90%	83.1	67.9	65.9	65.2	66.3
95%	52.1	61.2	62.2	61.9	61.8
99%	17.0	45.0	48.9	54.4	49.4

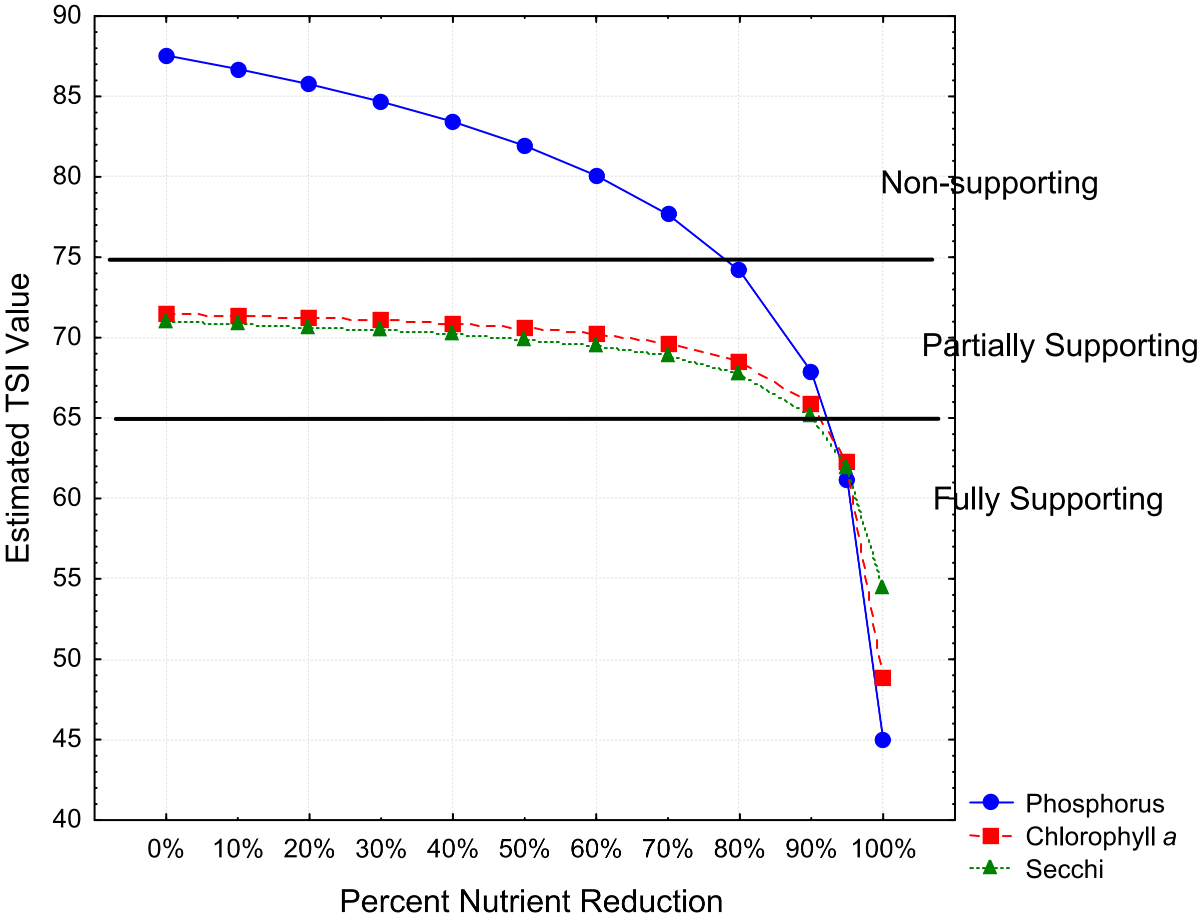

Figure 31. Model-predicted phosphorus, chlorophyll, and Secchi depth TSI values with successive 10-percent reductions in nutrient loading. Solid lines indicate beneficial use classifications for the Northwestern Glaciated Plains Ecoregion.

Predicted mean TSI value with no reduction of load was 76.7, which is classified as non-supporting beneficial uses. The model indicates a 40% reduction in phosphorus load is required to bring mean TSI values to an ecoregion-based beneficial use classification of partially supporting and a 95% reduction to achieve fully supporting status. However, a 40% reduction of phosphorus load is an attainable reduction and will meet the watershed-specific criteria (Figure 32).

Although BATHTUB model output indicates a 95% percent reduction is needed to meet ecoregion-based beneficial use criteria, economic and technical limitations prohibit this level of phosphorus load reduction. Drastic and unrealistic changes in land use and management would be necessary in order to achieve ecoregion-based beneficial use criteria. Thus, the TMDL should be derived from watershed-specific criteria, which are based on modeled, attainable reductions within the Cresbard Lake watershed. An appropriate TMDL goal for Cresbard Lake is a 40% reduction in total phosphorus load, yielding a mean TSI of 74.8 (Table 23).

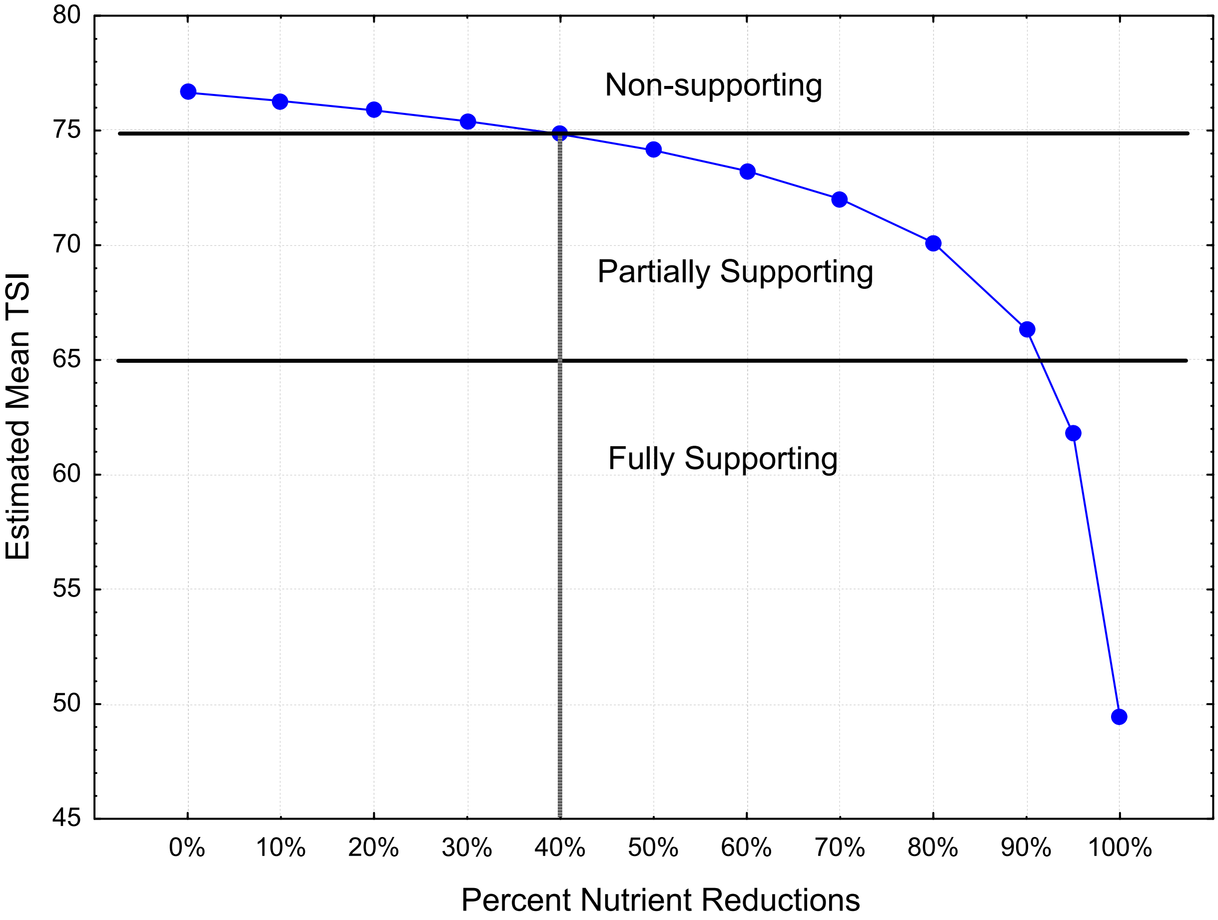

Figure 32. Model-predicted mean TSI values with successive 10-percent reductions in nutrient loading. Horizontal lines indicate beneficial use classifications for the Northwestern Glaciated Plains Ecoregion. Vertical line indicates an attainable percent reduction that will meet watershed-specific criteria.

Lake Biological Parameters

Fishery

The South Dakota Department of Game, Fish and Parks (SDGF&P) last conducted a fish survey on May 28, 1997. Electrofishing methods were used to sample the fish community along most of the shoreline.

Due to a winter kill during 1996-97, a limited number of species was sampled from this survey. The largemouth bass population that once inhabited Cresbard Lake was not sampled during this survey. Black crappie and northern pike were the only two species sampled.

At the time the report was written, the SDGF&P researcher recommended another assessment using frame nets and electrofishing methods and stockings of largemouth bass and panfish. The complete fisheries report for Cresbard Lake may be found in Appendix B.

Phytoplankton

Surface samples were collected monthly at the two inlake water quality monitoring sites, CL-1 and CL-2, from June 28, 2000 to June 5, 2001 (
Figure 3). The lake was not sampled in February 2001 and two samples were collected during the month of August 2000. A total of 111 algal taxa, including four unidentified categories, were identified for the period of this survey. Algae species richness in Cresbard Lake was rated as 'high' during this study when compared with other recently monitored eutrophic state lakes. Non-motile green algae (Chlorophyta : Chlorococcales) were the most diverse group of planktonic algae with 40 taxa collected, excluding 5 green flagellate species.

Diatoms (Bacillariophyceae) and five phyla of flagellated (motile) algae represented the next most diverse algae groups in Cresbard Lake with totals of 28 and 27 taxa, respectively. Yellow-brown flagellates (Chrysophyta) and dinoflagellates (Pyrrhophyta) were the most diverse of the motile algae with 9 and 7 taxa, respectively, followed by green flagellates (comprised mainly of *Chlamydomonas* sp.) with 5 taxa; and euglenoids (Euglenophyta) and cryptomonads (Cryptophyta) with 3 taxa each. Blue-green algae accounted for 14 taxa (Table 24).

In terms of annual algal biovolume (approximate biomass) produced during the period of this assessment, Cresbard Lake ranks in the lower 50% of monitored eutrophic state lakes. However, seasonal algae populations were probably 'artificially' reduced in this small reservoir, through dilution and flushing out, by relatively large rainfall events in late June and August 2000 and April 2001 (Figure 2 andFigure 33). Algae biovolume ranged from 480,030 um^3/ml in late April 2001 to 6,174,470 um^3/ml on January 29, 2001 (Table 25). Corresponding algal abundance (population density) for those dates was 3,839 cell/ml and 82,429 cells/ml, respectively. Average monthly density and biovolume for the study period was 14,533 cells/ml and 2,617,449 um3/ml, respectively.

Table 24. Cresbard Lake algae taxa list with algal type.

Taxa	Algal Type	Taxa	Algal Type
Actinastrum hantzschii	Non-Motile Green Algae	*Micractinium sp.*	Non-Motile Green Algae
Anabaena circinalis	Blue Green Algae	*Microcystis aeruginosa*	Blue Green Algae
Anabaena flos-aquae	Blue Green Algae	*Mougeotia sp.*	Non-Motile Green Algae
Anabaena sp.	Blue Green Algae	*Navicula sp.*	Diatom
Ankistrodesmus falcatus	Non-Motile Green Algae	*Nephrocytium sp.*	Non-Motile Green Algae
Ankistrodesmus sp.	Non-Motile Green Algae	*Nitzschia acicularis*	Diatom
Aphanizomenon flos-aquae	Blue Green Algae	*Nitzschia capitellata*	Diatom
Aphanocapsa sp.	Blue Green Algae	*Nitzschia dissipata*	Diatom
Aphanothece nidulans	Blue Green Algae	*Nitzschia microcephala*	Diatom
Asterionella formosa	Diatom	*Nitzschia paleacea*	Diatom
Ceratium hirundinella	Dinoflagellate	*Nitzschia sp.*	Diatom
Characium limneticum	Non-Motile Green Algae	*Nitzschia vermicularis*	Diatom
Characium sp.	Non-Motile Green Algae	*Ochromonas sp.*	Flagellated Algae
Chlamydomonas sp.	Flagellated Algae	*Oocystis lacustris*	Non-Motile Green Algae
Chlorella sp.	Non-Motile Green Algae	*Oocystis pusilla*	Non-Motile Green Algae
Chromulina sp.	Flagellated Algae	*Oocystis sp.*	Non-Motile Green Algae
Chroococcus minimus	Blue Green Algae	*Oscillatoria agardhii*	Blue Green Algae
Chrysochromulina parva	Flagellated Algae	*Oscillatoria limnetica*	Blue Green Algae
Chrysococcus rufescens	Flagellated Algae	*Oscillatoria sp.*	Blue Green Algae
Closteriopsis longissima	Non-Motile Green Algae	*Pandorina morum*	Flagellated Algae
Closteriopsis sp.	Non-Motile Green Algae	*Pediastrum duplex*	Non-Motile Green Algae
Closterium aciculare	Non-Motile Green Algae	*Peridinium cinctum*	Dinoflagellate
Cocconeis pediculus	Diatom	*Peridinium sp.*	Dinoflagellate
Cocconeis placentula	Diatom	*Plectonema notatum*	Blue Green Algae
Cocconeis sp.	Diatom	*Pleodorina sp.*	Flagellated Algae
Coelastrum cambricum	Non-Motile Green Algae	*Pteromonas angulosa*	Flagellated Algae
Coelastrum microporum	Non-Motile Green Algae	*Quadrigula sp.*	Non-Motile Green Algae
Coelastrum sp.	Non-Motile Green Algae	*Rhodomonas minuta*	Flagellated Algae
Crucigenia quadrata	Non-Motile Green Algae	*Rhodomonas minuta*	Flagellated Algae
Crucigenia tetrapedia	Non-Motile Green Algae	*Scenedesmus acuminatus*	Non-Motile Green Algae
Cryptomonas erosa	Flagellated Algae	*Scenedesmus arcuatus v. capitatus*	Non-Motile Green Algae
Cryptomonas sp.	Flagellated Algae	*Scenedesmus arcuatus v. platydisca*	Non-Motile Green Algae
Cyclotella meneghiniana	Diatom	*Scenedesmus armatus*	Non-Motile Green Algae
Cyclotella sp.	Diatom	*Scenedesmus bijuga*	Non-Motile Green Algae
Cyclotella stelligera	Diatom	*Scenedesmus quadricauda*	Non-Motile Green Algae
Dactylococcopsis sp.	Blue Green Algae	*Scenedesmus sp.*	Non-Motile Green Algae
Dictyosphaerium pulchellum	Non-Motile Green Algae	*Schroederia judayi*	Non-Motile Green Algae
Dinobryon sertularia	Flagellated Algae	*Schroederia setigera*	Non-Motile Green Algae
Elakatothrix sp.	Non-Motile Green Algae	*Scourfieldia sp.*	Flagellated Algae
Euglena sp.	Flagellated Algae	*Selenastrum minutum*	Non-Motile Green Algae
Fragilaria capucina	Diatom	*Selenastrum sp.*	Non-Motile Green Algae
Fragilaria crotonensis	Diatom	*Sphaerocystis schroeteri*	Non-Motile Green Algae
Glenodinium sp.	Dinoflagellate	*Stephanodiscus hantzschii*	Diatom
Gomphonema sp.	Diatom	*Stephanodiscus minutus*	Diatom
Gymnodinium palustre	Dinoflagellate	*Stephanodiscus niagarae*	Diatom
Gymnodinium sp.	Dinoflagellate	*Surirella angusta*	Diatom
Gyrosigma sp.	Diatom	*Surirella sp.*	Diatom
Hemidinium sp.	Dinoflagellate	*Synedra sp.*	Diatom
Kirchneriella sp.	Non-Motile Green Algae	*Synura sp.*	Flagellated Algae
Lyngbya subtilis	Blue Green Algae	*Tetrastrum sp.*	Non-Motile Green Algae
Mallomonas akrokomos	Flagellated Algae	*Tetrastrum staurogeniaeforme*	Non-Motile Green Algae
Mallomonas sp.	Flagellated Algae	*Trachelomonas hispida*	Flagellated Algae
Mallomonas tonsurata	Flagellated Algae	*Trachelomonas sp.*	Flagellated Algae
Melosira granulata	Diatom	Unidentified algae	Unidentified algae
Melosira granulata	Diatom	Unidentified flagellates	Flagellated Algae
Melosira granulata v. angustissima	Diatom	Unidentified green algae	Non-Motile Green Algae
		Unidentified pennate diatoms	Diatom

Table 25. Density and Biovolume of algal groups for Cresbard Lake.

Date	Group	Cells/ml	Density %	Biovolume	Biovolume %
28-Jun-00	Blue Green Algae	1,026	26.5%	110,125	2.2%
28-Jun-00	Diatom	463	12.0%	4,437,000	87.2%
28-Jun-00	Dinoflagellate	81	2.1%	340,200	6.7%
28-Jun-00	Flagellated Algae	1,168	30.2%	140,612	2.8%
28-Jun-00	Non-Motile Green Algae	1,127	29.2%	60,309	1.2%
28-Jun-00	**Total**	**3,865**		**5,088,246**	
18-Jul-00	Blue Green Algae	6,691	79.6%	819,216	31.9%
18-Jul-00	Diatom	223	2.7%	1,459,242	56.8%
18-Jul-00	Dinoflagellate	56	0.7%	109,200	4.2%
18-Jul-00	Flagellated Algae	152	1.8%	4,220	0.2%
18-Jul-00	Non-Motile Green Algae	1,286	15.3%	178,665	7.0%
18-Jul-00	**Total**	**8,408**		**2,570,543**	
7-Aug-00	Blue Green Algae	8,102	58.2%	805,752	36.4%
7-Aug-00	Diatom	1,042	7.5%	268,104	12.1%
7-Aug-00	Dinoflagellate	139	1.0%	375,700	17.0%
7-Aug-00	Flagellated Algae	2,895	20.8%	523,060	23.6%
7-Aug-00	Non-Motile Green Algae	1,748	12.6%	239,460	10.8%
7-Aug-00	**Total**	**13,926**		**2,212,076**	
21-Aug-00	Blue Green Algae	3,462	60.6%	405,054	39.1%
21-Aug-00	Diatom	40	0.7%	13,610	1.3%
21-Aug-00	Flagellated Algae	713	12.5%	211,836	20.4%
21-Aug-00	Non-Motile Green Algae	1,500	26.2%	406,673	39.2%
21-Aug-00	**Total**	**5,715**		**1,037,173**	
12-Sep-00	Blue Green Algae	2,889	29.7%	338,013	9.1%
12-Sep-00	Diatom	1,268	13.0%	977,410	26.2%
12-Sep-00	Dinoflagellate	16	0.2%	11,200	0.3%
12-Sep-00	Flagellated Algae	1,652	17.0%	764,352	20.5%
12-Sep-00	Non-Motile Green Algae	3,907	40.1%	1,634,320	43.9%
12-Sep-00	**Total**	**9,732**		**3,725,295**	
31-Oct-00	Blue Green Algae	675	15.8%	14,795	0.8%
31-Oct-00	Diatom	212	5.0%	780,830	44.2%
31-Oct-00	Dinoflagellate	4	0.1%	3,150	0.2%
31-Oct-00	Flagellated Algae	2,777	64.9%	848,970	48.0%
31-Oct-00	Non-Motile Green Algae	253	5.9%	109,567	6.2%
31-Oct-00	Unidentified algae	355	8.3%	10,650	0.6%
31-Oct-00	**Total**	**4,276**		**1,767,962**	
29-Jan-01	Blue Green Algae	3,064	3.7%	50,620	0.8%
29-Jan-01	Diatom	506	0.6%	146,755	2.4%
29-Jan-01	Dinoflagellate	202	0.2%	256,650	4.2%
29-Jan-01	Flagellated Algae	75,387	91.5%	5,615,410	90.9%
29-Jan-01	Non-Motile Green Algae	60	0.1%	8,735	0.1%
29-Jan-01	Unidentified algae	3,210	3.9%	96,300	1.6%
29-Jan-01	**Total**	**82,429**		**6,174,470**	
15-Mar-01	Blue Green Algae	300	3.8%	1,200	0.1%
15-Mar-01	Flagellated Algae	6,873	87.6%	908,031	97.7%
15-Mar-01	Non-Motile Green Algae	10	0.1%	250	0.0%
15-Mar-01	Unidentified algae	660	8.4%	19,800	2.1%
15-Mar-01	**Total**	**7,843**		**929,281**	
26-Apr-01	Blue Green Algae	370	9.6%	10,520	2.2%
26-Apr-01	Diatom	1,504	39.2%	308,480	64.3%
26-Apr-01	Dinoflagellate	4	0.1%	5,850	1.2%
26-Apr-01	Flagellated Algae	701	18.3%	82,608	17.2%
26-Apr-01	Non-Motile Green Algae	540	14.1%	50,972	10.6%
26-Apr-01	Unidentified algae	720	18.8%	21,600	4.5%
26-Apr-01	**Total**	**3,839**		**480,030**	
31-May-01	Blue Green Algae	205	2.9%	5,190	0.3%
31-May-01	Diatom	156	2.2%	71,750	4.1%
31-May-01	Flagellated Algae	4,230	60.6%	1,044,150	59.3%
31-May-01	Non-Motile Green Algae	2,117	30.3%	630,514	35.8%
31-May-01	Unidentified algae	270	3.9%	8,100	0.5%
31-May-01	**Total**	**6,978**		**1,759,704**	
5-Jun-01	Blue Green Algae	460	3.6%	5,300	0.2%
5-Jun-01	Diatom	754	5.9%	454,340	14.9%
5-Jun-01	Dinoflagellate	25	0.2%	57,600	1.9%
5-Jun-01	Flagellated Algae	8,693	67.7%	2,170,970	71.2%
5-Jun-01	Non-Motile Green Algae	1,607	12.5%	319,648	10.5%
5-Jun-01	Unidentified algae	1,310	10.2%	39,300	1.3%
5-Jun-01	**Total**	**12,849**		**3,047,158**	

The phytoplankton population during this study consisted of several phyla of flagellated taxa, primarily cryptomonads, *Chromulina* sp. and *Chlamydomonas* sp., which made up 43% of total algae numbers and 41% of total biovolume. Blue-green algae, mostly *Aphanizomenon* sp., comprised 27% of algal density but only 11% of total biovolume. This was in contrast to diatoms which contributed only 8% to total algal abundance but made up nearly 29% of the volume due to the presence of relatively moderate numbers of a large-sized centric species, *Stephanodiscus niagarae* (Table 26). Non-motile green algae were the next most common group, comprising 17% of population density and 15% of total biovolume. Dinoflagellates were of minor significance in Cresbard Lake during this survey, contributing less than 1% in numbers and 3% in total volume. However, in late July 1989, a summer bloom of *Glenodinium gymnodinium* constituted 66% of algal numbers and more than 90% of total biovolume (SDDENR, 1996). Unidentified algae made up 5% of total algae density and 1% of biovolume during the present survey.

Table 26. Cresbard Lake algae taxa list with algal group sorted by relative density.

Taxa	Density %	Algal Group	Taxa	Density %	Algal Group
Unidentified flagellates	17.68%	Flagellated Algae	Unidentified pennate diatoms	0.05%	Diatom
Chromulina sp.	15.50%	Flagellated Algae	*Nephrocytium sp.*	0.05%	Non-Motile Green Algae
Rhodomonas minuta	15.44%	Flagellated Algae	*Oscillatoria limnetica*	0.04%	Blue Green Algae
Aphanizomenon flos-aquae	11.15%	Blue Green Algae	*Dactylococcopsis sp.*	0.04%	Blue Green Algae
Cryptomonas sp.	7.11%	Flagellated Algae	*Cocconeis placentula*	0.04%	Diatom
Chlamydomonas sp.	6.95%	Flagellated Algae	*Melosira granulata v. angustissima*	0.04%	Diatom
Unidentified algae	4.08%	Unidentified algae	*Nitzschia capitellata*	0.04%	Diatom
Cryptomonas erosa	1.75%	Flagellated Algae	*Oocystis lacustris*	0.03%	Non-Motile Green Algae
Pediastrum duplex	1.70%	Non-Motile Green Algae	*Anabaena sp.*	0.03%	Blue Green Algae
Oocystis pusilla	1.62%	Non-Motile Green Algae	*Scenedesmus armatus*	0.03%	Non-Motile Green Algae
Oscillatoria sp.	1.59%	Blue Green Algae	*Dictyosphaerium pulchellum*	0.03%	Non-Motile Green Algae
Microcystis aeruginosa	1.39%	Blue Green Algae	*Gymnodinium sp.*	0.03%	Dinoflagellate
Anabaena circinalis	1.27%	Blue Green Algae	*Gomphonema sp.*	0.03%	Diatom
Oocystis sp.	0.96%	Non-Motile Green Algae	*Selenastrum sp.*	0.03%	Non-Motile Green Algae
Sphaerocystis schroeteri	0.80%	Non-Motile Green Algae	*Kirchneriella sp.*	0.03%	Non-Motile Green Algae
Melosira granulata	0.79%	Diatom	*Ceratium hirundinella*	0.03%	Dinoflagellate
Closteriopsis longissima	0.63%	Non-Motile Green Algae	*Hemidinium sp.*	0.02%	Dinoflagellate
Cyclotella meneghiniana	0.51%	Diatom	*Trachelomonas hispida*	0.02%	Flagellated Algae
Stephanodiscus minutus	0.49%	Diatom	*Pleodorina sp.*	0.02%	Flagellated Algae
Stephanodiscus niagarae	0.45%	Diatom	*Mougeotia sp.*	0.02%	Non-Motile Green Algae
Stephanodiscus hantzschii	0.45%	Diatom	*Tetrastrum staurogeniaeforme*	0.02%	Non-Motile Green Algae
Characium sp.	0.44%	Non-Motile Green Algae	*Schroederia setigera*	0.02%	Non-Motile Green Algae
Lyngbya subtilis	0.43%	Blue Green Algae	*Crucigenia quadrata*	0.02%	Non-Motile Green Algae
Crucigenia tetrapedia	0.43%	Non-Motile Green Algae	*Scenedesmus sp.*	0.02%	Non-Motile Green Algae
Aphanocapsa sp.	0.42%	Blue Green Algae	*Cyclotella stelligera*	0.02%	Diatom
Scenedesmus quadricauda	0.39%	Non-Motile Green Algae	*Scenedesmus arcuatus v. capitatus*	0.02%	Non-Motile Green Algae
Ankistrodesmus falcatus	0.33%	Non-Motile Green Algae	*Plectonema notatum*	0.02%	Blue Green Algae
Anabaena flos-aquae	0.31%	Blue Green Algae	*Cocconeis sp.*	0.02%	Diatom
Rhodomonas minuta	0.29%	Flagellated Algae	*Schroederia judayi*	0.01%	Non-Motile Green Algae
Fragilaria capucina	0.28%	Diatom	*Asterionella formosa*	0.01%	Diatom
Mallomonas tonsurata	0.27%	Flagellated Algae	*Micractinium sp.*	0.01%	Non-Motile Green Algae
Scenedesmus acuminatus	0.24%	Non-Motile Green Algae	*Quadrigula sp.*	0.01%	Non-Motile Green Algae
Coelastrum microporum	0.23%	Non-Motile Green Algae	*Cocconeis pediculus*	0.01%	Diatom
Aphanothece nidulans	0.22%	Blue Green Algae	*Navicula sp.*	0.01%	Diatom
Nitzschia paleacea	0.22%	Diatom	*Chroococcus minimus*	0.01%	Blue Green Algae
Ankistrodesmus sp.	0.19%	Non-Motile Green Algae	*Elakatothrix sp.*	0.01%	Non-Motile Green Algae
Unidentified green algae	0.18%	Non-Motile Green Algae	*Dinobryon sertularia*	0.01%	Flagellated Algae
Coelastrum sp.	0.17%	Non-Motile Green Algae	*Pandorina morum*	0.01%	Flagellated Algae
Nitzschia acicularis	0.13%	Diatom	*Characium limneticum*	0.01%	Non-Motile Green Algae
Mallomonas akrokomos	0.13%	Flagellated Algae	*Nitzschia microcephala*	0.01%	Diatom
Scourfieldia sp.	0.13%	Flagellated Algae	*Nitzschia dissipata*	0.01%	Diatom
Peridinium sp.	0.12%	Dinoflagellate	*Closterium aciculare*	0.01%	Non-Motile Green Algae
Oscillatoria agardhii	0.11%	Blue Green Algae	*Nitzschia vermicularis*	0.00%	Diatom
Trachelomonas sp.	0.11%	Flagellated Algae	*Synedra sp.*	0.00%	Diatom
Peridinium sp.	0.11%	Flagellated Algae	*Coelastrum cambricum*	0.00%	Non-Motile Green Algae
Melosira granulata	0.10%	Diatom	*Cyclotella sp.*	0.00%	Diatom
Ochromonas sp.	0.09%	Flagellated Algae	*Tetrastrum sp.*	0.00%	Non-Motile Green Algae
Chrysochromulina parva	0.09%	Flagellated Algae	*Synura sp.*	0.00%	Flagellated Algae
Nitzschia sp.	0.09%	Diatom	*Scenedesmus arcuatus v. platydisca*	0.00%	Non-Motile Green Algae
Glenodinium sp.	0.08%	Dinoflagellate	*Pteromonas angulosa*	0.00%	Flagellated Algae
Chlorella sp.	0.08%	Non-Motile Green Algae	*Euglena sp.*	0.00%	Flagellated Algae
Actinastrum hantzschii	0.06%	Non-Motile Green Algae	*Surirella sp.*	0.00%	Diatom
Chrysococcus rufescens	0.06%	Flagellated Algae	*Scenedesmus bijuga*	0.00%	Non-Motile Green Algae
Mallomonas sp.	0.06%	Flagellated Algae	*Gyrosigma sp.*	0.00%	Diatom
Peridinium cinctum	0.05%	Dinoflagellate	*Fragilaria crotonensis*	0.00%	Diatom
Surirella angusta	0.05%	Diatom	*Gymnodinium palustre*	0.00%	Dinoflagellate
Selenastrum minutum	0.05%	Non-Motile Green Algae	*Closteriopsis sp.*	0.00%	Non-Motile Green Algae

The seasonal distribution of algae populations in Cresbard Lake consisted of what was essentially a single large annual maximum in abundance that occurred on January 29, 2001 that was preceded by two small, poorly-defined peaks in August and September 2000. Flagellated algae, primarily *Rhodomonas*, *Chromulina* and *Chlamydomonas* sp. were responsible for the winter maximum while blue-green algae, mainly *Aphanizomenon*, were major components of the small summer peaks (Figure 33 and Table 25).

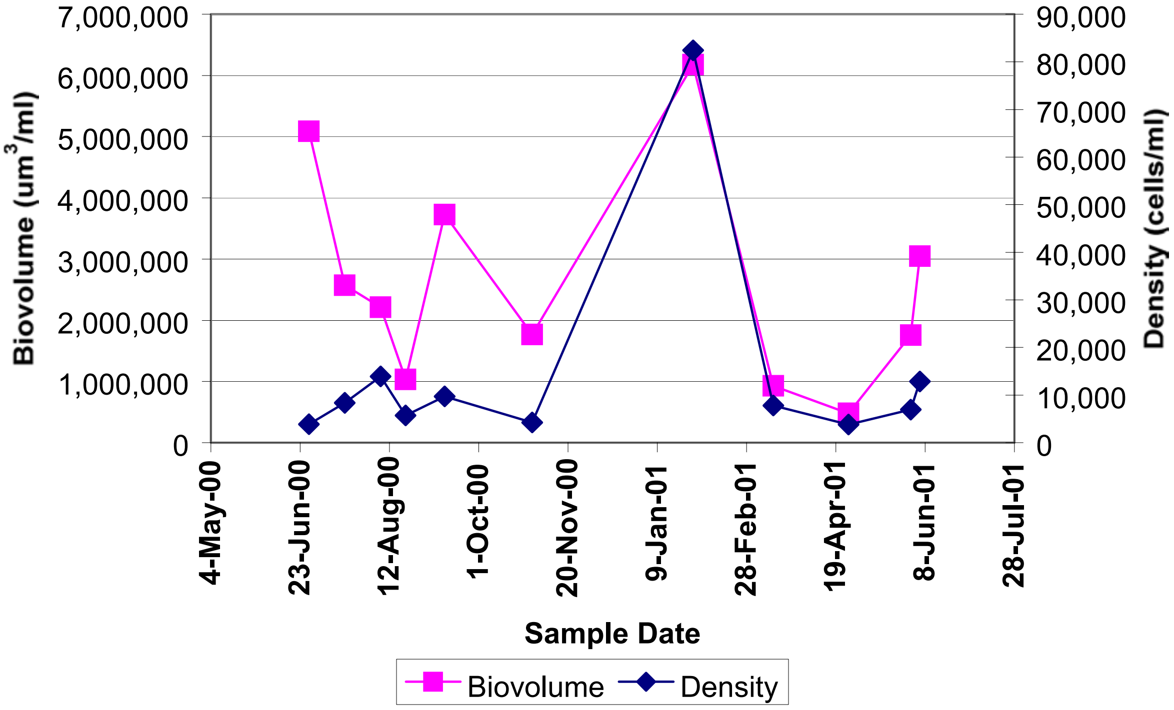

Figure 33. Total algal density and biovolume by sample date for Cresbard Lake.

Blooms of flagellated algae under winter ice cover are fairly common in some of the more fertile South Dakota lakes and elsewhere in the Midwest where they may contribute as much as quarter of annual primary production (Wetzel, 2001). Still water conditions under ice favor motile flagellates at the expense of competing non-motile species which require water turbulence to remain suspended in the water column (Ried, 1961). This advantage is mostly lost during open water seasons except in smaller waterbodies (e.g. ponds) that are protected from strong winds and therefore experience much less wind/wave action.

Three seasonal peaks in algal biovolume could be identified during this survey. They occurred in June, September, and January. The initial peak in late June 2000 was caused almost entirely by a single diatom species, *Stephanodiscus niagarae*, whereas the second peak was produced by a combination of several large species of green, blue-green, flagellate, and diatom. The January maximum was due almost exclusively to several flagellate species, as previously noted. In addition, the cryptomonad *Cryptomonas sp*. provided a large percentage of the January biovolume. Differences in the size of corresponding biovolume and algal abundance (density) peaks shown in Figure 33 are explained by the presence of moderate numbers of large-sized algae cells of various species on those sampling dates.

The importance of flagellates in the algae community of Cresbard Lake observed during this assessment (
Figure 34 and Figure 35) can be ascribed to lake morphology and local water quality. The pond-like characteristics of this small lake with a narrow wind-sheltered basin, abundant macrophytes, superabundant phosphorus and probable accumulation of organic matter derived from decaying local vegetation and imported from the drainage, may create favorable conditions for those motile species. Blue-green algae, including the nuisance species, were of secondary importance during this 1-year investigation. The density of the most abundant species, *Aphanizomenon flos-aquae* ranged from 201 cells/ml to 7,476 cells/ml. from late June to September when it was present in the plankton, with a mean of 3,939 cells/ml. These are considered moderate populations for a eutrophic lake.

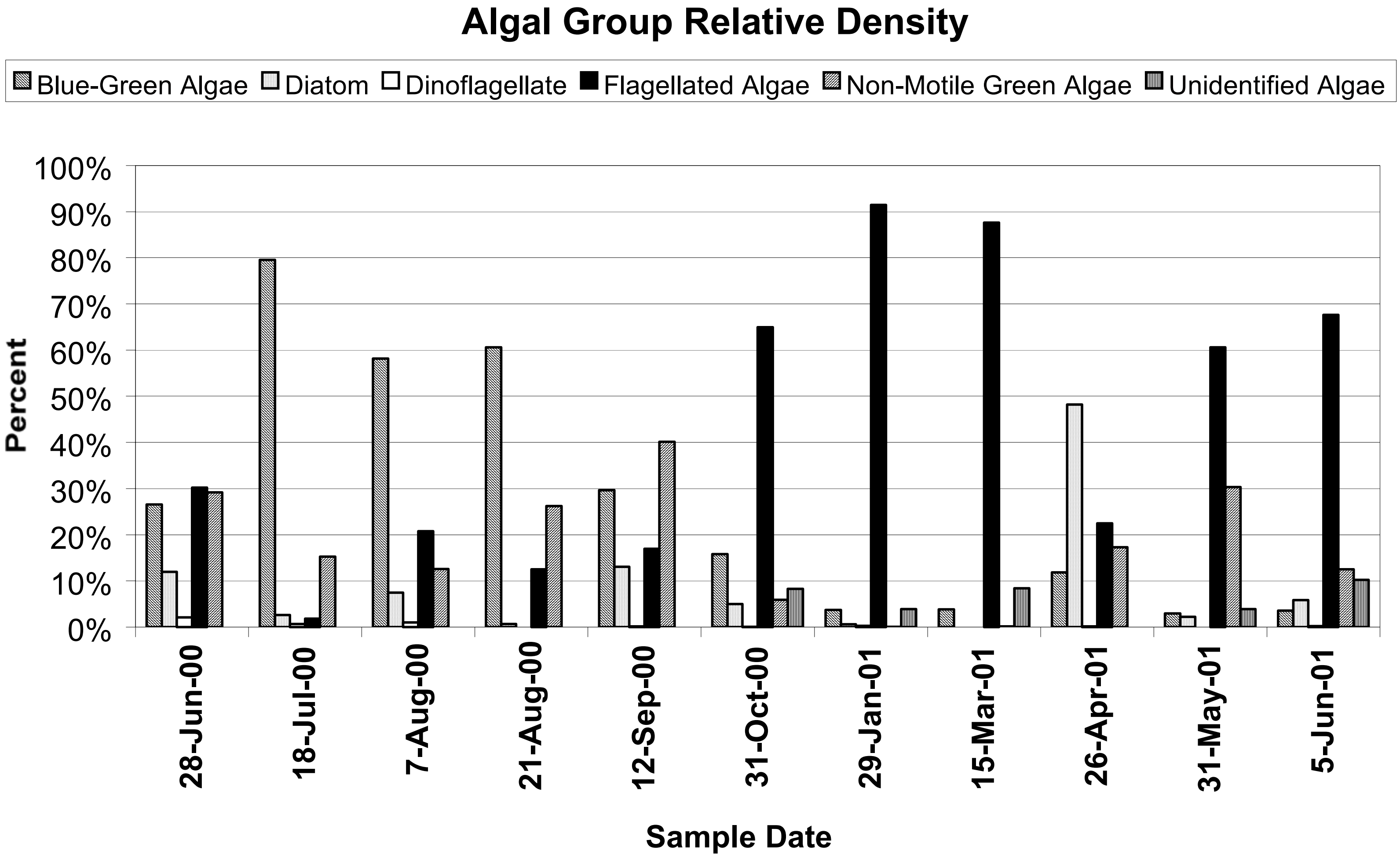

Figure 34. Algal group relative percent density for Cresbard Lake.

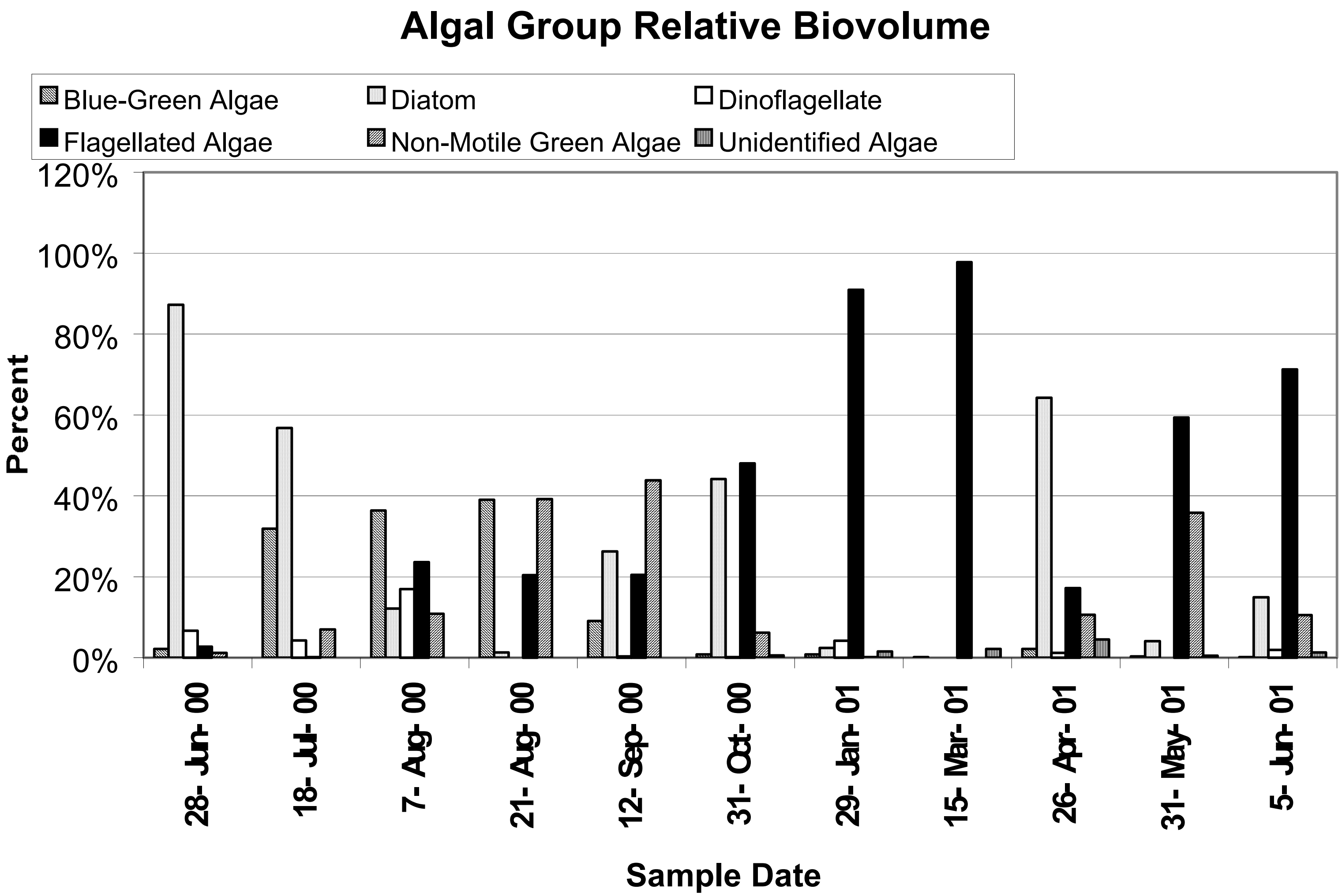

Figure 35. Algal group relative percent density for Cresbard Lake.

Chlorophyll

Chlorophyll is a green pigment involved in the process of energy fixation known as photosynthesis. Chlorophyll is often used as an estimation of algal biomass in lakes and streams. Chlorophyll consists of a group of related molecules – designated chlorophyll *a*, *b*, *c*, and *d*. Chlorophyll *a* is the dominant form of green algae and blue-green algae (cyanobacteria). For this reason, it is most often reported in chlorophyll analyses. Chlorophyll *d* is found only in marine red algae, but chlorophylls *b* and *c* are common in fresh water. Because chlorophyll *a* values are very dependent on precise methodology and are often highly variable, total chlorophyll is reported in addition to chlorophyll *a*. Total chlorophyll is a measure of all chlorophyll pigments and degradation products that absorb light at a wavelength of 665 nm. Although this value is limited in precision by interference from other pigments, it is the value most independent of chlorophyll methodology and provides historical consistency (Carlson and Simpson, 1996).

Chlorophyll data for Cresbard Lake was fairly limited. Data from several sample dates were removed due to unacceptable chlorophyll:phaeophytin (C:P) ratios. Samples with a C:P ratios of 1.7 are considered to contain no phaeophytin, while samples with a ratio of 1.0 contain pure phaeophytin (Eaton et al., 1995). Samples with C:P ratios outside of this range are considered unacceptable, and data from these samples are not presented here.

Chlorophyll *a* values ranged from 0 to 61.98 mg/m^3 (mean = 14.87). Total chlorophyll values ranged from 4.99 to 115.21 mg/m^3 (mean = 29.97) (Figure 36). Maximum chlorophyll *a* and total chlorophyll concentrations were observed in January, which correlated well with the algae abundances observed in the identification/enumeration samples. A large annual maximum in algae abundance was observed in a sample collected on January 29, 2001. A bloom of flagellated algae, primarily *Rhodomonas*, *Chromulina, Crptomonas sp.,* and *Chlamydomonas sp.*, caused the winter chlorophyll maximum.

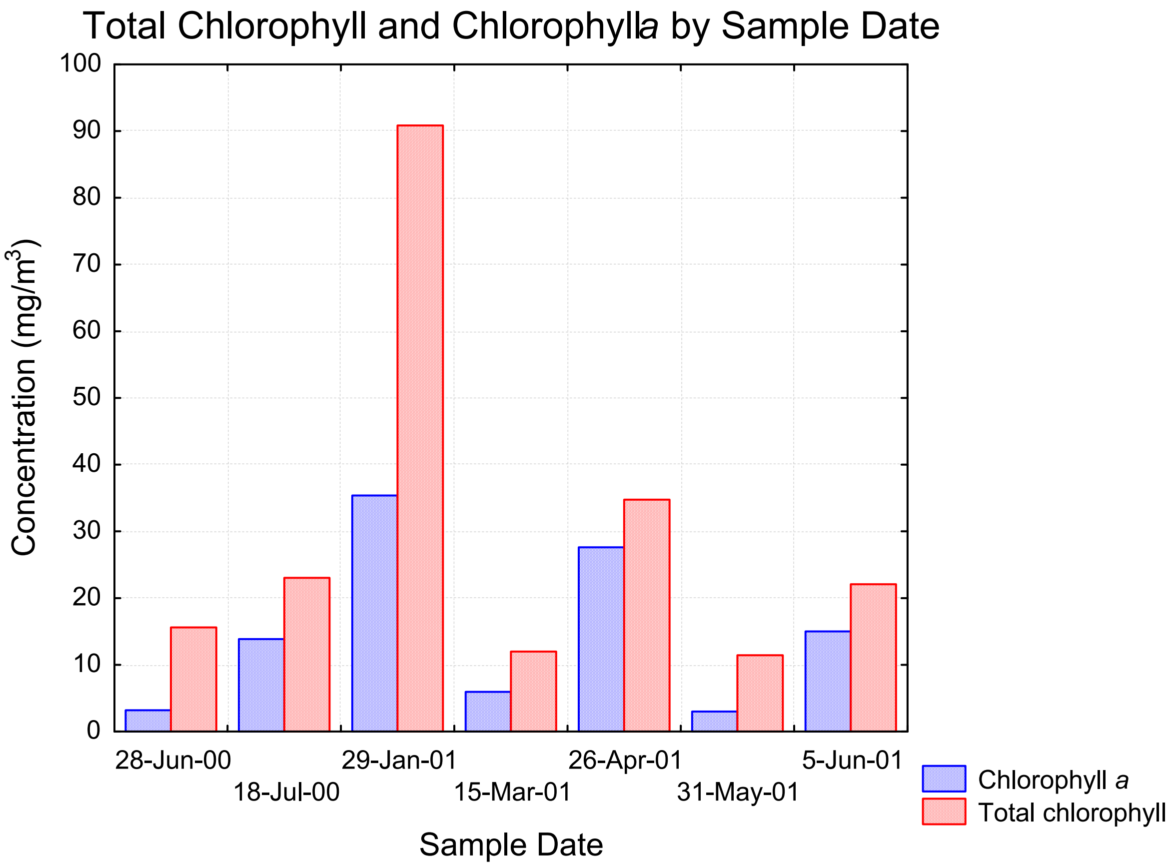

Figure 36. Average concentrations of total chlorophyll and chlorophyll *a* by sample date. Note: data for some sample dates were removed due to unacceptable chlorophyll:phaeophytin (C:P) ratios.

Aquatic Macrophyte Survey

SD DENR staff conducted an aquatic plant survey for Cresbard Lake on July 24, 2001. Data was collected to document emergent and submergent plant species present, density of plant species, and distribution of plant species within the waterbody.

Two locations (edge and middle) at each of ten sites were surveyed in Cresbard Lake. One sampling location was at the edge of the macrophyte bed and the second sampling location was midway between the shore and the edge position. At each sampling location (n=20), four positions were sampled by dragging a rake across the lake bottom. Those four positions were located at the 3, 6, 9, and 12 o'clock positions with the 12 o'clock position being closest to the shore (Figure 37). Density ratings of plant species were estimated using these four positions. If a plant species was found in all four casts and very dense, it was given a density rating of five. If a plant was found in all four casts but in a limited amount, it was assigned a rating of four. If the plant was found in three casts it was given a density rating of three, and so on. Density ratings for all locations were summed to give a total density rating. Macrophytes were identified to the species level, excluding the genus *Najas*. Secchi depth was also measured at each sampling location. Average secchi depth was 0.9 m.

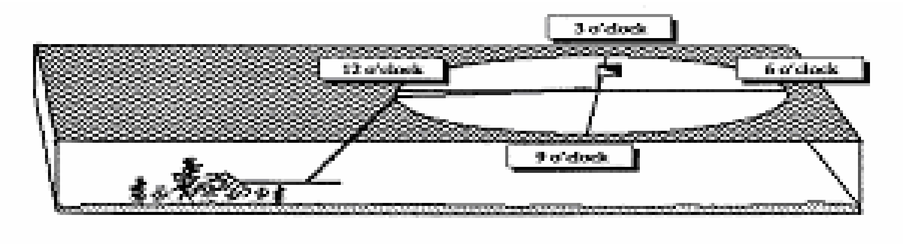

Figure 37. Macrophyte survey rake casting positions. Center flag indicates the boat location, and the 12 o'clock position was closest to shore.

Vegetation was fairly dense throughout most of the lake littoral zone. *Stukenia pectinatus*, commonly known as sago pondweed, was the most abundant aquatic macrophyte species identified in Cresbard Lake. This submergent macrophyte was found at 15 of the 20 sampling locations with a total density rating of 39. *Najas sp*., commonly known as bushy pondweed, was the second most abundant macrophyte genus and was present at 11 of the sampling locations with a total density rating of 23. Star duckweed (*Lemna trisulca)* was found at 10 sites with a total density rating of 21. Floating-leaf pondweed (*Potamogeton natans)* and Coontail (*Ceratophyllum demersum)* were observed at only one sampling location. Curly-leaf pondweed (*Potamogeton crispus*) was found at three sites (total density rating = 5) (Table 27).

Table 27. Number of sites that taxon was observed and sum of the density ratings for each identified aquatic macrophyte species (in decreasing order of density).

Common Name	**Scientific Name**	**Sum of Density Ratings**	**Number of Sites Taxa Found**
Sago Pondweed	*Stukenia pectinatus*	39	15
Bushy Pondweed	*Najas sp.*	23	11
Star Duckweed	*Lemna trisulca*	21	10
Curly-leaf Pondweed	*Potamogeton crispus*	5	3
Floating-leaf Pondweed	*Potamogeton natans*	2	1
Coontail	*Ceratophyllum demersum*	1	1

Curly-leaf pondweed is an exotic or introduced species. This submersed macrophyte was originally introduced from Eurasia in the mid-nineteenth century and is now common throughout southern Canada, the United States, Central America, and South America. While its density is relatively low in Cresbard Lake, this species can rapidly proliferate. This pondweed has a life cycle that is unique among submersed aquatic plants. Most aquatic plants come out of dormancy in early to mid-spring and reach their maximum growth in late summer or early fall. Curly-leaf pondweed begins its growth in late summer and grows throughout the winter. This species has the highest metabolic rate in cold water of any aquatic plant species. With its distinctive life cycle, curly-leaf pondweed can evade competition from other plant species and form dense mats that prohibit recreational uses of the lake (Madsen and Crowell, 2002).

Fecal Coliform Bacteria

Cresbard Lake is listed for the beneficial use of immersion recreation, which requires that no single sample exceed a concentration of 400 fecal bacteria colonies per 100ml of sample or a 30-day average (five samples) of 200 colonies per 100 ml. Approximately 6% of inlake samples (n=3) exceeded the single-sample standard, which were collected in August 2000, April 2001, and May 2001. The August sample was collected after a major rain event. Overall, lake sample concentrations ranged from <10 to 6,600 colonies per 100 ml (mean = 298).

Quality Assurance/Quality Control

Quality assurance/quality control (QA/QC) samples were collected throughout the project period to insure proper laboratory and field sampling methods. Blank and duplicate samples were collected for a minimum of 10% of all samples collected.

Five duplicate and four blank samples were collected on randomly chosen dates from Cresbard Lake. Five values (13%) were reported above the detection limit from all blank samples (total solids = 18 mg/L, ammonia = 0.05 mg/L, TKN = 2.30 mg/L, total phosphorus = 0.472 mg/L, and total dissolved phosphorus = 0.378mg/L). Four of the five values reported above the detection limit were from the same sample collected on January 29, 2001. This sample was most likely contaminated.

Percent difference was calculated for each duplicate and routine sample pair. Average percent difference ranged from 1.3% to 24.1%. The following three parameters had an average percent difference greater than ten percent: total suspended solids, total volatile suspended solids, and fecal coliform bacteria. The difference between duplicate and routine samples for these parameters may be due to contamination of the sample bottles/distilled water by the field sampler, natural variability, or laboratory error. See Appendix E for all QA/QC data.

Other Monitoring

Sediment Survey

Sedimentation continues to be one of the most destructive pollutants of lakes and streams. This impairment can cause an increase in phosphorus loading, decrease habitat availability for invertebrates and fish, and decrease the depth of the waterbody.

A sediment survey was conducted on Cresbard Lake in January 2001. Water depth and sediment depth was measured through holes drilled in the ice. A steel probe was lowered through the holes and pushed through the soft sediment until solid substrate was reached. Water and sediment depth was recorded at each site with Global Positioning System (GPS) equipment.

Average sediment depth for Cresbard Lake was 2 ft. Sediment depths ranged from 1 to 7 ft. (Figure 38). Total sediment volume in Cresbard Lake was calculated using ArcView Spatial Analyst. Sediment volume is 88 acre-feet or approximately 249,163 tons. This represents 10% of the total lake volume.

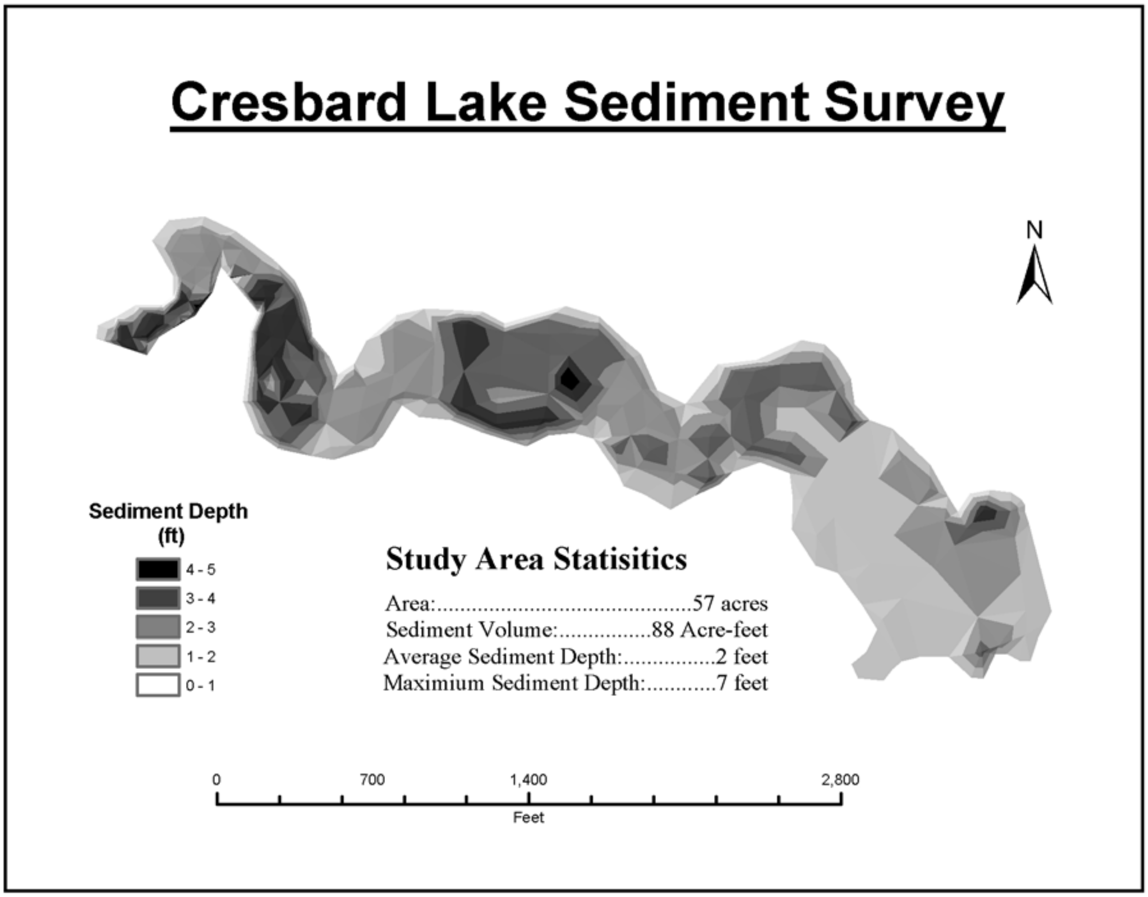

Figure 38. Sediment depths and study area statistics for Cresbard Lake.

Agricultural Non-Point Source Model

The Agricultural Non-Point Source Model (AGNPS) version 3.65 was selected to assess the non-point source loadings from the Cresbard Lake watershed. This model was developed by the United States Department of Agriculture – Agricultural Research Service to analyze the water quality of runoff events from the watershed. The model predicts runoff volume and peak rate, eroded and delivered sediment, chemical oxygen demand (COD), and nitrogen and phosphorus concentrations in the runoff and sediment erosion from a single storm event within the watershed area.

The watershed was divided into 40-acre cells with dimensions of 1,320 feet by 1,320 feet. Landuse and other field data were compiled for each of the 190 watershed cells. Table 28 lists the 21 field parameters collected for each cell. This information was then incorporated into the AGNPS model.

Table 28. Agricultural Non-point Source model input parameters.

AGNPS Model Input Parameters	
Receiving cell number	Practice factor
Runoff curve number	Surface condition constant
Land slope	Aspect
Slope shape factor	Soil texture
Field slope length	Fertilization level
Channel slope	Availability factor
Channel side slope	Point source indicator
Manning roughness coefficient	Gully source level
Soil erodibility factor	Chemical oxygen demand (COD)
Cropping factor	Impoundment factor
	Channel indicator

The primary objectives of modeling the Cresbard Lake watershed were to: (1) evaluate and quantify non-point source (NPS) yields from the watershed, (2) define critical NPS cells within the watershed (those with high sediment, nitrogen, and phosphorus loads), and (3) estimate the effective percent reduction of sediment and nutrients in the watershed by adding various Best Management Practices (BMPs).

Annual loadings were estimated for 40,760 acres by calculating the non-point source loadings from rainfall events during an average year. This includes a one-year, 24-hour event of 1.85” (energy intensity = 20), two six-month events (energy intensity = 11.2), and eleven one-month events (energy intensity = 3) for a total model rainfall factor (R factor) of 75.4. The R-factor established by the Natural Resource Conservation Service for Edmunds County is 75.

AGNPS nutrient output indicates that the Cresbard Lake watershed (at the inlet site) has a total nitrogen (soluble + sediment bound) delivery rate of 0.52 lbs/acre/year (10.6

tons/year) and a total phosphorus (soluble + sediment bound) delivery rate of 0.14 lbs/acre/year (2.9 tons/year). AGNPS estimated sediment delivery rate was 0.02 tons/acre/year (815 tons/year).

Sediment critical cells (n = 97) were identified in the Cresbard Lake watershed (see Appendix F for location of critical cells), which have an annual sediment yield greater than 0.59 tons/acre. Approximately 10% of the total number of watershed cells was identified as critical sediment cells or high erosion cells. The yields for each of these cells are also listed in Appendix F. Characteristics of sediment critical cells indicate elevated erosion potential in these areas. Cover management factors (C-factor) were greater than 0.17, representing conventional tillage practices. Land slopes of sediment critical cells ranged from 2 to 21% and the average slope was 4.2%.

Nitrogen critical cells (n = 115) were identified in the Cresbard Lake watershed (Appendix F). Approximately 11% of the modeled cells were considered critical nitrogen cells, which deliver greater than 4.02 lbs/acre. Average slope of nitrogen critical cells was 3.4%. Average cover management factor (C-factor) for nitrogen critical cells was 0.29, while the average for all watershed cells was 0.10. A high C-factor indicates a low percent ground cover after planting. Nitrogen yields for each critical cell can be found in Appendix F.

Phosphorus critical cells (n = 144) were identified in the Cresbard Lake watershed (Appendix F), which deliver greater than 0.852 lbs/acre. This equates to approximately 14% of the modeled cells. Phosphorus critical cell areas almost entirely encompass the nitrogen and sediment critical cell areas. Average slope of phosphorus critical cells was 3.5%. C-factor values for phosphorus critical cells were similar to nitrogen critical cells with an average of 0.29. Appendix F lists the yields for each phosphorus critical cell.

Eight livestock feeding areas ranging from an estimated 23 to 700 animal units were included in the AGNPS model and ranked using the AGNPS Feedlot Model. According to the model, these small operations slightly increase the nutrient loads from the watershed. When the feeding areas were removed from the model input data, both soluble nitrogen and phosphorus watershed loads were reduced by 0.01 lbs/acre (approximately 408 lbs/yr). Feeding areas of primary concern are located within AGNPS cell numbers 317, 438, 594, 642, and 781. These areas are in close proximity to intermittent or ephemeral stream reaches. A map of the AGNPS cells with livestock feeding areas and a table with the AGNPS animal feedlot rating values can be found in Appendix F.

Reductions of nutrient loads with the installation of BMPs on critical watershed cells were also assessed using the AGNPS model. The modeled BMPs include the conversion of conventional tillage to conservation tillage, reduction of fertilization levels, and installation of grassed waterways. Several AGNPS input parameters were altered for critical cells in order to simulate the BMPs. All critical cell C-factors were reduced to 0.10 to represent an improvement in cover management. Critical cell fertilization levels were reduced to a value representing low application levels (approximately 50 lb/acre of nitrogen and 20 lb/acre of phosphorus). Runoff curve numbers were reduced to 49 and surface condition constant was set at 1.0 for critical cells located adjacent to streams to model grassed waterways. These BMPs yielded a 31.3% reduction in nitrogen load and 45.8% reduction in phosphorus load (Table 29).

Table 29. Modeled percent reductions of nutrients from the watershed with the installation of BMPs.

Parameter	Before BMPs	After BMPs	% Reduction
Sediment – N	0.16 lbs/acre/yr	0.15 lbs/acre/yr	6.3%
Soluble – N	0.36 lbs/acre/yr	0.27 lbs/acre/yr	25.0%
Total Nitrogen			**31.3%**
Sediment – P	0.08 lbs/acre/yr	0.07 lbs/acre/yr	12.5%
Soluble – P	0.06 lbs/acre/yr	0.04 lbs/acre/yr	33.3%
Total Phosphorus			**45.8%**

For the purposes of TMDL development, the potential 45.8% phosphorus load reduction was rounded down to a 40% reduction. This allows for an approximate 6% margin of safety (error). As mentioned previously in the reduction response modeling section, a 40% reduction is an appropriate TMDL goal for the Cresbard Lake watershed.

Future Activity Recommendations

The following management recommendations are based on modeled BMPs and reductions achieved using both the AGNPS and BATHTUB models and best professional judgment.

Watershed Management Recommendations

Several high fecal coliform bacteria samples were collected during this study. The elevated concentrations were collected in August 2000 and during the spring of 2001 (immediately following periods of increased flow) from both lake and inlet stream sites. Highest fecal bacteria concentrations were collected from site CLT04, which was the study site located furthest upstream. Highest concentrations of nitrogen and phosphorus were also observed at this site, suggesting a significant livestock influence on nutrient loads. Grazing livestock and feeding areas are probable sources of the fecal coliform bacteria load. Feedlots and/or feeding areas within AGNPS cell numbers 317, 438, 594, 642, and 781 should be evaluated for potential operational or structural modifications. Grazing management strategies including lakeshore and stream bank fencing and expansion of buffer zones are suggested to reduce loadings of fecal coliform bacteria. Alternative water sources should be provided where livestock have been restricted from access to the stream or lake. Grazing intensity and season of use should be limited to provide sufficient rest for grazing acres to encourage plant vigor and growth.

Efforts to reduce sediment and nutrient loads from the watershed should involve the installation of appropriate BMPs, including the conversion of highly erodible cropland to rangeland or CRP, improvement of land surface cover (C-factor) on cropland and rangeland, reduction of fertilization to low levels (approximately 50 lb/acre of nitrogen and 20 lb/acre of phosphorus), and the installation of grassed waterways and riparian buffer zones.

An estimated 5,760 acres of crop and range lands are considered high priority or critical areas that would require the aforementioned management practices to attain the TMDL goal. All critical phosphorus cells (see Appendix F) should be targeted for increased surface cover management (i.e. a C-factor ≥ 0.1)

The AGNPS model displayed little nutrient and sediment reduction with the installation of grassed waterways, because the model lacks the ability to accurately simulate this practice. However, grassed waterways/riparian zone management should still be considered on critical cells with a defined drainage on approximately 440 acres (AGNPS model cells 250, 251, 281, 368, 421, 530, 704, 710, 995, 996, 999). The nitrogen, phosphorus, and sediment critical cells should be given high priority when installing any future BMPs. AGNPS cells targeted for management should also be field verified prior to the installation of any BMPs. Installing BMPs in critical watershed areas should produce the most cost-effective treatment plan in reducing sediment and nutrient loads to Cresbard Lake.

At present, Cresbard Lake is considered non-supporting of its beneficial uses as indicated by mean TSI values. The BATHTUB model estimated a 95% reduction in phosphorus concentrations would be necessary to bring Cresbard Lake to an ecoregion-based beneficial use classification of fully supporting. However, the ecoregion-based criteria do not appear to be suitable for Cresbard Lake, as demonstrated by the large reduction in total phosphorus needed to meet current ecoregion criteria. Economic and technical limitations prohibit this level of nutrient load reduction. Nutrient reductions of this magnitude would require extreme land use alterations and possibly the elimination of agriculture in the watershed. Therefore, the TMDL was developed based on realistic criteria using watershed-specific, attainable BMP reductions.

A predicted 40% reduction in total phosphorus load can be achieved in this watershed to meet the TMDL goal of 2,785 kg or a mean in-lake TSI of 74.8. Reductions beyond 40% would severely alter most agricultural practices in the watershed and would be cost prohibitive on a percent reduction basis. The recommended reduction in phosphorus load from the Cresbard Lake watershed will improve compliance with South Dakota’s narrative criteria as well as watershed-specific beneficial use criteria.

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Appendix A

Cresbard Lake Algae Data

Algae Sample Data

Date	Taxa	Cells/ml	Bio Volume	Algal Group
05-Jun-01	Anabaena sp.	40	3,200	Blue-Green Algae (filamentous)
05-Jun-01	Ankistrodesmus sp.	20	500	Non-Motile Green Algae (single)
05-Jun-01	Aphanothece nidulans	350	1,400	Blue Green Algae (colonial)
05-Jun-01	Asterionella formosa	8	1,760	Diatom (colonial, pennate)
05-Jun-01	Characium limneticum	10	23,090	Non-Motile Green Algae
05-Jun-01	Chlamydomonas sp.	1,150	172,500	Flagellated Algae (green)
05-Jun-01	Chromulina sp.	80	5,200	Flagellated Algae (single, yellow-brown)
05-Jun-01	Closteriopsis sp.	1	2,388	Non-Motile Green Algae
05-Jun-01	Coelastrum sp.	164	32,964	Non-Motile Green Algae (colonial)
05-Jun-01	Crucigenia tetrapedia	330	28,050	Non-Motile Green Algae (colonial)
05-Jun-01	Cryptomonas sp.	3,360	1,344,000	Flagellated Algae
05-Jun-01	Dictyosphaerium pulchellum	49	735	Non-Motile Green Algae (colonial)
05-Jun-01	Elakatothrix sp.	15	630	Non-Motile Green Algae (colonial)
05-Jun-01	Euglena sp.	3	1,740	Flagellated Algae (green)
05-Jun-01	Gymnodinium sp.	19	51,300	Flagellated Algae (dino)
05-Jun-01	Mallomonas akrokomos	10	15,030	Flagellated Algae (single, yellow-brown)
05-Jun-01	Mallomonas tonsurata	340	510,000	Flagellated Algae (single, yellow-brown)
05-Jun-01	Melosira granulata	163	89,650	Flagellated Algae
05-Jun-01	Melosira granulata v. angustissima	39	9,750	Diatom (centric)-filamentous
05-Jun-01	Micractinium sp.	21	714	Non-Motile Green Algae (colonial)
05-Jun-01	Nitzschia acicularis	6	1,680	Diatom (pennate)
05-Jun-01	Oocystis sp.	650	97,500	Non-Motile Green Algae (colonial)
05-Jun-01	Oscillatoria limnetica	70	700	Blue Green Algae (filamentous)
05-Jun-01	Pediastrum duplex	213	106,500	Non-Motile Green Algae (colonial)
05-Jun-01	Peridinium sp.	6	6,300	Flagellated Algae (dino)
05-Jun-01	Rhodomonas minuta	2,940	58,800	Flagellated Algae
05-Jun-01	Scenedesmus acuminatus	6	360	Non-Motile Green Algae (colonial)
05-Jun-01	Scenedesmus arcuatus v. capitatus	12	2,580	Non-Motile Green Algae (colonial)
05-Jun-01	Scenedesmus armatus	32	9,920	Non-Motile Green Algae (colonial)
05-Jun-01	Scenedesmus quadricauda	40	6,280	Non-Motile Green Algae (colonial)
05-Jun-01	Scenedesmus sp.	4	300	Non-Motile Green Algae (colonial)
05-Jun-01	Schroederia judayi	3	120	Non-Motile Green Algae
05-Jun-01	Schroederia setigera	13	585	Non-Motile Green Algae
05-Jun-01	Sphaerocystis schroeteri	24	6,432	Non-Motile Green Algae (colonial)
05-Jun-01	Stephanodiscus hantzschii	20	4,000	Diatom (centric)
05-Jun-01	Stephanodiscus minutus	470	164,500	Diatom (centric)
05-Jun-01	Stephanodiscus niagarae	18	180,000	Diatom (centric)
05-Jun-01	Trachelomonas sp.	20	40,000	Flagellated Algae (green, euglenoid)
05-Jun-01	Unidentified algae	1,310	39,300	Algae
05-Jun-01	Unidentified flagellates	790	23,700	Flagellated Algae
05-Jun-01	Unidentified pennate diatoms	30	3,000	Diatom (pennate)
07-Aug-00	Actinastrum hantzschii	97	23,280	Non-Motile Green Algae (colonial)
07-Aug-00	Anabaena circinalis	362	52,128	Blue-Green Algae (filamentous)
07-Aug-00	Ankistrodesmus falcatus	173	4,325	Non-Motile Green Algae (single)
07-Aug-00	Aphanizomenon flos-aquae	5,931	693,927	Blue-Green Algae (filamentous)
07-Aug-00	Ceratium hirundinella	32	313,600	Flagellated Algae (dino)
07-Aug-00	Chlamydomonas sp.	48	7,200	Flagellated Algae (green)
07-Aug-00	Chlamydomonas sp.	533	79,950	Flagellated Algae (green)
07-Aug-00	Chlorella sp.	94	5,640	Non-Motile Green Algae
07-Aug-00	Chromulina sp.	12	780	Flagellated Algae (single, yellow-brown)
07-Aug-00	Closteriopsis longissima	32	11,392	Non-Motile Green Algae (single)
07-Aug-00	Cocconeis placentula	32	11,392	Diatom (pennate)
07-Aug-00	Cryptomonas erosa	740	371,480	Flagellated Algae
07-Aug-00	Cyclotella meneghiniana	742	185,500	Diatom (centric)
07-Aug-00	Glenodinium sp.	75	52,500	Flagellated Algae (dino)
07-Aug-00	Hemidinium sp.	32	9,600	Flagellated Algae (dino)
07-Aug-00	Mallomonas sp.	63	31,500	Flagellated Algae (single, yellow-brown)
07-Aug-00	Microcystis aeruginosa	1,809	59,697	Blue-Green Algae (colonial)
07-Aug-00	Nitzschia acicularis	157	43,960	Diatom (pennate)
07-Aug-00	Nitzschia capitellata	63	22,680	Diatom (pennate)

07-Aug-00	Nitzschia paleacea	24	2,352	Diatom (pennate)
07-Aug-00	Nitzschia sp.	12	1,440	Diatom (pennate)
07-Aug-00	Oocystis pusilla	367	19,818	Non-Motile Green Algae (colonial)
07-Aug-00	Rhodomonas minuta	1,282	25,640	Flagellated Algae
07-Aug-00	Scenedesmus acuminatus	376	22,560	Non-Motile Green Algae (colonial)
07-Aug-00	Scenedesmus quadricauda	97	15,229	Non-Motile Green Algae (colonial)
07-Aug-00	Sphaerocystis schroeteri	512	137,216	Non-Motile Green Algae (colonial)
07-Aug-00	Stephanodiscus niagarae	12	780	Diatom (centric)
07-Aug-00	Unidentified flagellates	217	6,510	Flagellated Algae
12-Sep-00	Ankistrodesmus falcatus	113	2,825	Non-Motile Green Algae (single)
12-Sep-00	Aphanizomenon flos-aquae	2,889	338,013	Blue-Green Algae (filamentous)
12-Sep-00	Chlamydomonas sp.	32	4,800	Flagellated Algae (green)
12-Sep-00	Chlorella sp.	16	960	Non-Motile Green Algae
12-Sep-00	Closteriopsis longissima	949	337,844	Non-Motile Green Algae (single)
12-Sep-00	Coelastrum microporum	260	212,160	Non-Motile Green Algae (colonial)
12-Sep-00	Cryptomonas erosa	1,491	748,482	Flagellated Algae
12-Sep-00	Cyclotella meneghiniana	32	8,000	Diatom (centric)
12-Sep-00	Cyclotella stelligera	32	4,960	Diatom (centric)
12-Sep-00	Glenodinium sp.	16	11,200	Flagellated Algae (dino)
12-Sep-00	Mallomonas sp.	16	8,000	Flagellated Algae (single, yellow-brown)
12-Sep-00	Melosira granulata	1,123	617,650	Diatom (centric)-filamentous
12-Sep-00	Mougeotia sp.	16	25,120	Green Algae (filamentous)
12-Sep-00	Nephrocytium sp.	65	6,175	Non-Motile Green Algae (colonial)
12-Sep-00	Oocystis pusilla	319	17,226	Non-Motile Green Algae (colonial)
12-Sep-00	Pediastrum duplex	2,038	1,019,000	Non-Motile Green Algae (colonial)
12-Sep-00	Rhodomonas minuta	32	640	Flagellated Algae
12-Sep-00	Scenedesmus quadricauda	65	10,205	Non-Motile Green Algae (colonial)
12-Sep-00	Selenastrum minutum	33	660	Non-Motile Green Algae
12-Sep-00	Stephanodiscus astraea minutula	48	16,800	Diatom (centric)
12-Sep-00	Stephanodiscus niagarae	33	330,000	Diatom (centric)
12-Sep-00	Tetrastrum staurogeniaeforme	33	2,145	Non-Motile Green Algae (colonial)
12-Sep-00	Unidentified flagellates	81	2,430	Flagellated Algae
15-Mar-01	Ankistrodesmus sp.	10	250	Non-Motile Green Algae (single)
15-Mar-01	Aphanocapsa sp.	300	1,200	Blue Green Algae (colonial)
15-Mar-01	Chlamydomonas sp.	720	108,000	Flagellated Algae (green)
15-Mar-01	Chromulina sp.	2,030	131,950	Flagellated Algae (single, yellow-brown)
15-Mar-01	Chrysococcus rufescens	90	7,650	Flagellated Algae (single, yellow-brown)
15-Mar-01	Cryptomonas sp.	1,410	564,000	Flagellated Algae
15-Mar-01	Mallomonas akrokomos	7	10,521	Flagellated Algae (single, yellow-brown)
15-Mar-01	Rhodomonas minuta	610	12,200	Flagellated Algae
15-Mar-01	Scourfieldia sp.	10	2,010	Flagellated Algae (green, single)
15-Mar-01	Trachelomonas sp.	6	12,000	Flagellated Algae (green, euglenoid)
15-Mar-01	Unidentified algae	660	19,800	Algae
15-Mar-01	Unidentified flagellates	1,990	59,700	Flagellated Algae
18-Jul-00	Anabaena circinalis	1,347	193,968	Blue-Green Algae (filamentous)
18-Jul-00	Ankistrodesmus falcatus	33	825	Non-Motile Green Algae (single)
18-Jul-00	Aphanizomenon flos-aquae	5,344	625,248	Blue-Green Algae (filamentous)
18-Jul-00	Asterionella formosa	14	3,080	Diatom (colonial, pennate)
18-Jul-00	Ceratium hirundinella	8	78,400	Flagellated Algae (dino)
18-Jul-00	Chlamydomonas sp.	8	1,200	Flagellated Algae (green)
18-Jul-00	Chlorella sp.	8	480	Non-Motile Green Algae
18-Jul-00	Closteriopsis longissima	7	2,492	Non-Motile Green Algae (single)
18-Jul-00	Cocconeis pediculus	7	3,640	Diatom (pennate)
18-Jul-00	Cocconeis placentula	22	10,120	Diatom (pennate)
18-Jul-00	Crucigenia quadrata	33	2,805	Non-Motile Green Algae (colonial)
18-Jul-00	Glenodinium sp.	41	28,700	Flagellated Algae (dino)
18-Jul-00	Hemidinium sp.	7	2,100	Flagellated Algae (dino)
18-Jul-00	Melosira granulata	14	7,700	Diatom (centric)-filamentous
18-Jul-00	Navicula sp.	7	1,750	Diatom (pennate)
18-Jul-00	Nitzschia dissipata	8	2,152	Diatom (pennate)
18-Jul-00	Nitzschia microcephala	8	800	Diatom (pennate)
18-Jul-00	Oocystis lacustris	55	16,940	Non-Motile Green Algae (colonial)
18-Jul-00	Oocystis pusilla	665	35,910	Non-Motile Green Algae (colonial)
18-Jul-00	Rhodomonas minuta	130	2,600	Flagellated Algae

18-Jul-00	Scenedesmus quadricauda	97	15,229	Non-Motile Green Algae (colonial)
18-Jul-00	Sphaerocystis schroeteri	388	103,984	Non-Motile Green Algae (colonial)
18-Jul-00	Stephanodiscus niagarae	143	1,430,000	Diatom (centric)
18-Jul-00	Unidentified flagellates	14	420	Flagellated Algae
21-Aug-00	Ankistrodesmus falcatus	51	1,275	Non-Motile Green Algae (single)
21-Aug-00	Aphanizomenon flos-aquae	3,462	405,054	Blue-Green Algae (filamentous)
21-Aug-00	Chlamydomonas sp.	81	12,150	Flagellated Algae (green)
21-Aug-00	Chlorella sp.	5	300	Non-Motile Green Algae
21-Aug-00	Chromulina sp.	12	780	Flagellated Algae (single, yellow-brown)
21-Aug-00	Closteriopsis longissima	25	8,900	Non-Motile Green Algae (single)
21-Aug-00	Cocconeis placentula	16	7,360	Diatom (pennate)
21-Aug-00	Cryptomonas erosa	353	177,206	Flagellated Algae
21-Aug-00	Cyclotella meneghiniana	14	3,500	Diatom (centric)
21-Aug-00	Cyclotella sp.	5	1,000	Diatom (centric)
21-Aug-00	Dinobryon sertularia	15	12,000	Flagellated Algae
21-Aug-00	Mallomonas sp.	9	4,500	Flagellated Algae (single, yellow-brown)
21-Aug-00	Mougeotia sp.	18	28,260	Green Algae (filamentous)
21-Aug-00	Oocystis pusilla	310	16,740	Non-Motile Green Algae (colonial)
21-Aug-00	Pediastrum duplex	431	215,500	Non-Motile Green Algae (colonial)
21-Aug-00	Rhodomonas minuta	209	4,180	Flagellated Algae
21-Aug-00	Scenedesmus quadricauda	266	41,762	Non-Motile Green Algae (colonial)
21-Aug-00	Selenastrum minutum	47	940	Non-Motile Green Algae
21-Aug-00	Sphaerocystis schroeteri	347	92,996	Non-Motile Green Algae (colonial)
21-Aug-00	Stephanodiscus astraea minutula	5	1,750	Diatom (centric)
21-Aug-00	Unidentified flagellates	34	1,020	Flagellated Algae
26-Apr-01	Ankistrodesmus sp.	170	4,250	Non-Motile Green Algae (single)
26-Apr-01	Aphanocapsa sp.	120	480	Blue Green Algae (colonial)
26-Apr-01	Chlamydomonas sp.	90	13,500	Flagellated Algae (green)
26-Apr-01	Chrysochromulina parva	30	2,520	Flagellated Algae (single, yellow-brown)
26-Apr-01	Cryptomonas sp.	2	800	Flagellated Algae
26-Apr-01	Cyclotella meneghiniana	20	5,000	Diatom (centric)
26-Apr-01	Dactylococcopsis sp.	70	1,400	Blue-Green Algae(single or colonial)
26-Apr-01	Gymnodinium palustre	1	2,700	Flagellated Algae (dino)
26-Apr-01	Kirchneriella sp.	20	360	Non-Motile Green Algae (single or colonial)
26-Apr-01	Nitzschia acicularis	50	14,000	Diatom (pennate)
26-Apr-01	Nitzschia paleacea	320	31,360	Diatom (pennate)
26-Apr-01	Nitzschia sp.	70	8,400	Diatom (pennate)
26-Apr-01	Oscillatoria agardhii	180	8,640	Blue Green Algae (filamentous)
26-Apr-01	Peridinium sp.	3	3,150	Flagellated Algae (dino)
26-Apr-01	Pleodorina sp.	35	9,380	Flagellated Algae (green, colonial)
26-Apr-01	Pteromonas angulosa	3	1,572	Flagellated Algae (green)
26-Apr-01	Scenedesmus quadricauda	16	2,512	Non-Motile Green Algae (colonial)
26-Apr-01	Scenedesmus sp.	14	1,050	Non-Motile Green Algae (colonial)
26-Apr-01	Selenastrum sp.	40	800	Non-Motile Green Algae
26-Apr-01	Stephanodiscus hantzschii	700	140,000	Diatom (centric)
26-Apr-01	Stephanodiscus minutus	220	77,000	Diatom (centric)
26-Apr-01	Surirella angusta	80	27,600	Diatoms (pennate)
26-Apr-01	Synedra sp.	4	1,120	Diatoms (pennate)
26-Apr-01	Synura sp.	4	5,236	Flagellated Algae (colonial)
26-Apr-01	Trachelomonas sp.	17	34,000	Flagellated Algae (green, euglenoid)
26-Apr-01	Unidentified algae	720	21,600	
26-Apr-01	Unidentified flagellates	520	15,600	Flagellated Algae
26-Apr-01	Unidentified green algae	280	42,000	Non-Motile Green Algae
26-Apr-01	Unidentified pennate diatoms	40	4,000	Diatom (pennate)
28-Jun-00	Anabaena circinalis	322	46,368	Blue-Green Algae (filamentous)
28-Jun-00	Anabaena flos-aquae	503	40,240	Blue-Green Algae (filamentous)
28-Jun-00	Ankistrodesmus falcatus	161	4,025	Non-Motile Green Algae (single)
28-Jun-00	Aphanizomenon flos-aquae	201	23,517	Blue-Green Algae (filamentous)
28-Jun-00	Chlamydomonas sp.	81	12,150	Flagellated Algae (green)
28-Jun-00	Cryptomonas erosa	221	110,942	Flagellated Algae
28-Jun-00	Oocystis pusilla	926	50,004	Non-Motile Green Algae (colonial)
28-Jun-00	Peridinium cinctum	81	340,200	Flagellated Algae (dino)
28-Jun-00	Rhodomonas minuta	846	16,920	Flagellated Algae
28-Jun-00	Scenedesmus quadricauda	40	6,280	Non-Motile Green Algae (colonial)

28-Jun-00	Stephanodiscus astraea minutula	20	7,000	Diatom (centric)
28-Jun-00	Stephanodiscus niagarae	443	4,430,000	Diatom (centric)
28-Jun-00	Unidentified flagellates	20	600	Flagellated Algae
29-Jan-01	Ankistrodesmus sp.	5	125	Non-Motile Green Algae (single)
29-Jan-01	Aphanocapsa sp.	90	360	Blue Green Algae (colonial)
29-Jan-01	Chlamydomonas sp.	6,825	1,023,750	Flagellated Algae (green)
29-Jan-01	Chromulina sp.	22,140	1,439,100	Flagellated Algae (single, yellow-brown)
29-Jan-01	Closterium aciculare	5	3,750	Non-Motile Green Algae (desmid)
29-Jan-01	Cocconeis pediculus	13	6,760	Diatom (pennate)
29-Jan-01	Cocconeis sp.	25	1,875	Diatom (pennate)
29-Jan-01	Cryptomonas sp.	3,960	1,584,000	Flagellated Algae
29-Jan-01	Fragilaria capucina	450	114,750	Diatom (filamentous, pennate)
29-Jan-01	Gymnodinium sp.	27	72,900	Flagellated Algae (dino)
29-Jan-01	Kirchneriella sp.	20	360	Non-Motile Green Algae (single or colonial)
29-Jan-01	Lyngbya subtilis	638	1,276	Blue-Green Algae (filamentous)
29-Jan-01	Mallomonas akrokomos	30	45,090	Flagellated Algae (single, yellow-brown)
29-Jan-01	Melosira granulata	3	1,650	Diatom (centric)-filamentous
29-Jan-01	Nitzschia sp.	3	360	Diatom (pennate)
29-Jan-01	Ochromonas sp.	135	11,475	Flagellated Algae
29-Jan-01	Oocystis sp.	30	4,500	Non-Motile Green Algae (colonial)
29-Jan-01	Oscillatoria sp.	2,330	48,930	Blue Green Algae (filamentous)
29-Jan-01	Peridinium sp.	175	183,750	Flagellated Algae (dino)
29-Jan-01	Peridinium sp.	175	183,750	Flagellated Algae
29-Jan-01	Plectonema notatum	6	54	Blue-Green Algae
29-Jan-01	Rhodomonas minuta	18,465	369,300	Flagellated Algae
29-Jan-01	Scourfieldia sp.	195	39,195	Flagellated Algae (green, single)
29-Jan-01	Stephanodiscus niagarae	2	20,000	Diatom (centric)
29-Jan-01	Synedra sp.	2	560	Diatoms (pennate)
29-Jan-01	Trachelomonas sp.	110	220,000	Flagellated Algae (green, euglenoid)
29-Jan-01	Unidentified algae	3,210	96,300	
29-Jan-01	Unidentified flagellates	23,325	699,750	Flagellated Algae
29-Jan-01	Unidentified pennate diatoms	8	800	Diatom (pennate)
31-May-01	Anabaena sp.	15	1,200	Blue-Green Algae (filamentous)
31-May-01	Ankistrodesmus sp.	90	2,250	Non-Motile Green Algae (single)
31-May-01	Characium limneticum	2	4,618	Non-Motile Green Algae
31-May-01	Characium sp.	700	439,600	Non-Motile Green Algae
31-May-01	Chlamydomonas sp.	1,250	187,500	Flagellated Algae (green)
31-May-01	Chromulina sp.	430	27,950	Flagellated Algae (single, yellow-brown)
31-May-01	Chrysochromulina parva	30	2,520	Flagellated Algae (single, yellow-brown)
31-May-01	Coelastrum sp.	106	21,306	Non-Motile Green Algae (colonial)
31-May-01	Crucigenia tetrapedia	350	29,750	Non-Motile Green Algae (colonial)
31-May-01	Cryptomonas sp.	940	376,000	Flagellated Algae
31-May-01	Cyclotella meneghiniana	2	500	Diatom (centric)
31-May-01	Gyrosigma sp.	1	500	Diatom (pennate)
31-May-01	Mallomonas akrokomos	160	240,480	Flagellated Algae (single, yellow-brown)
31-May-01	Mallomonas tonsurata	90	135,000	Flagellated Algae (single, yellow-brown)
31-May-01	Melosira granulata	100	55,000	Diatom (centric)-filamentous
31-May-01	Melosira granulata v. angustissima	29	7,250	Diatom (centric)-filamentous
31-May-01	Navicula sp.	2	500	Diatom (pennate)
31-May-01	Oocystis sp.	760	114,000	Non-Motile Green Algae (colonial)
31-May-01	Oscillatoria sp.	190	3,990	Blue Green Algae (filamentous)
31-May-01	Pediastrum duplex	31	15,500	Non-Motile Green Algae (colonial)
31-May-01	Quadrigula sp.	20	480	Non-Motile Green Algae (colonial)
31-May-01	Rhodomonas minuta	460	9,200	Diatom (filamentous, centric)
31-May-01	Scenedesmus sp.	14	1,050	Non-Motile Green Algae (colonial)
31-May-01	Schroederia judayi	20	800	Non-Motile Green Algae
31-May-01	Schroederia setigera	20	900	Non-Motile Green Algae
31-May-01	Stephanodiscus minutus	20	7,000	Diatom (centric)
31-May-01	Surirella sp.	2	1,000	Diatoms (pennate)
31-May-01	Tetrastrum sp.	4	260	Non-Motile Green Algae (colonial)
31-May-01	Trachelomonas sp.	20	40,000	Flagellated Algae (green, euglenoid)
31-May-01	Unidentified algae	270	8,100	Algae
31-May-01	Unidentified flagellates	850	25,500	Flagellated Algae
31-Oct-00	Ankistrodesmus sp.	1	25	Non-Motile Green Algae (single)

31-Oct-00	Aphanocapsa sp.	160	640	Blue Green Algae (colonial)
31-Oct-00	Asterionella formosa	1	220	Diatom (colonial, pennate)
31-Oct-00	Chlamydomonas sp.	290	43,500	Flagellated Algae (green)
31-Oct-00	Chromulina sp.	65	4,225	Flagellated Algae (single, yellow-brown)
31-Oct-00	Chroococcus minimus	18	72	Blue Green (colonial)
31-Oct-00	Chrysochromulina parva	80	6,720	Flagellated Algae (single, yellow-brown)
31-Oct-00	Closterium aciculare	3	2,250	Non-Motile Green Algae (desmid)
31-Oct-00	Coelastrum cambricum	6	300	Non-Motile Green Algae (colonial)
31-Oct-00	Coelastrum microporum	50	40,800	Non-Motile Green Algae (colonial)
31-Oct-00	Coelastrum microporum	50	40,800	Non-Motile Green Algae (colonial)
31-Oct-00	Cryptomonas sp.	1,695	678,000	Flagellated Algae
31-Oct-00	Cyclotella meneghiniana	2	500	Diatom (centric)
31-Oct-00	Fragilaria crotonensis	2	1,680	Diatom (filamentous, pennate)
31-Oct-00	Glenodinium sp.	3	2,100	Flagellated Algae (dino)
31-Oct-00	Gomphonema sp.	45	9,000	Diatom (pennate)
31-Oct-00	Gyrosigma sp.	1	500	Diatom (pennate)
31-Oct-00	Lyngbya subtilis	50	100	Blue-Green Algae (filamentous)
31-Oct-00	Mallomonas sp.	1	500	Flagellated Algae (single, yellow-brown)
31-Oct-00	Mallomonas tonsurata	8	12,000	Flagellated Algae (single, yellow-brown)
31-Oct-00	Melosira granulata	17	9,350	Diatom (centric)-filamentous
31-Oct-00	Microcystis aeruginosa	255	8,415	Blue-Green Algae (colonial)
31-Oct-00	Microcystis aeruginosa	150	4,950	Blue-Green Algae (colonial)
31-Oct-00	Navicula sp.	10	2,500	Diatom (pennate)
31-Oct-00	Nephrocytium sp.	8	760	Non-Motile Green Algae (colonial)
31-Oct-00	Nitzschia sp.	52	6,240	Diatom (pennate)
31-Oct-00	Nitzschia vermicularis	7	840	Diatom (pennate)
31-Oct-00	Ochromonas sp.	5	425	Flagellated Algae
31-Oct-00	Oocystis sp.	87	13,050	Non-Motile Green Algae (colonial)
31-Oct-00	Oscillatoria sp.	20	420	Blue Green Algae (filamentous)
31-Oct-00	Pandorina morum	6	1,050	Flagellated Algae (green, colonial)
31-Oct-00	Pandorina morum	6	1,050	Flagellated Algae (green, colonial)
31-Oct-00	Peridinium sp.	1	1,050	Flagellated Algae (dino)
31-Oct-00	Plectonema notatum	22	198	Blue-Green Algae
31-Oct-00	Rhodomonas minuta	170	3,400	Flagellated Algae
31-Oct-00	Scenedesmus arcuatus v. capitatus	18	3,870	Non-Motile Green Algae (colonial)
31-Oct-00	Scenedesmus arcuatus v. platydisca	4	508	Non-Motile Green Algae (colonial)
31-Oct-00	Scenedesmus armatus	20	6,200	Non-Motile Green Algae (colonial)
31-Oct-00	Scenedesmus bijuga	2	376	Non-Motile Green Algae (colonial)
31-Oct-00	Scenedesmus quadricauda	4	628	Non-Motile Green Algae (colonial)
31-Oct-00	Stephanodiscus niagarae	75	750,000	Diatom (centric)
31-Oct-00	Trachelomonas hispida	38	79,800	Flagellated Algae (green, euglenoid)
31-Oct-00	Trachelomonas sp.	3	6,000	Flagellated Algae (green, euglenoid)
31-Oct-00	Unidentified algae	355	10,650	Algae
31-Oct-00	Unidentified flagellates	410	12,300	Flagellated Algae

Appendix B

Cresbard Lake Fishery Survey Report
Prepared by South Dakota Department of Game, Fish, and Parks

SOUTH DAKOTA STATEWIDE FISHERIES SURVEY

2102-F21-R-30

Name: Cresbard
County(ies): Faulk
Legal description: T120N, R68W, Sect. 27
Location from nearest town: 2 miles west of Cresbard
Dates of present survey: May 28,1997
Date last surveyeyed: May 25,1996
Management classification: Warm water semi-permanent
Contour mapped: Date: 1970
Report prepared by: Charles Pyle

Primary Species: (game and forage) Secondary and other species:

1. Largemouth Bass
2. Walleye
3. Black Bullhead
4. Northern Pike
5. Bluegill
6. Yellow Perch
7. Black Crappie

PHYSICAL CHARACTERISTICS

Surface Area: 53 acres; Watershed: 86960 acres
Maximum depth: 15 feet; Mean depth: 6.5 feet
Lake elevation at survey (from known benchmark): Full feet

1. Describe ownership of lake and adjacent lakeshore property:

Cresbard Lake is owned by the State of South Dakota and managed by the Game, Fish and Parks Dept. The lakeshore property is under private ownership and public access is gained through a section line.

2. Describe watershed condition and percentages of land use:

The watershed is comprised of cropland and pasture at 50% each.

3. Describe aquatic vegetative condition:

The entire shoreline is ringed with cattails and bulrushes. The shallower reaches in the western portion of the lake are solid stands of emergent vegetation. Submergent vegetation is quite extensive and does hamper boating activities.

4. Describe pollution problems:

Siltation and nutrient enrichment through runoff and inflow from Snake Creek are contributing greatly to the degradation of this WPA dam.

5. Describe condition of all structures, i.e. spillway, level, regulators, boatramps, etc.:

The ramp and dam are in good repair.

BIOLOGICAL DATA

Methods:

Cresbard Lake was electrofished using a Coeffelt shocking boat on May 28, 1997. Electrofishing was done after sunset. Electrofishing was conducted along portions of emergent vegetation. Conditions were good as winds were five mph and the night was partly cloudy. Most of the shoreline was electroshocked. Results and conditions are shown in Figure 1. Lengths (mm) and weights (g) were taken from all species and black crappie PSD, RSD, and Wr values were calculated using PC Minnow.

Results and Discussion:

The largemouth bass population that inhabited the lake in the past was not sampled this year due to a probable winter-kill during 1996-97. Therefore, the only species sampled by night electrofishing were black crappie and northern pike.

Black crappie made up most of the catch with CPUE of 38.82. PSD equaled 8, presenting its high abundance of small fish. Condition of these fish is good with Wr values of 103-125. Seven northern pike were sampled which had CPUE of 4.9. No other analysis was done.

The 1998 lake survey should consist of using both frame and gill nets to get a better understanding of the fish populations in Cresbard Lake. Black crappie population should be monitored to determine age and growth rate. Stockings should continue after a better diagnosis of the fishery.

RECOMMENDATIONS

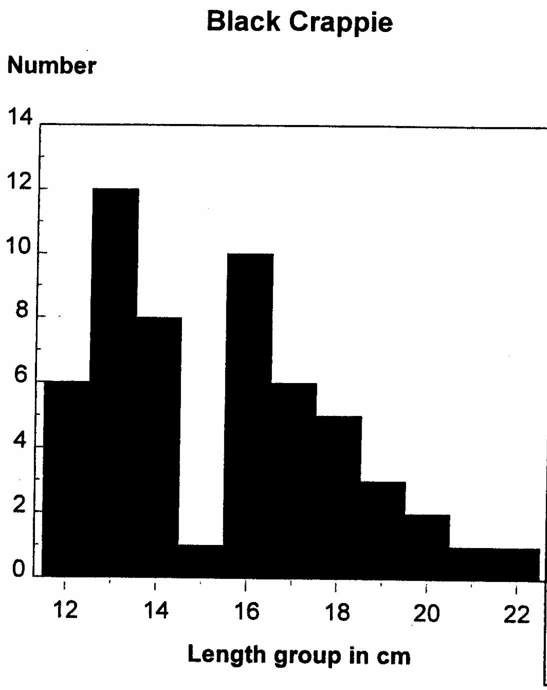
1. Frame net and electrofish in 1998 to better assess fish populations since winter-kill in 96-97.

2. Primarily manage for largemouth bass and panfish.

3. Continue stockings to re-establish bass and panfish population.

Table 2. Stocking record for Cresbard Lake, Faulk County, 1984-1997.

SPECIES	SIZE	NUMBER	YEAR
NOP	FRY	50,000	1984
WAE	FRY	50,000	1984
NOP	FRY	25,000	1985
BLG	FGL	20,200	1985
NOP	FRY	106,000	1986
NOP	FGL	1,600	1988
LMB	FGL	5,300	1990
LMB	LFG	5,300	1992
LMB	FGL	5,500	1997



Sample Description

Range	#	Mean Wr
<130	6	125
130-200	45	116
200-250	4	103

Mean CPUE = 38.82
PSD = 8(2 , 15)*
RSDP = 0

Conditions

Date May 28, 1997
Water Temp: 57
Conductivity: 375
Volt Output: 400
AMP Output: 7
Setting: AC
Time: 8:4-10:00 PM
Total Time: 1.25HR

* 90% C.I.

Figure 1.
Length frequency histogram and sample description of black crappie sampled during electrofishing on Cresbard Lake, May 1997.

Appendix C

Lake Assessment Data

Cresbard Lake Field Measurements

Site	Date	pH	Secchi (ft)	Temperature (C)	DO (mg/L)	Conductivity (umhos)
CL1	18-Jul-00	8.50		22.30	3.25	745
CL1	7-Aug-00	7.51	2.5		2.05	439
CL1	7-Aug-00	7.51	2.5		2.05	
CL1	7-Aug-00	7.51	2.5		2.05	379
CL1	21-Aug-00	7.85	4.7	20.37	3.58	530
CL1	21-Aug-00	8.28	4.7	22.13	5.67	583
CL1	31-Oct-00	8.70	1.0	11.44	18.40	482
CL1	31-Oct-00	8.67	1.0	11.43	18.40	484
CL1	29-Jan-01	8.67	0.7	-0.04	11.00	440
CL1	29-Jan-01	8.72	0.7	1.38	3.80	457
CL1	29-Jan-01	8.72	0.7	1.38	3.80	457
CL1	17-Mar-01	6.90		0.34	3.17	867
CL1	30-Mar-01	7.79		3.52	26.70	749
CL1	12-Apr-01	8.78		4.40	15.72	682
CL1	14-Apr-01	7.55		2.86	8.17	545
CL1	5-Jun-01	8.12	0.8	16.13	8.90	711
CL1	5-Jun-01	8.19	0.8	16.08	8.85	710
CL1	5-Jun-01	8.12		16.13	8.90	856
CL2	28-Jun-00				7.70	
CL2	28-Jun-00	8.20			6.50	
CL2	18-Jul-00	8.49	2.5	20.62	4.81	
CL2	18-Jul-00	8.43		22.73	2.61	
CL2	7-Aug-00	8.45	3.5		2.36	
CL2	7-Aug-00	7.37	3.5		1.99	
CL2	7-Aug-00	7.37	3.8		1.99	
CL2	21-Aug-00	8.10	2.0	21.85	6.22	
CL2	21-Aug-00	7.81	2.0	20.89	4.34	
CL2	31-Oct-00	8.73	0.7	1.50	3.80	462
CL2	31-Oct-00	8.76	1.1	11.44	18.40	482
CL2	31-Oct-00	8.70	1.1	11.44	18.40	482
CL2	29-Jan-01	8.63	8.9	-0.06	4.00	445
CL2	29-Jan-01	8.63	8.9	-0.06	4.00	445
CL2	29-Jan-01	8.73	8.9	1.50	3.80	462
CL2	17-Mar-01	6.95		0.16	3.86	868
CL2	5-Jun-01	8.07	1.0	15.94	8.47	706
CL2	5-Jun-01	7.98	1.0	15.84	7.54	705

Cresbard Lake Sample Data

SITE	DEPTH	DATE	ALKA	TOTS	TSS	TDS	TVSS	AMMO	UNION	NIT	TKN	TOT N	ORG NIT	INOR NIT	TOT P	TDP
CL02	S	28-Jun-00	193	605	15	590	6.0	0.01		0.05	0.99	1.04	0.98	0.06	0.276	0.207
CL02	B	28-Jun-00	194	634	41	593	3.0	0.01		0.05	1.51	1.56	1.50	0.06	0.420	0.226
CL01	S	28-Jun-00	193	615	16	599	6.0	0.01		0.05	1.20	1.25	1.19	0.06	0.172	0.249
CL01	B	28-Jun-00	9	620	21	599	8.0	0.01		0.05	1.11	1.16	1.10	0.06	0.174	0.260
CL02	B	18-Jul-00	194	658	70	588	18.0	0.07		0.05	1.30	1.35	1.23	0.12	0.641	0.389
CL01	S	18-Jul-00	192	631	13	618	8.0	0.04	0.01	0.05	1.04	1.09	1.00	0.09	0.466	0.358
CL01	B	18-Jul-00	193	637	31	606	9.0	0.03		0.05	1.18	1.23	1.15	0.08	0.471	0.379
CL02	S	18-Jul-00	194	631	24	607	9.0	0.04	0.00	0.05	1.14	1.19	1.10	0.09	0.504	0.374
CL01	B	7-Aug-00	73	321	12	309	5.0	0.08		0.20	1.71	1.91	1.63	0.28	0.994	0.932
CL02	B	7-Aug-00	166	563	29	534	6.0	0.22		0.30	1.90	2.20	1.68	0.52	0.807	0.593
CL01	S	7-Aug-00	77	318	12	306	9.0	0.01		0.20	1.86	2.06	1.85	0.21	0.988	0.896
CL02	S	7-Aug-00	170	561	8	553	6.0	0.01		0.20	1.28	1.48	1.27	0.21	0.642	0.555
CL02	B	21-Aug-00	148	476	10	466	3.0	0.34		0.05	1.64	1.69	1.30	0.39	1.010	0.964
CL01	S	21-Aug-00	147	470	6	464	3.0	0.24	0.01	0.05	1.53	1.58	1.29	0.29	1.000	0.956
CL02	S	21-Aug-00	147	473	7	466	2.0	0.34	0.02	0.05	1.60	1.65	1.26	0.39	1.060	0.980
CL01	B	21-Aug-00	148	461	4	457	2.0	0.22		0.05	1.59	1.64	1.37	0.27	0.971	1.060
CL01	S	14-Sep-00	156	479	11	468	7.0	0.01		0.05	1.45	1.50	1.44	0.06	0.978	0.829
CL02	B	14-Sep-00	156	482	18	464	9.0	0.01		0.05	1.47	1.52	1.46	0.06	0.838	0.802
CL02	S	14-Sep-00	156	480	15	465	6.0	0.01		0.05	1.42	1.47	1.41	0.06	0.792	0.767
CL01	B	14-Sep-00	151	479	8	471	5.0	0.01		0.05	1.52	1.57	1.51	0.06	0.822	0.820
CL01	S	31-Oct-00	166	497	4	493	4.0	0.03	0.00	0.05	1.22	1.27	1.19	0.08	0.371	0.314
CL02	B	31-Oct-00	163	509	27	482	2.0	0.02		0.05	1.41	1.46	1.39	0.07	0.401	0.310
CL02	S	31-Oct-00	165	499	7	492	3.0	0.02	0.00	0.05	1.31	1.36	1.29	0.07	0.393	0.320
CL01	B	31-Oct-00	166	506	21	485	6.0	0.03		0.05	1.65	1.70	1.62	0.08	0.392	0.328
CL01	B	28-Dec-00	203	603	6	597	2.0	0.15		0.10	1.48	1.58	1.33	0.25	0.336	0.144
CL01	S	28-Dec-00	203	605	4	601	1.0	0.15		0.10	1.65	1.75	1.50	0.25	0.335	0.276
CL02	B	28-Dec-00	205	604	5	599	2.0	0.15		0.10	1.59	1.69	1.44	0.25	0.329	0.285
CL02	S	28-Dec-00	205	603	4	599	0.5	0.15		0.05	1.57	1.62	1.42	0.20	0.331	0.279
CL01	S	29-Jan-01	215	656	32	624	11.0	0.06	0.00	0.10	2.10	2.20	2.04	0.16	0.491	0.354
CL02	B	29-Jan-01	218	670	44	626	16.0	0.08		0.05	2.37	2.42	2.29	0.13	0.486	0.331
CL02	S	29-Jan-01	219	686	58	628	18.0	0.05	0.00	0.10	2.53	2.63	2.48	0.15	0.525	0.340
CL01	S	15-Mar-01	224	637	6	631	3.0	0.31	0.00	0.05	1.78	1.83	1.47	0.36	0.504	0.428
CL01	B	15-Mar-01	224	632	5	627	3.0	0.30		0.05	1.83	1.88	1.53	0.35	0.564	0.554
CL02	S	15-Mar-01	223	634	4	630	3.0	0.26	0.00	0.05	1.41	1.46	1.15	0.31	0.453	0.427
CL02	B	15-Mar-01	235	648	7	641	4.0	0.54		0.05	1.97	2.02	1.43	0.59		0.128
CL02	S	26-Apr-01	106	391	23	368	9.0	0.14		0.50	1.78	2.28	1.64	0.64	0.550	0.424
CL02	B	26-Apr-01	105	397	21	376	7.0	0.14		0.50	1.68	2.18	1.54	0.64	0.542	0.424
CL01	B	26-Apr-01	106	390	25	365	10.0	0.15		0.50	1.61	2.11	1.46	0.65	0.575	0.475
CL01	S	26-Apr-01	105	393	25	368	9.0	0.17		0.50	1.73	2.23	1.56	0.67	0.547	0.477
CL01	S	31-May-01	161	529	3	526	1.0	0.01		0.05	1.49	1.54	1.48	0.06	0.543	0.442
CL02	B	31-May-01	162	507	6	501	5.0	0.01		0.05	1.68	1.73	1.67	0.06	0.604	0.417
CL01	B	31-May-01	161	523	6	517	3.0	0.01		0.05	1.57	1.62	1.56	0.06	0.520	0.402
CL02	S	31-May-01	161	504	2	502	1.0	0.01		0.05	1.21	1.26	1.20	0.06	0.542	0.415
CL01	B	5-Jun-01	164	526	9	517	5.0	0.01		0.05	1.61	1.66	1.60	0.06	0.542	0.468
CL01	S	5-Jun-01	157	523	9	514	4.0	0.01	0.00	0.05	1.44	1.49	1.43	0.06	0.543	0.489
CL02	B	5-Jun-01	164	525	9	516	4.0	0.01		0.05	1.29	1.34	1.28	0.06	0.552	0.472
CL02	S	5-Jun-01	164	517	9	508	5.0	0.01	0.00	0.05	1.31	1.36	1.30	0.06	0.546	0.492

Parameter Abbreviations

ALKA = alkalinity
TOTS = total solids
TSS = total suspended solids
TDS = total dissolved solids
TVSS = total volatile suspended solids
AMMO = ammonia
UNION = unionized ammonia
NIT = nitrate
TKN = total Kjeldahl nitrogen

TOT N = total nitrogen
ORG NIT = organic nitrogen
INORG NIT = inorganic nitrogen
TOT P = total phosphorus
TDP = total dissolved phosphorus

NOTE: all data units are mg/L

Cresbard Lake Biological and TSI Data

SITE	DEPTH	TYPE	DATE	FECAL	TOT CHL	CHL A	P TSI	CHL TSI	SEC TSI	MEAN TSI
CL02	S	REP	28-Jun-00	5			85.24			
CL02	B	REP	28-Jun-00	5			91.30			
CL01	S	REP	28-Jun-00	5	7.11	15.47	78.42	66.47		
CL01	B	REP	28-Jun-00	10			78.58			
CL02	B	REP	18-Jul-00	5			97.40		63.92	
CL01	S	REP	18-Jul-00	5	13.58	23.27	92.80	70.48	63.92	75.73
CL01	B	REP	18-Jul-00	10			92.95		63.92	
CL02	S	REP	18-Jul-00	5	14.14	22.81	93.93	70.29	63.92	76.05
CL01	B	REP	7-Aug-00	6600			103.73		61.05	
CL02	B	REP	7-Aug-00	270			100.72		61.05	
CL01	S	REP	7-Aug-00	160	53.77	42.86	103.64	76.47	61.05	80.39
CL02	S	REP	7-Aug-00	170			97.42		61.05	
CL02	B	REP	21-Aug-00	5			103.96		59.70	
CL01	S	REP	21-Aug-00	30			103.82		59.70	
CL02	S	REP	21-Aug-00	10			104.66		59.70	
CL01	B	REP	21-Aug-00	5			103.39		59.70	
CL01	S	REP	14-Sep-00	5			103.50			
CL02	B	REP	14-Sep-00	10			101.27			
CL02	S	REP	14-Sep-00	5			100.45			
CL01	B	REP	14-Sep-00	5			100.99			
CL01	S	REP	31-Oct-00	5			89.51		77.44	
CL02	B	REP	31-Oct-00	10			90.63		77.44	
CL02	S	REP	31-Oct-00	10			90.34		77.44	
CL01	B	REP	31-Oct-00	10			90.30		77.44	
CL01	B	REP	28-Dec-00	5			88.08			
CL01	S	REP	28-Dec-00	5			88.04			
CL02	B	REP	28-Dec-00	5			87.78			
CL02	S	REP	28-Dec-00	5			87.86			
CL01	S	REP	29-Jan-01	5	61.98	115.21	93.55	86.18	54.51	78.08
CL02	B	REP	29-Jan-01	5			93.41		54.51	
CL02	S	REP	29-Jan-01	5	8.81	66.50	94.52	80.78	54.51	76.60
CL01	S	REP	15-Mar-01	5	7.81	19.02	93.93	68.50		
CL01	B	REP	15-Mar-01	5			95.55			
CL02	S	REP	15-Mar-01	5	4.11	4.99	92.39	55.38		
CL02	B	REP	15-Mar-01	5						
CL02	S	REP	26-Apr-01	1300	31.04	37.87	95.19	75.26		
CL02	B	REP	26-Apr-01	800			94.98			
CL01	B	REP	26-Apr-01	800			95.83			
CL01	S	REP	26-Apr-01	3200	24.23	31.64	95.11	73.50		
CL01	S	REP	31-May-01	20	5.61	11.34	95.01	63.43		
CL02	B	REP	31-May-01	5			96.54			
CL01	B	REP	31-May-01	5			94.38			
CL02	S	REP	31-May-01	450	0.40	11.55	94.98	63.61		
CL01	B	REP	5-Jun-01	5			94.98		78.89	
CL01	S	REP	5-Jun-01	5	15.32	24.92	95.01	71.15	78.89	81.68
CL02	B	REP	5-Jun-01	5			95.24		78.89	
CL02	S	REP	5-Jun-01	5	14.72	19.26	95.09	68.63	78.89	80.87

Parameter Abbreviations

FECAL = fecal coliform bacteria (number of colonies/100ml)
TOT CHL = total chlorophyll (mg/cm^3)
CHL A = chlorophyll *a* (mg/cm^3)
P TSI = phosphorus trophic state index
CHL TSI = chlorophyll trophic state index
SEC TSI = secchi depth trophic state index
MEAN TSI = mean trophic state index

Appendix D

Tributary Assessment Data

Tributary Field Data

Site	Date	Temp (Celsius)	Conductivity (umhos)	DO (mg/L)	Field pH
CLO01	12-Apr-01	3.74	279	11.57	7.98
CLO01	12-Apr-01	3.68	279	10.59	7.71
CLT02	30-Mar-01	2.19	388	27.26	7.32
CLT02	12-Apr-01	6.01	467	11.30	7.75
CLT02	14-Apr-01	6.39	638	11.90	7.90
CLT02	5-Jun-01	15.94	853	8.47	8.07
CLT03	30-Mar-01	2.54	220	15.39	8.03
CLT03	12-Apr-01	5.39	455	9.19	7.50
CLT03	13-Apr-01	6.68	491	8.92	7.60
CLT03	14-Apr-01	5.42	592	12.64	7.89
CLT03	5-Jun-01	17.24	954	4.19	7.25
CLT04	30-Mar-01	3.20	1110	29.65	7.44
CLT04	12-Apr-01	4.24	699	5.67	7.44

Tributary Lab Data

SITE	DATE	ALKA	TOTS	TSS	TDS	TVSS	AMMO	NIT	TKN	INOR NIT	ORG NIT	TOT N	TOT P	TDP
CLO01	28-Mar-01	191	609	42.0	567.0	20.0	0.53	0.20	4.13	0.73	3.60	4.33	1.110	0.746
CLO01	28-Mar-01	191	659	98.0	561.0	26.0	0.55	0.20	5.21	0.75	4.66	5.41	1.120	0.747
CLO01	10-Apr-01	60	243	30.0	213.0	6.0	0.42	1.00	1.34	1.42	0.92	2.34	0.571	0.476
CLO01	12-Apr-01	100	345	20.0	325.0	0.5	0.50	0.70	1.76	1.20	1.26	2.46	0.656	0.542
CLO01	25-Apr-01	335	1028	24.0	1004.0	9.0	0.10	0.50	1.48	0.60	1.38	1.98	0.214	0.102
CLO01	26-Apr-01	107	390	21.0	369.0	5.0	0.19	0.50	1.93	0.69	1.74	2.43	0.536	0.438
CLO01	31-May-01	172	588	0.5	587.5	0.5	0.05	0.05	1.42	0.10	1.37	1.47	0.539	0.349
CLO01	5-Jun-01	164	519	10.0	509.0	6.0	0.01	0.05	1.56	0.06	1.55	1.61	0.552	0.468
CLT02	5-Aug-00	126	1008	324.0	684.0	52.0	1.06	2.50	6.63	3.56	5.57	9.13	3.230	2.540
CLT02	6-Aug-00	60	266	34.0	232.0	6.0	0.01	0.10	1.48	0.11	1.47	1.58	0.963	0.772
CLT02	16-Aug-00	207	559	7.0	552.0	5.0	0.05	0.05	1.63	0.10	1.58	1.68	1.960	1.850
CLT02	30-Aug-00	316	827	8.0	819.0	2.0	0.13	0.30	2.11	0.43	1.98	2.41	3.080	2.820
CLT02	30-Aug-00	312	819	12.0	807.0	2.0	0.12	0.30	2.25	0.42	2.13	2.55	2.880	2.850
CLT02	28-Mar-01	98	319	16.0	303.0	7.0	0.69	1.00	1.92	1.69	1.23	2.92	0.992	0.904
CLT02	10-Apr-01	85	349	11.0	338.0	4.0	0.69	1.30	2.21	1.99	1.52	3.51	0.800	0.687
CLT02	12-Apr-01	98	496	128.0	368.0	4.0	0.71	0.80	2.11	1.51	1.40	2.91	0.890	0.533
CLT02	26-Apr-01	101	354	25.0	329.0	6.0	0.03	0.20	1.93	0.23	1.90	2.13	0.462	0.312
CLT02	31-May-01	306	879	6.0	873.0	4.0	0.11	2.10	2.55	2.21	2.44	4.65	1.280	0.992
CLT03	5-Aug-00	20	268	15.0	253.0	8.0	0.14	0.40	1.09	0.54	0.95	1.49	0.467	0.440
CLT03	6-Aug-00	53	219	16.0	203.0	5.0	0.01	0.05	1.41	0.06	1.40	1.46	0.634	0.570
CLT03	16-Aug-00	166	405	8.0	397.0	4.0	0.01	0.05	1.88	0.06	1.87	1.93	2.000	1.820
CLT03	30-Aug-00	272	539	52.0	487.0	26.0	0.01	0.05	2.11	0.06	2.10	2.16	5.120	2.680
CLT03	30-Aug-00	278	559	66.0	493.0	26.0	0.01	0.05	2.64	0.06	2.63	2.69	4.900	2.580
CLT03	26-Mar-01	105	289	6.0	283.0	0.5	0.23	0.30	1.16	0.53	0.93	1.46	0.484	0.450
CLT03	10-Apr-01	82	332	18.0	314.0	2.0	0.75	1.00	1.97	1.75	1.22	2.97	0.757	0.557
CLT03	12-Apr-01	90	381	22.0	359.0	3.0	0.60	0.70	1.85	1.30	1.25	2.55	0.661	0.381
CLT03	26-Apr-01	97	316	10.0	306.0	3.0	0.01	0.05	1.66	0.06	1.65	1.71	0.375	0.314
CLT03	31-May-01	274	568	1.0	567.0	0.5	0.01	0.05	1.83	0.06	1.82	1.88	1.590	1.320
CLT03	5-Jun-01	282	592	24.0	568.0	6.0	0.05	0.10	1.73	0.15	1.68	1.83	1.530	1.270
CLT04	5-Aug-00	50	363	26.0	337.0	7.0	1.37	9.60	5.12	10.97	3.75	14.72	2.250	2.240
CLT04	6-Aug-00	55	307	18.0	289.0	9.0	0.01	0.10	2.18	0.11	2.17	2.28	1.280	1.170
CLT04	16-Aug-00	178	628	10.0	618.0	6.0	0.21	0.05	3.03	0.26	2.82	3.08	3.650	3.450
CLT04	30-Aug-00	249	649	10.0	639.0	3.0	0.59	0.05	3.47	0.64	2.88	3.52	3.820	3.690
CLT04	30-Aug-00	251	647	11.0	636.0	5.0	0.59	0.05	2.88	0.64	2.29	2.93	3.880	3.660
CLT04	26-Mar-01	279	837	36.0	801.0	17.0	8.88	0.10	20.60	8.98	11.72	20.70	5.330	4.640
CLT04	26-Mar-01	61	340	20.0	320.0	3.0	0.10	16.50	3.27	16.60	3.17	19.77	0.531	0.379
CLT04	10-Apr-01	113	501	13.0	488.0	5.0	2.06	3.10	4.87	5.16	2.81	7.97	1.340	0.958
CLT04	12-Apr-01	143	587	42.0	545.0	8.0	3.41	1.70	6.89	5.11	3.48	8.59	1.760	0.970
CLT04	26-Apr-01	92	353	14.0	339.0	10.0	0.40	0.10	2.88	0.50	2.48	2.98	0.618	0.516
CLT04	31-May-01	255	565	2.0	563.0	1.0	0.52	0.05	2.70	0.57	2.18	2.75	3.270	2.490

NOTE: all data units are mg/L

Parameter Abbreviations

ALKA = alkalinity
TOTS = total solids
TSS = total suspended solids
TDS = total dissolved solids
TVSS = total volatile suspended solids
TOT P = total phosphorus
TDP = total dissolved phosphorus
AMMO = ammonia
UNION = unionized ammonia
NIT = nitrate
TKN = total Kjeldahl nitrogen
INORG NIT = inorganic nitrogen
ORG NIT = organic nitrogen

Appendix E

Quality Assurance/Quality Control (QA/QC) Data

QA/QC data for duplicate and routine sample pairs

Site	Depth	Type	Date	Fecal	Alk	Tot Sol	TSS	TVSS	Amm	Nit	TKN	Tot P	TDP
CL01	S	REP	7-Aug-00	160	77	318	12.0	9.0	0.01	0.20	1.86	0.988	0.896
CL01	S	DUP	7-Aug-00	360	76	320	12.0	8.0	0.01	0.20	1.73	0.983	0.880
Percent Difference				38.5%	0.7%	0.3%	0.0%	5.9%	0.0%	0.0%	3.6%	0.3%	0.9%
CL01	B	REP	15-Mar-01	5	224	632	5.0	3.0	0.30	0.05	1.83	0.564	0.554
CL01	B	DUP	15-Mar-01	5	225	636	7.0	4.0	0.32	0.05	1.78	0.550	0.566
Percent Difference				0.0%	0.2%	0.3%	16.7%	14.3%	3.2%	0.0%	1.4%	1.3%	1.1%
CL01	B	DUP	5-Jun-01	5	164	526	9.0	5.0	0.01	0.05	1.61	0.542	0.468
CL01	B	REP	5-Jun-01	5	164	526	9.0	5.0	0.01	0.05	1.61	0.542	0.468
Percent Difference				0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
CL02	B	DUP	7-Aug-00	650	165	588	54.0	20.0	0.25	0.30	1.59	0.830	0.605
CL02	B	REP	7-Aug-00	270	166	563	29.0	6.0	0.22	0.30	1.90	0.807	0.593
Percent Difference				41.3%	0.3%	2.2%	30.1%	53.8%	6.4%	0.0%	8.9%	1.4%	1.0%
CL02	B	REP	29-Jan-01	5	218	670	44.0	16.0	0.08	0.05	2.37	0.486	0.331
CL02	B	DUP	29-Jan-01	5	220	817	196.0	44.0	0.09	0.10	2.13	0.593	0.307
Percent Difference				0.0%	0.5%	9.9%	63.3%	46.7%	5.9%	33.3%	5.3%	9.9%	3.8%
Average Percent Difference				**16.0%**	**0.3%**	**2.5%**	**22.0%**	**24.1%**	**3.1%**	**6.7%**	**3.8%**	**2.6%**	**1.3%**

QA/QC data for blank samples

Site	Depth	Type	Date	Fecal	Alk	Tot Sol	TSS	TVSS	Amm	Nit	TKN	Tot P	TDP
CL02	B	BLK	29-Jan-01	5	3	4	0.5	0.5	0.01	0.05	0.18	0.001	0.001
CL02	S	BLK	15-Mar-01	5	3	4	0.5	0.5	0.01	0.05	0.18	0.001	0.001
CL01	B	BLK	29-Jan-01	5	3	4	0.5	0.5	0.05	0.05	2.30	0.472	0.378
CL01	S	BLK	28-Dec-00	5	3	18	0.5	0.5	0.01	0.05	0.18	0.001	0.001

Note: Shaded values indicate concentrations above detection limit.

Parameter Abbreviations

Fecal = fecal coliform bacteria
Alk = alkalinity
Tot Sol = total solids
TSS = total suspended solids
TVSS = total volatile suspended solids
Amm = ammonia
Nit = nitrate
TKN = total Kjeldahl nitrogen
Tot P = total phosphorus
TDP = total dissolved phosphorus

Appendix F

Agricultural Non-Point Source Model Results

AGNPS Feedlot Model Output

Cell # 588		**Cell # 642**	
Nitrogen concentration (ppm)	69	Nitrogen concentration (ppm)	270
Phosphorus concentration (ppm)	20	Phosphorus concentration (ppm)	77
COD concentration (ppm)	1035	COD concentration (ppm)	4050
Nitrogen mass (lbs)	7	Nitrogen mass (lbs)	85
Phosphorus mass (lbs)	2	Phosphorus mass (lbs)	24
COD mass (lbs)	102	COD mass (lbs)	1276
Animal feedlot rating number	**0**	Animal feedlot rating number	**30**
Cell # 781		**Cell # 438**	
Nitrogen concentration (ppm)	75	Nitrogen concentration (ppm)	180
Phosphorus concentration (ppm)	21	Phosphorus concentration (ppm)	51
COD concentration (ppm)	1125	COD concentration (ppm)	2700
Nitrogen mass (lbs)	54	Nitrogen mass (lbs)	87
Phosphorus mass (lbs)	15	Phosphorus mass (lbs)	25
COD mass (lbs)	815	COD mass (lbs)	1300
Animal feedlot rating number	**25**	Animal feedlot rating number	**30**
Cell # 21		**Cell # 585**	
Nitrogen concentration (ppm)	113	Nitrogen concentration (ppm)	300
Phosphorus concentration (ppm)	32	Phosphorus concentration (ppm)	85
COD concentration (ppm)	1688	COD concentration (ppm)	4500
Nitrogen mass (lbs)	65	Nitrogen mass (lbs)	92
Phosphorus mass (lbs)	18	Phosphorus mass (lbs)	26
COD mass (lbs)	978	COD mass (lbs)	1385
Animal feedlot rating number	**27**	Animal feedlot rating number	**30**
Cell # 594		**Cell # 317**	
Nitrogen concentration (ppm)	29	Nitrogen concentration (ppm)	225
Phosphorus concentration (ppm)	4	Phosphorus concentration (ppm)	64
COD concentration (ppm)	608	COD concentration (ppm)	3375
Nitrogen mass (lbs)	42	Nitrogen mass (lbs)	170
Phosphorus mass (lbs)	6	Phosphorus mass (lbs)	48
COD mass (lbs)	880	COD mass (lbs)	2548
Animal feedlot rating number	**27**	Animal feedlot rating number	**39**

Phosphorus, Nitrogen, and Erosion Critical Cells with Annual Loads

Phosphorus Critical Cell Number	Annual Phosphorus Load (lbs)	Nitrogen Critical Cell Number	Annual Nitrogen Load (lbs)	Erosion Critical Cell Number	Annual Sediment Load (tons)
88	203.2	88	726.67	88	238.0
407	119.2	478	632.67	407	110.1
229	104.3	408	626.40	229	100.0
704	100.5	426	623.47	704	91.1
259	94.3	368	589.60	794	80.0
302	91.7	590	560.53	302	76.3
794	86.5	231	553.47	250	67.2
478	84.9	232	548.13	259	67.2
408	83.2	593	540.80	230	66.1
234	82.7	938	531.20	298	60.7
426	82.0	978	531.20	687	60.7
230	81.5	924	527.87	334	57.7
590	80.7	975	519.60	234	56.1
250	75.2	939	513.47	494	54.1
593	75.2	977	513.47	495	54.1
231	73.2	570	481.73	559	54.1
368	72.3	1006	481.07	793	54.1
687	72.1	407	455.87	353	50.8
232	71.9	166	424.53	405	50.8
938	71.6	259	393.73	406	50.8
978	71.6	229	382.67	688	50.8
298	70.5	704	381.07	994	50.3
924	70.0	302	360.13	349	50.1
570	68.9	234	352.13	402	50.1
1006	68.1	262	351.87	457	50.1
975	67.9	196	337.47	505	49.7
591	66.1	230	321.33	591	49.7
939	66.1	794	316.93	123	47.2
977	66.1	363	314.27	251	46.3
262	65.5	187	302.13	135	44.3
494	65.1	354	297.20	138	44.3
495	65.1	659	292.67	201	44.3
559	65.1	131	284.67	710	44.3
793	65.1	299	280.13	254	44.1
334	64.1	250	272.93	156	40.9
994	62.9	687	272.27	157	40.9
688	62.1	689	271.60	186	40.9
299	61.5	591	266.00	188	40.9
196	61.2	298	262.67	464	40.9
138	60.9	669	253.87	574	40.9
710	60.9	494	242.80	850	40.9
405	60.7	495	242.80	556	40.8
406	60.7	559	242.80	621	40.3
123	60.3	793	242.80	622	40.3
353	60.0	138	242.67	686	40.3
402	59.7	710	242.67	878	40.3
505	59.3	621	237.20	116	39.9

349	59.1	622	237.20	261	39.9
457	59.1	878	237.20	335	39.9
251	58.5	994	237.20	132	39.3
135	58.0	601	236.93	571	39.3
156	58.0	617	236.93	462	36.8
621	57.7	325	236.40	299	36.3
622	57.7	758	236.40	558	36.3
878	57.7	156	233.07	38	33.5
131	57.3	688	232.13	218	33.5
571	55.2	123	230.13	87	33.3
850	54.9	425	228.80	131	33.3
157	53.5	498	227.87	425	33.3
186	53.5	996	226.00	543	33.3
188	53.5	571	224.40	869	33.3
425	53.5	334	224.00	221	32.8
574	53.5	251	222.93	590	32.7
686	53.5	135	221.87	993	30.0
166	52.4	405	220.67	264	29.9
132	52.3	406	220.67	117	29.3
464	52.1	353	216.53	262	29.3
254	51.3	402	215.47	49	27.5
369	51.1	258	213.33	876	27.5
187	50.0	349	211.33	879	27.5
261	50.0	457	211.33	925	27.5
462	50.0	850	210.53	932	27.5
258	48.3	505	210.40	933	27.5
201	47.7	686	206.80	155	26.9
558	47.7	132	203.60	233	26.9
38	47.2	104	202.67	258	26.9
218	47.2	157	202.67	281	26.9
116	47.1	186	202.67	418	26.9
335	47.1	188	202.67	465	26.9
87	46.7	574	202.67	471	26.9
869	46.7	879	195.60	530	26.9
879	45.9	925	195.60	618	26.9
925	45.9	932	195.60	685	26.9
932	45.9	933	195.60	806	26.9
933	45.9	17	195.33	872	26.9
363	45.3	1007	194.53	995	26.9
498	43.9	1015	194.53	820	26.8
872	43.7	462	193.73	136	26.4
995	43.7	464	193.07	570	26.4
993	43.6	372	186.27	478	26.0
354	43.3	373	186.27	196	25.9
543	43.2	38	184.67	593	25.9
49	41.6	218	184.67	999	25.9
876	41.6	872	184.67	641	24.3
689	41.5	87	184.13	463	23.9
372	41.3	869	184.13	527	23.9
373	41.3	261	183.47	619	23.9
556	41.3	558	183.20		
233	40.8	995	183.20		

155	40.7	201	181.20		
136	39.9	254	180.67		
221	39.9	1016	180.13		
465	39.2	421	174.53		
471	39.2	18	174.27		
618	39.2	993	170.93		
685	39.2	39	168.53		
806	39.2	362	167.20		
104	38.8	997	166.53		
117	38.8	592	166.13		
641	38.5	116	166.00		
996	38.3	335	166.00		
421	37.9	49	165.20		
820	37.5	876	165.20		
463	37.3	233	163.87		
264	37.2	155	162.27		
167	36.9				
168	36.9				
169	36.9				
198	36.9				
592	36.9				
659	36.7				
530	36.3				
669	36.3				
619	35.9				
133	35.6				
228	35.6				
301	35.6				
660	35.6				
661	35.6				
999	35.6				
623	35.3				
877	35.3				
926	35.3				
934	35.3				
326	35.2				
281	34.8				
418	34.8				
562	34.8				
627	34.8				
868	34.5				
1014	34.1				
84	34.0				
846	33.9				
847	33.9				

Appendix G

Total Maximum Daily Load (TMDL) Summary

TOTAL MAXIMUM DAILY LOAD EVALUATION

For

Cresbard Lake

(HUC 10160008)

Faulk County, South Dakota

South Dakota Department of
Environment and Natural Resources

1/2/2004

Cresbard Lake Total Maximum Daily Load

Waterbody Type: Lake (Impoundment)
303(d) Listing Parameter: TSI
Designated Uses: 1) Warmwater semipermanent fish propagation
2) Immersion recreation
3) Limited contact recreation
4) Fish and wildlife propagation, recreation and stock watering
Size of Waterbody: 69 acres
Size of Watershed: 40,858 acres
Water Quality Standards: Narrative and Numeric
Indicators: Mean TSI, water chemistry
Analytical Approach: Models including AGNPS, BATHTUB, and FLUX
Location: HUC Code: 10160008
Goal: 40% reduction of external phosphorus load
Target: Mean TSI of 74.8

Objective

The intent of this summary is to clearly identify the components of the TMDL submittal to support adequate public participation and facilitate the US Environmental Protection Agency (EPA) review and approval. The TMDL was developed in accordance with Section 303(d) of the federal Clean Water Act and guidance developed by EPA.

Introduction

Cresbard Lake is a 69-acre impoundment located within the James River Basin (HUC 10160008) in northwest Faulk County and southwest Edmunds County, South Dakota (Figure 1).

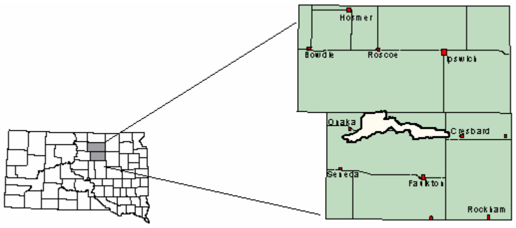


Figure 1. Location of the Cresbard Lake watershed in Faulk County and Edmunds County, South Dakota.

The lake reaches a maximum depth at 14.0 feet (4.3 m) and holds a total water volume of 904 acre-ft. The major inlet is located on the east side of the lake. Due to its shallow nature, the lake is not subject to stratification. The 1998 South Dakota 303(d) Waterbody List identified Cresbard Lake for TMDL development for trophic state index (TSI).

Problem Identification

The Cresbard Lake watershed (40,858 acres) predominantly drains grazing and cropland acres (Figure 2). The stream carries sediment and nutrient loads, which degrade water quality in the lake and have caused increased eutrophication. An estimated 3,409 kg of phosphorus enter Cresbard Lake from the watershed each year.

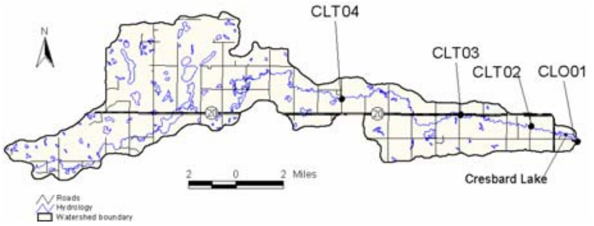


Figure 2. Delineation of the Cresbard Lake watershed and location of stream sites.

Description of Applicable Water Quality Standards & Numeric Water Quality Targets

Cresbard Lake has been assigned beneficial uses by the state of South Dakota Surface Water Quality Standards regulations. Along with these assigned uses are narrative and numeric criteria that define the desired water quality of the lake. These criteria must be maintained for the lake to satisfy its assigned beneficial uses, which are listed below:

1) Warmwater semipermanent fish propagation
2) Immersion recreation
3) Limited contact recreation
4) Fish and wildlife propagation, recreation and stock watering.

Individual parameters, including the lake's TSI value, determine the support of beneficial uses and compliance with standards. Cresbard Lake experiences external phosphorus loading from its watershed, which has caused its increasing eutrophication state. Cresbard Lake is identified in both the 1998 South Dakota 303(d) Waterbody List and "Ecoregion Targeting for Impaired Lakes in South Dakota" as non-supporting in terms of beneficial use.

South Dakota has several applicable narrative standards that may be applied to the undesired eutrophication of lakes and streams. Administrative Rules of South Dakota Article 74:51 contains language that prohibits the existence of materials causing pollutants to form, visible pollutants, taste and odor producing materials, and nuisance aquatic life.

If adequate numeric criteria are not available, the South Dakota Department of Environment and Natural Resources (SD DENR) uses surrogate measures to indicate impairment. To assess the trophic status of a lake, SD DENR uses the Trophic State Index or TSI (Carlson, 1977) which incorporates secchi depth, chlorophyll *a* concentrations, and phosphorus concentrations. SD DENR has developed an EPA approved protocol that establishes desired TSI levels for lakes based on an ecoregion approach.

This protocol was used to assess impairment and determine a numeric target for Cresbard Lake. Cresbard Lake currently has a predicted mean TSI of 76.7 (from BATHTUB model), which is indicative of high levels of primary productivity. Assessment monitoring indicates that the primary cause of the high productivity is high phosphorus loads from the watershed.

Pollutant Assessment

Point Sources

There are no point source pollutants of concern in this watershed. The municipalities of Wecota and Norbeck do not contribute significant point source discharges.

Nonpoint Sources

The BATHTUB model estimated a 95% reduction in phosphorus concentrations would be necessary to bring Cresbard Lake to an ecoregion-based beneficial use classification of fully supporting. However, the ecoregion-based criteria do not appear to be suitable for Cresbard Lake, as demonstrated by the large reduction in total phosphorus needed to meet current ecoregion criteria. Economic and technical limitations prohibit this level of nutrient load reduction. Nutrient reductions of this magnitude would require extreme land use alterations and possibly the elimination of agriculture in the watershed. Therefore, the TMDL was developed based on realistic criteria using watershed-specific, attainable BMP reductions.

A predicted 40% reduction in total phosphorus load can be achieved in this watershed to meet the TMDL goal of 2,785 kg or a mean in-lake TSI of 74.8. The recommended reduction in phosphorus load from the Cresbard

Lake watershed will improve compliance with South Dakota's narrative criteria as well as watershed-specific beneficial use criteria.

The current total phosphorus load from the Cresbard Lake watershed is 4,641 kg/yr. Reducing this load by 40% will yield an annual total phosphorus load of 2,785 kg, which will lower the lake's mean TSI from 76.7 to 74.8. This can be accomplished by implementing the recommended watershed BMPs.

Linkage Analysis

Water quality data was collected at two lake sites and four tributary sites. Samples collected at each site were taken according to South Dakota's EPA approved Standard Operating Procedures for Field Samplers. Water samples were sent to the State Health Laboratory in Pierre for analysis. Quality Assurance/Quality Control samples were collected on 10% of the samples according to South Dakota's EPA approved Clean Lakes Quality Assurance/ Quality Control Plan. Details concerning water sampling techniques, analysis, and quality control are addressed in the assessment final report.

The Agricultural Non-Point Source Model (AGNPS) was used to define critical non-point source (NPS) pollution cells within the watershed (those with high sediment, nitrogen, and phosphorus loads) and estimate the effective percent reduction of sediment and nutrients in the watershed by adding various Best Management Practices (BMPs). See the AGNPS section of the final report for a complete summary of the results.

The impacts of phosphorus reductions on the condition of Cresbard Lake were calculated using BATHTUB, an Army Corps of Engineers model. The model predicted that reductions of phosphorus loadings to the lake by 40 percent would result in a reduction of mean TSI score by 2 points. This would lower the current mean TSI from 76.7 to 74.8, the TMDL target. The recommended reduction will improve compliance with South Dakota's narrative criteria and the designated beneficial uses of Cresbard Lake.

TMDL Allocations

Wasteload Allocations (WLAs)

There are no point sources of pollutants of concern in this watershed. Therefore, the "wasteload allocation" component of this TMDL is considered a zero value. The TMDL is considered wholly included within the "load allocation" component.

Load Allocations (LAs)

A 40% reduction of external phosphorus load to Cresbard Lake may be achieved through the implementation of BMPs including conservation tillage, reduced fertilization, and grassed waterways.

Seasonal Variation

Different seasons of the year can yield differences in water quality due to changes in precipitation and agricultural practices. To determine seasonal differences, Cresbard Lake sample data was graphed by sample date to facilitate viewing seasonal differences. Seasonal loadings from the watershed were also calculated for spring (March-May), summer (June-August), fall (September-November), and winter (December-February) months.

Margin of Safety

The margin of safety is implicit in that all total phosphorus reductions were calculated using conservative estimations of modeled best management practices (cover management factors, reduced fertilization levels, and grassed waterways).

A 6% margin of safety is explicit in that the TMDL goal was set at a 40% reduction of phosphorus load, when a predicted 45.8% reduction of phosphorus load could be achieved with the implementation of watershed BMPs.

Critical Conditions

The impairments to Cresbard Lake are most severe during late summer. This is the result of warm water temperatures and peak phosphorus concentrations.

Follow-Up Monitoring

Monitoring and evaluation efforts will be targeted toward the effectiveness of implemented BMP's. Sample sites will be based on BMP site selection and parameters will be based on a product specific basis.

Samples will be collected both upstream and downstream of the proposed BMP project area to measure impact of the specific site.

Once the implementation project is completed, post-implementation monitoring will be necessary to assure that the TMDL has been reached and improvement to the beneficial uses occurs.

Public Participation

Efforts were taken to gain public education, review, and comment during development of the TMDL including Dakota Central Conservation Association board meetings and local newspaper articles.

The findings from these public meetings and comments have been taken into consideration in development of the Cresbard Lake TMDL.

Implementation Plan

South Dakota DENR is working with the Faulk County Conservation District to initiate an implementation project beginning in 2003. It is expected that a local sponsor will request project assistance during the spring 2003 EPA Section 319 funding round.

Appendix H

Public Comments, Correspondence, and Response to Comments

Public Comment and DENR Response to Comments

From: Berry.Vern@epamail.epa.gov [mailto:Berry.Vern@epamail.epa.gov]
Sent: Monday, March 03, 2003 6:31 PM
To: Leland.Baron@state.sd.us
Cc: Lofstedt.Doug@epamail.epa.gov
Subject: EPA Comments on TMDLs for Lake Alice and Cresbard Lake

Leland,

Thanks for the opportunity to comment on these TMDLs. We have the following comments on the TMDLs for Lake Alice and Cresbard Lake.

Lake Alice - no comments. Based on the current data, and as indicated in the draft TMDL, this waterbody seems to be meeting the TSI goals established by SD DENR, and is eligible for de-listing.

Cresbard Lake
* The TMDL target is a mean TSI of 74.8, which requires a 40% reduction in phosphorous load. Based on SD DENR's ecoregion TSI criteria this would meet the partially supporting beneficial use classification. The modeling done for the Lake assessment report shows that a 95% reduction in phosphorous is necessary to achieve fully supporting status. The assessment report explains why the 95% reduction in phosphorous is not technically or economically achievable, however this explanation is not included in the TMDL. This explanation should be included in the TMDL write-up.

Vern Berry
US EPA Region 8
Denver, CO
303-312-6234

DENR Response to Comment

Author agrees with EPA's comment, and suggested changes were incorporated. The following statement was added to the TMDL summary report:

"The BATHTUB model estimated a 95% reduction in phosphorus concentrations would be necessary to bring Cresbard Lake to an ecoregion-based beneficial use classification of fully supporting. However, the ecoregion-based criteria do not appear to be suitable for Cresbard Lake, as demonstrated by the large reduction in total phosphorus needed to meet current ecoregion criteria. Economic and technical limitations prohibit this level of nutrient load reduction. Nutrient reductions of this magnitude would require extreme land use alterations and possibly the elimination of agriculture in the watershed. Therefore, the TMDL was developed based on realistic criteria using watershed-specific, attainable BMP reductions."

Public Comment and DENR Response to Comments

From: Lofstedt.Doug@epamail.epa.gov
Sent: Fri 12/20/2002 1:43 PM
To: Aaron.Larson@state.sd.us
Cc: Gene.Stueven@state.sd.us; Berry.Vern@epamail.epa.gov; jim.feeney@state.sd.us
Subject: Cresbard Lake Assessment/TMDL Report

Thanks Aaron for sending us the referenced report for review. Vern Berry from the TMDL program plans to review/comment during the formal public notice period for the TMDL.

One thing that was helpful throughout the document was to show the monitored and modeled values, such as at the lake inlet and outlet.

Just a few comments for you to consider:

1. Page 9 - I would suggest defining the flow volume and rate abbreviations in Table 5. Also, what is the average cfs for the unnamed tributary?

2. Pages 42-45 - I like how you display the predicted concentrations of total phosphorus and TSI values with successive 10-percent reductions in phosphorus inputs. The analysis relates well to discussions of feasible implementation options.

3. Page 62 - Regarding the Watershed Management Recommendations, it would be helpful to have an estimated acreage of grazing and cropland that needs treatment. Improvements in grazing management are discussed for lakeshore, streambank and buffer zones. Could you describe briefly the extent of these problems, quantify an estimated acreage or length of area needing treatment, and somehow indicate in the appendix where this treatment is needed? This type of information could be very useful for the implementation plan. Likewise, a proposed target for land surface cover (C-factor) for crop and rangeland would also be useful to carry forward to the implementation plan (similar to what you did for fertilization targets).

4. TMDL page 3 - Since Wecota and Norbeck are in the watershed, it could be clarified that the towns don't have point source discharges, or otherwise explain why there aren't "point source pollutants of concern in this watershed." Vern may have thoughts on this as well.

Hope this helps, and if there are any questions, just let me know.

Doug
303-312-6835

DENR Response to Comment

The following are the above comments and DENR's response (in bold):

1. I would suggest defining the flow volume and rate abbreviations in Table 5. Also, what is the average cfs for the unnamed tributary?

Author agrees with EPA's comment, and suggested changes were incorporated. Definitions of abbreviations were included under Table 5 (page 8) of the report.

2. I like how you display the predicted concentrations of total phosphorus and TSI values with successive 10-percent reductions in phosphorus inputs. The analysis relates well to discussions of feasible implementation options.

No changes necessary

3. Regarding the Watershed Management Recommendations, it would be helpful to have an estimated acreage of grazing and cropland that needs treatment. Improvements in grazing management are discussed for lakeshore, streambank and buffer zones. Could you describe briefly the extent of these problems, quantify an estimated acreage or length of area needing treatment, and somehow indicate in the appendix where this treatment is needed? This type of information could be very useful for the implementation plan. Likewise, a proposed target for land surface cover (C-factor) for crop and rangeland would also be useful to carry forward to the implementation plan (similar to what you did for fertilization targets).

Author agrees with EPA's comment, and suggested changes were incorporated. The following paragraph was added to the Watershed Management section of the report:
"An estimated 5,760 acres of crop and range lands are considered high priority or critical areas that would require the aforementioned management practices to attain the TMDL goal. All critical phosphorus cells (see Appendix F) should be targeted for increased surface cover management (i.e. a C-factor ≥ 0.1)"

4. Since Wecota and Norbeck are in the watershed, it could be clarified that the towns don't have point source discharges, or otherwise explain why there aren't "point source pollutants of concern in this watershed." Vern may have thoughts on this as well.

Author agrees with EPA's comment, and suggested changes were incorporated. The following statement was added to the TMDL summary report:
"The municipalities of Wecota and Norbeck do not contribute significant point source discharges."

NOTICE OF
TOTAL MAXIMUM DAILY LOADS

The South Dakota Department of Environment and Natural Resources (DENR) announces the availability of the following Total Maximum Daily Loads (TMDLs) for review and comment.

Lake Alice, Deuel County	**Cresbard Lake, Faulk County**

The TMDLs were developed in accordance with Section 303(d) of the federal Clean Water Act. These TMDLs were developed on a watershed basis that included public involvement.

TMDLs are an important tool for the management of water quality. The goal of a TMDL is to ensure that waters of the state attain water quality standards and provide designated beneficial uses. A TMDL is defined as "the sum of the individual waste load allocations for point sources and load allocations for both nonpoint source and natural background sources established at a level necessary to achieve compliance with applicable surface water quality standards." In other words, a TMDL identifies the total pollution load that any given water body can receive and still remain healthy. TMDLs are required on waters that do not attain water quality standards or assigned beneficial uses.

Any person interested in reviewing any TMDL document may request a copy by telephone or by mail. Also, each document has been placed on DENR's website at the Internet address http://www.state.sd.us/denr/DFTA/WatershedProtection/tmdlpage.htm.

Copies of the draft may also be obtained from Leland Baron by writing to the address below, emailing Leland Baron at Leland.Baron@state.sd.us**, or by calling 1-800-438-3367.**

Any person desiring to comment on the list may submit comments to the address below. Persons are encouraged to comment electronically by sending the comments to Leland Baron at the email address in the above paragraph. The department must receive the comments by March 3rd 2003.

Department of Environment and Natural Resources
Water Resources Assistance Program
523 East Capitol Avenue – Joe Foss Building
Pierre, South Dakota 57501-3181

Steven M. Pirner
Secretary
Department of Environment and Natural Resources

January 14, 2003

Bruce Zander – 8EPR-EP
US Environmental Protection Agency – Region 8
999 18th Street Suite 300
Denver, Colorado 80202-2466

Vern Berry – 8EPR-EP
US Environmental Protection Agency – Region 8
999 18th Street Suite 300
Denver, Colorado 80202-2466

Bill Wuerthle – 8EPR-EP
US Environmental Protection Agency – Region 8
999 18th Street Suite 300
Denver, Colorado 80202-2466

Dear Sirs:

The South Dakota Department of Environment and Natural Resources (DENR) submits the following Total Maximum Daily Loads (TMDLs) for your review and approval.

Lake Alice, Deuel County **Cresbard Lake, Faulk County**

These TMDLs were developed by the department with public input in accordance with section 303(d) of the federal Clean Water Act. The TMDLs have been established at levels necessary to meet applicable water quality standards with consideration of seasonal variation, margin of safety, and all sources of pollution.

The TMDLs begin a 30 day public comment period that will end with the close of business, March 3, 2003. We look forward to receiving your approval for these TMDLs.

If you have questions or need more information, please contact me at Leland.Baron@state.sd.us, or by calling 605-773-4254.

Sincerely,

Leland Baron
Water Resources Assistance Program

Enclosures

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 8
999 18TH STREET - SUITE 300
DENVER, CO 80202-2466
http://www.epa.gov/region08

December 3, 2003

Ref: 8EPR-EP

Steven M. Pirner, Secretary
Department of Environment & Natural Resources
Joe Foss Building
523 East Capitol
Pierre, SD 57501-3181

Re: TMDL Approvals
Cresbard Lake

Dear Mr. Pirner:

We have completed our review, and have received ESA Section 7 concurrence from the US Fish and Wildlife Service, on the total maximum daily loads (TMDLs) as submitted by your office for the waterbodies listed in the enclosure to this letter. In accordance with the Clean Water Act (33 U.S.C. 1251 *et. seq.*), we approve all aspects of the TMDLs as developed for the water quality limited waterbodies as described in Section 303(d)(1).

Based on our review, we feel the separate TMDL elements listed in the enclosed review table adequately address the pollutants of concern, taking into consideration seasonal variation and a margin of safety. Please find enclosed a detailed review of these TMDLs.

For years, the State has sponsored an extensive clean lakes program. Through the lakes assessment and monitoring efforts associated with this program, priority waterbodies have been identified for cleanup. It is reasonable that these same priority waters have been a focus of the Section 319 nonpoint source projects as well as one of the priorities under the State's Section 303(d) TMDL efforts.

Thank you for your submittal. If you have any questions concerning this approval, feel free to contact Vernon Berry of my staff at 303-312-6234.

Sincerely,

/s/ by Max H. Dodson

Max H. Dodson
Assistant Regional Administrator
Office of Ecosystems Protection and
Remediation

Enclosure

Enclosure

APPROVED TMDLS

Waterbody Name*	**TMDL Parameter/ Pollutant**	**Water Quality Goal/Endpoint**	**TMDL**	**Section 303(d)1 or 303(d)3 TMDL**	**Supporting Documentation** (not an exhaustive list of supporting documents)
Cresbard Lake*	phosphorus	TSI mean ≤ 74.8	Total phosphorous load of 2,785 kg/yr (40% reduction in tributary phosphorus loads)	Section 303(d)(1)	■ Section 319 Nonpoint Source Pollution Control Program Assessment/Planning Project Final Report, Cresbard Lake, Faulk County, South Dakota (SD DENR, October 2002)

* An asterisk indicates the waterbody has been included on the State's Section 303(d) list of waterbodies in need of TMDLs.

■ TMDL Checklist ■

EPA Region VIII

State/Tribe: South Dakota
Waterbody Name: Cresbard Lake, Faulk County
Point Source-control TMDL: Nonpoint Source-control TMDL: X (check one or both)
Date Received: October 20, 2003 Date Review completed: October 28, 2003 VEB

A. Water Quality Standards - **Approved**	The State's submittal provides a good description of the geographic scope of the TMDL as well as information on the watershed and land use characteristics of Cresbard Lake. The South Dakota Department of Environment and Natural Resources (SD DENR) has identified Cresbard Lake as a water that is intended to support a range of designated uses including: warmwater semipermanent fish life propagation, immersion recreation, limited contact recreation, fish and wildlife propagation, recreation and stock watering. The narrative standards being implemented in this TMDL are: "*Materials which produce nuisance aquatic life may not be discharged or caused to be discharged into surface waters of the state in concentrations that impair a beneficial use or create a human health problem.*" (See ARSD §74:51:01:09) "*All waters of the state must be free from substances, whether attributable to human-induced point source discharges or nonpoint source activities, in concentration or combinations which will adversely impact the structure and function of indigenous or intentionally introduced aquatic communities.*" (See ARSD §74:51:01:12)
B. Water Quality Standards Targets - **Approved**	Water quality targets for this TMDL are based on interpretation of narrative provisions found in State water quality standards. In May 2000, SD DENR published *Ecoregion Targeting for Impaired Lakes in South Dakota*. This document proposed ecoregion-specific targeted Trophic State Index (TSI) values based on beneficial uses. EPA approved the use of these ecoregion-specific targets to evaluate lakes using beneficial use categories. In South Dakota algal blooms can limit contact and immersion recreation beneficial uses. Also algal blooms can deplete oxygen levels which can affect aquatic life uses. SD DENR considers several algal species to be nuisance aquatic species. TSI measurements can be used to estimate how much algal production may occur in lakes. Therefore, TSI is used as a measure of the narrative standard in order to determine whether beneficial uses are being met. The overall mean TSI for Cresbard Lake during the period of the assessment (June 2000 through June 2001) was 76.7. Nutrient reduction response modeling was conducted with BATHTUB, an Army Corps of Engineers eutrophication response model. The results of the modeling show that 95% or more reduction in the total phosphorous loading from the watershed would be necessary to meet the ecoregion-based beneficial use TSI target of 65 or less. However, Cresbard Lake does not appear to fit the ecoregion-based beneficial use criteria due to legacy phosphorous loading to the lake and the technical and financial inability to fully treat new loading to the lake. Therefore, a higher TSI target has been established for Cresbard Lake. The target used in this TMDL is: ■ TSI mean less than 74.8 (annual average)
C. Significant Sources - **Approved**	The TMDL identifies the major sources of phosphorous as coming from nonpoint source grazing and cropland landuses within the watershed. In particular, a loading analysis was done for nutrients and sediment considering various agricultural land use and land management factors.

State/Tribe: South Dakota
Waterbody Name: Cresbard Lake, Faulk County
Point Source-control TMDL: Nonpoint Source-control TMDL: X (check one or both)
Date Received: October 20, 2003 Date Review completed: October 28, 2003 VEB

D. Technical Analysis - **Approved**	The technical analysis addresses the needed phosphorous reduction to achieve the desired water quality. The TMDL recommends a 40% reduction in phosphorous loading from the watershed to Cresbard Lake to achieve the desired results. This reduction is based in large part on the BATHTUB mathematical modeling of the Lake and its predicted response to nutrient load reductions. The Agricultural Non-Point Source Model (AGNPS) model was used to simulate alterations in land use practices and the resulting nutrient reduction response. The analysis of which nutrient loading sources were in need of control was based on a identification of targeted or "critical" cells. In the Cresbard Lake watershed, phosphorus critical cells are those that deliver greater than 0.852 lbs/acre of total phosphorus; nitrogen critical cells deliver greater than 4.02 lbs/acre of total nitrogen; and sediment critical cells deliver greater than 0.59 tons/acre of sediment. All critical cells were defined as those cells that delivered greater than one standard deviation plus the mean of the export coefficient (e.g. lbs/acre) for the parameter of concern. The initial load reductions under this TMDL will be achieved through controls on the identified critical cells within the watershed combined with modification of grazing practices.
E. Margin of Safety & Seasonality - **Approved**	An appropriate margin of safety is included through conservative assumptions in the derivation of the target and in the modeling. Implementation of all of the identified voluntary BMPs could achieve an additional 6% phosphorous load reduction. Also, ongoing monitoring has been proposed to assure water quality goals are achieved. Seasonality was adequately considered by evaluating the cumulative impacts of the various seasons on water quality and by proposing that BMPs be tailored to seasonal needs.
F. TMDL - **Approved**	The TMDL established for Cresbard Lake is 2,785 kg/year total phosphorous loading to the lake (40% reduction in annual tributary phosphorous loading). Since the annual loading varies from year-to-year, this TMDL is considered a long term average reduction in phosphorous loading.
G. Allocation - **Approved**	This TMDL addresses the need to achieve further reductions in nutrients to attain water quality goals in Cresbard Lake. The allocation for the TMDL was a "load allocation" attributed to nonpoint sources. The allocation for phosphorous was attributed to such sources as animal feeding areas and cropland fertilization and tillage practices. Controls that will reduce phosphorous loading in the watershed include conversion of highly erodible cropland from conventional tillage to conservation tillage or conversion to conservation reserve program (CRP) use, reduction of fertilization levels, and installation of grassed waterways and riparian buffer zones. Modification of grazing practices may also be necessary. Additional phosphorous load reductions are possible if all of the cropping and grazing uses were converted to CRP use, or through extensive inlake restoration activities. However, economic and technical limitations make it infeasible to drastically reduce or eliminate agricultural landuse in the watershed. Cresbard Lake is narrow and shallow and is in a rural area which would make it difficult to obtain local support and funding for extensive inlake restoration activities that would be necessary to achieve significantly higher phosphorous load reductions. The proposed 40% reduction in phosphorous loading is considered reasonably achievable.
H. Public Participation - **Approved**	The State's submittal includes a summary of the public participation process that has occurred which describes the ways the public has been given an opportunity to be involved in the TMDL development process. In particular, the State has encouraged participation through public meetings in the watershed, articles in local newspapers, and widespread solicitation of comments on the draft TMDL. The State has also use the Internet to post the draft TMDL and to solicit comments. The level of public participation is found to be adequate.