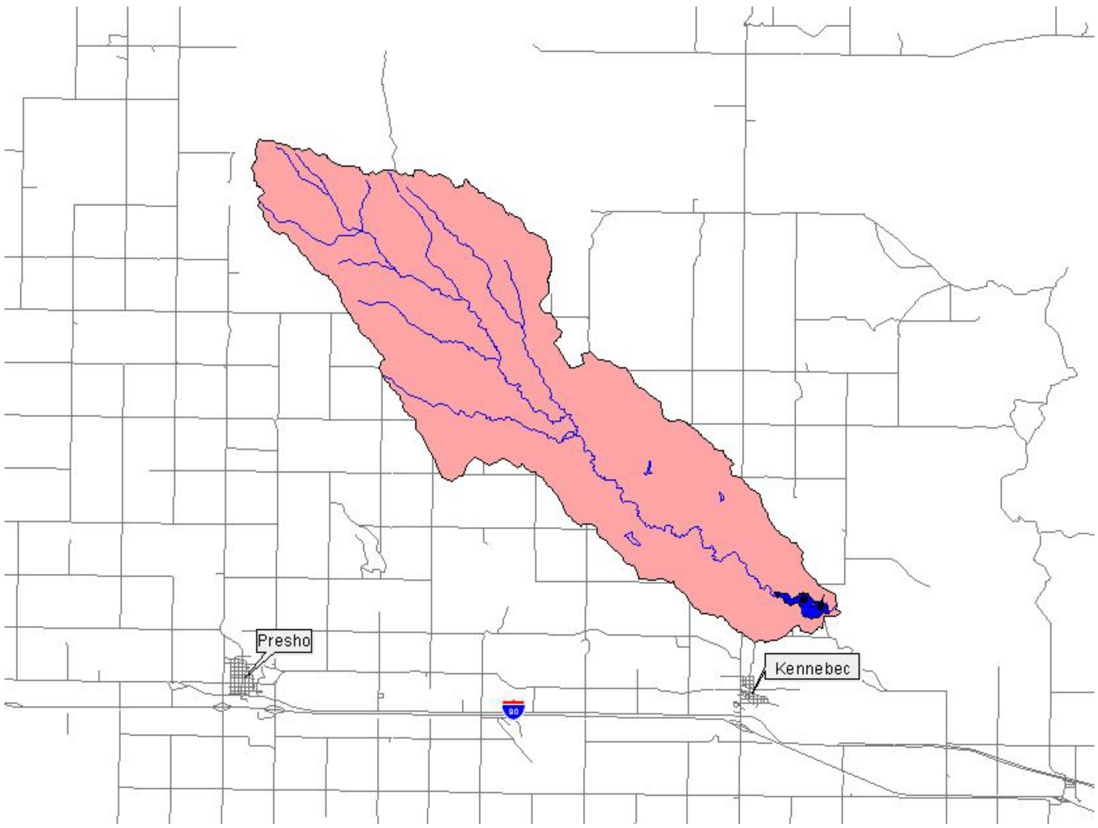
PHASE I
WATERSHED ASSESSMENT FINAL REPORT
AND TMDL

BYRE LAKE / GROUSE CREEK
LYMAN COUNTY, SOUTH DAKOTA



South Dakota Water Resources Assistance Program
Division of Financial and Technical Assistance
South Dakota Department of Environment and Natural Resources
Steven M. Pirner, Secretary

April 2003

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South Dakota Water Resources Assistance Program
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Prepared By

Robert L. Smith, Environmental Program Scientist

State of South Dakota
M. Michael Rounds, Governor

April 2003

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

BYRE LAKE / GROUSE CREEK WATERSHED ASSESSMENT AND TMDL

(PART OF THE MEDICINE CREEK WATERSHED ASSESSMENT PROJECT)

by:
Robert L. Smith

Project Sponsor:
American Creek Conservation District

April 2003

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

EPA Grant # C9998185-00

Executive Summary

Project Title: Medicine Creek Watershed Assessment Project

Project Start Date: April 1, 2000 **Project Completion Date:** December 31, 2001

Funding:	**Total Budget:** $ 169,660
Total EPA Budget:	$ 101,796
Total Expenditures of EPA Funds:	$ 101,796
Total Section 319 Match Accrued:	$ 75,238.38
Budget Revisions:	No Revisions
Total Expenditures:	$ 177,034.38

Summary of Accomplishments

Byre Lake is a reservoir located in the Northwestern Great Plains (43) ecoregion (Level III) in central South Dakota and is located at 43.927642° North Latitude and 99.939203° West Longitude. Grouse Creek drains a watershed of approximately 9,286 ha (22,946 acres) and is impounded Byre Lake. Byre Lake is a recreational lake of approximately 51.5 ha (127.3 acres) and has been impacted by periodic algal blooms. The lake is owned by the Town of Kennebec. Byre Dam breached in May of 1986 and repairs were completed in the fall of 1990. The assessment project was sponsored by the American Creek Conservation District (ACCD). Byre Lake / Grouse Creek was not listed on South Dakota's 1998 or 2002 303(d) Impaired Waterbody List.

This assessment was the initial phase of a watershed-wide restoration project. Water quality monitoring, stream gauging, stream channel and land use analysis were used to document the sources of impairment and calculate a Total Maximum Daily Load (TMDL) for Byre Lake.

A total of 11 tributary and 21 in-lake samples were collected by the sponsor from April 2000 through May 2001. Water quality and hydrologic data from Grouse Creek was modeled using the FLUX model. FLUX data was used to calculate the annual sediment and nutrient loading to Byre Lake. In-lake water quality data was modeled using the BATHTUB model. BATHTUB was used to model TSI reductions based on tributary load reductions. Loading and reduction data was used to determine the TMDL for Byre Lake.

Landuse data was also collected by the project sponsor from the watershed for use in the AnnAGNPS model. AnnAGNPS is a data intensive watershed model that routes sediment and nutrients through a watershed by utilizing land uses and topography. The watershed is broken up into cells of varying sizes based on topography. Each cell is then assigned a primary land use and soil type. Best Management Practices (BMPs) are then simulated by altering the land use in the individual cells and reductions are calculated at the outlet to the watershed. The model was used to identify critical areas and priority ranking in the watershed for sediment erosion and nutrient runoff for targeting during implementation. AnnAGNPS was also used to estimate/model Best Management Practice (BMP) reductions in sediment and nutrient loads. Water quality loading and AGNPS data were sufficient to develop a TMDL for Byre Lake.

Mean TSI values were originally used to set current ecoregional beneficial use criteria for lakes in South Dakota (SD DENR, 2000a). Currently, the target for full support in ecoregion 43 is a mean TSI values ≤ 55.00. However, current ecoregional (ecoregion 43) target criteria appear not to fit Byre Lake based on AnnAGNPS watershed loading and BATHTUB in-lake eutrophication modeling. AnnAGNPS model was used to estimate watershed loading under ideal conditions (entire watershed converted to grassland with a minimum grass height of 10.2 cm (4 inches)) indicate the maximum phosphorus reduction in this watershed would be 28.1 percent (Appendix B). BATHTUB was then used to model AnnAGNPS phosphorus reduction to in-lake trophic response under ideal conditions. Data indicate under ideal conditions (mean TSI 64.16); Byre Lake could not meet ecoregional-based beneficial use criteria based on current targets.

Current watershed conditions (loading) result in a mean in-lake TSI value of 66.24 (Table 39). The Byre Lake/Grouse Creek watershed can not meet current ecoregional based beneficial use criteria which are unrealistic and unachievable in the Byre Lake watershed. Alternative site specific (watershed specific) evaluation criteria (fully supporting, mean TSI ≤ 65.00) is proposed based on AnnAGNPS modeling, BMPs and watershed specific phosphorus reduction attainability (Figure 63).

The recommended reductions will improve compliance with South Dakota's narrative criteria and the designated beneficial uses of the watershed, specifically, domestic water supply, warmwater permanent fish life propagation, immersion recreation, limited contact recreation, fish and wildlife propagation, recreation, and stock watering and irrigation water. Based upon data from this assessment, a phase II implementation project should be designed and initiated in this watershed to achieve this goal.

The TMDL for total phosphorus in Byre Lake is 7,550 kg/yr producing a mean TSI of 65.00. The load allocation for phosphorus is 1,841 kg/yr and the background load for phosphorus is 5,709 kg/yr based on 2000 through 2001 assessment data.

Acknowledgements

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

US EPA Non-Point Source Program
Lyman County
Jones County
South Dakota Conservation Commission
South Dakota Association of Conservation Districts
American Creek Conservation District
Jones County Conservation District
Natural Resource Conservation Service – Lyman County
Natural Resource Conservation Service – Jones County
SD Department of Game, Fish and Parks
SD Department of Environment and Natural Resources – Water Rights Program
SD Department of Environment and Natural Resources – Drinking Water Program
SD Department of Environment and Natural Resources – Ground Water Program
SD Department of Environment and Natural Resources – Water Resources Assistance Program
Lower Brule Sioux Tribe

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Waterbody Type:	Lake
Pollutant:	Trophic State Index (TSI) – Total phosphorus.
Designated Uses:	Domestic water supply, warmwater permanent fish life propagation, immersion recreation, limited contact recreation, fish and wildlife propagation and stock watering and irrigation waters.
Size of Waterbody:	Byre Lake- 51.5 hectares (127.3 acres).
Size of Watershed:	9,286 ha (22,946 acres), HUC Code: 10140104.
Water Quality Standards:	Numeric: TSI.
Indicators:	Nutrient enrichment, water clarity and algal blooms.
Analytical Approach:	Effects of nutrients and sediment on Byre Lake and the Grouse Creek watershed.

1.0 Introduction

Byre Lake is a reservoir located in the Northwestern Great Plains (43) ecoregion (Level III) in central South Dakota. Byre Lake was constructed in 1937 by the Works Progress Administration (WPA). Byre Lake was named after the original settler, O. J. Byre, who donated the site for the lake (WWP, 1941). Byre Lake is located at 43.927642° North Latitude and 99.939203° West Longitude.

The lake is owned by the Town of Kennebec. Byre Dam breached in May of 1986 and repairs were completed in the fall of 1990. The primary spillway was repaired and renovated in 1994, and in the spring of 2000 the outlet reach above the dam was cleared of debris.

Byre Lake was not listed on the 1998 or 2002 303(d) Impaired Waterbody List (SD DENR 1998 and SD DENR 2002). However, Grouse Creek is a natural stream that drains portions of Lyman County in South Dakota (Figure 1). Grouse Creek drains a watershed of approximately 9,286 ha (22,960 acres) and is impounded as Byre Lake. Byre Lake is a recreational lake of approximately 51.5 ha (127.3 acres) and has been impacted by periodic algal blooms. The American Creek Conservation District (ACCD) sponsored this project.

This project is intended to be the initial phase of a watershed-wide restoration project. Water quality monitoring, stream gauging, stream channel and land use analysis were used to document the sources of impairment to Grouse Creek and Byre Lake. Feasible alternatives for both watershed and in-lake restoration are presented in this final report.

Land use in the watershed is primarily agricultural. Approximately 56 percent of the land use is cropland (cultivated and non-cultivated) and 44 percent is range and pastureland. No animal feeding areas/operations were identified in the Byre Lake watershed.

The major soil association found in the Byre Lake watershed is the Millboro association. The Millboro association consists of deep, well drained, nearly level to moderately sloping clayey soils formed in clayey material.

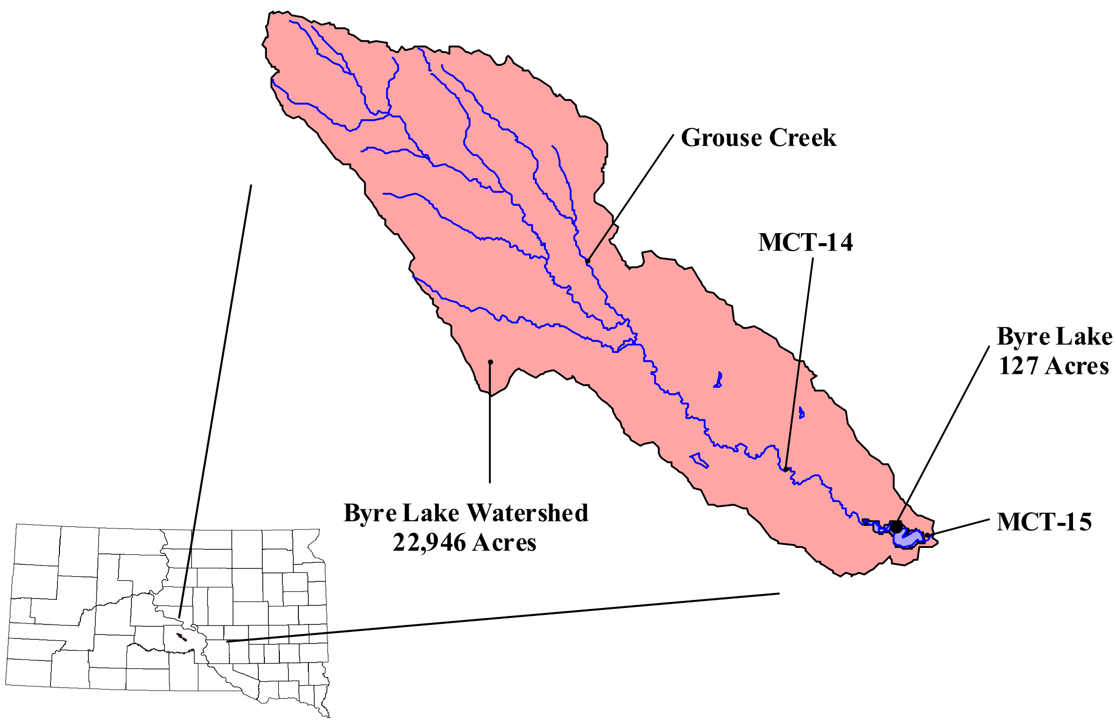


Figure 1. The Byre Lake watershed and its location in the State of South Dakota.

The average annual precipitation in the watershed is 17 inches of which 13 inches or nearly 80% usually falls in April through September. During this study (April 2000 through May 2001) 22.1 inches of rainfall was recorded in Kennebec, South Dakota. Tornadoes and severe thunderstorms strike occasionally. These storms are local and of short duration and occasionally produce heavy rainfall events. The average seasonal snowfall is 30.9 inches per year (USDA, 1984).

Land elevation ranges from about 1,639.4 feet msl in the west and north parts of the watershed to about 2,083.6 msl in the northwestern part.

The 2000 305(b) report to the U.S. Congress reported the 5-year water quality trend for drinking water in Byre Lake as stable, while the 2002 305(b) report (the most current) reported that Byre

Lake based on drinking water as fully supporting (SD DENR, 2000 and SD DENR, 2002). The 2002 305(b) also listed Byre Lake use support as warmwater permanent fish life propagation, immersion recreation, limited contact recreation and fish and wildlife propagation, recreation, and stock watering waters with use support as unknown due to lack of data (SD DENR, 2002).

The entire Byre Lake watershed is in the Northwestern Great Plains (43) ecoregion (Level III). Level III ecoregions can be refined to Level IV to elicit more resolution and landscape conditions. The Byre Lake watershed is located in one Level IV ecoregion, the Subhumid Pierre Shale Plains (43f), is located within the Northwestern Great Plains (43) (Bryce et al., 1997).

In the 1998 South Dakota Unified Watershed Assessment, the Medicine Creek Hydrologic Unit Code (HUC # 10140104) was scored, categorized and ranked as being a watershed in need of restoration. Some factors involved in the ranking were landuse, treatment needs and point source density; but the ranking was weighted based on the density of TMDL acres within the HU. The final priority ranking for Medicine Creek was 4 out of a total 39 HU (watersheds) assessed in this manner (SD DENR, 1998b).

The 1999 South Dakota Nonpoint Source Management Plan schedule is based on the 1998 Section 305(b) report and the related 1998 Section 303(d) list of impaired waters needing Total Maximum Daily Loads (TMDL).

South Dakota Department of Environment and Natural Resources (SD DENR) has not monitored Byre Lake as part of the statewide lakes assessment. Assessment data from this report will be used as an indication of use support for Byre Lake.

2.0 Project Goals, Objectives and Activities

Goals

The long-term goal of the Medicine Creek Watershed Assessment Project is to locate and document sources of nonpoint source pollution in the watershed and produce feasible restoration alternatives in order to provide adequate background information needed to drive a watershed implementation project to improve sedimentation and nutrient problems with the creeks and lakes in the watershed. This project will result in four TMDL reports for three 303(d) listed waters.

Project Description

Medicine Creek is a natural stream that drains portions of Lyman and Jones Counties in South Dakota and is the outlet tributary for Brakke Dam, Fate Dam and Byre Lake in Lyman County. The creek receives runoff from agricultural operations and both the creek and lakes have experienced declining water quality. The Medicine Creek watershed is approximately 437,892 acres with 14,435 acres above Brakke Dam, 16,957 acres above Fate Dam and 22,946 acres above Byre Lake. The watershed is predominately agricultural land use with cropland and grazing.

This project is intended to be the initial phase of a watershed-wide restoration project. Through water quality monitoring, stream gauging, stream channel analysis and land use analysis, the sources of impairment to the stream and the watershed will be documented and feasible alternatives for restoration will be presented in the final project report.

Objectives and Activities

OBJECTIVE 1: The objective of this task is to determine current conditions in the lakes and calculate the trophic state of each lake. This information will be used to determine the total amount nutrient and sediment trapping that is occurring in each of the lakes and the amount of nutrient and sediment reduction required to improve the trophic condition of Fate Dam, Brakke Dam and Byre Lake.

<u>Task 1</u> Nutrient and solids parameters will be sampled at two in-lake sites on Fate Dam, Brakke Dam and Byre Lake. All samples will be analyzed by the South Dakota State Health Laboratory in Pierre. Samples will be collected from the surface and bottom of Fate Dam, Brakke Dam and Byre Lake on a monthly schedule, except during periods of unsafe ice cover, for a period of 1 year. The total number of samples to be collected will be 120 for all three lakes in the project area.

<u>Task 2</u> The purpose of the in-lake samples is to assess ambient nutrient concentrations in the lake and identify trophic states. Water column dissolved oxygen and temperature profiles will be collected on a monthly basis. Water samples will be collected with a Van Dorn sampler and the sample bottles will be iced and shipped to the lab by the most rapid means available. Fecal coliform samples will be analyzed by the SD State Health Lab in Pierre. All other biological samples will be analyzed by staff from Watershed Protection in the Matthew Training Center Laboratory, Pierre, SD.

<u>Task 3</u> All samples will be collected using the methods described in the "*Standard Operating Procedures for Field Samplers*" by the State of South Dakota Water Resources Assistance Program. Figure 2 is a map of the lake sampling sites.

SITE	LOCATION	STORET NUMBER
Lake Sampling Locations – <u>Fate Dam</u>		
FD-1	Lat. 43.938726 Long. -100.007263 This site is located in the south central portion of the lake.	
FD-2	Lat. 43.944529 Long. -100.009913 Approximate north central portion of the lake	

Lake Sampling Locations – Brakke Dam

BD-1 Lat. 43.884496
Long. –99.944617
This site is located in the south central portion of the lake.

BD-2 Lat. 43.893604
Long. -99.954908
Approximate north central portion of the lake.

Lake Sampling Locations – Byre Lake

BL-1 Lat. 43.92978
Long. –99.83468
This site is located in the southeast portion of the lake.

BL-2 Lat. 43.92798
Long. -99.84155
Approximate northwest portion of the lake.

OBJECTIVE 2: Estimate the sediment and nutrient loadings from Medicine Creek and the individual tributaries in the Fate Dam, Brakke Dam and Byre Lake watersheds through hydrologic and chemical monitoring. The information will be used to locate critical areas in the watershed to be targeted for implementation.

TASK 4 Install water level recorders on tributary monitoring sites and maintain a continuous stage record for the project period, with the exception of winter months after freeze up (Figure 2).

Site	Location
MC-1	Lat. 43.955531 Long. -100.328842
MC-2	Lat. 43.926020 Long. -100.186033
MC-3	Lat. 43.944717 Long. -100.130243
MC-4	Lat. 43.947701 Long. -100.089670
MC-5	Lat. 44.009901 Long. -100.086023
MC-6	Lat. 43.973990 Long. -100.048308

MC-7	Lat.	43.923644
	Long.	–100.077286
MCFDO-8	Lat.	43.938141
	Long.	-100.002275
MC-9	Lat.	43.896513
	Long.	-100.023068
MCLBO-10	Lat.	43.897975
	Long.	-99.953841
MC-11	Lat.	43.861707
	Long.	-99.954456
MC-12	Lat.	43.859372
	Long.	-99.923395
MC-13	Lat.	43.911083
	Long.	-99.822682
MC-14	Lat.	43.948913
	Long.	–99.885828
MC-15	Lat.	43.926849
	Long.	–99.832414

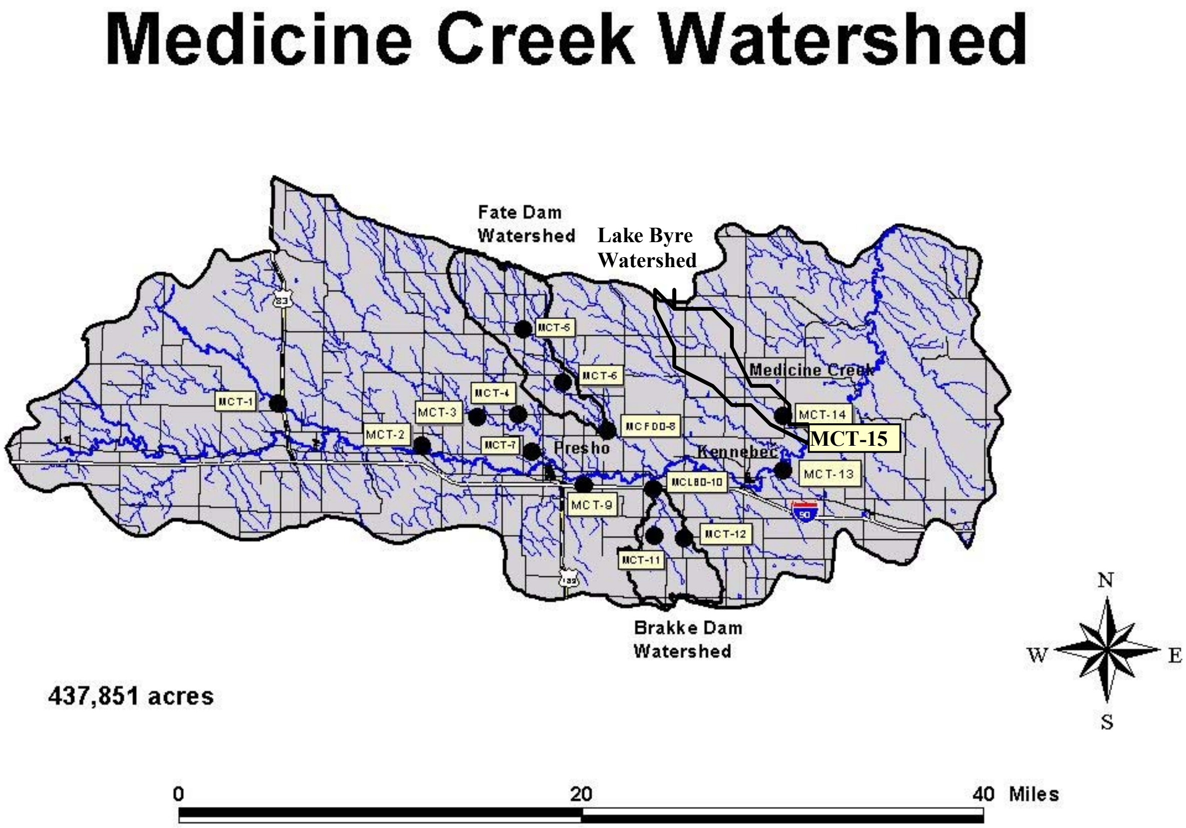


Figure 2. Medicine Creek watershed, Lyman and Jones Counties, South Dakota.

<u>TASK 5</u> Discrete discharge measurements will be taken on a regular schedule and during storm surges. Discharge measurements will be taken with a hand-held current velocity meter.

<u>TASK 6</u> Discharge measurements and water level data will be used to calculate a hydrologic budget for the creek system. This information will be used with concentrations of sediment and nutrients to calculate loadings from the watershed.

<u>TASK 7</u> Collect water quality samples from 15 tributary monitoring sites. Samples will be collected during spring runoff, storm events, and monthly base flows. Proposed water quality monitoring sites may be found in Figure 2.

<u>TASK 8</u> Samples will be collected twice weekly during the first week of spring snowmelt runoff and once a week thereafter until runoff ceases. Storm events and base flows will be sampled throughout the project period for an estimated total number of 148 samples.

PARAMETERS MEASURED FOR TRIBUTARY SAMPLES

PHYSICAL	CHEMICAL	BIOLOGICAL
Air temperature	Total solids	Fecal coliform bacteria
Water temperature	Total suspended solids	
Discharge	Dissolved oxygen	
Depth	Ammonia	
Visual observations	Un-ionized ammonia (calculated)	
Water level	Nitrate-nitrite	
	TKN	
	Total phosphate	
	Total dis. phosphate	
	Field pH	

QUALITY ASSURANCE/QUALITY CONTROL:

Approved QA/QC procedures will be utilized on all sampling and field data collection on the Medicine Creek project. Please refer to the South Dakota Water Resources Assistance Program Quality Assurance Project Plan for the details of the procedures to be followed.

PRODUCTS:

A tributary water quality report, which will include a description of the relationship and influence of chemical and physical data. Hydrologic and nutrient loads will be calculated for the entire watershed.

RESPONSIBLE AGENCIES:

Task Prioritization:

Project Coordinator
Project Sponsor

Design and Technical Assistance:

South Dakota Department of Environment and Natural Resources

WORK ACTIVITIES:

Water samples will be collected with a suspended sediment sampler when possible. All sample bottles will be iced and shipped to the lab and collected using the methods described in the

"*Standard Operating Procedures for Field Samplers*" by the State of Dakota Water Resources Assistance Program. Nutrient and solids parameters will be sampled at fourteen tributary sites in the Medicine Creek watershed. All samples will be analyzed by the South Dakota State Health Laboratory in Pierre, SD. The watershed water quality data will be integrated with hydrologic loading to provide a complete analysis of the Medicine Creek, Brakke Dam, Fate Dam and Byre Lake hydrologic systems.

OBJECTIVE 3: Ensure that all water quality samples are accurate and defendable through the use of approved Quality Assurance/Quality Control procedures.

<u>TASK 9</u> The collection of all field water quality data will be accomplished in accordance with the "*Standard Operating Procedures for Field Samplers*", South Dakota Water Resources Assistance Program.

<u>TASK 10</u> A minimum of 10 percent of all the water samples collected will be QA/QC samples. QA/QC samples will consist of field blanks and field duplicate samples. An estimated 50 QA/QC samples will be collected during the project.

<u>TASK 11</u> All QA/QC activities will be conducted in accordance with the Water Resources Assistance Program Quality Assurance Project Plan.

<u>TASK 12</u> The activities involved with QA/QC procedures and the results of QA/QC monitoring will be compiled and reported in a section of the final project report and in all project reports.

PRODUCTS:

A Quality Assurance/Quality Control monitoring report.

RESPONSIBLE AGENCIES:

<u>Task Prioritization</u>:

Project Coordinator
Project Sponsor

<u>Design and Technical Assistance</u>:

South Dakota Department of Environment and Natural Resources

WORK ACTIVITIES:

Approved QA/QC procedures will be utilized on all sampling and field data collected during the Medicine Creek project. Please refer to the South Dakota Water Resources Assistance Program Quality Assurance Plan and the South Dakota Water Resources Assistance Program Standard Operating Procedures for Field Samplers for details of the procedures to be followed.

OBJECTIVE 4: Evaluation of agricultural impacts on the water quality of the watershed using the Annualized Agricultural Nonpoint Source (AnnAGNPS) model.

TASK 13 The Medicine Creek, Fate Dam, and Brakke Dam watersheds will be modeled using the AnnAGNPS model. AnnAGNPS is a comprehensive land use model which estimates soil loss and delivery and evaluates the impact of livestock feeding areas. The watershed will be divided into cells. Each cell will be analyzed using 21 separate parameters with additional information collected for animal feeding operations.

TASK 14 The model will be used to identify critical areas of nonpoint source pollution to the surface waters in the watershed. Contributors of nutrients and sediment to surface water in the Medicine Creek, Fate Dam, Brakke Dam and Byre Lake watersheds will be identified.

PRODUCTS:

Report on land use in the watershed.
Recommendations for remediation of pollution sources in the watershed.

RESPONSIBLE AGENCIES:

Task Prioritization:

Project Coordinator
Project Sponsor

Design and Technical Assistance:

South Dakota Department of Environment and Natural Resources

OBJECTIVE 5: Public participation and involvement will be provided for and encouraged.

TASK 15 Informational meetings will be held on a quarterly basis for the general public and to inform the involved parties of progress on the study. These meetings will provide an avenue for input from the residents in the area.

TASK 16 News releases will be prepared and released to local news media on a quarterly basis. These releases will be provided to local newspapers, radio stations and TV stations.

PRODUCTS:

Public input to the project.
Information and education about the Medicine Creek project.
Involvement and input from the public will be documented.

RESPONSIBLE AGENCIES:

Task Prioritization:

Project Coordinator
Project Sponsor

Design and Technical Assistance:

South Dakota Department of Environment and Natural Resources

WORK ACTIVITIES:

Informational meetings will be held on a frequent basis for the general public to inform the involved parties of progress on the study and provide a means of public input.

OBJECTIVE 6: Development of watershed restoration alternatives.

TASK 17 Once the field data is collected, an extensive review of the historical and project data will be conducted.

TASK 18 Loading calculations based on project data will be done and a hydrologic, sediment and nutrient budget will be developed for each watershed.

TASK 19 The results of the AnnAGNPS modeling of the watershed will be used in conjunction with the water quality and hydrologic budget to determine critical areas in the watersheds.

TASK 20 Feasible management practices will be compiled into a list of alternatives for the development of an implementation project and included in the final project report.

PRODUCTS:

A list of viable watershed restoration alternatives and recommendations for the Medicine Creek, Fate Dam, Brakke Dam and Byre Lake watersheds.

RESPONSIBLE AGENCIES:

Task Prioritization:

Project Coordinator
Project Sponsor

Design and Technical Assistance:

South Dakota Department of Environment and Natural Resources

WORK ACTIVITIES:

An extensive review and study of the historical and current data will be done to determine the Best Management Practices and hydrologic restoration techniques needed to improve water quality and reduce sediment transport in the Medicine Creek, Fate Dam, Brakke Dam and Byre Lake watersheds.

OBJECTIVE 7: Produce and publish a final report containing water quality results and restoration alternatives.

TASK 21: Produce loading calculations based on water quality sampling and hydrologic measurements.

TASK 22 Summarize the results of the AnnAGNPS model for the watershed and report locations of critical areas.

TASK 23 Write a summary of historical water quality and land use information and compare with project data to determine any possible trends.

TASK 24 Based on data, evaluate the hydrology of the Medicine Creek, Fate Dam, Brakke Dam and Byre Lake watersheds and the chemical, biological, and physical condition of the streams.

TASK 25 Produce a summary report of all QA/QC activities conducted during the project and include in the final project report.

TASK 26 Write a description of feasible restoration alternatives for use in planning watershed nonpoint source implementation.

PRODUCTS:

A final report incorporating all previously described objectives

RESPONSIBLE AGENCIES:

South Dakota Department of Environment and Natural Resources

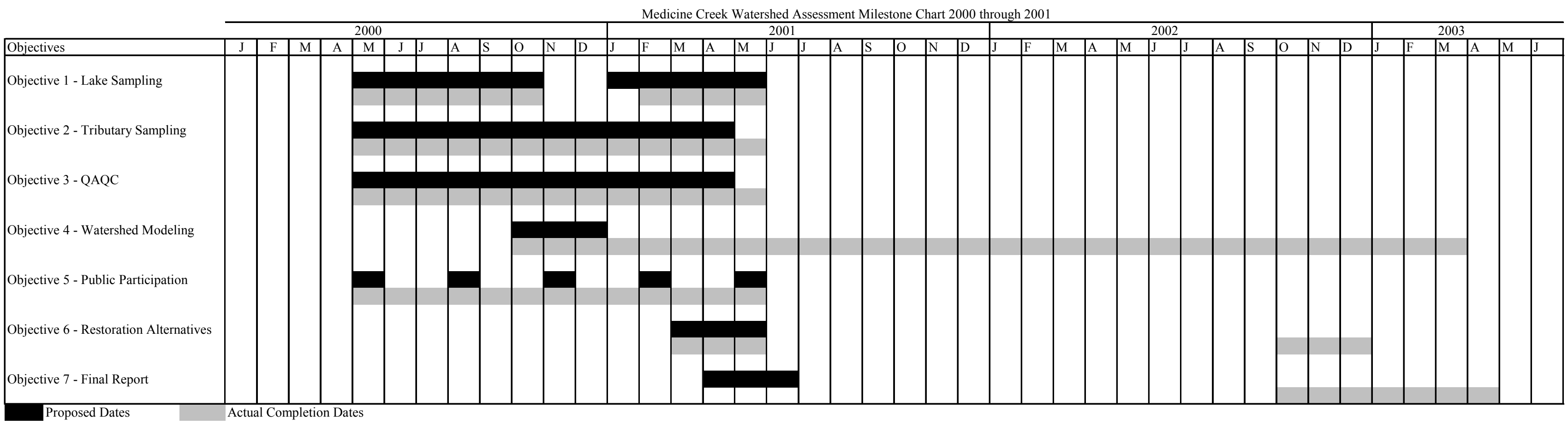
WORK ACTIVITIES:

Statistical evaluation of all water quality and field data produced during the course of the study. A review and compilation of historical data will be completed. Restoration alternatives will be developed. Graphic presentations of the information will be produced.

2.1 PLANNED AND ACTUAL MILESTONES, PRODUCTS AND COMPLETION DATES

The Medicine Creek Assessment Project was started in April 2000. The sampling effort continued through May 2001. Logistical difficulty was encountered in the collection of Annualized Agricultural Nonpoint Source Model (AnnAGNPS) landuse data which was not completed until fall 2002. This situation resulted in a delay in watershed modeling and report generation. See the attached Byre Lake/ Grouse Creek Assessment Project milestone table (Table 1).

Table 1. Proposed and actual completion dates for the Byre Lake/Grouse Creek (Medicine Creek) Watershed Assessment Project, 2000 through 2001.



2.2 Evaluation of Goal Achievement

Fate Dam and Brakke Dam are listed on the State of South Dakota's 303(d) list of impaired waterbodies as priority-one waterbodies for Trophic State Index (TSI) for increased nutrients. Medicine Creek is also listed on the state's 303(d) list for conductivity and total dissolved solids. Byre Lake is not listed on the state's 303(d) list; however, watershed and lake data was collected to assess trophic condition and to see if it was meeting its designated beneficial uses. This study assessed Medicine Creek, Fate Dam, Brakke Dam, Byre Lake and their watersheds for background data to develop TMDLs; identified targeted areas of increased nutrient and sediment load impacting specific watersheds; and recommended specific Best Management Practices (BMPs) for targeted areas in these watersheds. The project meets one of the goals of the Non-Point Source (NPS) program by assessing impaired waterbodies on the 303(d) list and has met all project goals outlined above. A future implementation project is planned in the near future.

2.3 Supplemental Information

Loading reduction estimates for suggested BMPs outlined in this report were derived from AnnAGNPS modeled land use data. The AnnAGNPS model estimated the expected load reduction after application of selected BMPs within the Medicine Creek, Fate Dam, Brakke Dam and Byre Lake watersheds. These practices should be implemented on targeted areas having increased nutrient and sediment export coefficients (loading). Implementing recommended BMPs within the watershed will have the greatest effect on reducing overall loading to Medicine Creek, Fate Dam, Brakke Dam and Byre Lake.

3.0 Monitoring Results

Tributary Methods

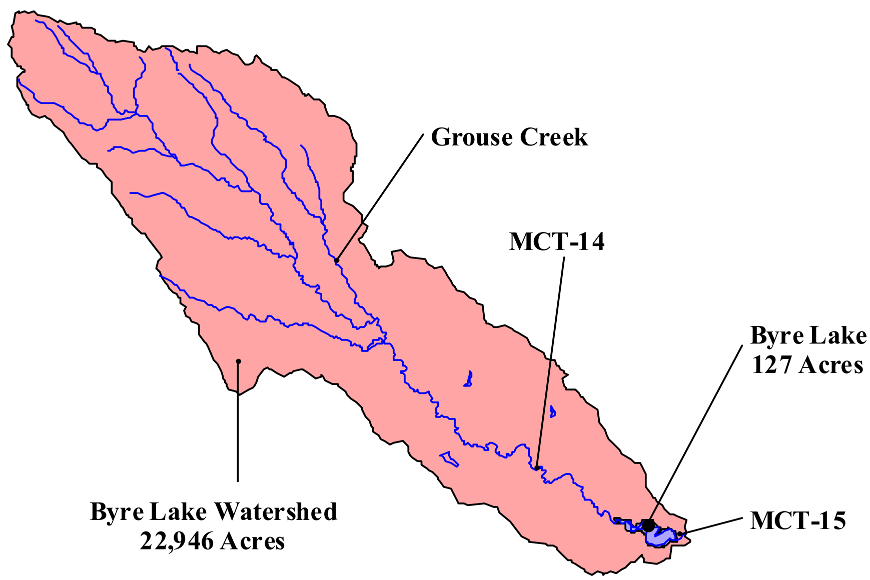


Figure 3. Grouse Creek sampling sites and sub-watersheds for 1999 and 2000.

One tributary location was chosen for collecting hydrologic and nutrient information from the Byre Lake watershed (Figure 3). Tributary site locations were chosen that would best show watershed managers which sub-watersheds were contributing the largest nutrient and sediment loads. OTT Thalimedes data loggers were placed on Grouse Creek near the inlet to Byre Lake (MCT-14) and near the outlet spillway (MCT-15) to record the lake level (stage) in Byre Lake and to calculate lake discharge back to Grouse Creek. The data loggers were checked and downloaded bi-monthly to update the database and check for mechanical problems. All discharge data was collected according to South Dakota's *Standard Operating Procedures for Field Samples* (SD DENR 2000). Actual stage and discharge measurements were used to calculate regression equations for each site (Appendix A). These equations were used to calculate average daily discharge for each site.

Outlet data for the Byre Lake spillway was calculated by using the following standard equation:

Equation 1. Byre Lake spillway discharge equation.

$$Q = C * L * \left(H^{3/2}\right)$$

Where: Q = Flow in CFS
L = Length (width of spillway)
H = Stage Height
C = Coefficient, C = 2.3

Hydrologic Data Collection Methods

Instantaneous discharge measurements were collected for each station during the time each sample was collected. A Marsh-McBirney Model 201 was used to collect the discharge measurements. The stage and flow data from each monitoring site were used to develop a stage/discharge table that was used to calculate average daily loadings for each site. The individual discharge equations and data for each monitoring site can be found in Appendix A.

Tributary Water Quality Sampling

Samples collected at each tributary site were taken according to South Dakota's EPA-approved *Standard Operating Procedures for Field Samplers* (SD DENR 2000). Tributary physical, chemical and biological water quality sample parameters are listed in Table 2. All water samples were sent to the State Health Laboratory in Pierre for analysis. Quality Assurance/Quality Control samples were collected for approximately 10 percent of the samples according to South Dakota's EPA-approved *Non-Point Source Quality Assurance/Quality Control Plan* (SD DENR, 1998c). These documents can be referenced by contacting the South Dakota Department of Environment and Natural Resources at (605) 773-4254.

Table 2. Tributary physical, chemical and biological parameters analyzed in Grouse Creek, Lyman County, South Dakota in 2000 through 2001.

Physical	Chemical	Biological
Air Temperature	Total Alkalinity	Fecal Coliform
Water Temperature	Field pH	E. *coli*
Depth	Dissolved Oxygen	
Visual Observations	Total Solids	
	Total Suspended Solids	
	Total Dissolved Solids (calculated)	
	Volatile Total Suspended Solids	
	Ammonia	
	Un-ionized Ammonia (calculated)	
	Nitrate-Nitrite	
	Total Kjeldahl Nitrogen	
	Total Phosphorus	
	Total Dissolved Phosphorus	
	Conductivity	

Tributary Modeling Methods

Tributary Loading Calculations

The FLUX program was used to develop nutrient and sediment loadings for Grouse Creek. The US Army Corps of Engineers developed the FLUX program for eutrophication (nutrient enrichment) assessment and prediction for reservoirs (Walker, 1996). The FLUX program uses six different calculation techniques for calculating nutrient and sediment loadings. The sample and flow data for this program can be stratified (adjusted) until the coefficient of variation (standard error of the mean loading divided by the mean loading =CV) for all six methods converge or are all similar. The uncertainty in the estimated loading is reflected by the CV value. The lower the CV value the greater the accuracy (less error) there is in loading estimates. This scenario was applied to each relevant sampling parameter to determine the appropriate method (model) for specific parameters. Methods (models) and CV values for each parameter and sampling site are listed in Table 3. These methods were used on the tributary site (inlet site) and the outlet site of Byre Lake to calculate nutrient and sediment loadings for this project.

Table 3. Model and coefficient of variation by parameter for FLUX analysis in Grouse Creek, Lyman County, South Dakota from 2000 through 2001.

	MCT-14 (Inlet)		MCT-15 (Outlet)	
Parameter	Model (Method)	Coefficient of Variation (CV)	Model (Method)	Coefficient of Variation (CV)
Alkalinity	IJC	0.003	Q wt C	0.131
Total Solids	IJC	0.421	Q wt C	0.034
Total Dissolved Solids	IJC	0.117	Q wt C	0.113
Total Suspended Solids	IJC	0.736	Q wt C	0.479
Volatile Total Suspended Solids	IJC	0.743	IJC	0.050
Ammonia	IJC	0.148	Q wt C	0.617
Nitrate-Nitrite	Q wt C	0.173	Q wt C	0.229
Total Kjeldahl Nitrogen	Q wt C	0.181	Q wt C	0.346
Organic Nitrogen	Q wt C	0.218	IJC	0.073
Inorganic Nitrogen	Q wt C	0.173	Q wt C	0.212
Total Nitrogen	Q wt C	0.008	Q wt C	0.438
Total Phosphorus	IJC	0.562	Q wt C	0.360
Total Dissolved Phosphorus	IJC	0.094	Q wt C	0.283

Q wt C = Flow weighted Concentration model
IJC = International Joint Committee model (modifies Q wt C by a factor to adjust for bias where concentrations varies with flow)

After the loadings for all sites were calculated, export coefficients were developed for each of the parameters. Export coefficients are calculated by taking the total nutrient or sediment load (kilograms) and dividing by the total area of the sub-watershed (in acres). This calculation results in the determination of the number of kilograms of sediment and nutrients per acre delivered from that sub-watershed (kg/acre). These values were used to target areas within the watershed with excessive nutrient and sediment loads. These areas will be targeted recommended BMPs for a projected implementation project.

Landuse Modeling – Annualized Agricultural Non-Point Source Model, Version 2.22 (AnnAGNPS) and Agricultural Non-Point Source Model, Version 3.65 (AGNPS)

In addition to water quality monitoring, information was collected to complete a comprehensive watershed land use model. AnnAGNPS (Annualized Agricultural Non-Point Source) is a landuse model to simulate/model sediment and nutrient loadings from watersheds. AnnAGNPS is a data intensive watershed model that routes sediment and nutrients through a watershed by utilizing land uses and topography. The watershed is broken up into cells of varying sizes based on topography. Each cell is then assigned a primary land use and soil type. Best Management Practices (BMPs) are then simulated by altering the land use in the individual cells and reductions in sediment and nutrients are calculated at the outlet to the watershed.

The input data set for AnnAGNPS Pollutant Loading model consists of 33 sections of data, which can be supplied by the user in a number of ways. This model execution utilized digital elevation maps (DEMs) to determine cell and reach geometry, Soil Survey Geographic Database (SSURGO) soil layers to determine primary soil types and the associated National Soil Information System (NASIS) data tables for each soils properties, and primary landuse based on a 40 acre grid pattern, collected initially with the intention of executing the AGNPS version 3.65 model. Impoundment data was obtained using Digital OrthoQuads (DOQs) layers using ArcView Global Information System (GIS)® software. Weather data was generated using a synthetic weather generator based on climate information from the Kennebec weather station. It is important to note that these model results are based on 25 simulated years of data with precipitation ranging from 13.4 to 29.6 inches per year. Mean annual precipitation for this watershed is about 17 inches.

Part of the modeling process also includes the assessment of Animal Feeding Operations (AFOs) located in the watershed. However, data provided from the American Creek Conservation District indicated no AFO were present in the Byre Lake/Grouse Creek watershed.

Findings from the AnnAGNPS report can be found throughout the water quality assessment and in the watershed modeling report found in Appendix B. Conclusions and recommendations will rely on both water quality and AnnAGNPS data.

3.1 Tributary Surface Water Chemistry

Tributary Water Quality Standards

South Dakota's numeric water quality standards are based on beneficial use categories. Beneficial use classifications are listed in Table 4. All streams in the state are assigned the beneficial uses (category 9) fish and wildlife propagation, recreation and stock watering and (category 10) irrigation (ARSD § 74:51:03:01).

Table 4. South Dakota's beneficial use classifications for waters of the state.

Category	Beneficial Use
1	Domestic water supply waters;
2	Coldwater permanent fish life propagation waters;
3	Coldwater marginal fish life propagation waters;
4	Warmwater permanent fish life propagation waters;
5	Warmwater semipermanent fish life propagation waters;
6	Warmwater marginal fish life propagation waters;
7	Immersion recreation waters;
8	Limited-contact recreation waters;
9	Fish and wildlife propagation, recreation, and stock watering waters;
10	Irrigation waters; and
11	Commerce and industry waters.

Grouse Creek in Lyman County has been assigned the beneficial uses of (9) fish and wildlife propagation, recreation, and stock watering water and (10) irrigation water (Table 5).

In addition to physical and chemical standards, South Dakota has developed narrative criteria for the protection of aquatic life uses. *All waters of the state must be free from substances, whether attributable to human-induced point source discharge or nonpoint source activities, in concentration or combinations which will adversely impact the structure and function of indigenous or intentionally introduced aquatic communities* (ASRD § 74:51:01:12).

Table 5. Assigned beneficial uses for Grouse Creek, Lyman County, South Dakota.

Water Body	From	To	Beneficial Uses*	County
Grouse Creek* (a tributary of Medicine Creek)	Lake Sharpe	U.S. Highway 83	9,10	Lyman

*** = Grouse Creek is a tributary of Medicine Creek for which these beneficial uses apply.**

Each beneficial use classification has a set of numeric standards uniquely associated with that specific category. Water quality values that exceed those standards, applicable to specific beneficial uses, impair beneficial use and violate water quality standards. Table 6 lists the most stringent water quality parameters for Grouse Creek. Four of the fourteen parameters (total petroleum hydrocarbon, oil and grease, un-disassociated hydrogen sulfide and sodium adsorption ratio) listed for Grouse Creek beneficial use categories were not sampled during this project.

Table 6. The most stringent water quality standards for Grouse Creek (Medicine Creek tributary) based on beneficial use classifications.

Water Body	Beneficial Uses	Parameter	Standard Value
Grouse Creek (Tributary to Medicine Creek)	9,10	Total alkalinity as calcium carbonate [1]	≤ 1,313 mg/L
		Total dissolved solids [2]	≤ 4,375 mg/L
		Conductivity at 25° C [3]	≤ 4,375 μmhos/cm
		Nitrates as N [4]	≤ 88 mg/L
		Undisassociated hydrogen sulfide [5]	≤ 0.002 mg/L
		Total petroleum hydrocarbon [5]	≤ 10 mg/L
		Oil and grease [5]	≤ 10 mg/L
		Sodium adsorption ratio [5, 6]	≤ 10 mg/L

[1] = The daily maximum for total alkalinity as calcium carbonate is ≤ 1,313 mg/L or ≤ 750 mg/L for a 30-day average.
[2] = The daily maximum for total dissolved solids is ≤ 4,375 mg/L or ≤ 2,500 mg/L for a 30-day average.
[3] = The daily maximum for conductivity at 25° C is ≤ 7,000 mg/L or ≤ 4,000 mg/L for a 30-day average.
[4] = The daily maximum for nitrates is ≤ 88 mg/L or ≤ 50 mg/L for a 30-day average.
[5] = Parameters not measured during this project.
[6] = The sodium absorption ratio is a calculated value that evaluates the sodium hazard of irrigation water based on the Gapon equation and expressed by the mathematical equation:

Equation 2. Sodium Adsorption Ratio (SAR) (Gapon Equation)

$$\text{SAR} = Na^{+} \Big/ \sqrt{\frac{Ca^{+2} + \text{Mg}^{+2}}{2}}$$

Where Na^{+}, Ca^{+2} and Mg^{+2} are expressed in milliequivalents per liter.

Grouse Creek Water Quality Exceedances

There were no tributary water quality standards violations based on assigned beneficial uses for Grouse Creek, (9) Fish and wildlife propagation, recreation, and stock watering water and (10) Irrigation water during the project.

Seasonal Tributary Water Quality

Typically, water quality parameters will vary depending upon season due to changes in temperature, precipitation and agricultural practices. Eleven tributary water quality samples were collected during the project. These data were separated seasonally: winter (January – March) and spring (April – June). No runoff was recorded during 2000 at either sampling site. During this project, approximately seven discrete samples were collected in the winter at MCT-14 and four samples were collected at both MCT-14 and MCT-15 in the spring.

Sediment and nutrient concentrations can change dramatically with changes in water volume. Large hydrologic loads at a site may have small concentrations; however, more water usually increases nonpoint source runoff and thus higher loadings of nutrients and sediment may result. Average seasonal tributary concentrations for Grouse Creek by year and season are provided in Table 7.

Table 7. Average seasonal tributary concentrations from Grouse Creek, Lyman County, South Dakota[1] for 2000 and 2001.

	Year / Station / Season													
	2000						2001							
	MCT-14 and MCT-15						MCT-14				MCT-15			
	Spring 00		Summer 00		Fall 00		Winter 01		Spring 01		Winter 01		Spring 01	
Parameter	**Count**	**Average**	**Count**	**Average**	**Count**	**Average**	**Count**	**Average**	**Count**	**Average**	**Count**	**Average**	**Count**	**Average**
Water Temperature (oC)	-	-	-	-	-	-	3	0.46	4	8.36	-	-	4	12.05
Dissolved Oxygen	-	-	-	-	-	-	3	8.83	4	10.59	-	-	4	11.13
pH (su)[2]	-	-	-	-	-	-	1	8.37	1	8.56	-	-	1	8.43
Conductivity (uS/cm3)	-	-	-	-	-	-	3	574.33	4	645.00	-	-	4	468.00
Fecal Coliform Bacteria (colonies/100 ml)	-	-	-	-	-	-	3	7.00	4	479.00	-	-	4	404.00
Alkalinity (mg/L)	-	-	-	-	-	-	3	69.33	4	124.50	-	-	4	106.50
Total Solids (mg/L)	-	-	-	-	-	-	3	448.33	4	743.25	-	No -	4	390.50
Total Dissolved Solids (mg/L)	-	-	**No Flow in 2000**		-	-	3	416.67	4	503.25	-	Winter -	4	347.25
Total Suspended Solids (mg/L)	-	-	-	-	-	-	3	31.67	4	240.00	-	Outflow	4	43.25
Volatile Total Suspended Solids (mg/L)	-	-	-	-	-	-	3	4.17	4	21.50	-	in 2001 -	4	7.00
Ammonia (mg/L)	-	-	-	-	-	-	3	0.23	4	0.04	-	-	4	0.06
Un-ionized Ammonia (mg/L)	-	-	-	-	-	-	3	0.00328	4	0.00069	-	-	4	0.00449
Nitrate - Nitrite (mg/L)	-	-	-	-	-	-	3	1.33	4	1.18	-	-	4	1.08
Total Kjeldahl Nitrogen (mg/L)	-	-	-	-	-	-	3	1.14	4	0.94	-	-	4	0.93
Total Nitrogen (mg/L)	-	-	-	-	-	-	3	2.47	4	2.11	-	-	4	1.77
Organic Nitrogen (mg/L)	-	-	-	-	-	-	3	0.91	4	0.90	-	-	4	1.05
Inorganic Nitrogen (mg/L)	-	-	-	-	-	-	3	1.56	4	1.22	-	-	4	1.18
Total Phosphorus (mg/L)	-	-	-	-	-	-	3	0.386	4	0.584	-	-	4	0.279
Total Dissolved Phosphorus (mg/L)	-	-	-	-	-	-	3	0.282	4	0.219	-	-	4	0.155
Total Nitrogen : Total Phosphorus Ratio	-	-	-	-	-	-	3	6.77	4	6.11	-	-	4	6.23

[1] = Highlighted areas are the highest recorded average concentrations for a given parameter in 2001.
[2] = pH is highest concentration not average.

Seasonal Tributary Concentrations

Fecal coliform bacteria are an indicator of waste material from warm-blooded animals and usually indicate the presence of animal or human wastes. Average fecal coliform concentrations were highest in the spring. Average seasonal concentrations were high at both sampling sites. Season-long grazing, runoff from animal feeding areas and poor manure management were the most likely sources of increased fecal coliform counts.

Higher total dissolved solids, total suspended solids and volatile total suspended solids concentrations were observed in the spring at MCT-14. Intense rains on agricultural lands typically cause higher erosion and higher total suspended solids in streams.

Average nitrate-nitrite, Total Kjeldahl Nitrogen (TKN), total nitrogen and inorganic nitrogen concentrations were higher in the winter at MCT-14.

Ammonia was highest in the winter at MCT-14 while un-ionized ammonia concentrations were higher in the spring at MCT-15. This correlates with relatively higher temperatures and pH at MCT-15 in the spring of 2001. Sources for high ammonia concentrations could be animal feeding areas, decomposition of organic matter, or runoff from land-applied fertilizer and/or manure.

Total phosphorus concentrations were higher in the spring; however, the highest average dissolved phosphorus concentrations were in the winter of 2001 at MCT-14 (Table 7).

Seasonalized Tributary Hydrologic Loadings

One tributary monitoring site was set up on Grouse Creek (MCT-14) and one (MCT-15) at the outlet of Byre Lake. All sites were monitored 393 days from April 2000 through May 2001 excluding the winter months. Approximately 7.3 million cubic meters (5,929 acre-feet) of water flowed into Byre Lake from Grouse Creek over the project period. The overall tributary export coefficient (amount of water delivered per acre) was 318 m^3/acre (0.26 acre-foot/acre). Export coefficients and seasonal loading percentages for MCT-14 and MCT-15 are provided in Table 8.

Table 8. Cumulative hydrologic loading and export coefficients for Byre Lake and Medicine Creek from Grouse Creek, Lyman County, South Dakota in 2000 and 2001.

		Hydrologic Loading			Export Coefficient	
Site	**Season**	**Meters^3**	**Acre-feet**	**Percent**	**Meters^3/acre**	**Acre-feet/acre**
MCT-14	**Spring - 00**	0	0	0	0	0
	Summer - 00	0	0	0	0	0
	Fall - 00	0	0	0		0
	Winter - 01	270,890	219.70	3.7	12.37	0.01
	Spring - 01	7,040,134	5,709.76	96.3	321.48	0.26
Byre Lake	**Total**	**7,311,024**	**5,929.46**	**100.0**	**219.50**	**0.27**
MCT-15	**Spring - 00**	0	0	0	0	0
	Summer - 00	0	0	0	0	0
	Fall - 00	0	0	0	0	0
	Winter - 01	1,211,000	981.76	20.7	52.78	0.04
	Spring - 01	4,632,000	3,755.16	79.3	201.87	0.16
Medicine Creek	**Total**	5,843,000	4,736.92	100.0	254.64	0.20

The peak hydrologic load for Byre Lake and Medicine Creek (MCT-14 and MCT-15) occurred during the spring of 2001. Approximately 96.3 percent of the hydrologic load was delivered to Byre Lake and 79.3 percent was delivered to Medicine Creek during the spring 2001 sampling period.

Tributary Water Quality and Loadings

Dissolved Oxygen

Dissolved oxygen concentrations in most unpolluted streams and rivers remain above 80 percent saturation. Solubility of oxygen generally increases as temperature decreases and decreases with decreasing atmospheric pressure (either by a change in elevation or barometric pressure) (Hauer and Hill, 1996). Stream morphology, turbulence and flow can also have an effect on oxygen concentrations. Dissolved oxygen concentrations are not uniform within or between stream reaches. Upwelling of interstitial waters at the groundwater and streamwater mixing zone (hyporheic zone) or side flow of ground waters may create patches within a stream reach where dissolved oxygen concentrations are significantly lower than surrounding water (Hauer and Hill, 1996). Grouse Creek dissolved oxygen concentrations averaged 5.80 mg/L (median 5.85 mg/L) during this study.

Seasonal and daily concentrations of chemicals (biotic and abiotic) in water can also affect dissolved oxygen concentrations. Higher chemical concentrations also increase Biochemical and Sediment Oxygen Demand (BOD and SOD). These processes use oxygen in the system to break down or convert organic and inorganic compounds.

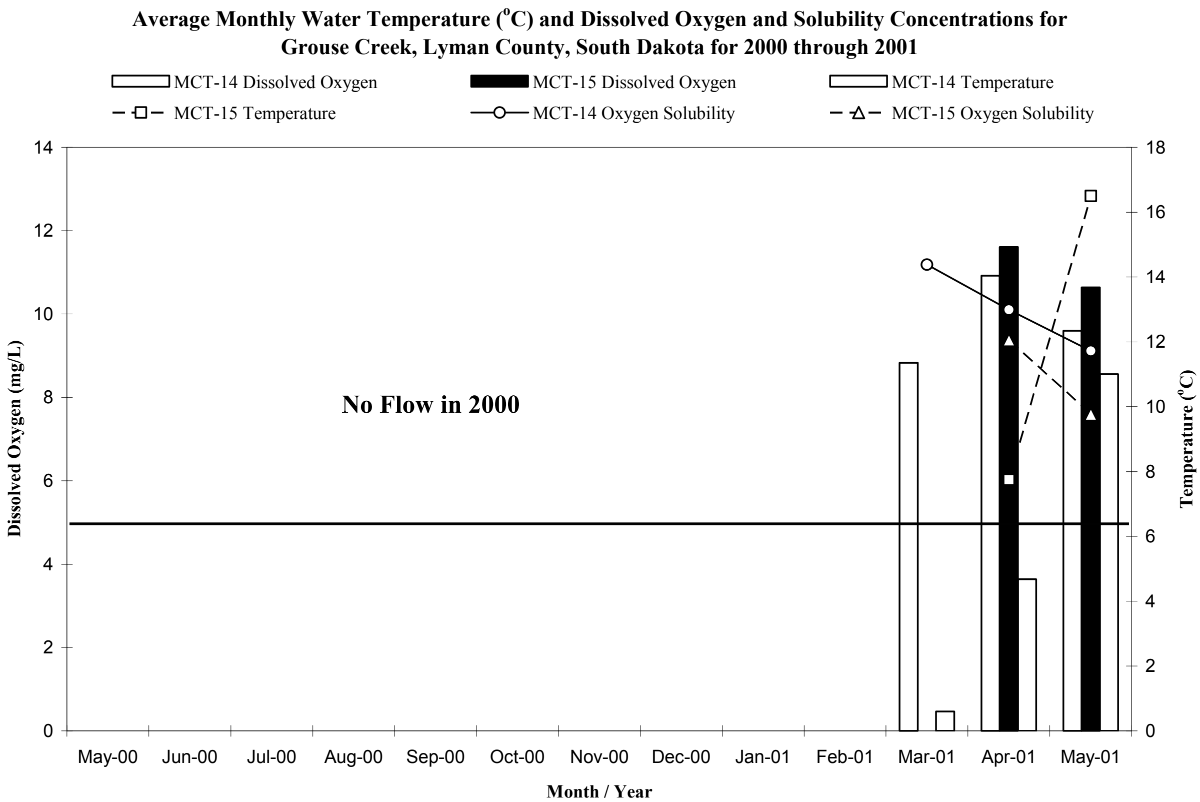


Figure 4. Monthly average dissolved oxygen concentrations and temperature for Grouse Creek, Lyman County, South Dakota from 2000 through 2001.

The maximum dissolved oxygen concentration in Grouse Creek was 12.99 mg/L. The sample was collected at site MCT-15 on April 10, 2001 (Appendix C). The minimum dissolved oxygen concentration was 7.47 mg/L at MCT-14 on March 13, 2001. April tributary samples had the highest average dissolved oxygen concentrations (Figure 4). No dissolved oxygen exceedances were observed at either sampling site on Grouse Creek (MCT-14 and MCT-15 (outlet of Byre Lake)) during the project. Byre Lake with its increased hydrologic retention time and algae production modified/increased dissolved oxygen concentrations at the downstream (MCT-15) sampling site (Figure 4).

Table 7 shows seasonal tributary average dissolved oxygen concentrations by tributary monitoring site for Grouse Creek during the project. Seasonal average oxygen levels were lowest in the winter 2001 (averaged 8.83 mg/L), increase in the spring (averaged 10.59 mg/L) and were the highest below Byre Lake at MCT-15 in the spring of 2001 (averaged 11.13 mg/L, attributed to algae oxygen production).

pH

pH is a measure of hydrogen ion concentration, the more free hydrogen ions, (i.e. more acidic) the lower the pH in water. The pH concentrations in Grouse Creek were not extreme in any tributary sample. The relatively high alkalinity concentrations in Grouse Creek work to buffer dramatic pH changes. Lower pH values are normally observed during increased decomposition of organic matter.

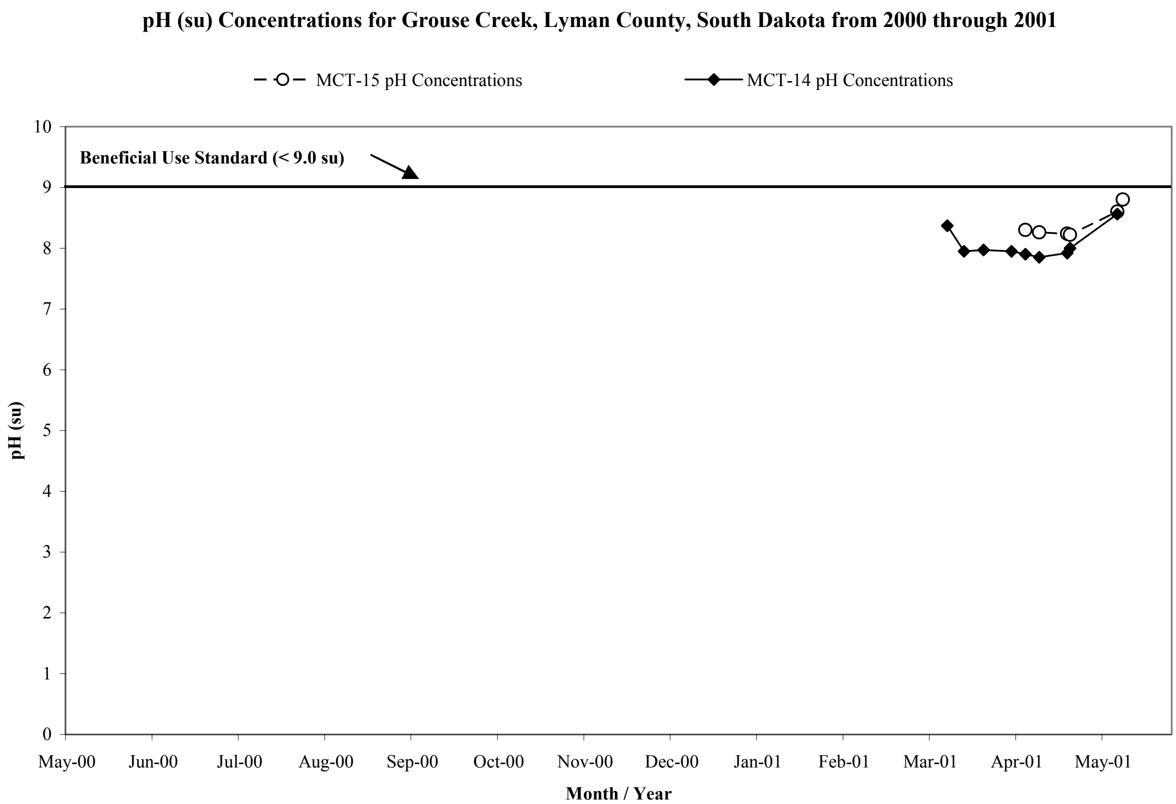


Figure 5. Monthly pH values for Grouse Creek, Lyman County, South Dakota from 2000 through 2001.

The pH concentrations in Grouse Creek had a maximum pH of 8.80 su and a minimum pH of 7.85 su. Generally, pH concentrations were higher in May 2001 for both sampling sites (Figure 5). Table 7 lists seasonal maximum pH concentrations by tributary sampling site. The highest concentrations were in the spring of 2001 at MCT-14.

Total Alkalinity

Alkalinity refers to the quantity of different compounds that shift the pH to the alkaline side of neutral (>7 su). These various bicarbonate and carbonate compounds generally originate from dissolution of sedimentary rock (Allan, 1995). Alkalinity in natural environments usually ranges from 20 to 200 mg/L (Lind, 1985).

Table 9. Total alkalinity loading per year by site for Grouse Creek, Lyman County, South Dakota from 2000 through 2001.

	Station	Gauged Watershed Acreage (Acres)	Percent Hydrologic Load	Kilograms by site	Export Coefficient (kg/acre)
Total Gauged Load to Byre Lake	**MCT-14**	**20,681**	**89.0**	**687,487**	**32.86**
Byre Lake Outlet - Load to Medicine Creek	**MCT-15**	**22,946**	**100.0**	**552,902**	**24.90**
Byre Lake Reduction Coefficient*	**1.24**				

*** = Reduction coefficient is the estimated reduction efficiency of Byre Lake on loading to Medicine Creek (Inlet Load/Total Watershed Acres) / (Outlet Load/Total Watershed Acres).**

The average alkalinity in Grouse Creek was 102.9 mg/L with a median of 105 mg/L. The minimum alkalinity concentration was 51 mg/L and was collected at site MCT-14 on March 19, 2001 (Appendix C). The maximum alkalinity sample was 165 mg/L collected at site MCT-14 on May 13, 2001. Alkalinity concentrations were statistically similar between MCT-14 and MCT-15 ($U_{0.05\ (2),\ 7,\ 4}$ = 11.00, p>0.05). Seasonally, Grouse Creek average alkalinity concentrations were higher in the spring for MCT-14 and MCT-15 (Table 7); MCT-15 (Byre Lake outlet) only flowed in the spring of 2001.

Total alkalinity loading by site was highest at site MCT-14 with 636,194 kg/year or 92.5 percent of the total alkalinity load (Figure 6). Alkalinity loading between MCT-14 and MCT-15 were not statistically different ($U_{0.05\ (2),\ 3,\ 3}$ = 3.00, p>0.05). Sub-watershed export coefficients (kilograms/acre) were highest in the MCT-14 (32.86 kg/acre) sub-watershed (Table 9). Byre Lake reduces / modifies Grouse Creek alkalinity loading to Medicine Creek (reduction coefficient) by approximately 1.2 times or 134,585 kg.

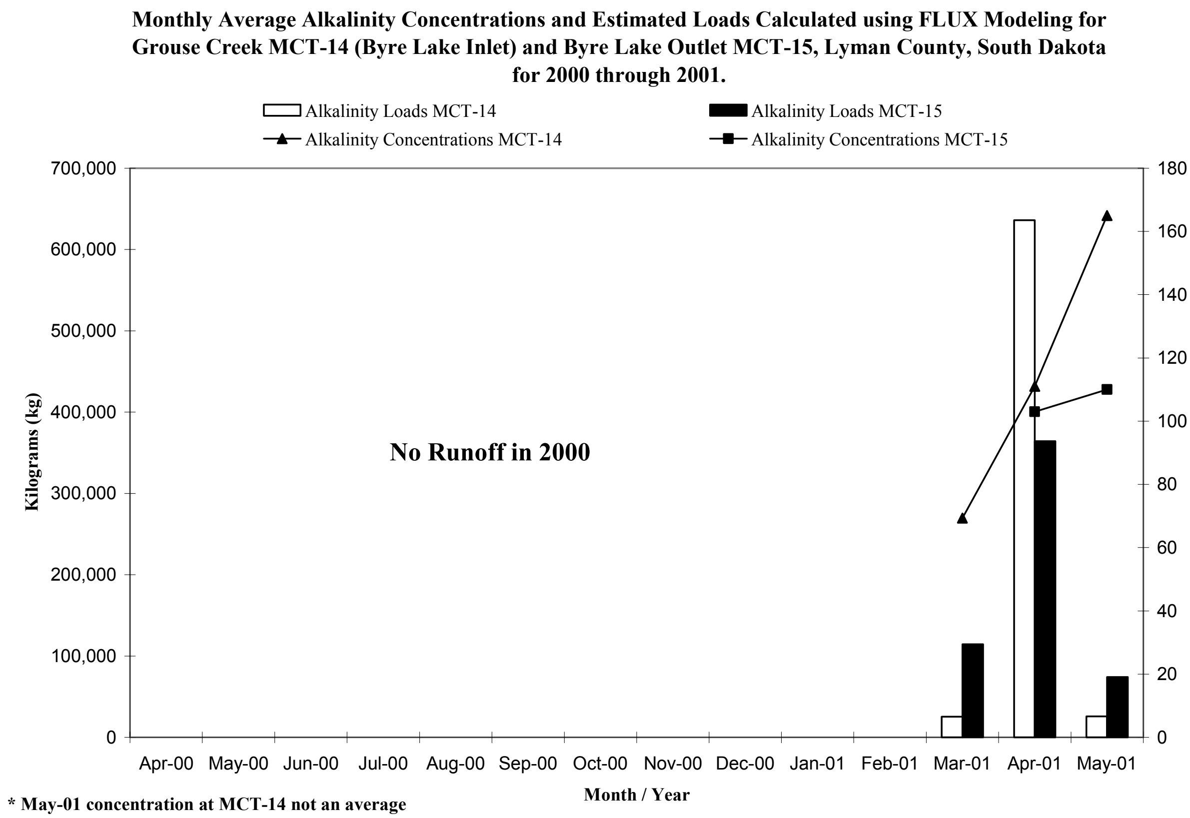


Figure 6. Monthly average total alkalinity concentrations and estimated loads by tributary to Byre Lake and Medicine Creek from Grouse Creek, Lyman County, South Dakota in 2000 and 2001.

Solids

Total solids are materials, suspended or dissolved, present in natural water. Dissolved solids include materials that pass through a filter. Suspended solids are the materials that do not pass through a filter, e.g. sediment and algae. Subtracting suspended solids from total solids derives total dissolved solids concentrations. Volatile total suspended solids are that portion of suspended solids that are organic (organic matter that burns in a 500^{o} C muffle furnace).

The total solids concentrations in Grouse Creek averaged 534.5 mg/L with a maximum of 1,043 mg/L and a minimum of 277 mg/L. Total dissolved solids concentrations averaged 422.9 mg/L with a maximum of 666 mg/L and a minimum concentration of 205 mg/L. With no flow/loading occurring in the 2000 sampling season, seasonality in concentration and loading data could not be ascertained; however, monthly estimations could be made using spring of 2001 data. Generally, total and dissolved solids concentrations peaked in April 2001 at both tributary sites (Figure 7 and Figure 8). Concentrations were higher at MCT-14 for all dates data was available, although not significantly ($U_{0.05\,(2),\,7,\,4} = 4.00$, $p>0.05$). Seasonal averages for total and dissolved solids concentrations were highest in the spring (Table 7).

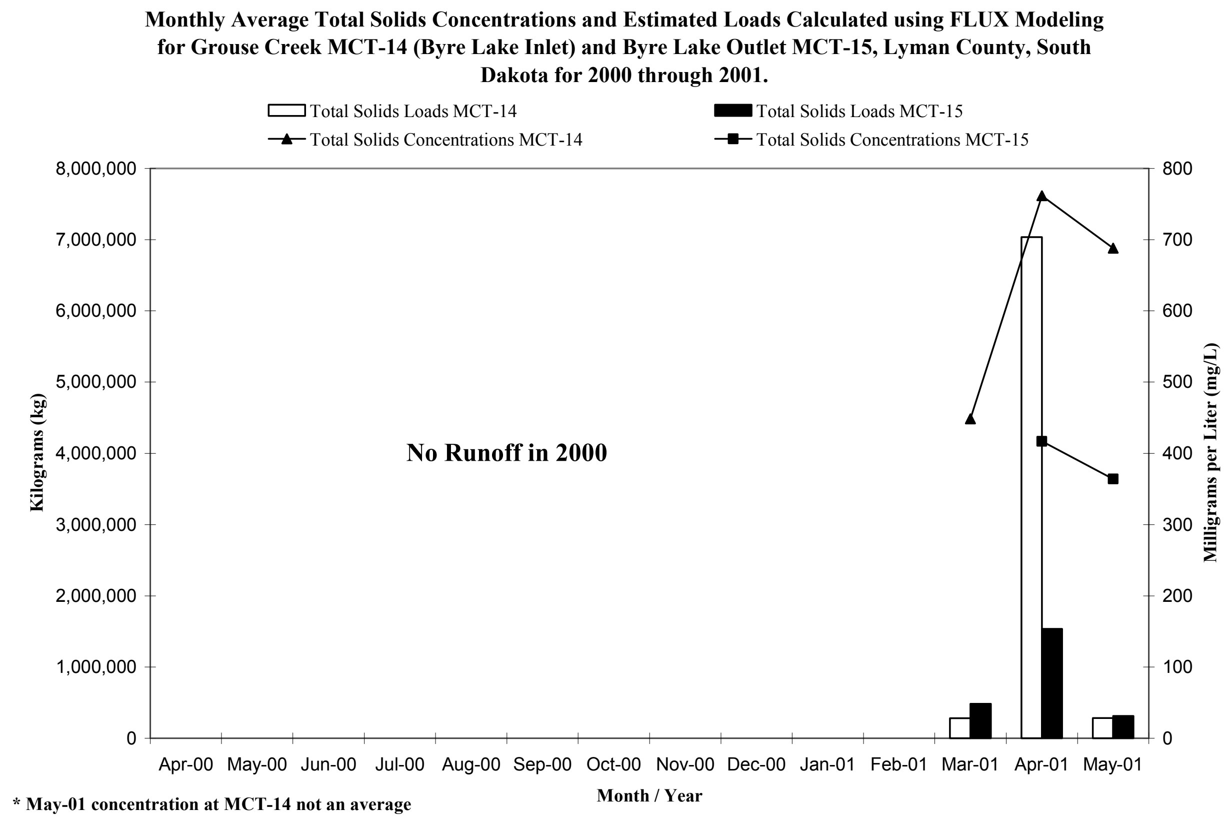


Figure 7. Monthly average total solids concentrations and estimated loads by tributary to Byre Lake and Medicine Creek from Grouse Creek, Lyman County, South Dakota from 2000 and 2001.

Table 10. Total solids loading per year by site for Grouse Creek, Lyman County, South Dakota from 2000 through 2001.

	Station	Gauged Watershed Acreage (Acres)	Percent Hydrologic Load	Kilograms by site	Export Coefficient (kg/acre)
Total Gauged Load to Byre Lake	**MCT-14**	**20,681**	**89.0**	**7,601,815**	**367.57**
Byre Lake Outlet - Load to Medicine Creek	**MCT-15**	**22,946**	**100.0**	**2,330,587**	**101.57**
Byre Lake Reduction Coefficient*	**3.26**				

*** = Reduction coefficient is the estimated reduction efficiency of Byre Lake on loading to Medicine Creek (Inlet Load/Total Watershed Acres) / (Outlet Load/Total Watershed Acres).**

Total solids loading by site was highest at site MCT-14 with 7,601,815 kg/year (Table 10). Total dissolved solids loadings were also the highest at site MCT-14 with 2,804,055 kg/year (Table 11). Sub-watershed export coefficients (kilograms/acre) were highest in the MCT-14 sub-watershed (367.57 kg/acre) for total solids and 135.95 kg/acre for total dissolved solids. Total solids loads at MCT-14 were not significantly higher than loads at MCT-15 ($U_{0.05\ (2),\ 3,\ 3} = 3.00$, $p>0.05$) and total dissolved solids loading at MCT-14 and MCT-15 were not statistically different ($U_{0.05\ (2),\ 3,\ 3} = 3.00$, $p>0.05$). The highest loading of both total and dissolved solids to Byre Lake (MCT-14) occurred in April 2001 (Figure 7 and Figure 8).

Table 11. Total dissolved solids loading per year by site for Grouse Creek from 2000 through 2001.

	Station	Gauged Watershed Acreage (Acres)	Percent Hydrologic Load	Kilograms by site	Export Coefficient (kg/acre)
Total Gauged Load to Byre Lake	**MCT-14**	**20,681**	**89.0**	**2,804,055**	**135.59**
Byre Lake Outlet - Load to Medicine Creek	**MCT-15**	**22,946**	**100.0**	**1,910,872**	**83.28**
Byre Lake Reduction Coefficient*	**1.47**				

*** = Reduction coefficient is the estimated reduction efficiency of Byre Lake on loading to Medicine Creek (Inlet Load/Total Watershed Acres) / (Outlet Load/Total Watershed Acres).**

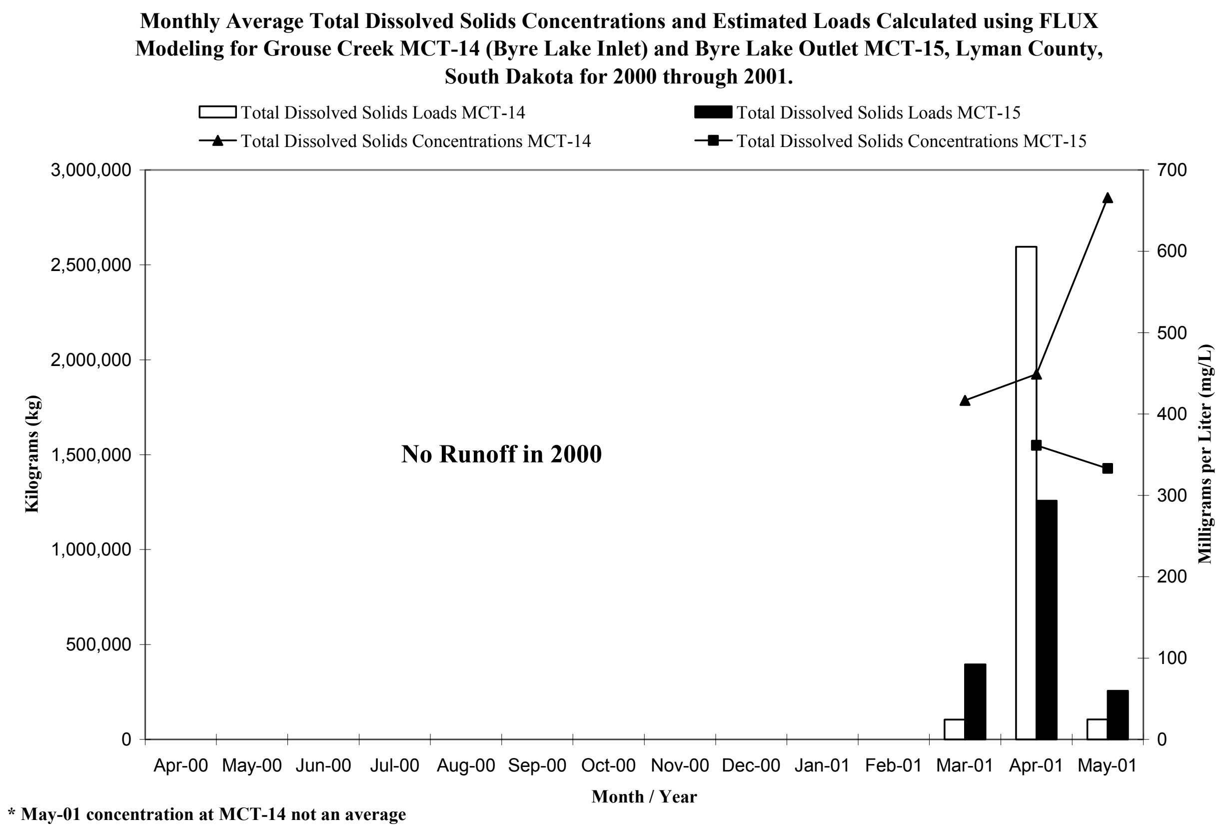


Figure 8. Monthly average total dissolved solids concentrations and estimated loads by tributary to Byre Lake and Medicine Creek from Grouse Creek, Lyman County, South Dakota from 2000 through 2001.

Byre Lake reduces / modifies Grouse Creek total solids loading to Medicine Creek (reduction coefficient) by approximately 3.26 times or 5,271,228 kg and reduces / modifies Grouse Creek total dissolved solids loading to Medicine Creek by approximately 1.47 times or 893,183 kg (Table 10 and Table 11).

The total suspended solids concentrations in Grouse Creek averaged 111.6 mg/L with a maximum of 660 mg/L and a minimum of 4.0 mg/L. Volatile total suspended solids concentrations averaged 11.5 mg/L with a maximum of 60 mg/L and a minimum concentration of 0.5 mg/L. Total suspended and volatile total suspended solids concentrations between sampling sites were not statistically different (total suspended solids ($U_{0.05\ (2),\ 7,\ 4}$ = 11.00, p>0.05) and volatile total suspended solids ($U_{0.05\ (2),\ 7,\ 4}$ = 12.00, p>0.05)). Generally, average total suspended and volatile total suspended solids concentrations peaked in April 2001 for both sampling sites (MCT-14 and MCT-15) on Grouse Creek (Figure 9 and Figure 10). Table 7 indicates that seasonal averages for total suspended solids and volatile total suspended solids had higher concentrations at MCT-14 in the spring of 2001 (240 mg/L and 21.5 mg/L, respectively).

Table 12. Total suspended solids loading per year by site for Grouse Creek, Lyman County, South Dakota from 2000 through 2001.

	Station	Gauged Watershed Acreage (Acres)	Percent Hydrologic Load	Kilograms by site	Export Coefficient (kg/acre)
Total Gauged Load to Byre Lake	**MCT-14**	**20,681**	**89.0**	**4,797,761**	**231.99**
Byre Lake Outlet - Load to Medicine Creek	**MCT-15**	**22,946**	**100.0**	419,716	**18.29**
Byre Lake Reduction Coefficient*	**11.43**				

*** = Reduction coefficient is the estimated reduction efficiency of Byre Lake on loading to Medicine Creek (Inlet Load/Total Watershed Acres) / (Outlet Load/Total Watershed Acres).**

Total suspended solids loading by site was highest at site MCT-14 with 4,797,761 kg/year (Table 12). Volatile total suspended solids loadings were also the highest at site MCT-14 with 436,142 kg/year (Table 13). Sub-watershed export coefficients (kilograms/acre) were highest in the MCT-14 sub-watershed (231.99 kg/acre) for total suspended solids and 21.09 kg/acre at MCT-14 for volatile total suspended solids (Table 12 and Table 13). Total suspended and volatile total suspended solids loads at MCT-14 were similar to loads at MCT-15 (total suspended solids ($U_{0.05\ (2),\ 3,\ 3}$ = 2.00, p>0.05) and volatile total suspended solids ($U_{0.05\ (2),\ 3,\ 3}$ = 2.00, p>0.05). The highest loading of both total suspended solids and volatile total suspended solids to Byre Lake (MCT-14) occurred in April 2001 (Figure 9 and Figure 10).

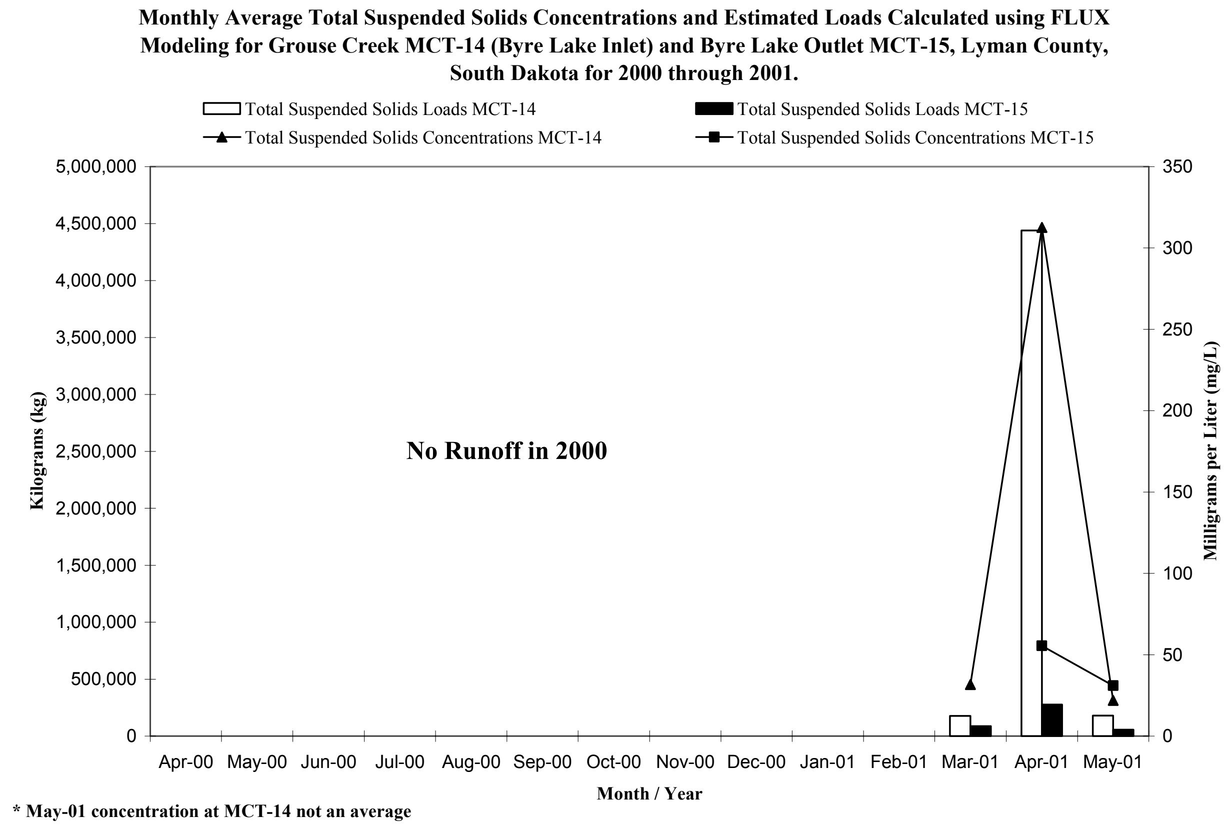


Figure 9. Monthly average total suspended solids concentrations and estimated loads by tributary to Byre Lake and Medicine Creek from Grouse Creek, Lyman County, South Dakota from 2000 through 2001.

Byre Lake dramatically reduced/modifies Grouse Creek total suspended solids loading to Medicine Creek (reduction coefficient) by approximately 11.4 times or 4,378,045 kg and reduced / modifies Grouse Creek volatile total suspended solids loading to Medicine Creek by approximately 9.29 times or 398,214 kg (Table 12 and Table 13).

Table 13. Volatile total suspended solids loading per year by site for Grouse Creek, Lyman County, South Dakota from 2000 through 2001.

	Station	Gauged Watershed Acreage (Acres)	Percent Hydrologic Load	Kilograms by site	Export Coefficient (kg/acre)
Total Gauged Load to Byre Lake	**MCT-14**	**20,681**	**89.0**	**436,142**	**21.09**
Byre Lake Outlet - Load to Medicine Creek	**MCT-15**	**22,946**	**100.0**	**46,928**	**2.05**
Byre Lake Reduction Coefficient*	**9.29**				

*** = Reduction coefficient is the estimated reduction efficiency of Byre Lake on loading to Medicine Creek (Inlet Load/Total Watershed Acres) / (Outlet Load/Total Watershed Acres).**

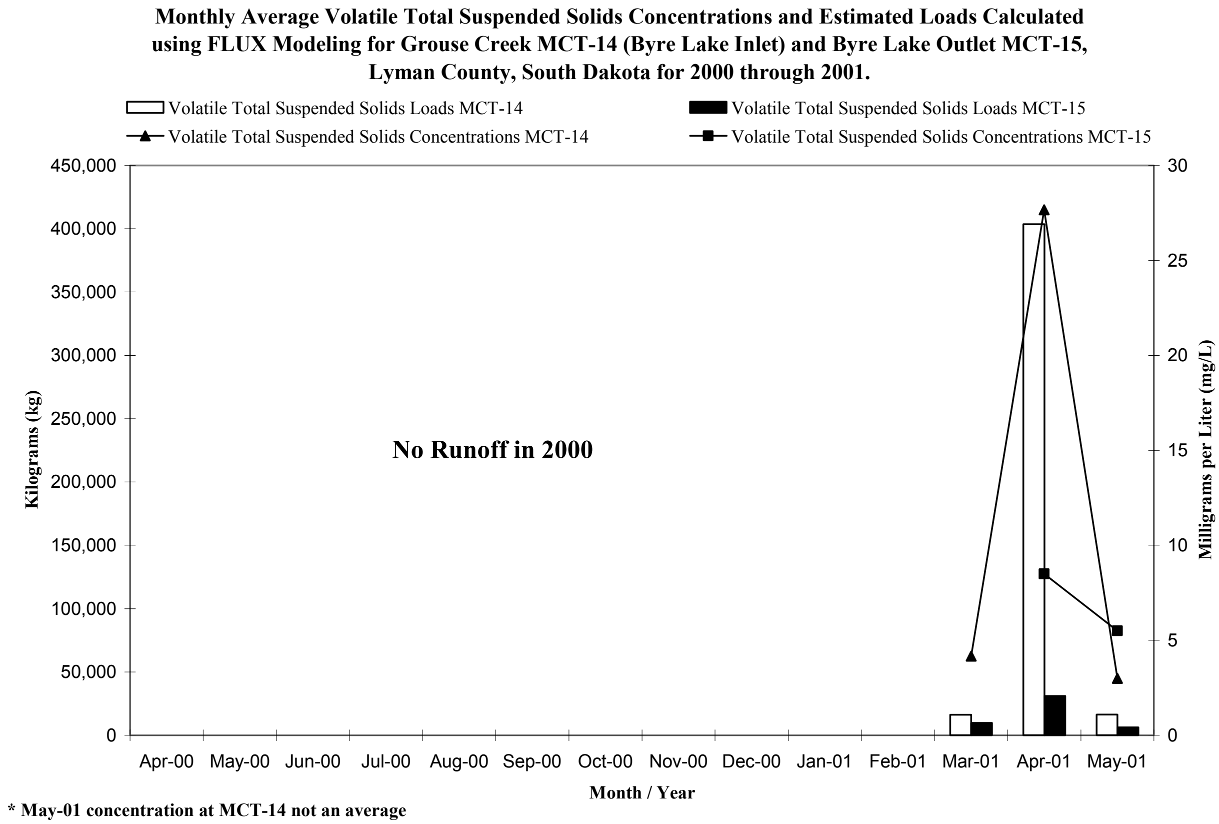


Figure 10. Monthly average volatile total suspended solids concentrations and estimated loads by tributary to Byre Lake and Medicine Creek from Grouse Creek, Lyman County, South Dakota from 2000 through 2001.

Byre Lake is not on the current (2002) 303(d) list (impaired waterbody list); however, TSI (Trophic State Index) values collected during this study indicate the mean TSI value (mean TSI 68.30) exceeds the ecoregion 43 TSI full support threshold (mean TSI $\leq$ 55.00) (SD DENR, 2000). Decreasing sediment (erosion) inputs from Grouse Creek will improve (lower) TSI values. Reducing sediment will reduce non-algal turbidity, which will increase Secchi transparency, decreasing Secchi TSI values. Increasing transparency should also increase the growth of submerged macrophytes, which would increase the uptake of nitrogen and phosphorus, reducing available nutrients that could cause algal blooms. Reducing sediment also reduces sediment-related phosphorus, which may lower in-lake phosphorus concentrations and phosphorus TSI values. Reductions in sediment-related available phosphorus for algae growth and uptake will have a two-fold effect on TSI values. Dramatically decreasing sediment-related phosphorus could lessen algal densities and blooms in Byre Lake, which will reduce algal turbidity, improving Secchi TSI values. Lower algal densities will also decrease chlorophyll-*a* concentrations, reducing chlorophyll-*a* TSI values. These reductions over time should reverse the increasing TSI trend observed in Byre Lake.

Sub-watersheds that should be targeted for sediment (erosion) mitigation, based on delivered loads and not watershed assessment export coefficients due to the mitigating factors of Byre Lake, are presented in priority ranking in Table 14:

Table 14. Grouse Creek watershed mitigation priority sub-watersheds for sediment (total suspended solids), based on the 2000 and 2001 watershed assessment.

Priority Ranking	Sub-watershed	Total Suspended Solids Export Coefficient (kg/acre)	Total Suspended Solids Kilograms Delivered
1	MCT-14	231.99	4,797,761
2	MCT-15	18.29	419,716

Ammonia

Ammonia is the nitrogen product of bacterial decomposition of organic matter and is the form of nitrogen most readily available to plants for uptake and growth. Sources of ammonia in the watershed may come from animal feeding areas, decaying organic matter or bacterial conversion of other nitrogen compounds.

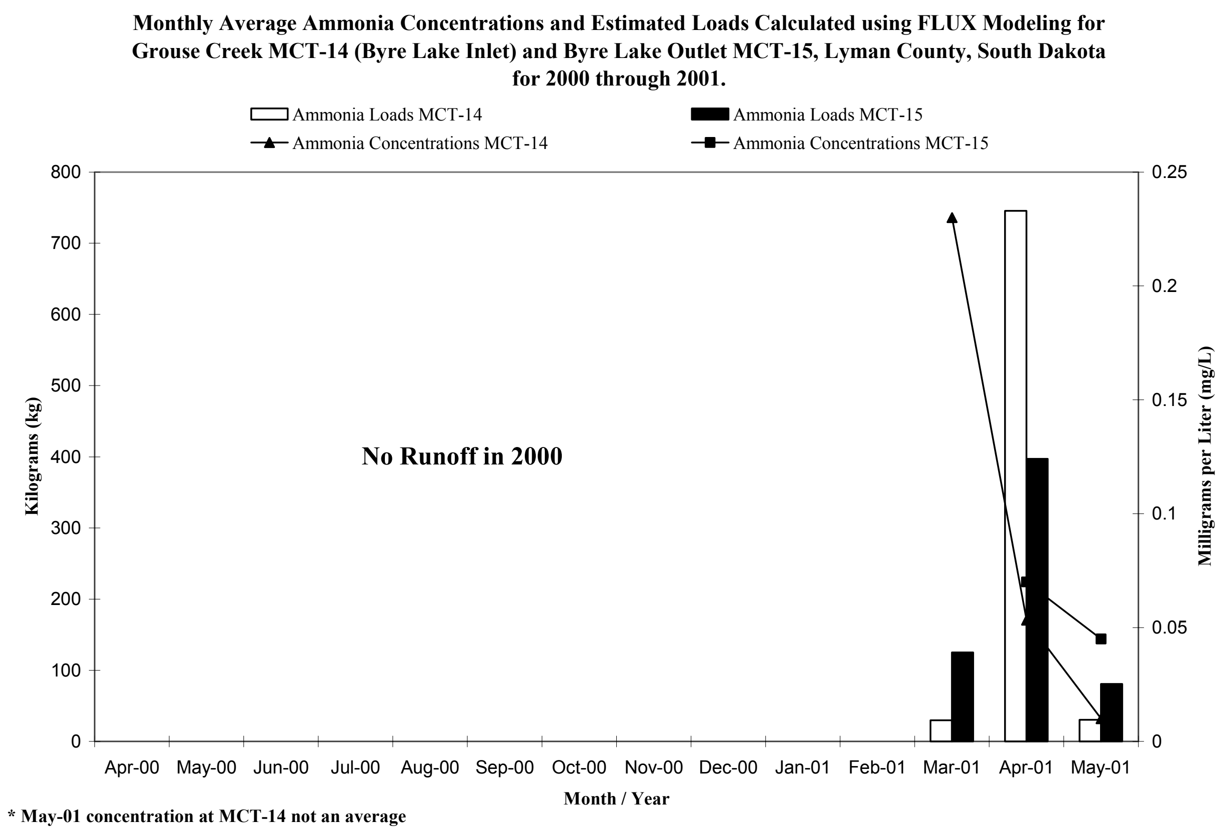


Figure 11. Monthly average ammonia concentrations and estimated loads to Byre Lake and Medicine Creek from Grouse Creek, Lyman County, South Dakota from 2000 through 2001.

The mean ammonia concentration in Grouse Creek was 0.10 mg/L with a median of 0.08 mg/L. The standard deviation was 0.11 mg/L which indicates a large variation in sample concentrations. Ammonia concentrations rose dramatically in March, declined in April and again in May for MCT-14 (Byre Lake inlet) and increased in April at MCT-15 (Byre Lake outlet) and declined in May (Figure 11). Ammonia concentrations between sampling sites were not statistically different ($U_{0.05\ (2),\ 7,\ 4} = 9.00$, $p>0.05$). Seasonally the highest concentrations of ammonia occurred in the winter of 2001 at MCT-14 (0.23 mg/L). Average spring concentrations at both sampling sites were above laboratory detection limits (Table 7).

Table 15. Ammonia loading per year by site for Grouse Creek, Lyman County, South Dakota from 2000 through 2001.

	Station	Gauged Watershed Acreage (Acres)	Percent Hydrologic Load	Kilograms by site	Export Coefficient (kg/acre)
Total Gauged Load to Byre Lake	**MCT-14**	**20,681**	**89.0**	**805.6**	**0.039**
Byre Lake Outlet - Load to Medicine Creek	**MCT-15**	**22,946**	**100.0**	**603.0**	**0.026**
Byre Lake Reduction Coefficient*	**1.34**				

*** = Reduction coefficient is the estimated reduction efficiency of Byre Lake on loading to Medicine Creek (Inlet Load/Total Watershed Acres) / (Outlet Load/Total Watershed Acres).**

Ammonia loading by sampling site was highest at site MCT-14 with 805.6 kg/year (Table 15). Sub-watershed export coefficients (kilograms/acre) were also highest at the Grouse Creek inlet to Byre Lake (MCT-14) with 0.039 kg/acre. Ammonia loading between sampling sites was not statistically different ($U_{0.05\ (2),\ 3,\ 3} = 3.00$, $p>0.05$). Like most parameters, peak ammonia loading occurred in April 2001 at MCT-14 (Figure 11).

Byre Lake reduced/modified Grouse Creek ammonia loading to Medicine Creek (reduction coefficient) by approximately 1.34 times or 202.6 kg (Table 15).

Un-ionized Ammonia

Un-ionized ammonia (NH_4-OH) is the fraction of ammonia that is toxic to aquatic organisms. The concentration of un-ionized ammonia is calculated and dependent on temperature and pH. As temperature and pH increase so does the percent of ammonia which is toxic to aquatic organisms. Since pH, temperature and ammonia concentrations are constantly changing, un-ionized ammonia is calculated instantaneously (by sample) to determine compliance with tributary water quality standards rather than from a loading basis.

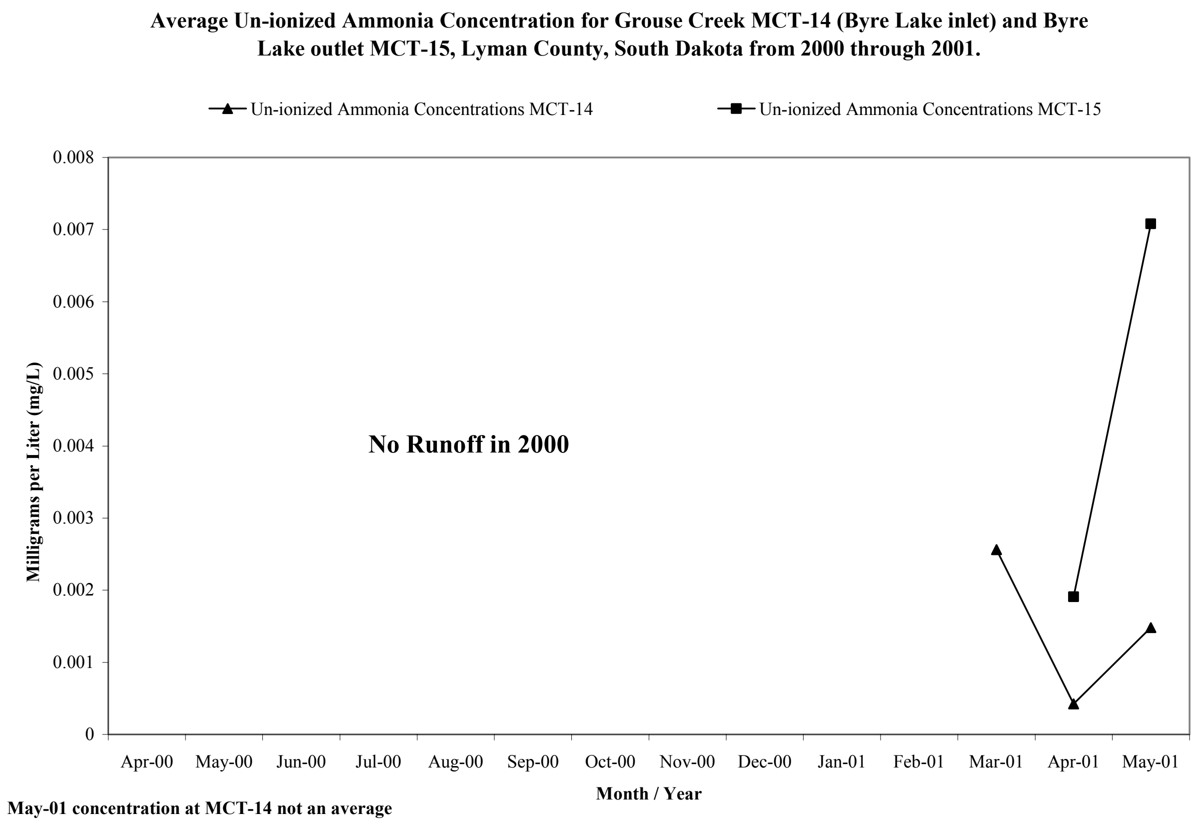


Figure 12. Monthly average un-ionized ammonia concentrations to Byre Lake and Medicine Creek from Grouse Creek, Lyman County, South Dakota from 2000 through 2001.

The mean un-ionized ammonia concentration for Grouse Creek was 0.0026 mg/L. The maximum concentration was 0.0131 mg/L and the minimum concentration was 0.0001 mg/L. Average un-ionized ammonia concentrations peaked in May 2001 at MCT-15 (Figure 12).

Nitrate-Nitrite

Nitrate and nitrite (NO_3^- and NO_2^-) are inorganic forms of nitrogen easily assimilated by algae and macrophytes. Sources of nitrate and nitrite can be from agricultural practices and direct input from septic tanks, precipitation, groundwater, and from decaying organic matter. Nitrate-nitrite can also be converted from ammonia through de-nitrification by bacteria. This process increases with increasing temperature and decreasing pH.

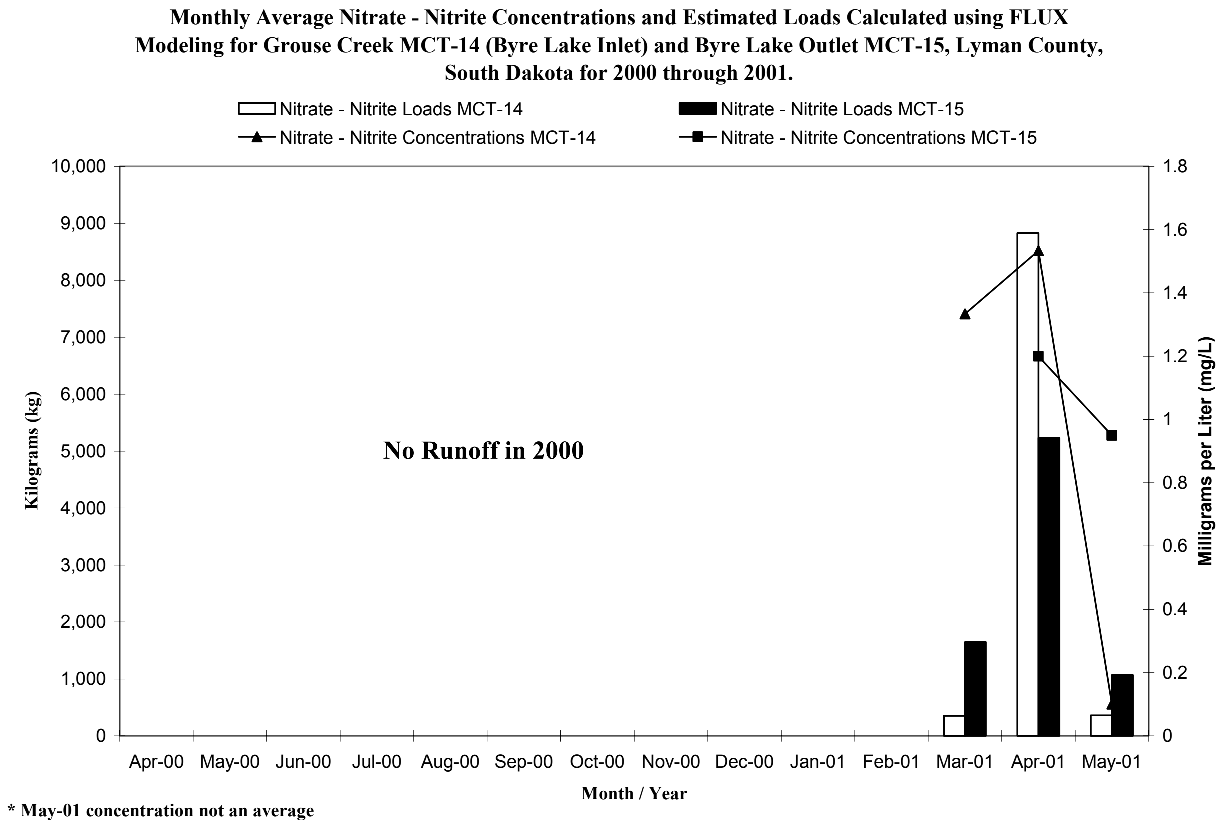


Figure 13. Monthly average nitrate-nitrite concentrations and estimated loads to Byre Lake and Medicine Creek from Grouse Creek, Lyman County, South Dakota from 2000 through 2001.

The average nitrate-nitrite concentration for Grouse Creek was 1.18 mg/L (median 1.00 mg/L) during the project. The maximum concentration of nitrate-nitrite was 2.30 mg/L on March 26, 2001 at MCT-14 and a minimum of 0.10 mg/L (laboratory detection limit) in one sample collected on May 13, 2001 at MCT-14 (Appendix C). One peak was observed in monthly average nitrate-nitrite concentrations in April 2001 at both MCT-14 and MCT-15 (Figure 13). Nitrate-nitrite concentrations between sampling sites were not statistically different ($U_{0.05\,(2),\,7,\,4}$ = 11.50, $p>0.05$). Seasonally, average nitrate-nitrite concentrations were elevated in the winter of 2001 at 1.33 mg/L (Table 7).

Nitrate-nitrite loading by site was highest at site MCT-14 at 9,541 kg (Table 16). Nitrate-nitrite loading between sampling sites was not statistically different ($U_{0.05\,(2),\,3,\,3}$ = 3.00, $p>0.05$). Sub-watershed export coefficients (kilograms/acre) were highest in the MCT-14 sub-watershed at 0.46 kg/acre.

Byre Lake reduced/modified Grouse Creek nitrate-nitrite loading to Medicine Creek (reduction coefficient) by approximately 1.20 times or 1,596 kg (Table 16).

Periodic elevated nitrate-nitrite concentrations in this watershed may have origins in geologic formations. Soils in the Medicine Creek watershed, of which the Byre Lake watershed is a part, were developed from Pierre shale. Layers have been identified in the bedded material that are high in and contribute nitrate-nitrites to groundwater that seeps through these areas. There are three possible sources for increased nitrate-nitrites to enter seepage water in the watershed. (1.) Natural seeps that occur along the drainage ways may deliver nitrate-nitrites to the draws and the nitrate-nitrites are flushed downstream when runoff occurs. (2.) The water table that occurs below and downstream of impoundments (stock dams) may be intercepting some of these layers high in nitrate-nitrites and cause it to flow to the surface downstream of the dam. (3.) There may be seeps that developed in cropland. The Pierre soils have a history of seeps developing and enlarging where native range has been converted to cropland. This is caused where the annual moisture exceeds the cropland needs and a water table develops bringing seep water to the ground surface (Kuck, 2003).

Table 16. Nitrate-nitrite loading per year by site for Grouse Creek, Lyman County, South Dakota from 2000 through 2001.

	Station	Gauged Watershed Acreage (Acres)	Percent Hydrologic Load	Kilograms by site	Export Coefficient (kg/acre)
Total Gauged Load to Byre Lake	**MCT-14**	**20,681**	**89.0**	**9,541**	**0.46**
Byre Lake Outlet - Load to Medicine Creek	**MCT-15**	**22,946**	**100.0**	**7,945**	**0.35**
Byre Lake Reduction Coefficient*	**1.20**				

*** = Reduction coefficient is the estimated reduction efficiency of Byre Lake on loading to Medicine Creek (Inlet Load/Total Watershed Acres) / (Outlet Load/Total Watershed Acres).**

Total Kjeldahl Nitrogen

Total Kjeldahl Nitrogen (TKN) is organic nitrogen including ammonia. Sources of TKN can include release from dead or decaying organic matter, septic systems or agricultural waste.

TKN concentrations in Grouse Creek averaged 0.99 mg/L (median 1.14 mg/L) with a maximum concentration of 1.41 mg/L and a minimum of 0.18 mg/L. Total Kjeldahl Nitrogen concentrations between sampling sites were not statistically different ($U_{0.05\ (2),\ 7,\ 4} = 14.00$, $p>0.05$). Seasonal TKN concentrations were highest in the winter at MCT-14 (Table 7).

Table 17. Total Kjeldahl Nitrogen loading per year by site for Grouse Creek, Lyman County, South Dakota from 2000 through 2001.

	Station	Gauged Watershed Acreage (Acres)	Percent Hydrologic Load	Kilograms by site	Export Coefficient (kg/acre)
Total Gauged Load to Byre Lake	**MCT-14**	**20,681**	**89.0**	**8,381**	**0.41**
Byre Lake Outlet - Load to Medicine Creek	**MCT-15**	**22,946**	**100.0**	**6,125**	**0.27**
Byre Lake Reduction Coefficient*	**1.37**				

*** = Reduction coefficient is the estimated reduction efficiency of Byre Lake on loading to Medicine Creek (Inlet Load/Total Watershed Acres) / (Outlet Load/Total Watershed Acres).**

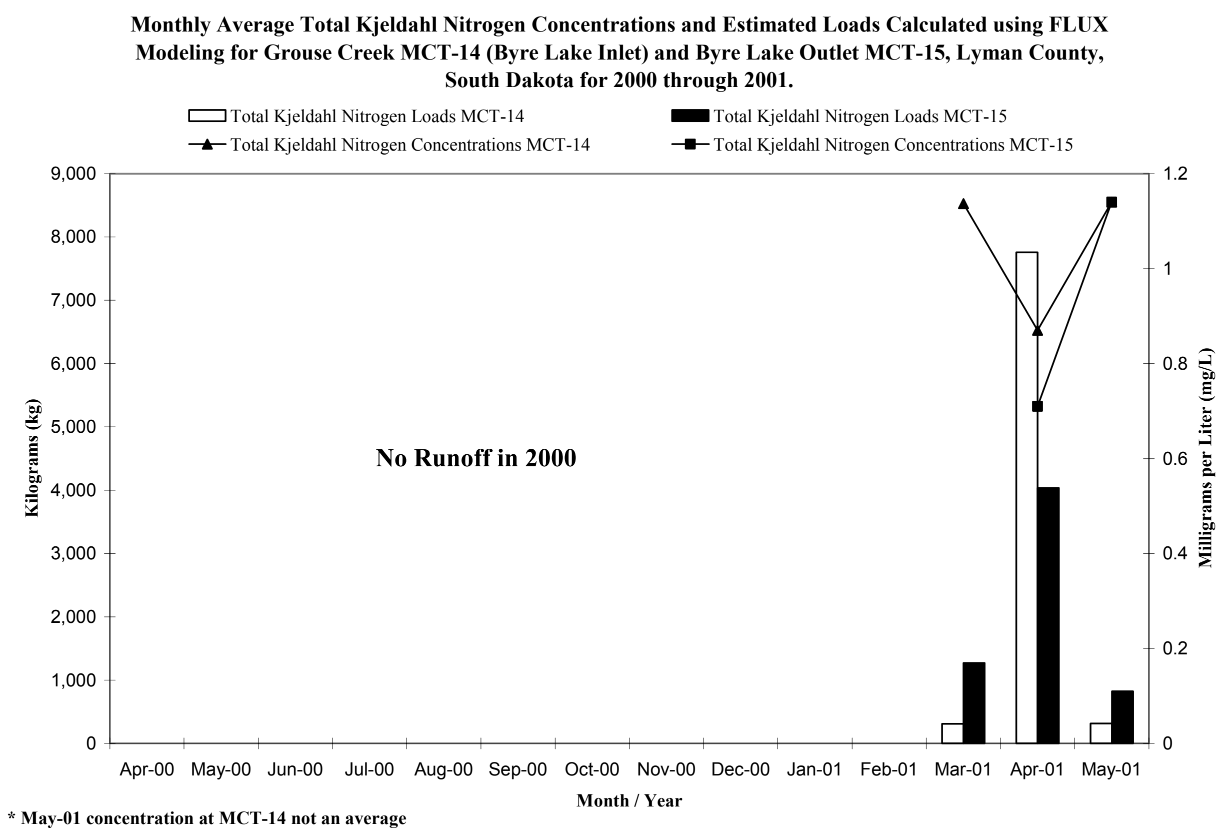


Figure 14. Monthly average Total Kjeldahl Nitrogen concentrations and estimated loads to Byre Lake and Medicine Creek from Grouse Creek, Lyman County, South Dakota from 2000 through 2001.

TKN loading by site was highest at site MCT-14 at 8,381 kg (Table 17). Approximately 92.5 percent of the total load to Byre Lake (MCT-14) occurred in April (Figure 14). TKN loading between sampling sites was not statistically different ($U_{0.05\ (2),\ 3,\ 3} = 3.00$, $p>0.05$). Sub-watershed export coefficients (kilograms/acre) were highest in the MCT-14 sub-watershed at 0.41 kg/acre.

Byre Lake dramatically reduced/modified Grouse Creek Total Kjeldahl Nitrogen loading to Medicine Creek (reduction coefficient) by approximately 1.37 times or 2,256 kg (Table 17).

Organic Nitrogen

Organic nitrogen is calculated by subtracting ammonia from TKN. Organic nitrogen is broken down to more usable ammonia and other forms of inorganic nitrogen by bacteria.

Organic nitrogen concentrations in Grouse Creek averaged 0.96 mg/L (median 0.94 mg/L) with a maximum of 1.25 mg/L and a minimum concentration of 0.59 mg/L. Since organic nitrogen is calculated from TKN, Figure 14 and Figure 15 are similar. Organic nitrogen concentrations between sampling sites were not statistically different ($U_{0.05\ (2),\ 7,\ 4} = 9.00$, $p>0.05$). Seasonal averages for organic nitrogen concentrations were also highest in the spring at MCT-15 (Table 7).

Table 18. Organic nitrogen loading per year by site for Grouse Creek, Lyman County, South Dakota from 2000 through 2001.

	Station	Gauged Watershed Acreage (Acres)	Percent Hydrologic Load	Kilograms by site	Export Coefficient (kg/acre)
Total Gauged Load to Byre Lake	**MCT-14**	**20,681**	**89.0**	**7,574**	**0.37**
Byre Lake Outlet - Load to Medicine Creek	**MCT-15**	**22,946**	**100.0**	**6,356**	**0.28**
Byre Lake Reduction Coefficient*	**1.19**				

*** = Reduction coefficient is the estimated reduction efficiency of Byre Lake on loading to Medicine Creek (Inlet Load/Total Watershed Acres) / (Outlet Load/Total Watershed Acres).**

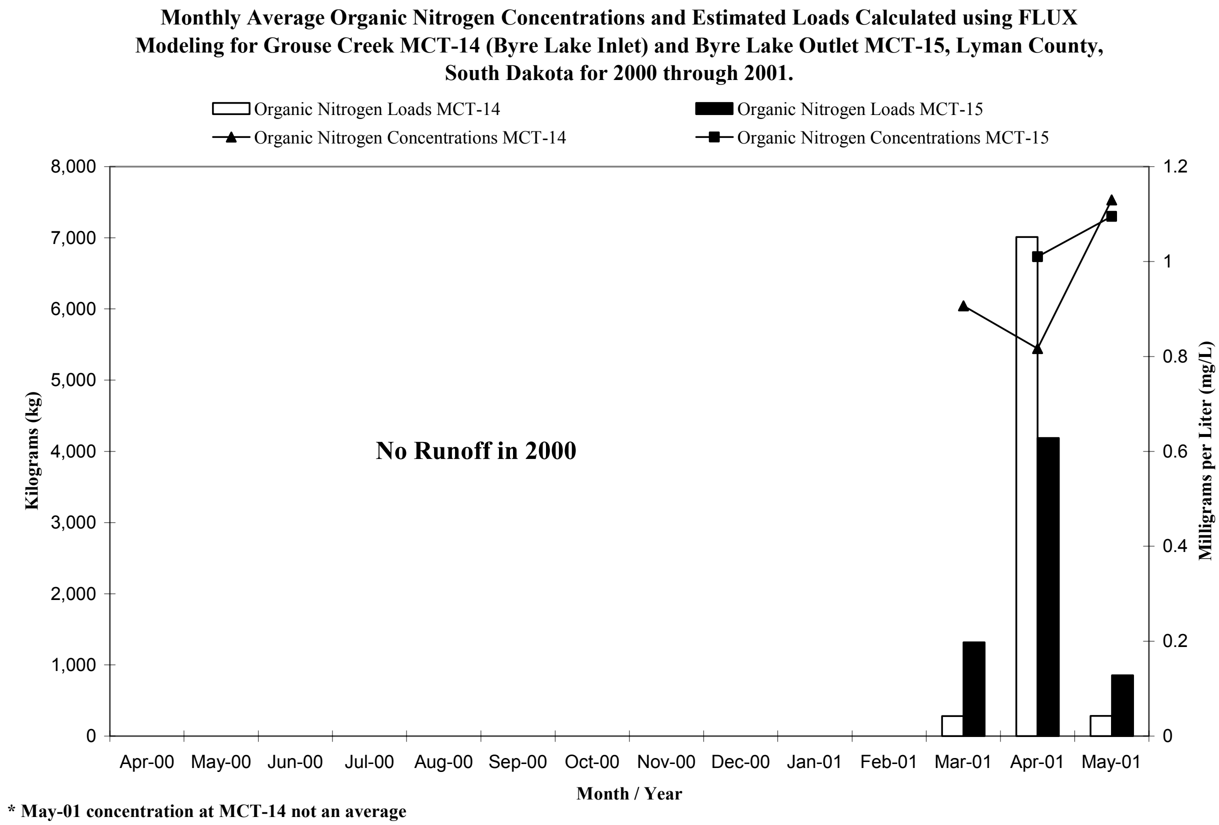


Figure 15. Monthly average organic nitrogen concentrations and estimated loads to Byre Lake and Medicine Creek from Grouse Creek, Lyman County, South Dakota from 2000 through 2001.

Organic nitrogen loading by site was highest at site MCT-14 at 7,574 kg (Table 18). Approximately 92.5 percent of the total load to Byre Lake (MCT-14) occurred in April (Figure 15). Organic nitrogen loading between sampling sites was not statistically different ($U_{0.05\ (2),\ 3,\ 3} = 3.00$, $p>0.05$). Sub-watershed export coefficients (kilograms/acre) were highest in the MCT-14 sub-watershed at 0.37 kg/acre.

Byre Lake reduced/modified Grouse Creek organic nitrogen loading to Medicine Creek (reduction coefficient) by approximately 1.19 times or 1,218 kg (Table 18).

Inorganic Nitrogen

Inorganic nitrogen is the sum of ammonia plus nitrate-nitrite. Inorganic nitrogen is readily broken down to more usable ammonia by biological dissimilation.

Inorganic nitrogen concentrations in Grouse Creek averaged 1.30 mg/L (median 1.35 mg/L) with a maximum of 2.44 mg/L and a minimum concentration of 0.11 mg/L. Inorganic nitrogen concentrations between sampling sites were not statistically different ($U_{0.05\ (2),\ 7,\ 4} = 11.00$, p>0.05). Seasonal averages for inorganic nitrogen concentrations were highest in the winter at MCT-14 (Table 7).

Table 19. Inorganic nitrogen loading per year by site for Grouse Creek, Lyman County, South Dakota from 2000 through 2001.

	Station	Gauged Watershed Acreage (Acres)	Percent Hydrologic Load	Kilograms by site	Export Coefficient (kg/acre)
Total Gauged Load to Byre Lake	**MCT-14**	**20,681**	**89.0**	**10,348**	**0.50**
Byre Lake Outlet - Load to Medicine Creek	**MCT-15**	**22,946**	**100.0**	**9,068**	**0.40**
Byre Lake Reduction Coefficient*	**1.14**				

*** = Reduction coefficient is the estimated reduction efficiency of Byre Lake on loading to Medicine Creek (Inlet Load/Total Watershed Acres) / (Outlet Load/Total Watershed Acres).**

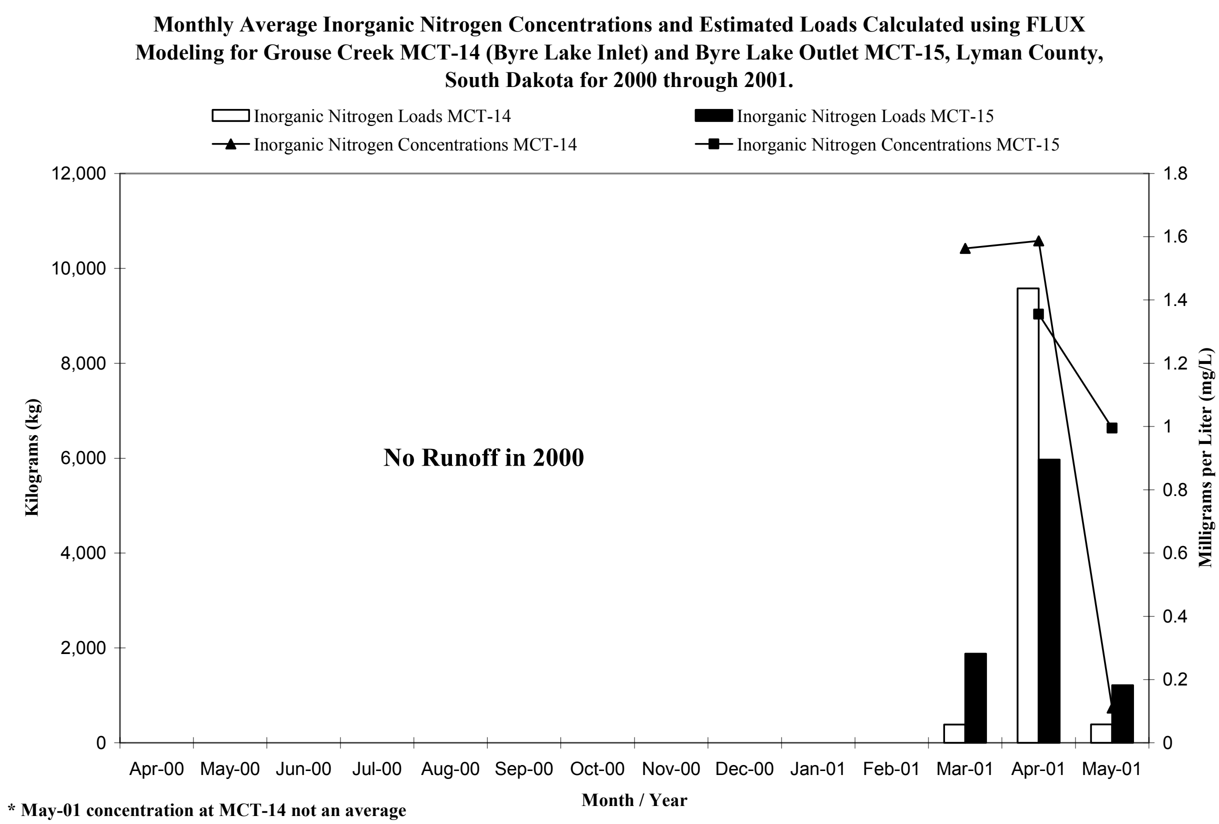


Figure 16. Monthly average inorganic nitrogen concentrations and estimated loads to Byre Lake and Medicine Creek from Grouse Creek, Lyman County, South Dakota from 2000 through 2001.

Inorganic nitrogen loading by site was highest at site MCT-14 at 10,348 kg (Table 19). Approximately 92.5 percent of the total load to Byre Lake (MCT-14) occurred in April (Figure

16). Inorganic nitrogen loading between sampling sites was not statistically different ($U_{0.05\ (2),\ 3,\ 3}$ = 3.00, p>0.05). Sub-watershed export coefficients (kilograms/acre) were highest in the MCT-14 sub-watershed at 0.50 kg/acre.

Byre Lake slightly reduced/modified Grouse Creek inorganic nitrogen loading to Medicine Creek (reduction coefficient) by approximately 1.14 times or 1,280 kg (Table 19). This may indicate that biological processes minimally utilized/converted inorganic nitrogen into biomass in Byre Lake, suggesting a phosphorus-limited system.

Total Nitrogen

Total nitrogen is the sum of nitrate-nitrite and TKN. Total nitrogen is used mostly in determining the limiting nutrient (nitrogen or phosphorus) for plant growth and will be discussed in the lake section of this report. The maximum total nitrogen concentration found in Grouse Creek was 3.03 mg/L at MCT-14 on March 26, 2001 (Appendix C). The mean concentration for the entire project was 2.09 mg/L and the standard deviation for total nitrogen was 0.79 mg/L. Total nitrogen concentrations between sampling sites were not statistically different ($U_{0.05\ (2),\ 7,\ 4}$ = 10.00, p>0.05). The organic nitrogen fraction ranged from 15.7 percent to 91.1 percent and averaged 40.9 percent, while the inorganic nitrogen fraction ranged from 8.9 percent to 84.3 percent and averaged 59.1 percent of total nitrogen. Seasonally, average total nitrogen concentrations were higher in the winter at MCT-14 (Table 7).

Total nitrogen loading by site was highest at site MCT-14 at 17,922 kg (Table 20). Approximately 92.5 percent of the total load to Byre Lake (MCT-14) occurred in April (Figure 17). Total nitrogen loading between sampling sites was not statistically different ($U_{0.05\ (2),\ 3,\ 3}$ = 3.00, p>0.05). Sub-watershed export coefficients (kilograms/acre) were highest in the MCT-14 sub-watershed at 0.87 kg/acre.

Byre Lake reduced/modified Grouse Creek total nitrogen loading to Medicine Creek (reduction coefficient) by approximately 1.36 times or 4,770 kg (Table 20).

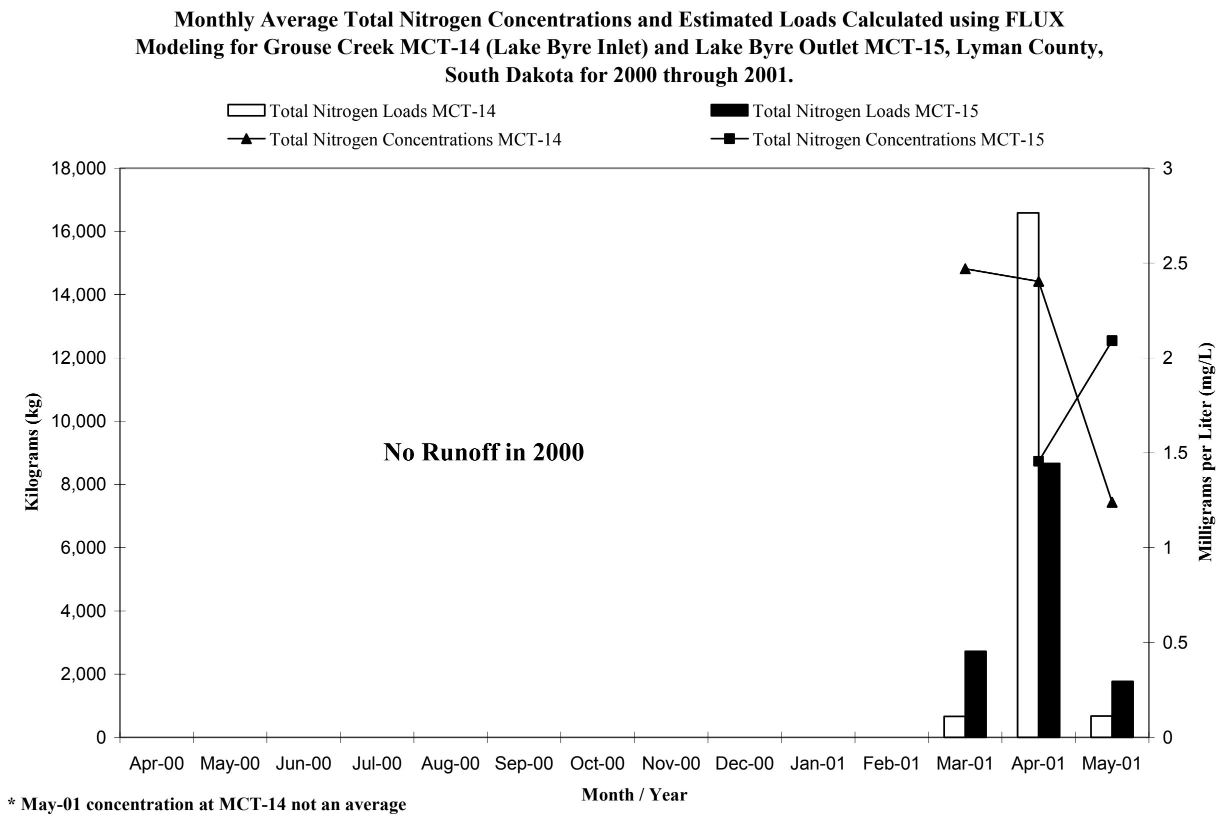


Figure 17. Monthly average total nitrogen concentrations and estimated loads to Byre Lake and Medicine Creek from Grouse Creek, Lyman County, South Dakota from 2000 through 2001.

Table 20. Total nitrogen loading per year by site for Grouse Creek, Lyman County, South Dakota from 2000 through 2001.

	Station	Gauged Watershed Acreage (Acres)	Percent Hydrologic Load	Kilograms by site	Export Coefficient (kg/acre)
Total Gauged Load to Byre Lake	MCT-14	20,681	89.0	17,922	0.87
Byre Lake Outlet - Load to Medicine Creek	MCT-15	22,946	100.0	13,152	0.57
Byre Lake Reduction Coefficient*	1.36				

* = Reduction coefficient is the estimated reduction efficiency of Byre Lake on loading to Medicine Creek (Inlet Load/Total Watershed Acres) / (Outlet Load/Total Watershed Acres).

Decreasing nitrogen inputs from Grouse Creek and the ungauged sub-watershed may improve (lower) in-lake TSI values. Reducing nitrogen (especially organic nitrogen) could reduce non-algal turbidity, which would decrease Secchi TSI values. Increasing transparency could increase the growth of submerged macrophytes, which would increase the uptake of nitrogen and phosphorus, reducing available nutrients that could cause algal blooms in Byre Lake. A dramatic reduction in both nitrogen and phosphorus is needed to reduce algal growth in Byre Lake. Reduced densities of algae should decrease chlorophyll-*a* concentrations. Reducing available in-lake nitrogen, phosphorus and algal densities should decrease all TSI values. These reductions over time should improve the long-term TSI trend. Increasing the densities of submerged macrophytes in Byre Lake will also create littoral zone cover for macroinvertebrates, forage fish and ambush points for predator species.

Sub-watersheds that should be targeted for total nitrogen mitigation based on delivered loads to Byre Lake are presented by priority ranking in Table 21.

Table 21. Grouse Creek watershed mitigation priority sub-watersheds for total nitrogen based on 2000 – 2001 watershed assessment modeling.

Priority Ranking	Sub-watershed	Total Nitrogen Export Coefficient (kg/acre)	Total Nitrogen Kilograms Delivered
1	MCT-14	0.87	17,922
2	MCT-15	0.57	13,152

Total Phosphorus

Phosphorus differs from nitrogen in that it is not as water-soluble and will sorb on to sediments and other substrates. Once phosphorus sorbs on to any substrate, it is not readily available for uptake and utilization. Phosphorus sources in the Byre Lake watershed can be natural from geology and soil, from decaying organic matter, waste from septic tanks or agricultural runoff. Nutrients such as phosphorus and nitrogen tend to accumulate during low flows because they are associated with fine particles whose transport is dependent upon discharge (Allan, 1995). These nutrients are also retained and released on stream banks and floodplains within the watershed. Phosphorus will remain in the stream sediments unless released by increased stage (water level), discharge or current. Re-suspending phosphorus and other nutrients associated with sediment into the water column (stream) should show increased concentrations during rain events (increased stage and flow). Reduced flows and discharge may deposit phosphorus and other nutrients associated with sediment on the stream banks and floodplains of Grouse Creek. Rain events increase flows and re-suspend sediment and phosphorus stored in the floodplain and stream banks. These concentrations combine with event-based concentrations to increase overall nutrient loading, producing peak concentrations of total phosphorus and total nitrogen in Grouse Creek.

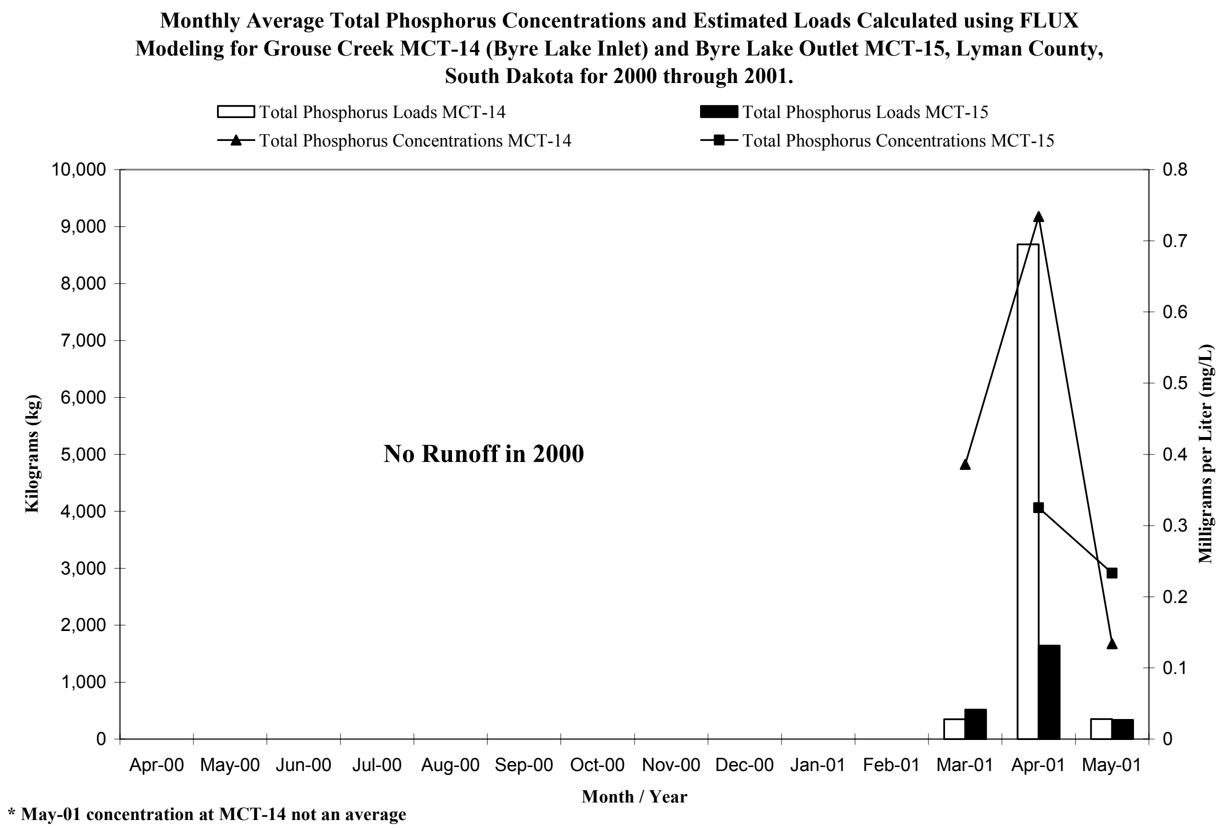


Figure 18. Monthly average total phosphorus concentrations and estimated loads to Byre Lake and Medicine Creek from Grouse Creek, Lyman County, South Dakota from 2000 through 2001.

The average total phosphorus concentration for Grouse Creek was 0.419 mg/L (median 0.268 mg/L) during the project. The maximum concentration of total phosphorus was 1.290 mg/L on April 25, 2001 at MCT-14 and a minimum of 0.134 mg/L at MCT-14 on May 13, 2000 (Appendix C). Total phosphorus concentrations between sampling sites were not statistically different ($U_{0.05\ (2),\ 7,\ 4} = 10.00$, $p>0.05$). Since algae/periphyton only need 0.02 mg/L of phosphorus to produce algal blooms in lakes (Wetzel, 2001), the Grouse Creek average concentration of total phosphorus was approximately 20.9 times the phosphorus needed to produce algal blooms in Byre Lake. Seasonally, average total phosphorus concentrations were highest in the spring of 2001 at 0.584 mg/L at site MCT-14 (Table 7).

Table 22. Total phosphorus loading per year by site for Grouse Creek, Lyman County, South Dakota from 2000 through 2001.

	Station	Gauged Watershed Acreage (Acres)	Percent Hydrologic Load	Kilograms by site	Export Coefficient (kg/acre)
Total Gauged Load to Byre Lake	**MCT-14**	**20,681**	**89.0**	**9,391**	**0.45**
Byre Lake Outlet - Load to Medicine Creek	**MCT-15**	**22,946**	**100.0**	**2,493**	**0.11**
Byre Lake Reduction Coefficient*	**3.77**				

*** = Reduction coefficient is the estimated reduction efficiency of Byre Lake on loading to Medicine Creek (Inlet Load/Total Watershed Acres) / (Outlet Load/Total Watershed Acres).**

Figure 18 indicates a substantial phosphorus load impacted Byre Lake during April 2001. This may have been the catalyst for the large in-lake algal diatom bloom (71,606 cells/ml total) recorded in mid-May 2001. Conceivably, this surge in growth utilized substantial phosphorus, nitrogen and carbon concentrations for growth. Total phosphorus concentrations between sampling sites were not statistically different ($U_{0.05\ (2),\ 7,\ 4} = 7.00$, $p>0.05$).

Total phosphorus loading by site was highest at site MCT-14 with 9,391 kg/year (Table 22). Approximately 92.5 percent of the total phosphorus load to Byre Lake (MCT-14) occurred in April of 2001 (Figure 18). Total phosphorus loading between sampling sites was not significantly different ($U_{0.05\ (2),\ 3,\ 3} = 4.00$, $p>0.05$). Sub-watershed export coefficients (kilograms/acre) were highest in the MCT-14 sub-watershed (0.45 kg/acre). Monthly total phosphorus loading was similar to most other parameter observations in Grouse Creek. The greatest monthly total phosphorus loading occurred in April (Figure 18).

Byre Lake dramatically reduced/modified Grouse Creek total phosphorus loading to Medicine Creek (reduction coefficient) by approximately 3.77 times or 6,898 kg (Table 22). This reduction suggests that phosphorus (total and dissolved) were utilized in biological processes and biomass production in Byre Lake

Reductions in total phosphorus loads are needed in both the watershed and in Byre Lake to maintain phosphorus-limitation throughout the year and improve TSI values in Byre Lake. Tributary total phosphorus reductions are needed to achieve in-lake TSI reductions. Alterations should be implemented in existing management practices to improve current conditions in both the watershed and Byre Lake. Every effort should be made to reduce total phosphorus loads to meet TMDL goals in the Byre Lake watershed.

Decreasing total phosphorus inputs from the Grouse Creek watershed will improve (lower) TSI values. Reducing total phosphorus will decrease algal turbidity, which should increase Secchi transparency and decrease Secchi TSI values. Reducing phosphorus input should lower in-lake phosphorus concentrations and phosphorus TSI values. Reduced phosphorus concentrations may reduce available phosphorus for algae growth and uptake, which could lower algal densities that in turn decreases chlorophyll-*a* concentrations, reducing chlorophyll-*a* TSI values. Reductions in phosphorus over time should reverse elevated TSI values observed in Byre Lake.

Sub-watersheds that should be targeted for phosphorus mitigation based on delivered loads to Byre Lake and are presented in Table 23.

Table 23. Grouse Creek watershed mitigation priority sub-watersheds for total phosphorus based on 2000 – 2001 watershed assessment modeling.

Priority Ranking	Sub-watershed	Total Phosphorus Export Coefficient (kg/acre)	Total Phosphorus Kilograms Delivered
1	MCT-14	0.45	9,391
2	MCT-15	0.11	2,493

Total Dissolved Phosphorus

Total dissolved phosphorus is the fraction of total phosphorus that is readily available for use by algae and macrophytes. Dissolved phosphorus will sorb on suspended materials (both organic and inorganic) if they are present in the water column and if they are not already saturated with phosphorus.

The average total dissolved phosphorus concentration for Grouse Creek was 0.212 mg/L (median 0.226 mg/L). The maximum concentration of total dissolved phosphorus was 0.327 mg/L on March 26, 2001 at MCT-14 and a minimum of 0.074 mg/L at MCT-14 on May 13, 2001 (Appendix C). Total dissolved phosphorus concentrations between sampling sites were not statistically different ($U_{0.05\ (2),\ 7,\ 4} = 13.00$, $p>0.05$). During this study, the percentage of total dissolved phosphorus to total phosphorus ranged from 23.9 percent in the summer to 94.6 percent in spring and averaged 50.7 percent over the project.

Table 24. Total dissolved phosphorus loading per year by site for Grouse Creek, Lyman County, South Dakota from 2000 through 2001.

	Station	Gauged Watershed Acreage (Acres)	Percent Hydrologic Load	Kilograms by site	Export Coefficient (kg/acre)
Total Gauged Load to Byre Lake	**MCT-14**	**20,681**	**89.0**	**2,251**	**0.11**
Byre Lake Outlet - Load to Medicine Creek	**MCT-15**	**22,946**	**100.0**	**1,232**	**0.05**
Byre Lake Reduction Coefficient*	**1.83**				

*** = Reduction coefficient is the estimated reduction efficiency of Byre Lake on loading to Medicine Creek (Inlet Load/Total Watershed Acres) / (Outlet Load/Total Watershed Acres).**

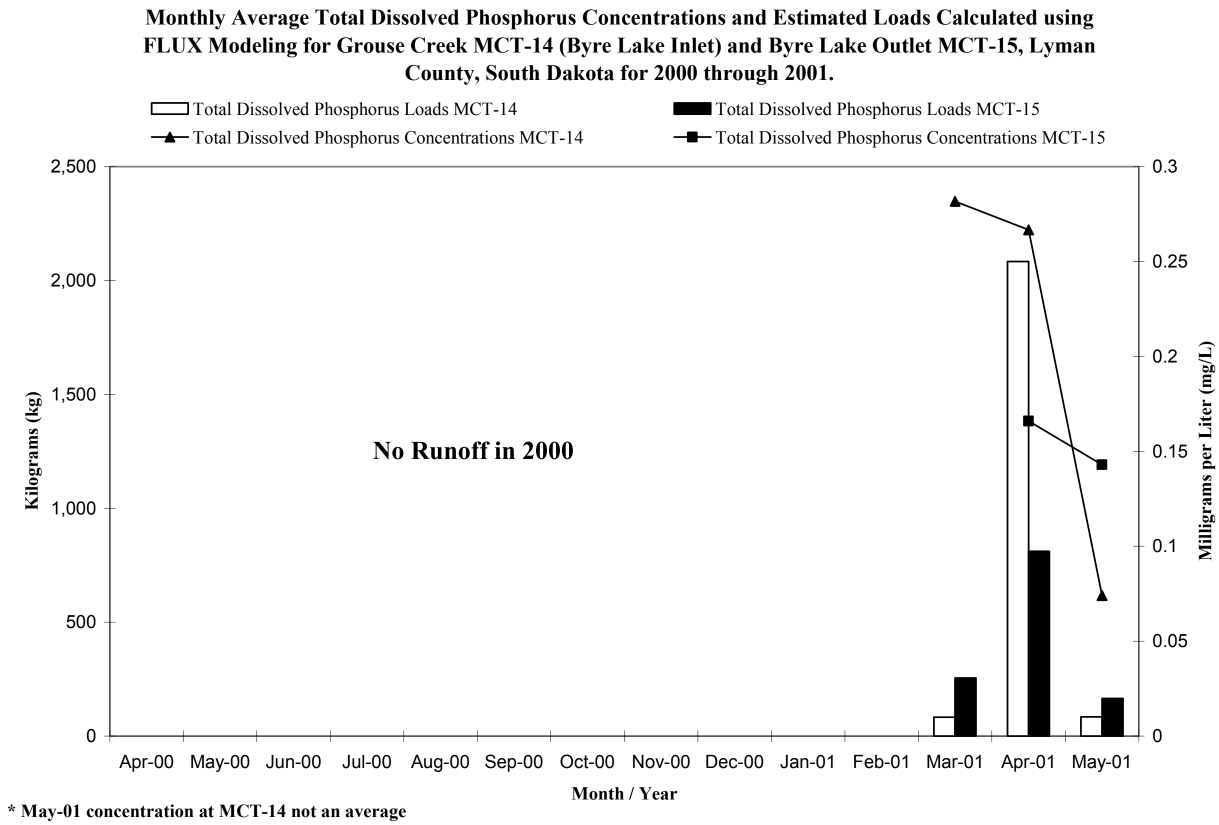


Figure 19. Monthly average total dissolved phosphorus concentrations and estimated loads to Byre Lake and Medicine Creek from Grouse Creek, Lyman County, South Dakota from 2000 through 2001.

Average total dissolved phosphorus concentrations were similar to total phosphorus with decreases in monthly average total dissolved phosphorus concentrations from April through May 2001 (Figure 19). Seasonally, total dissolved phosphorus concentrations were higher in the winter with 0.282 mg/L (Table 7).

Total dissolved phosphorus loading by site was highest at site MCT-14 with 2,251 kg/year (Table 24). Total phosphorus loading between sampling sites was not statistically different ($U_{0.05\,(2),\,3,\,3} = 3.00$, $p>0.05$). Sub-watershed export coefficients (kilograms/acre) were highest (0.11 kg/acre) at MCT-14 (Table 24). Again, monthly total dissolved phosphorus loading was similar to most other parameter observations in Grouse Creek, with the greatest monthly total phosphorus loading occurring in April 2001 (Figure 19).

Byre Lake dramatically reduced / modified Grouse Creek total dissolved phosphorus loading to Medicine Creek (reduction coefficient) by approximately 1.83 times or 1,019 kg (Table 24).

Fecal Coliform Bacteria

Fecal coliform bacteria are found in the intestinal tract of warm-blooded animals and are used as indicators of waste and presence of pathogens in a waterbody. Many outside factors can influence the concentration of fecal coliform. Sunlight and time can lessen fecal coliform concentrations although nutrient concentrations remain high. As a rule, just because fecal bacteria concentrations are low or non-detectable, does not mean animal waste is not present in a waterbody. South Dakota water quality standards for fecal coliform are in effect from May 1 through September 30.

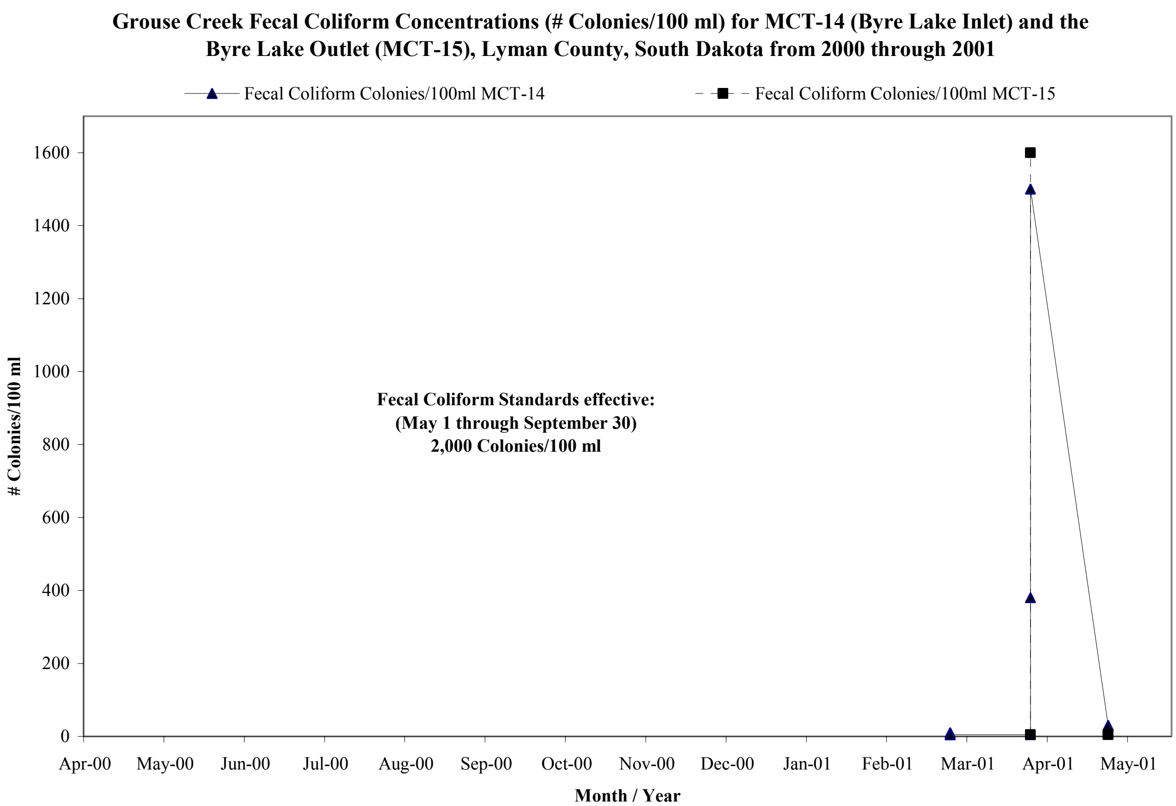


Figure 20. Monthly fecal coliform concentrations (# colonies/100 ml) to Byre Lake and Medicine Creek from Grouse Creek, Lyman County, South Dakota in 2000 and 2001.

Figure 20 and Table C-1 in Appendix C identifies three elevated fecal coliform samples collected in mid to late April of 2001 in Grouse Creek. Two of the elevated samples were collected at MCT-14 (380 and 1,500 colonies/100 ml) and one at MCT-15 (1,600 colonies/100 ml). Both of the higher counts occurred during peak hydrologic flows. Fecal coliform bacteria counts were not statistically different between MCT-14 and MCT-15 ($U_{0.05\ (2),\ 7,\ 4} = 11.50$, $p>0.05$). This suggests that elevated fecal coliform concentrations/loadings may be related to watershed runoff events. However, in-lake fecal coliform samples during this period were at or below laboratory detection limits (Figure 43, Table D-1 in Appendix D and Table 30). This indicates that fecal coliform decay rate, sunlight and in-lake dilution affect bacteria concentrations in Byre Lake. Water quality standards violations for fecal coliform are a concern in Grouse Creek to maintain/protect immersion recreation use in Byre Lake; and, implementing suggested tributary Best Management Practices (BMPs) will reduce tributary fecal coliform concentrations.

Tributary Total Nitrogen /Total Phosphorus Ratios (Limiting Nutrient)

Nutrients are inorganic materials necessary for life, the supply of which is potentially limiting to biological activity within lotic (stream) and lentic (lake) ecosystems. Lakes that have average concentrations of total phosphorus of 0.01 mg/L or less are considered oligotrophic, while lakes with more than 0.030 mg/L, usually eutrophic (Wetzel, 2001). The conventions of oligotrophic and eutrophic states do not have the same utility for running water that they do for lakes, nor is there evidence for a natural process of eutrophication corresponding to lake succession (Hynes, 1969). Studies from diverse regions of North America (Omernik, 1977, Stockner and Shortreed, 1978 and Pringle and Bowers, 1984) imply that phosphorus limitation is widespread in streams. It is apparent that variations in nutrient concentrations and nitrogen-to-phosphorus ratios have predictable consequences for algae/periphyton community structure and metabolism in running waters (Allan, 1995).

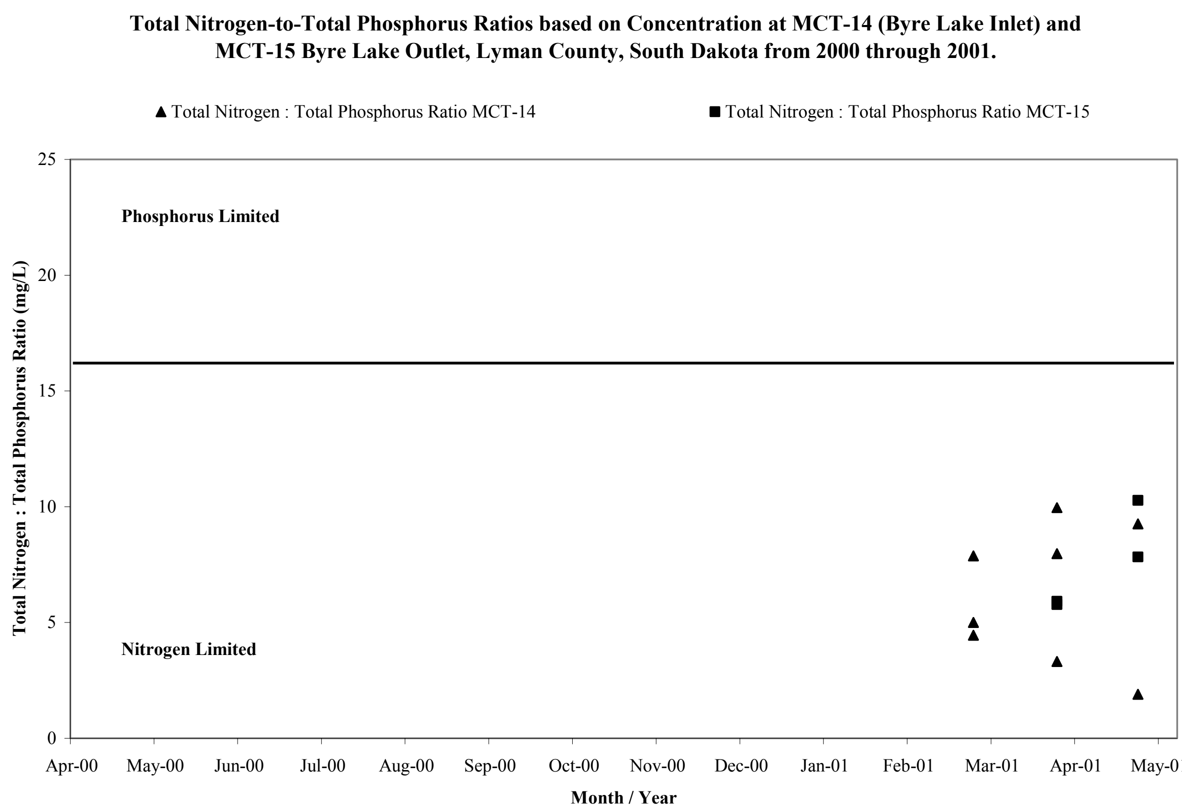


Figure 21. Total nitrogen-to-total phosphorus ratios based on concentrations at MCT-14 and MCT-15 for Grouse Creek, Lyman County, South Dakota in 2000 and 2001.

Most estimates of the total nitrogen-to-total phosphorus ratio in freshwaters are above 16:1, based on the Redfield ratio (Redfield et al, 1963) and numerous bioassay experiments (Allan, 1995). This suggests that nitrogen is in surplus and phosphorus is in limited supply. The Environmental Protection Agency (EPA) has suggested total nitrogen-to-total phosphorus ratios for lakes of 10:1 as being the break for phosphorus limitation (US EPA, 1990). For tributary samples, a total nitrogen-to-total phosphorus ratio of 16:1 was used to determine phosphorus limitation based on Allan, 1995. Even if the total nitrogen-to-total phosphorus convention for lakes (10:1) is used on tributary data, Grouse Creek would still be considered nitrogen-limited.

Nitrogen and phosphorus ratios were calculated for all tributary samples (11 samples), however, only data from MCT-14 was evaluated because those concentrations (ratios) influence Byre Lake directly. Individual ratios for MCT-14 and MCT-15 are shown in Figure 21. Total nitrogen-to-total phosphorus ratios were not statistically different between MCT-14 and MCT-15 ($U_{0.05\,(2),\,7,\,4} = 13.00$, $p>0.05$).

Average seasonal tributary total nitrogen-to-total phosphorus ratios were generally lower in the spring. Most tributary total nitrogen-to-total phosphorus ratios (both individually and seasonally) indicate that the Grouse Creek system in the Byre Lake watershed is nitrogen-limited (Figure 21 and Table 7). Theoretically, based on the criteria previously proposed, metabolic activity and community structure based on nutrient limitation was a factor in Grouse Creek due to nitrogen limitation (indicating excess phosphorus in the watershed).

In-lake Methods

Byre Lake is a 51.5 ha (127 acres) impoundment in Lyman County, South Dakota. Two in-lake sample locations were chosen for collecting nutrient, biological and sediment data from Byre Lake during the study. The locations of the in-lake sampling sites are shown in Figure 22. A sample set consisted of one surface and one bottom sample collected from each site (BL-1 and BL-2) each month. These samples were used to analyze seasonal water quality trends over time.

Chlorophyll *a* samples were used with total phosphorus and Secchi disk data to evaluate the trophic status in Byre Lake (Carlson, 1977).

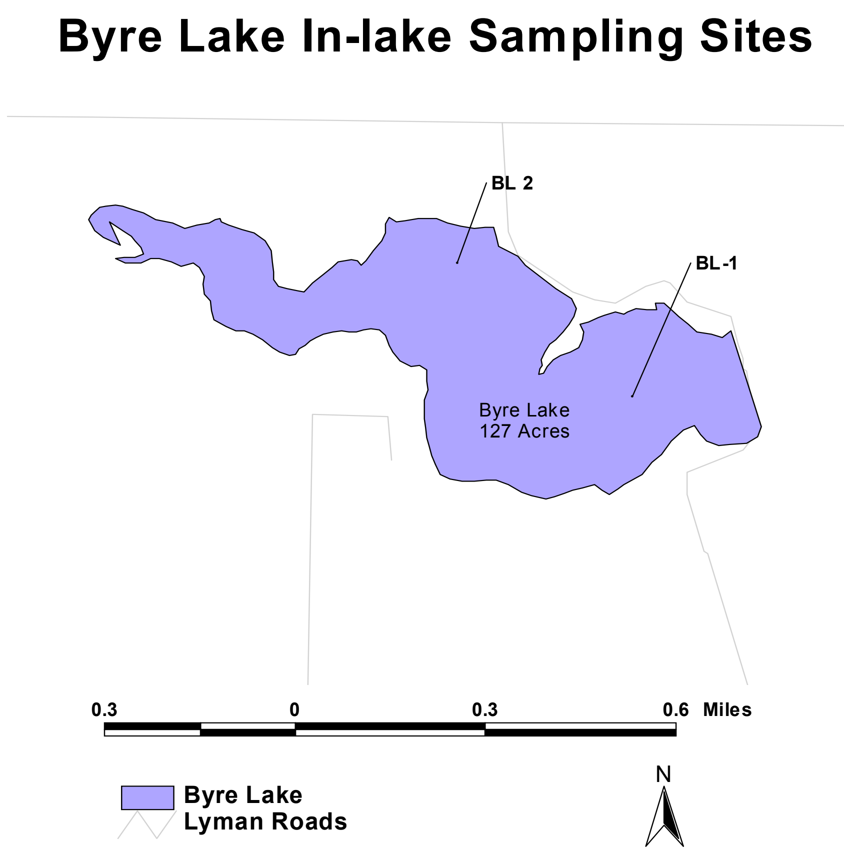


Figure 22. Byre Lake in-lake sampling sites for 2000 and 2001.

In-lake Water Quality Sampling

Samples collected at each in-lake site were taken according to South Dakota's EPA-approved *Standard Operating Procedures for Field Samplers* (SD DENR 2000). In-lake physical, chemical and biological water quality sample parameters are listed in Table 25. All water samples were sent to the State Health Laboratory in Pierre for analysis. Quality Assurance/Quality Control samples were collected for approximately ten percent of the samples according to South Dakota's EPA-approved *Non-Point Source Quality Assurance/Quality Control Plan* (SD DENR, 1998c). These documents can be referenced by contacting the South Dakota Department of Environment and Natural Resources at (605) 773-4254.

Table 25. In-lake physical, chemical and biological parameters analyzed in Byre Lake, Lyman County, South Dakota in 2000 and 2001.

Physical	Chemical	Biological
Air Temperature	Total Alkalinity	Fecal Coliform
Water Temperature	Field pH	Chlorophyll-*a*
Secchi Transparency	Dissolved Oxygen	Aquatic Macrophytes
Total Depth	Total Solids	Algae
Visual Observations	Total Suspended Solids	
	Total Dissolved Suspended Solids (calculated)	
	Volatile Total Suspended Solids	
	Ammonia	
	Un-ionized Ammonia (calculated)	
	Nitrate-Nitrite	
	Total Kjeldahl Nitrogen	
	Total Phosphorus	
	Total Dissolved Phosphorus	
	Conductivity	

Algae samples were analyzed by SD DENR staff with enumeration results entered into a database to calculate biovolume (Appendix E).

In-lake Modeling Methods

The reduction response model used to predict in-lake response to reductions in tributary loading was BATHTUB (Walker, 1999). BATHTUB is predictive in that it will assess impacts of changes in water and/or nutrient loadings, and estimate nutrient loadings consistent with given water quality management objectives. In-lake and tributary data collected from the assessment project was used to calculate existing conditions and to predict parameter-specific and mean TSI values based on general reductions in loadings from Grouse Creek from 2000 through 2001.

3.1.1. In-lake Surface Water Chemistry

In-lake Water Quality Standards

South Dakota's numeric water quality standards are based on beneficial use categories. Beneficial use classifications are listed in Table 26. All lakes in the state are assigned the beneficial uses (category 9) fish and wildlife propagation, recreation and stock watering (ARSD § 74:51:02:01).

Table 26. South Dakota's beneficial use classifications for all waters of the state.

Category	Beneficial Use
1	Domestic water supply waters;
2	Coldwater permanent fish life propagation waters;
3	Coldwater marginal fish life propagation waters;
4	Warmwater permanent fish life propagation waters;
5	Warmwater semipermanent fish life propagation waters;
6	Warmwater marginal fish life propagation waters;
7	Immersion recreation waters;
8	Limited contact recreation waters;
9	Fish and wildlife propagation, recreation, and stock watering waters;
10	Irrigation waters; and
11	Commerce and industry waters.

Byre Lake in Lyman County has been also assigned the beneficial uses of (1) Domestic water supply water, (4) Warmwater permanent fish life propagation water, (7) Immersion recreation water, (8) Limited contact recreation water and (9) Fish and wildlife propagation, recreation, and stock watering water (Table 27).

In addition to physical and chemical standards, South Dakota has developed narrative criteria for the protection of aquatic life uses. *All waters of the state must be free from substances, whether attributable to human-induced point sources discharges or nonpoint source activities, in concentration or combinations which will adversely impact the structure and function of indigenous or intentionally introduced aquatic communities* (ARSD § 74:51:01:12).

Table 27. Assigned beneficial uses for Byre Lake, Lyman County, South Dakota.

Water Body	To	Beneficial Uses*	County
Byre Lake	Byre Lake	1, 4, 7, 8, 9	Lyman

*** = See Table 26 above**

Each beneficial use classification has a set of numeric standards uniquely associated with that specific category. Water quality values that exceed those standards unique to specific beneficial uses, impair beneficial use and violate water quality standards. Table 28 lists the most stringent water quality parameters for Byre Lake. Seven of the seventeen parameters (conductivity, un-disassociated hydrogen sulfide, barium, fluoride, sulfate, total petroleum hydrocarbon and oil and grease) listed for Byre Lake beneficial use classifications were not in the scope of this project and were not sampled.

Table 28. The most stringent water quality standards for Byre Lake based on beneficial use classifications.

Water Body	Beneficial Uses	Parameter	Standard Value
Byre Lake	1, 4, 7, 8, 9	Un-ionized ammonia nitrogen as N [1]	≤ 0.04 mg/L
		Dissolved oxygen	≥ 5.0 mg/L
		pH	≥ 6.5 - ≤ 9.0
		Total Suspended Solids [2]	≤ 158 mg/L
		Temperature (°C)	≤ 26.7°C
		Fecal coliform [3]	≤ 400 colonies/100mL
		Total alkalinity as calcium carbonate [4]	≤ 1,313 mg/L
		Total dissolved solids [5]	≤ 1,750 mg/L
		Conductivity at 25° C [6, 10]	≤ 7,000 µmhos/cm
		Nitrates as N [7]	≤ 10 mg/L
		Undissociated hydrogen sulfide [10]	≤ 0.002 mg/L
		Barium [10]	≤ 1.0 mg/L
		Chloride [8]	≤ 438 mg/L
		Fluoride [10]	≤ 4.0 mg/L
		Sulfate [9, 10]	≤ 875 mg/L
		Total petroleum hydrocarbon [10]	≤ 1 mg/L
		Oil and grease [10]	≤ 10 mg/L

[1] = Un-ionized ammonia is the fraction of ammonia that is toxic to aquatic life. The concentration of un-ionized ammonia is calculated and dependent on temperature and pH. As temperature and pH increase so does the percent of ammonia which is toxic. The 30-day standard is ≤ 0.04 mg/L and the daily maximum is 1.75 times the applicable criterion in the South Dakota Surface Water Quality Standards in mg/L based upon the water temperature and pH where the sample was taken.

[2] = The daily maximum for total suspended solids is ≤ 158 mg/L or ≤ 90 mg/L for a 30-day average (an average of 5 samples (minimum) taken in separate 24-hour periods).

[3] = The fecal coliform standard is in effect from May 1 to September 30. The ≤ 400 counts/100 ml is for a single sample or ≤ 200 counts/100 ml over a 30-day average (an average of 5 samples (minimum) taken in separate 24-hour periods).

[4] = The daily maximum for total alkalinity as calcium carbonate is ≤ 1,313 mg/L or ≤ 750 mg/L for a 30-day average.

[5] = The daily maximum for total dissolved solids is ≤ 1,750 mg/L or ≤ 1,000 mg/L for a 30-day average.

[6] = The daily maximum for conductivity at 25° C is ≤ 7,000 mg/L or ≤ 4,000 mg/L for a 30-day average.

[7] = The daily maximum for nitrates is ≤ 10 mg/L.

[8] = The daily maximum for chloride is ≤ 438 mg/L or ≤ 250 mg/L for a 30-day average.

[9] = The daily maximum for sulfate is ≤ 875 mg/L or ≤ 500 mg/L for a 30-day average.

[10] = Parameters not measured during this project.

Byre Lake Water Quality Exceedance

One water quality parameter, pH, exceeded in-lake water quality standards in Byre Lake during the project. Surface samples at site BL-1 and BL-2 in Byre Lake exceeded in-lake water quality standards for pH on May 15, 2001 (Table 29).

Table 29. pH water quality standards exceedances in Byre Lake from 2000 through 2001.

Sites	Date	Season	pH (s u)	In-lake Water Quality Standard
BL-1	5/15/01	Spring	9.08	≥ 6.5 - ≤ 9.0
BL-2	5/15/01	Spring	9.23	≥ 6.5 - ≤ 9.0

The water quality standard violation in pH at both sampling sites (BL-1 and BL-2) in Byre Lake (9.08 su and 9.23 su, respectively) were the highest surface pH values recorded at those sites during the project (Appendix D). These violations were in conjunction with the largest algal bloom (cells/ml) during the project (Figure 23 and Table 39). Algal blooms are known to increase pH in lakes; by reducing and controlling in-lake phosphorus concentrations the frequency of nuisance algal blooms will be reduced mitigating in-lake pH concerns.

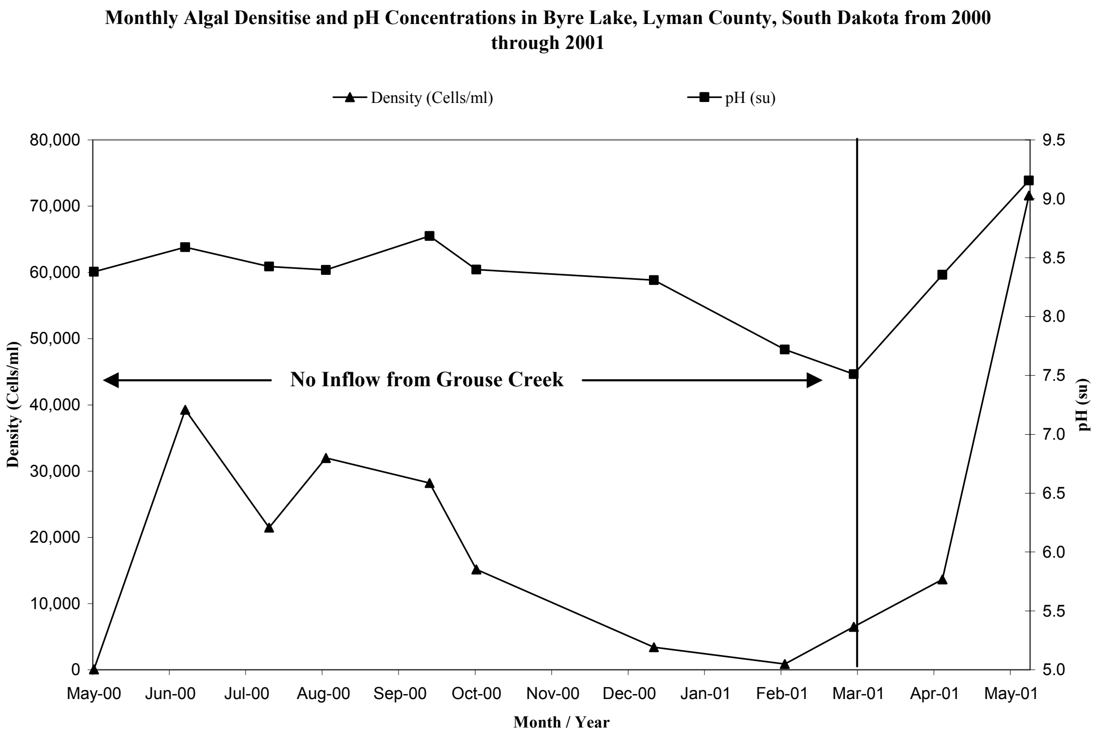


Figure 23. Average monthly algal densities (cells/ml) and pH concentrations for Byre Lake, Lyman County, South Dakota from 2000 through 2001.

Seasonal In-lake Water Quality

Typically, water quality parameters will vary with season due to changes in temperature, precipitation, biological activity and agricultural practices. Twenty-four in-lake water quality samples were collected during the project (21 surface and 7 bottom samples). These data were separated seasonally into winter (January – March), spring (April – June), summer (July – September), and fall (October – December). During the project, six discrete surface samples were collected in the summer, four samples in the fall and two samples in the spring of 2000 (Table 30).

Seasonal In-lake Concentrations

Sediment and nutrient concentrations can change dramatically with changes in season. Hydrologic loads to the lake in the spring may have relatively small nutrient and sediment concentrations; however, more water during spring runoff usually results in higher loadings of nutrients and sediment. In-lake concentrations are also affected by internal loading, especially in lakes that seasonally stratify; however, based on samples collected during this study, Byre Lake may not usually stratify. Average concentrations of measured parameters at in-lake sampling sites are listed by season in Table 30.

Dissolved oxygen concentrations were highest in the spring due to cooler water temperatures (cooler water can hold more oxygen) and increased algal densities (diatom blooms).

During this study, in-lake fecal coliform counts (fecal coliform colonies/100 ml) were generally below 10 colonies per 100 ml (laboratory detection limits). Although low, the highest average seasonal concentrations of fecal coliform bacteria during this study were in the fall of 2000 and the spring of 2001 at BL-2 (Table 30). The fall 2000 samples were collected while no runoff was entering the lake and the spring 2001 samples during runoff events.

Water quality standard violations of pH at sites BL-1 and BL-2 (9.08 su and 9.23 su, respectively) in May of 2001 were the highest surface pH values recorded at Byre Lake during the project. These pH samples were collected during a dramatic increase in algae densities (diatom bloom). Increased surface pH has been attributed to algae blooms in other waterbodies in the state (Smith, 2002; Kruger, 2001; Kruger, 2001a and Stueven et. al 2000). Carbonates and bicarbonates are utilized by algae during blooms which reduce buffering capacity and increases pH.

Average seasonal alkalinity concentrations were highest in the winter of 2001 for both in-lake sampling sites. The lowest average seasonal alkalinity concentrations occurred in the spring of 2001 which correlates with increased algal densities. Higher alkalinity in winter may be attributed to the concentration of total dissolved solids due to the volume of ice covering Byre Lake (Table 30 and Figure 31).

Total solids and total dissolved solids average concentrations were highest in the winter of 2001 for both sampling sites in Byre Lake, which may be due to winter ice cover increasing solids in Byre Lake. Average total suspended solids and volatile total suspended solids concentrations were highest in the summer of 2000 for both sampling sites; this may be due to increased algal densities and wind/wave action suspending bottom sediments (Table 30).

Average nitrate-nitrite, total nitrogen, Total Kjeldahl Nitrogen (TKN), organic and inorganic nitrogen concentrations were highest in the spring of 2001. In the spring of 2001, average inorganic nitrogen and nitrate-nitrite concentrations were higher at BL-1, while Total Kjeldahl Nitrogen (TKN) and organic nitrogen concentrations were higher at BL-2.

Ammonia concentrations were highest at BL-1 in the winter of 2001. Un-ionized ammonia (NH_4-OH) is the fraction of ammonia that is toxic to aquatic organisms. Sources for high in-lake ammonia concentrations could be tributary loading, livestock wading in the lake, animal feeding areas, decomposition of organic matter, or runoff from applied manure (fertilizer). The highest un-ionized ammonia fractions were present in the summer of 2000 at BL-1. The increased fraction of un-ionized ammonia during this period may be the result of increased water temperature and pH concentrations at this site. These parameters (water temperature and pH) are used in calculating the un-ionized ammonia.

Table 30. Average[1] seasonal surface water concentrations of measured parameters by site from Byre Lake, Lyman County, South Dakota for 2000 and 2001[2].

	Spring 2000				Summer 2000				Fall 2000				Winter 2001				Spring 2001			
Data	Sample Count	BL-1	Sample Count	BL-2	Sample Count	BL-1	Sample Count	BL-2	Sample Count	BL-1	Sample Count	BL-2	Sample Count	BL-1	Sample Count	BL-2	Sample Count	BL-1	Sample Count	BL-2
Water Temperature (ºC)	2	17.75	2	17.45	3	22.87	3	23.08	2	9.35	2	8.80	2	3.19	1	3.00	2	13.65	2	13.65
Dissolved Oxygen (mg/L)	2	9.10	2	9.40	3	10.75	3	10.50	2	10.85	2	11.47	2	11.63	1	10.98	2	14.23	2	13.87
pH (su)	2	8.49	2	8.48	3	8.54	3	8.46	2	8.37	2	8.35	2	7.68	1	7.60	2	8.76	2	8.76
Conductivity (µS/cm3)	1	600	1	603	3	628.9	3	630.17	2	663	2	664	2	861	1	849	2	513	2	519
Secchi Depth (m)	1	0.40	1	0.30	3	0.58	3	0.60	2	1.07	2	0.89	-	-	-	-	2	0.40	2	0.38
Fecal Coliform	2	5	2	5	3	5	3	7	2	5	2	8	2	5	1	5	2	5	2	8
Alkalinity (mg/L)	2	164	2	164	3	162	3	162	2	173	2	175	2	202	1	204	2	117	2	116
Total Solids (mg/L)	2	447	2	458	3	475	3	480	2	511	2	519	2	605	1	616	2	399	2	403
Total Dissolved Solids (mg/L)	2	431	2	441	3	455	3	451	2	498	2	503	2	596	1	591	2	375	2	381
Total Suspended Solids (mg/L)	2	16	2	18	3	20	3	29	2	13	2	16	2	10	1	25	2	24	2	22
Volatile Total Suspended Solids (mg/L)	2	3	2	2	3	5	3	7	2	2	2	3	2	3	1	7	2	7	2	7
Ammonia (mg/L)	2	0.01	2	0.01	3	0.04	3	0.01	2	0.01	2	0.02	2	0.06	1	0.01	2	0.05	2	0.01
Un-ionized Ammonia (mg/L)	2	0.00064	2	0.00172	3	0.00585	3	0.00143	2	0.00097	2	0.00110	2	0.00043	1	0.00007	2	0.00174	2	0.00018
Nitrate-Nitrite (mg/L)	2	0.15	2	0.10	3	0.05	3	0.07	2	0.08	2	0.08	2	0.10	1	0.10	2	0.90	2	0.75
Total Kjeldahl Nitrogen (mg/L)	2	1.00	2	0.98	3	0.90	3	0.67	2	0.90	2	0.94	2	0.93	1	1.05	2	0.76	2	1.64
Organic Nitrogen (mg/L)	2	0.99	2	0.97	3	0.86	3	0.66	2	0.89	2	0.92	2	0.87	1	1.04	2	0.71	2	1.63
Inorganic Nitrogen (mg/L)	2	0.16	2	0.11	3	0.09	3	0.08	2	0.09	2	0.10	2	0.16	1	0.11	2	0.95	2	0.76
Total Nitrogen (mg/L)	2	1.15	2	1.08	3	0.95	3	0.74	2	0.97	2	1.02	2	1.03	1	1.15	2	1.66	2	2.39
Total Phosphorus (mg/L)	2	0.077	2	0.080	3	0.070	3	0.084	2	0.044	2	0.053	2	0.033	1	0.064	2	0.202	2	0.189
Total Dissolved Phosphorus (mg/L)	2	0.022	2	0.019	3	0.022	3	0.022	2	0.025	2	0.024	2	0.016	1	0.019	2	0.118	2	0.096
Phosphorus TSI	2	66.77	2	67.33	3	64.63	3	66.80	2	58.30	2	60.98	2	33.04	1	64.15	2	80.69	2	79.39
Chlorophyll-*a* TSI	2	63.53	1	64.86	3	69.26	1	70.12	2	65.43	1	61.88	1	41.69	-	-	2	78.57	-	-
Secchi TSI	1	73.36	1	77.14	3	70.85	3	68.15	2	60.53	2	64.98	-	-	-	-	2	73.53	2	74.22
Total Nitrogen-to-Total Phosphorus Ratio	2	15.0	2	13.7	3	15.1	3	9.0	2	23.5	2	20.7	2	34.2	1	18.0	2	8.0	2	14.2

[1] = A one (1) in the sample count column indicates a single sample value and not an average

[2] = Highlighted areas are the seasons that recorded the highest concentrations or values for a given parameter.

Average total phosphorus and total dissolved phosphorus concentrations were highest in the spring of 2001 at BL-1 (Table 30).

Both phosphorus and chlorophyll-*a* average Trophic State Index (TSI) values were highest in the spring of 2001, while Secchi TSI was highest in the spring of 2000 (Table 30).

In-lake Water Quality

Water Temperature

Water temperature is an essential component to the health of a lake. Temperature affects and regulates many chemical and biological processes in the aquatic environment. Increased temperatures have the potential to raise the fraction of un-ionized ammonia in water; increased concentrations of un-ionized ammonia are toxic to fish. Biological processes such as algal succession and growth are also regulated by water temperature. Certain species of diatoms are more abundant in cooler waters while blue-green algae are more prevalent in warmer waters. Fish life and propagation are also temperature dependent.

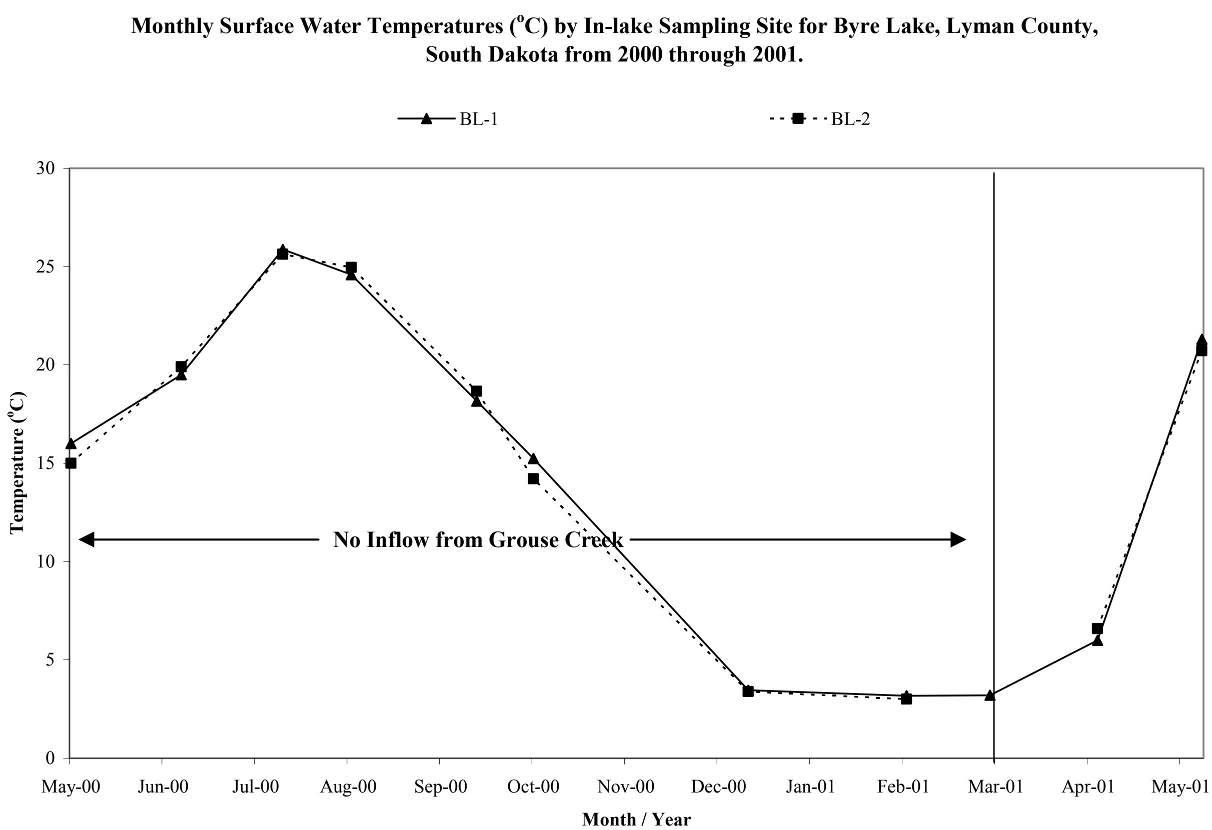


Figure 24. Monthly surface water temperatures by date and sampling site for Byre Lake, Lyman County, South Dakota from 2000 through 2001.

The mean surface water temperature in Byre Lake over the sampling season was 14.7° C (median 16.0º C). Figure 24 shows surface water temperatures throughout the project period for both in-lake sampling sites. No significant differences were detected within (surface vs. bottom) or between sampling sites ($U_{0.05\ (2),\ 10,\ 11} = 53.00$, $p>0.05$). The maximum surface water temperature measured during the sampling season was 25.9^{o} C taken in mid-July 11, 2000. No violations of the temperature standard (26.7 °C) were recorded.

Dissolved Oxygen

Dissolved oxygen concentrations normally change with the growth and decomposition of living organisms in a lake system. As algae and plants grow and photosynthesize, they release oxygen into the water. When organisms die and decompose, the bacteria involved in the decomposition process use oxygen from the system and replace it with carbon dioxide (CO_2). This process usually takes place near the sediment-water interface. Dissolved oxygen concentrations also change at the surface air-water interface. Wave action and other turbulence can also increase surface oxygen levels.

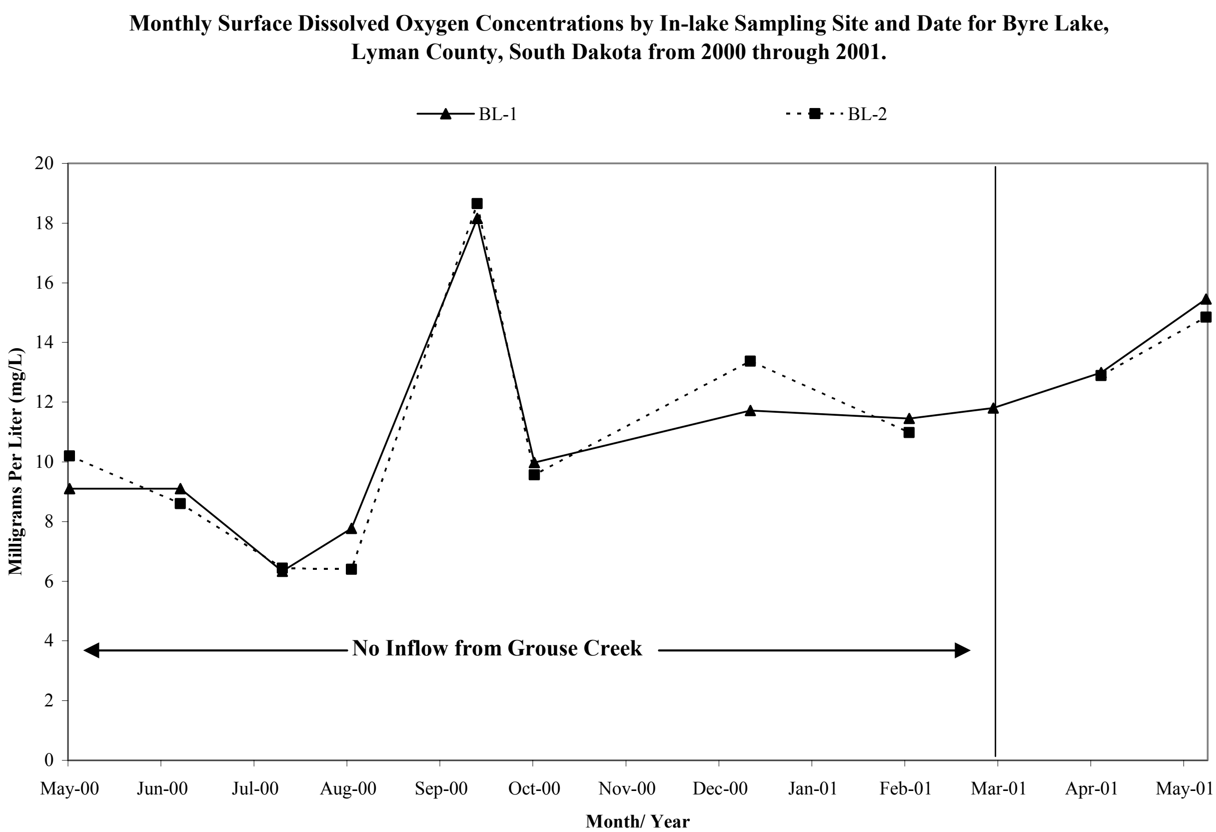


Figure 25. Monthly surface dissolved oxygen concentrations by sampling site for Byre Lake, Lyman County, South Dakota in 2000 and 2001.

Surface water dissolved oxygen averaged 11.2 mg/L (median 10.0 mg/L) over the entire duration of the study (Appendix D). The maximum surface oxygen concentration in Byre Lake was 18.6 mg/L.

That sample was collected at BL-2 on September 14, 2000. The minimum dissolved oxygen concentration was 6.3 mg/L at the surface of BL-1 on July 11, 2000 (Figure 25). Typically, as much oxygen as is produced by photosynthesis in a day, is used in respiration, or uptake of oxygen, at night. The maximum oxygen concentration usually occurs in the afternoon on clear days, and the minimum immediately after dawn (Reid, 1961).

Oxygen stratification was not observed in the water column at either site. Surface water dissolved oxygen samples were not statistically different between sites ($U_{0.05\ (2),\ 10,\ 11}$ = 55.00, $p>0.05$) and between surface and bottom dissolved oxygen concentrations ($U_{0.05\ (2),\ 11,\ 9}$ = 24.00, $p>0.05$). Although surface and bottom were not significantly different, dissolved oxygen profiles at BL-1 during July and August of 2000 indicate stratification (Appendix F).

pH

pH is the measure of hydrogen ion concentrations. More free hydrogen ions lower the pH in water. During decomposition, carbon dioxide is released from the sediments. Carbon dioxide (CO_2) reacts with water to create carbonic acid. Carbonic acid creates hydrogen ions. Bicarbonate can be converted to carbonate and another hydrogen ion. Extra hydrogen ions created from decomposition will tend to lower pH in the hypolimnion (lowest water layer of the lake).

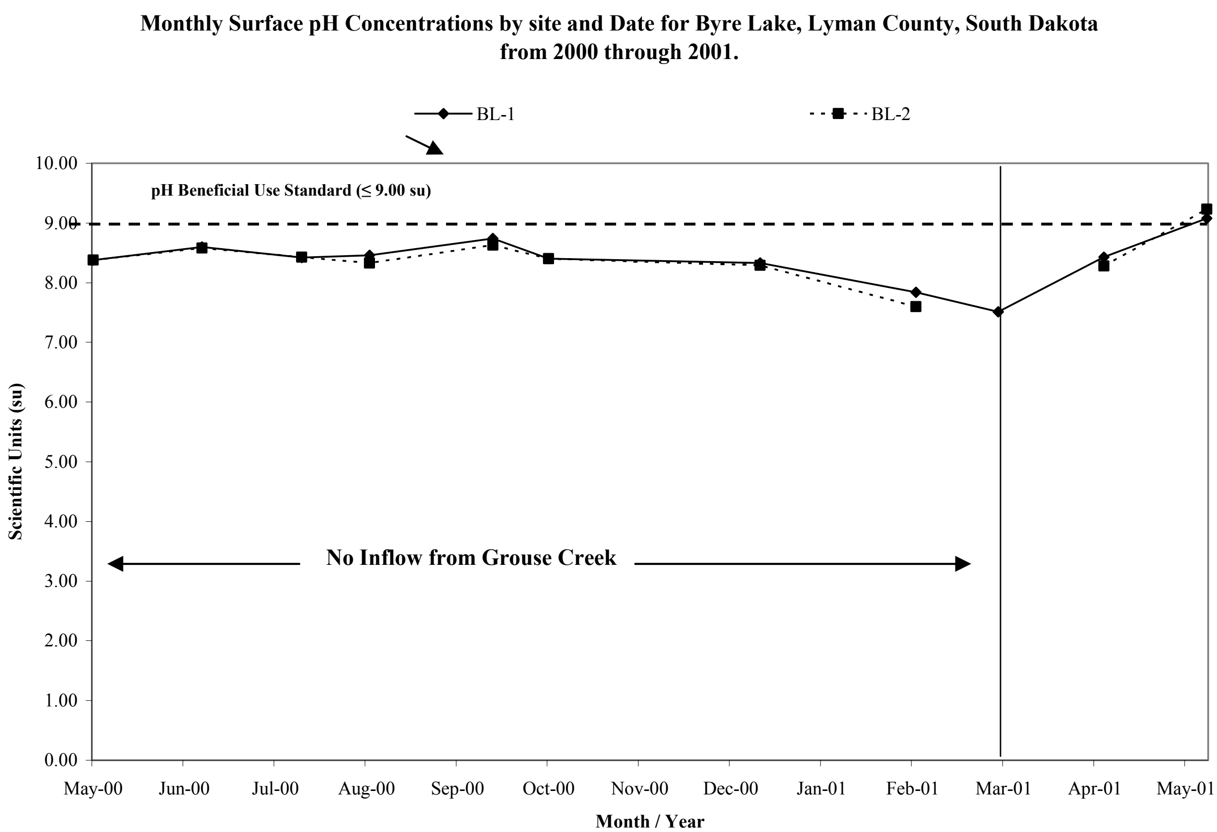


Figure 26. Monthly surface pH concentrations by date and sampling site for Byre Lake, Lyman County, South Dakota from 2000 through 2001.

Increases in the different species of carbon come at the expense of oxygen. Decomposers will use oxygen to break down organic material into different carbon species. In addition, the lack of light in the hypolimnion prevents plant growth, so no oxygen can be created through photosynthesis. Typically, the higher the decomposition and respiration rates the lower the oxygen concentrations and the lower the pH in the hypolimnion. The inverse occurs when photosynthesizing plants increase pH. Plants use carbon dioxide for photosynthesis and release oxygen to the system. This process can reverse the process discussed previously, increasing pH.

The pH concentrations declined in the winter of 2001 and gradually increased in the spring (Figure 26). During this period, the pH concentration went from 7.84 su in February of 2001 to 9.08 su in May of 2001 at BL-1 and 7.60 su in February of 2001 to 9.23 su in May of 2001 at BL-2. One water quality standard violation in pH occurred at each in-lake sampling site (BL-1 and BL-2) in May of 2001. These water quality violations are attributed to an algal bloom (Figure 23) in Byre Lake in May of 2001 and are discussed in the previous paragraph. This seems to indicate that decreased concentrations of CO_2 in April and May of 2001 were an event and not an anomaly.

During the project, surface pH concentrations ranged from 7.60 su to 9.23 su and a median of 8.40 su. In-lake pH concentrations were not statistically different between sites ($U_{0.05\ (2),\ 10,\ 11} = 50.00$, $p>0.05$) and between surface and bottom at in-lake sampling site BL-1 ($U_{0.05\ (2),\ 11,\ 9} = 29.00$, $p>0.05$).

Secchi Depth

Secchi depth is a measure of in-lake water clarity and turbidity. The Secchi disk is 20 cm in diameter and usually painted with opposing black and white quarters (Lind, 1985). The Secchi disk is used worldwide for determination and comparison of transparency of lakes. Secchi disk readings are one of three parameters used in calculating Carlson's Trophic State Indices (TSI). Carlson's TSI is a measure of trophic condition and overall health of a lake. One limitation of the Secchi disk method is that it cannot distinguish whether organic or inorganic matter is limiting water transparency. Low Secchi depth readings may indicate hyper-eutrophy because of suspended sediments and/or high algal biomass.

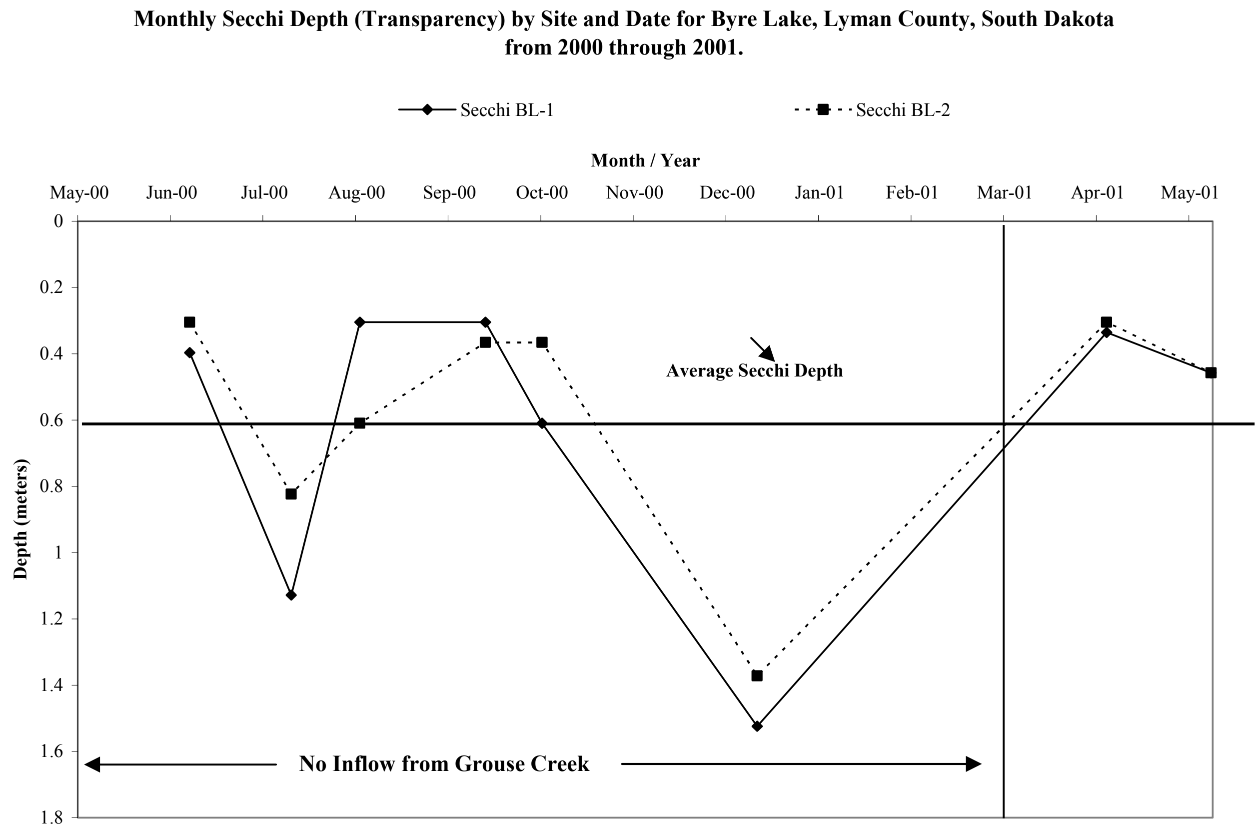


Figure 27. Monthly Secchi depth by date and sampling site for Byre Lake, Lyman County, South Dakota in 2000 through 2001.

Figure 27 shows lower (shallower) Secchi depth readings in summer of 2000 (increased density in blue green algae (Table 39)), especially at site BL-1. The highest (deepest) Secchi disk reading was 1.37 meters (4.5 feet) at BL-2 on December 14, 2000. This relates to the lower numbers of algae, lower total suspended solids, volatile total suspended solids and chlorophyll-*a* concentrations in December 2000 at both in-lake sampling sites that increased Secchi depth (Figure 23, Table 39, Figure 32 and Figure 33). Secchi transparency between sampling sites was not statistically different in Byre Lake ($U_{0.05\ (2),\ 8,\ 8} = 31.00$, $p>0.05$). Average seasonal Secchi depths were highest in the fall of 2000 particularly at BL-1 (Figure 27 and Table 30). Since Secchi transparency depth is one parameter used in measuring trophic state, Secchi TSI values between sites were also not statistically different ($U_{0.05\ (2),\ 8,\ 8} = 31.00$, $p>0.05$).

Alkalinity

As discussed previously (tributary section), alkalinity refers to the quantity of different compounds that shift the pH to the alkaline side of neutral (>7.00 su). The average alkalinity in Byre Lake was 161.1 mg/L with a median of 162.0 mg/L. The maximum alkalinity concentration (210 mg/L) was collected at BL-1 in March of 2001 while the minimum alkalinity concentration (115 mg/L) was collected at BL-2 in May of 2001.

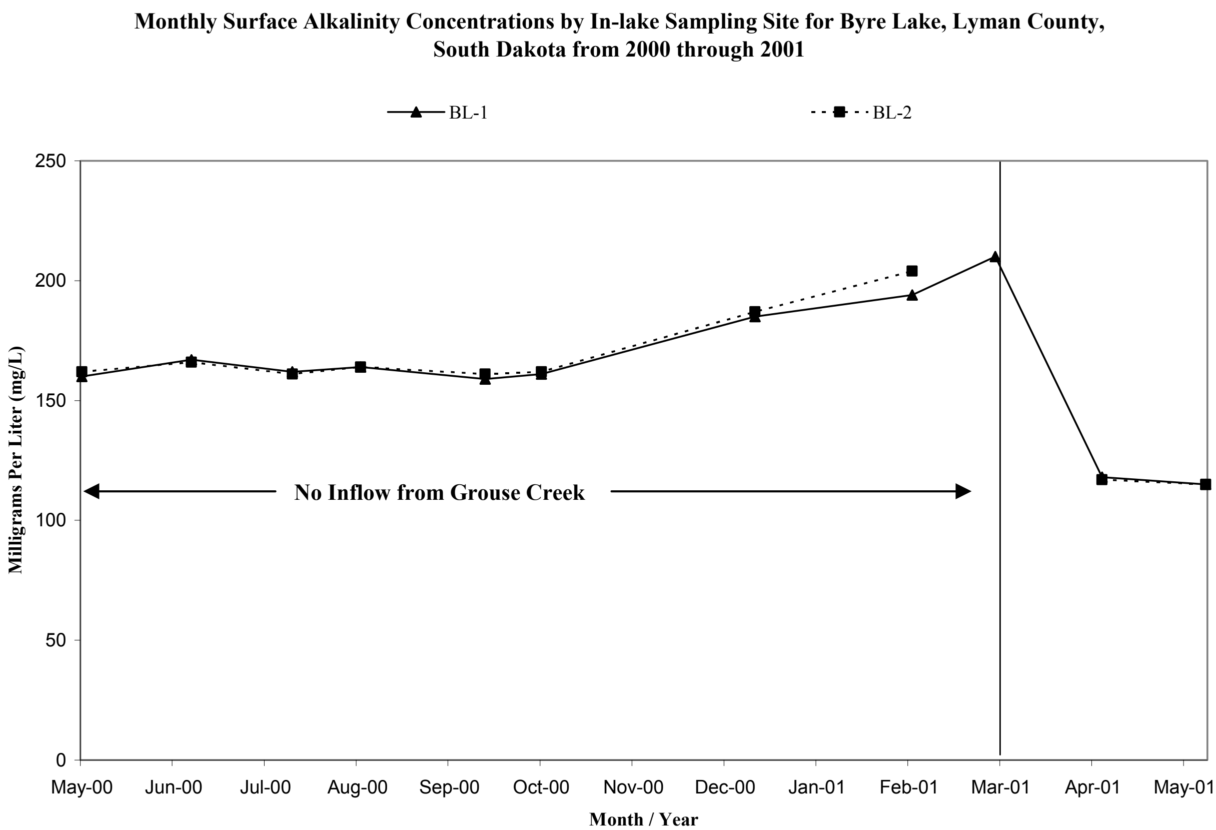


Figure 28. Monthly surface alkalinity concentrations by date and sampling site for Byre Lake, Lyman County, South Dakota from 2000 through 2001.

Generally, alkalinity concentrations were consistent throughout the sampling period (Figure 28) and were not statistically different between BL-1 and BL-2 ($U_{0.05\ (2),\ 11,\ 17} = 86.50$, $p>0.05$). However, in-lake hydrogen ion concentrations were reduced during the spring 2001 sampling period (increasing pH), indicating other conditions such as increased phytoplankton densities, decomposition or respiration rates affected (varied) alkalinity (Figure 29) and pH concentrations. Seasonally, the highest average concentration occurred in the winter of 2001 (average 204 mg/L) at BL-2 due to the effects of ice cover.

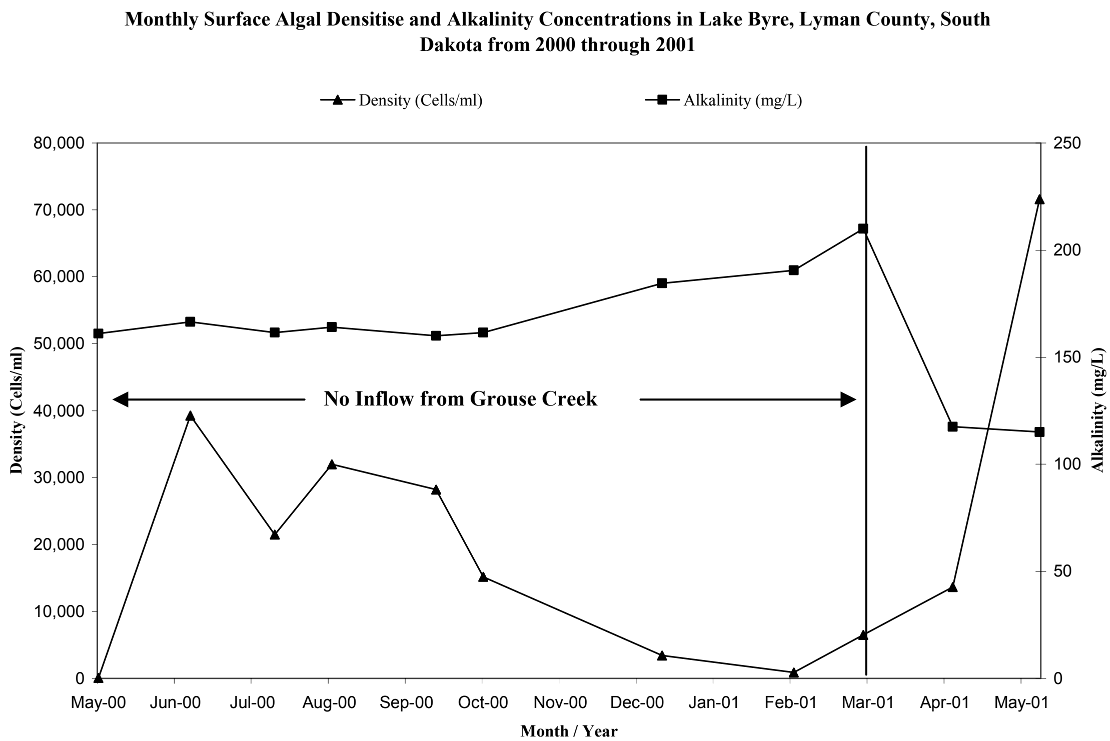


Figure 29. Monthly surface algal densities and alkalinity concentrations for Byre Lake, Lyman County, South Dakota from 2000 through 2001.

Total Solids

Total solids are the materials, suspended or dissolved, present in natural water. Dissolved solids include materials that pass through a 0.45 µm filter. Suspended solids are the materials that do not pass through the filter, e.g. sediment and algae. Subtracting suspended solids from total solids derives total dissolved solids concentrations. Suspended volatile solids are that portion of suspended solids that are organic (organic matter that burns in a 500º C muffle furnace).

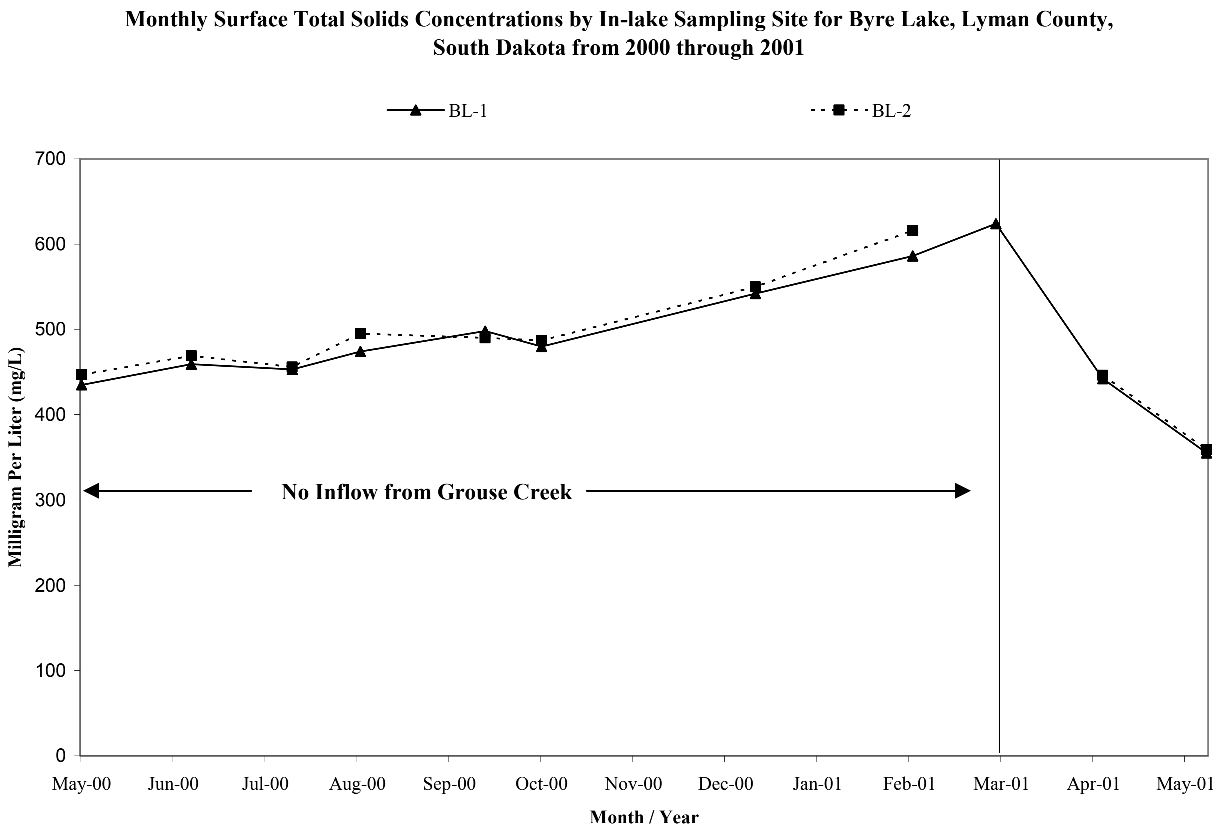


Figure 30. Monthly surface total solids concentration by date and sampling site for Byre Lake, Lyman County, South Dakota from 2000 through 2001.

The total solids concentrations in Byre Lake averaged 467.4 mg/L (median 458.5 mg/L) with a maximum of 624.0 mg/L and a minimum of 181.0 mg/L. Generally, total solids concentrations were lower in the late spring and summer and gradually peaked in late winter (Figure 30). Seasonal averages for total solids concentrations were highest in the winter of 2001 at BL-2 (Table 30). Total solids concentrations were not statistically different between in-lake sampling sites ($U_{0.05\,(2),\,11,\,17} = 71.00$, $p>0.05$).

Total Dissolved Solids

Total dissolved solids is that portion of total solids that pass through a 0.45 µm filter and are typically composed of earth compounds, particularly bicarbonates, carbonates, sulfates and chlorides that also determine salinity (Wetzel, 1983). Generally, total dissolved solids make up by far the larger percentage of total solids.

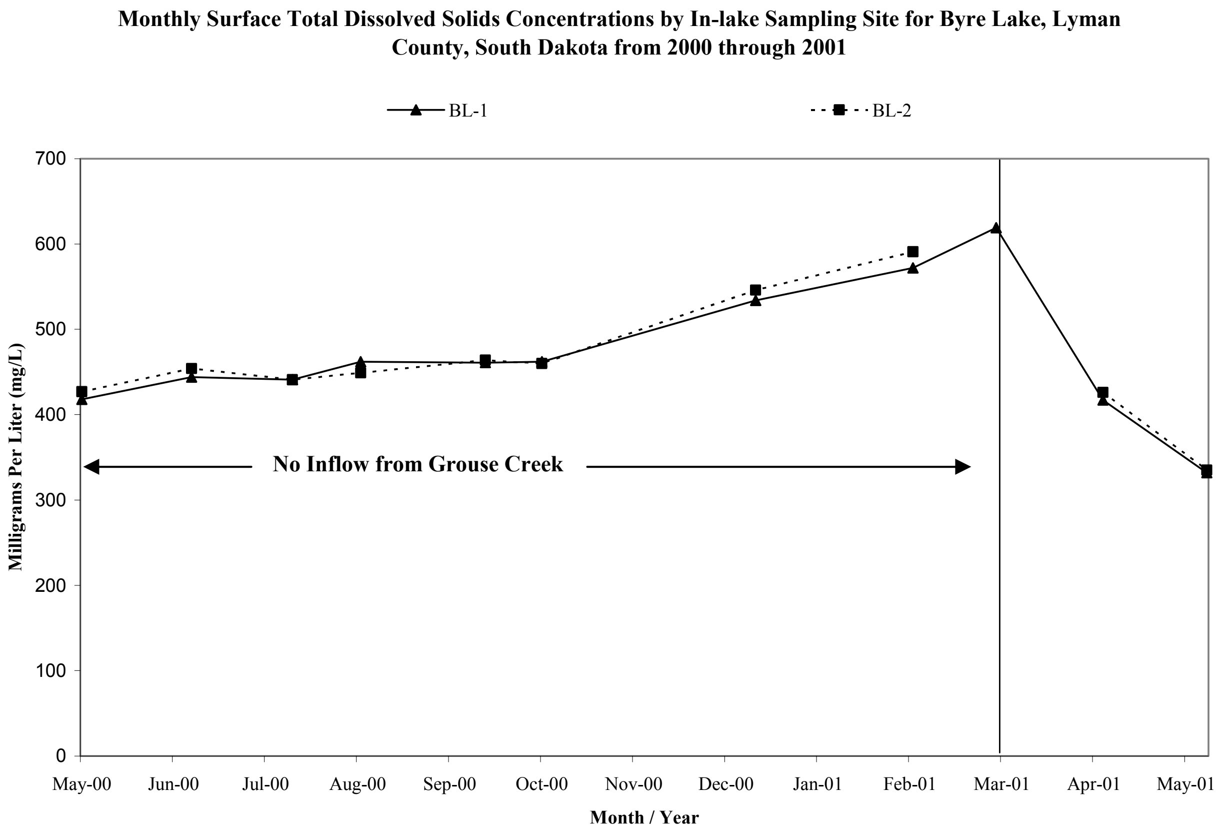


Figure 31. Monthly surface total dissolved solids concentration by date and sampling site for Byre Lake, Lyman County, South Dakota from 2000 through 2001.

Total dissolved solids concentrations in Byre Lake averaged 447.9 mg/L (median 446.0 mg/L) with a maximum of 619.0 mg/L and a minimum of 162.0 mg/L. Similar to total solids, total dissolved solids concentrations were lower in the late spring and summer and gradually peaked in late winter (Figure 31). Total dissolved solids concentrations comprised between 90.7 percent and 99.3 percent of total solids concentrations. Total dissolved solids concentrations between BL-1 and BL-2 were not statistically different ($U_{0.05\,(2),\,11,\,17} = 73.50$, $p>0.05$).

Total Suspended Solids

Total suspended solids are organic and inorganic particles that do not pass through a 0.45 µm filter. In-lake concentrations and sedimentation rates are related to tributary loading, wind and wave action and discharge concentrations.

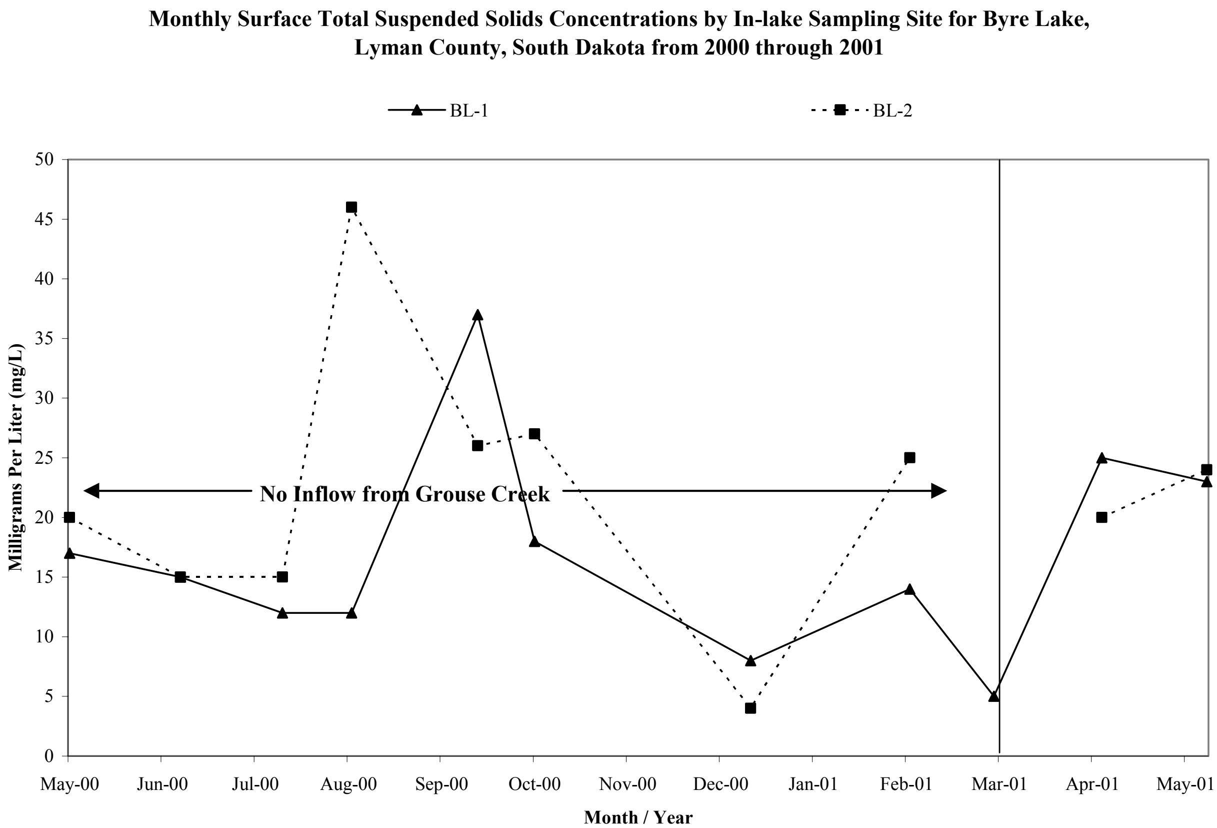


Figure 32. Monthly surface total suspended solids concentrations by date and sampling site for Byre Lake, Lyman County, South Dakota from 2000 through 2001.

The total suspended solids concentrations in Byre Lake averaged 19.5 mg/L (median 18.5 mg/L) with a maximum of 46.0 mg/L and a minimum of 4.0 mg/L. Seasonal averages for total suspended solids concentrations were highest in the summer of 2000 at BL-2 (Table 30). The surface sample with the highest total suspended solids concentration was collected in August 3, 2000 at BL-2 (Appendix D). Total suspended solids data supports the trend observed in Secchi disk depth, with decreased Secchi depth in the summer of 2000 and increased depth in the fall (December 2000). Total suspended solids concentrations between in-lake sampling sites were not significantly different ($U_{0.05\,(2),\,11,\,17} = 55.50$, $p>0.05$) during this study (Figure 32).

Volatile Total Suspended Solids

Volatile total suspended solids are that portion of total suspended solids that volatilize at 500° Celsius. Volatile solids are composed of allochthonous material, organic material produced and transported from the watershed (plants and organic debris) and autochthonous, organic material produced within the lake such as plants and algae.

Volatile total suspended solids concentrations averaged 4.5 mg/L (median 4.0 mg/L) with a maximum of 9.0 mg/L and a minimum concentration of 0.5 mg/L. Seasonal average volatile total suspended solids concentrations were highest in the summer of 2000 and the spring of 2001 (Table 30). The maximum surface water concentrations of volatile total suspended solids were collected in September 14, 2000 and April 10, 2001 at BL-1 and on May 15, 2001 at BL-2 (9.0 mg/L) (Figure 33). No significant differences were detected between in-lake sampling sites ($U_{0.05\ (2),\ 11,\ 17} = 68.00$, $p>0.05$).

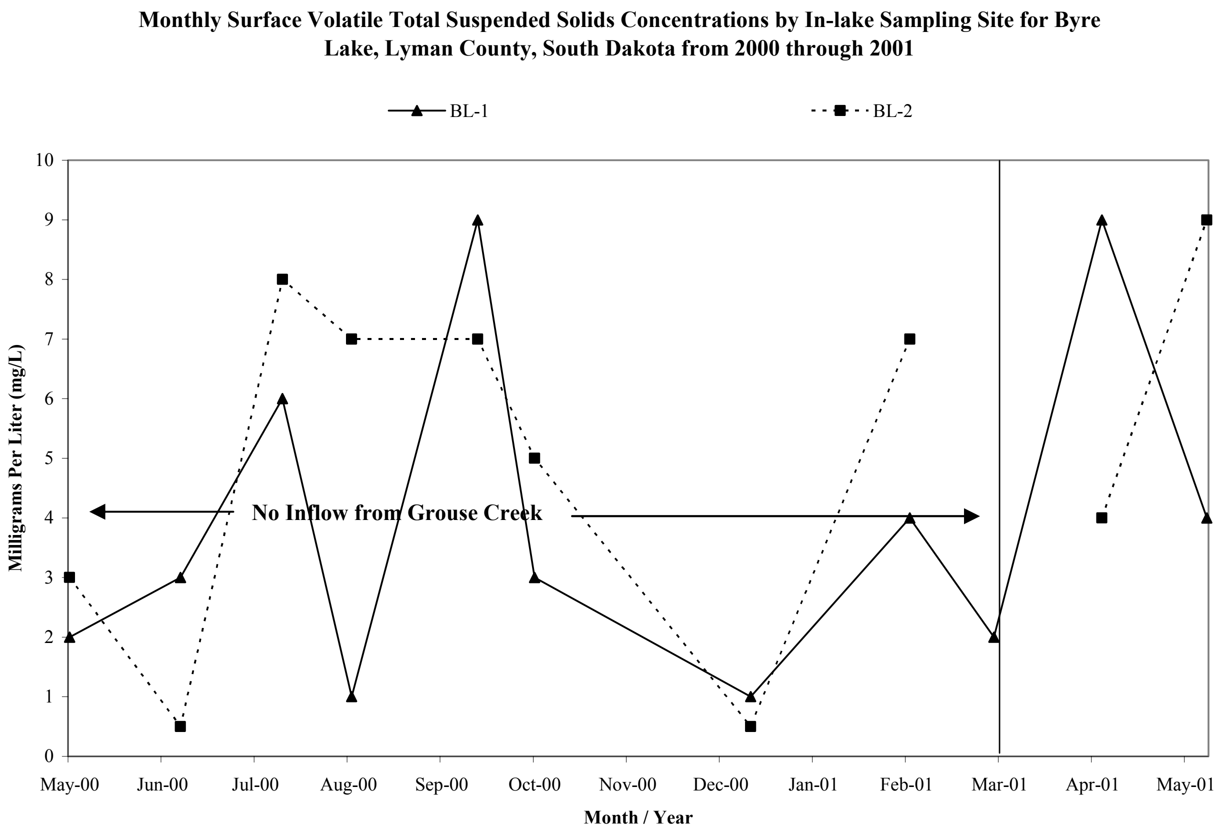


Figure 33. Monthly surface volatile total suspended solids concentrations by date and sampling site for Byre Lake, Lyman County, South Dakota from 2000 through 2001.

The percentage of volatile total suspended solids in total suspended solids by site ranged widely. BL-1 percent volatile suspended solids ranged from 8.3 percent to 40.0 percent and in-lake sampling site BL-2 ranged from 3.3 percent to 53.3 percent.

Total suspended solids and volatile total suspended solids affect Secchi transparency and chlorophyll-*a* concentrations, respectively. Increased total suspended solids and volatile total suspended solids in the September 2000 samples are reflected in a decrease in Secchi depth. Although Byre Lake is not currently listed on the 2002 303(d) list (impaired waterbody list), current assessment data indicate elevated TSI values (Trophic State Index) (SD DENR, 2002). Theoretically, a decrease in in-lake total suspended solids (both organic and inorganic) should improve (lower) all TSI values, and over time, improve in-lake clarity and overall water quality of Byre Lake.

Ammonia

Ammonia (NH_3) is the nitrogen product of bacterial decomposition of organic matter and is the form of nitrogen most readily available to plants for uptake and growth. Ammonia in Byre Lake comes from Grouse Creek loadings, runoff from ungauged areas of the watershed, livestock (cattle) with direct access to the lake, decaying organic matter and bacterial conversion of other nitrogen compounds.

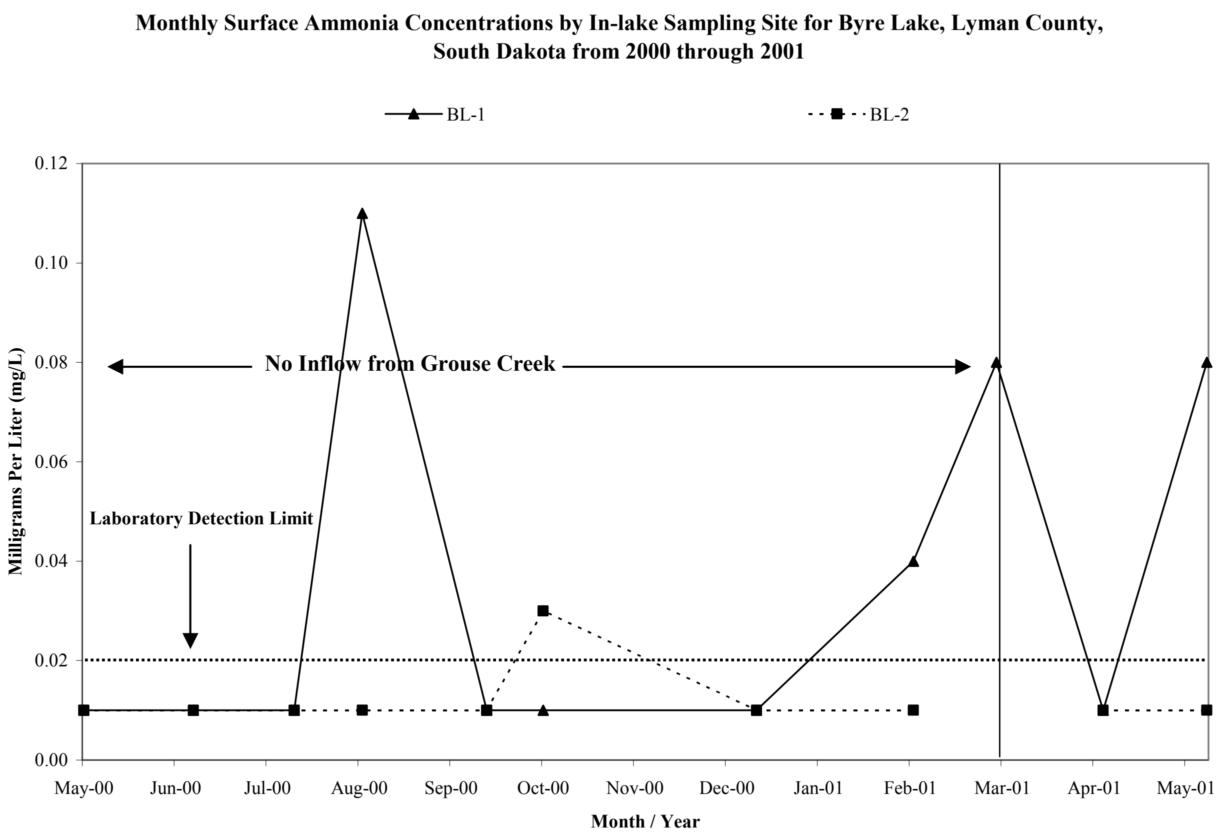


Figure 34. Monthly ammonia concentrations by date and sampling site for Byre Lake, Lyman County, South Dakota from 2000 through 2001.

The average concentration of ammonia in Byre Lake was 0.06 mg/L with a median of 0.01 mg/L. The standard deviation was 0.16 mg/L which indicates a slight variation in sample concentrations, especially at BL-1 (Figure 34). Seventy-six percent of all surface samples collected at Byre Lake were below laboratory detection limits (0.02 mg/L). Seasonal concentrations were highest in the winter of 2001 (average 0.06 mg/L) at BL-1 (Table 30). Increased winter average ammonia concentrations may be due to the break down of organic matter and/or reduced algal densities utilizing less ammonia during this time in Byre Lake No significant differences in ammonia concentrations were detected between BL-1 and BL-2 during this study ($U_{0.05\ (2),\ 11,\ 17} = 60.50$, $p>0.05$).

Decomposer bacteria in the sediment and blue-green algae in the water column can convert free nitrogen (N_2) to ammonia. Blue-green algae can then use the ammonia for growth. Although algae use both nitrate-nitrite and ammonia, highest growth rates are found when ammonia is available (Wetzel, 1983).

Un-ionized Ammonia

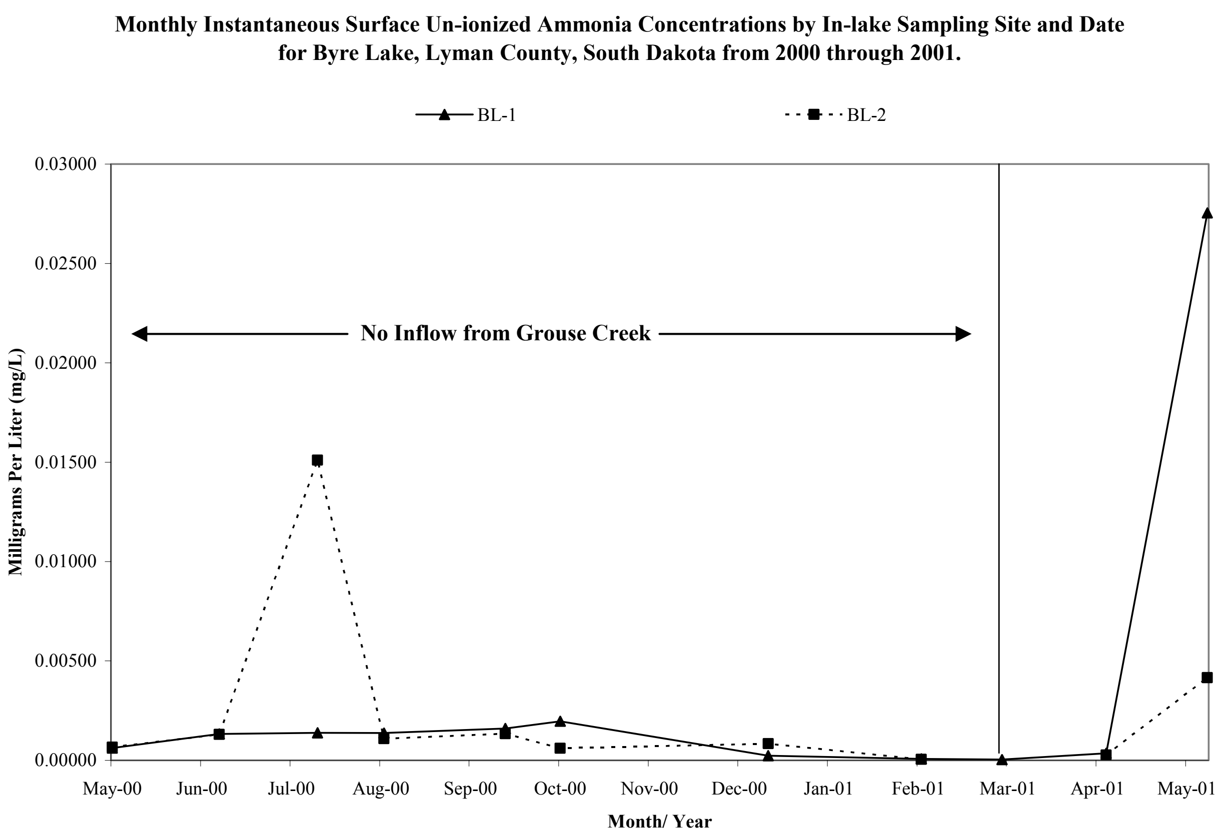


Figure 35. Monthly instantaneous un-ionized ammonia concentrations by date and sampling site for Byre Lake, Lyman County, South Dakota from 2000 through 2001.

As indicated in the tributary section of this report, un-ionized ammonia (NH_4-OH) is toxic to aquatic organisms and is calculated using temperature and pH. Un-ionized ammonia concentrations are calculated values, dependent on temperature, pH and total ammonia, and are instantaneous concentrations and not a load. The mean un-ionized ammonia concentration for Byre Lake was 0.00295 mg/L (median 0.00108 mg/L). The maximum concentration was 0.02754 mg/L and a minimum concentration of 0.00003 mg/L. Un-ionized ammonia concentrations peaked in the summer of 2000 at BL-2 and in the spring at BL-1 (Figure 35). The spring peak was the result of increased total ammonia concentrations at BL-1 in May. The concentrations of un-ionized ammonia at Byre Lake were not statistically different ($U_{0.05\ (2),\ 11,\ 10} = 55.00$, $p>0.05$) from 2000 through 2001.

Nitrate-Nitrite

Nitrate and nitrite (NO_3^- and NO_2^-) are inorganic forms of nitrogen easily assimilated by algae and macrophytes. Sources of nitrate and nitrite can be from agricultural practices and direct input from septic tanks, municipal and industrial discharges, precipitation, ground water, and from decaying organic matter. Nitrate-nitrite can also be converted from ammonia through denitrification by bacteria. This process increases with increasing temperature and decreasing pH.

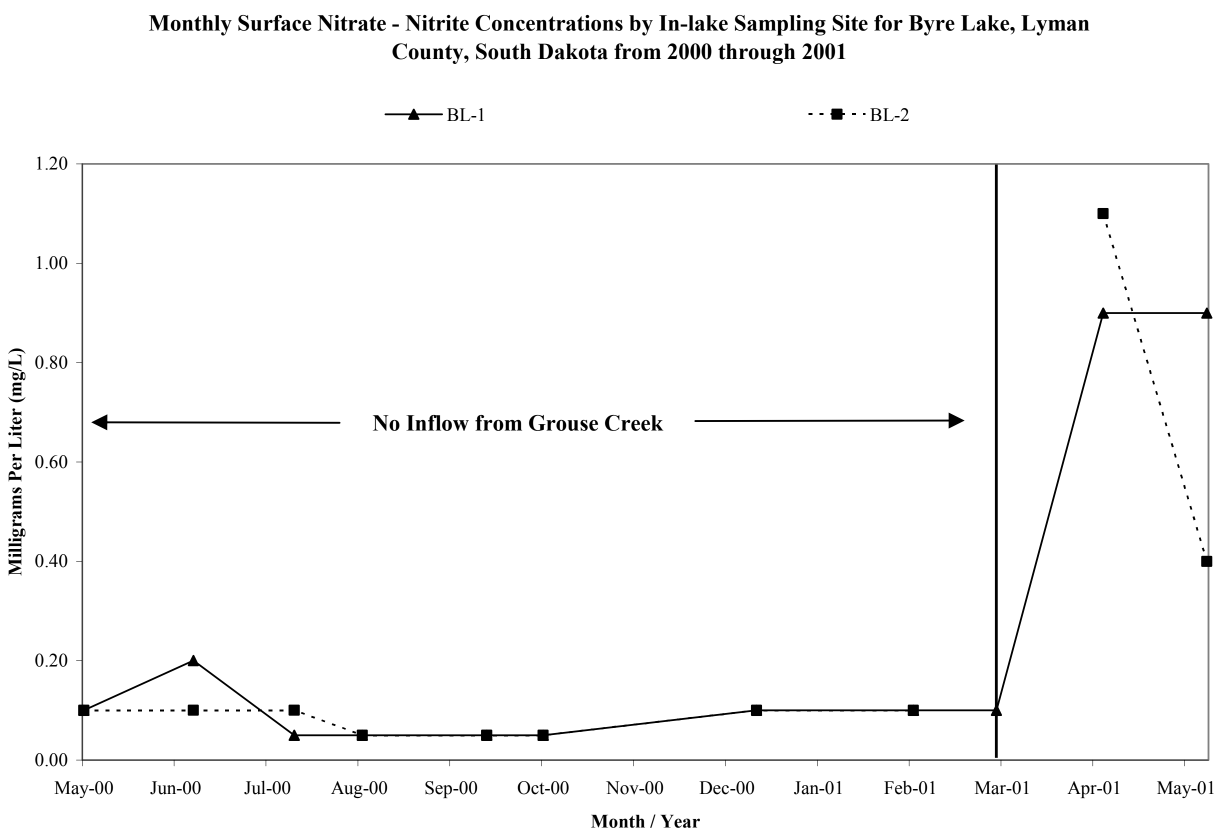


Figure 36. Monthly surface nitrate-nitrite concentrations by date and sampling site for Byre Lake, Lyman County, South Dakota from 2000 through 2001.

The average nitrate-nitrite concentration for Byre Lake was 0.22 mg/L (median 0.10 mg/L), with a maximum of 1.10 mg/L and a minimum concentration of 0.05 mg/L. Monthly average nitrate–nitrite concentrations were relatively steady during the 2000 sampling season with no input from Grouse Creek and reduced lake levels (evaporative loss). Nitrate–nitrite concentrations peaked in the spring of 2001 at 1.10 mg/L at BL-2 in April (Figure 36 and Table 30). Nitrogen and phosphorus concentrations in eutrophic lakes are frequently higher after ice out (spring) due to accumulation over the winter through decay, low algal numbers and loading from the watershed, however, with no input from Grouse Creek in 2000 and inflow occurring during ice out, this situation may have been masked in Byre Lake during the study. Nitrate-nitrite and ammonia make up the inorganic portion of total nitrogen. No significant differences in nitrate–nitrite concentrations were detected between in-lake sampling sites ($U_{0.05\ (2),\ 11,\ 17} = 90.00$, $p>0.05$).

Inorganic Nitrogen

Inorganic nitrogen is the sum of ammonia plus nitrate-nitrite. Inorganic nitrogen is readily broken down to more usable (assimilated) ammonia by biological dissimilation.

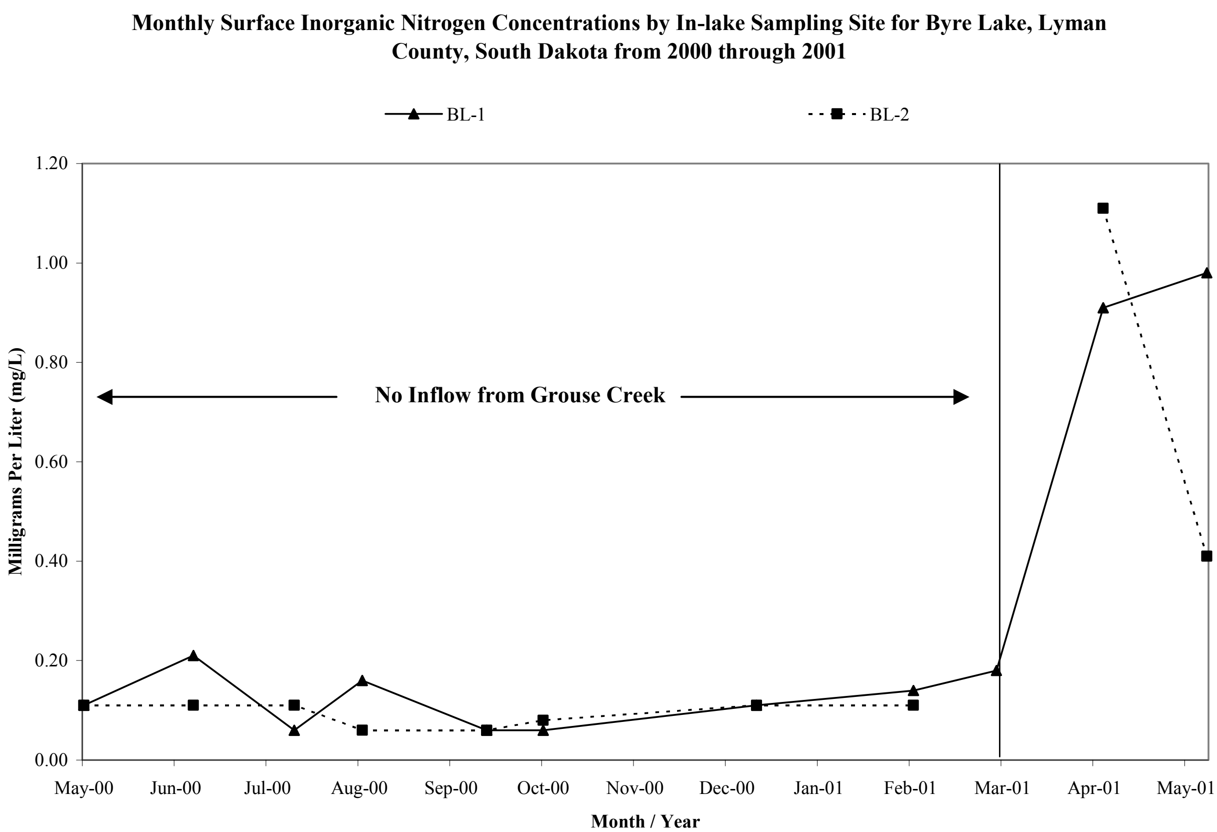


Figure 37. Monthly surface inorganic nitrogen concentrations by date and sampling site for Byre Lake, Lyman County, South Dakota from 2000 through 2001.

Inorganic nitrogen concentrations in Byre Lake averaged 0.29 mg/L (median 0.11 mg/L) with a maximum of 1.11 mg/L and a minimum concentration of 0.06 mg/L. Inorganic nitrogen concentrations peaked in the spring of 2001 and are similar to the nitrate-nitrite graph (Figure 36), because as mentioned above, inorganic nitrogen incorporates nitrate-nitrite in the calculation (Figure 37). Inorganic nitrogen concentrations between sampling sites were not statistically different ($U_{0.05\ (2),\ 11,\ 17} = 64.00$, $p>0.05$). Seasonal averages for inorganic nitrogen concentrations were highest in the spring of 2001 at BL-1 (Table 30).

Total Kjeldahl Nitrogen

Total Kjeldahl Nitrogen (TKN) is used to calculate organic and total nitrogen. TKN is usually composed mostly of organic nitrogen. Sources of organic nitrogen can include releases from dead or decaying organic matter, lakeside septic systems, or agricultural waste. Organic nitrogen is broken down to more usable ammonia and other forms of inorganic nitrogen.

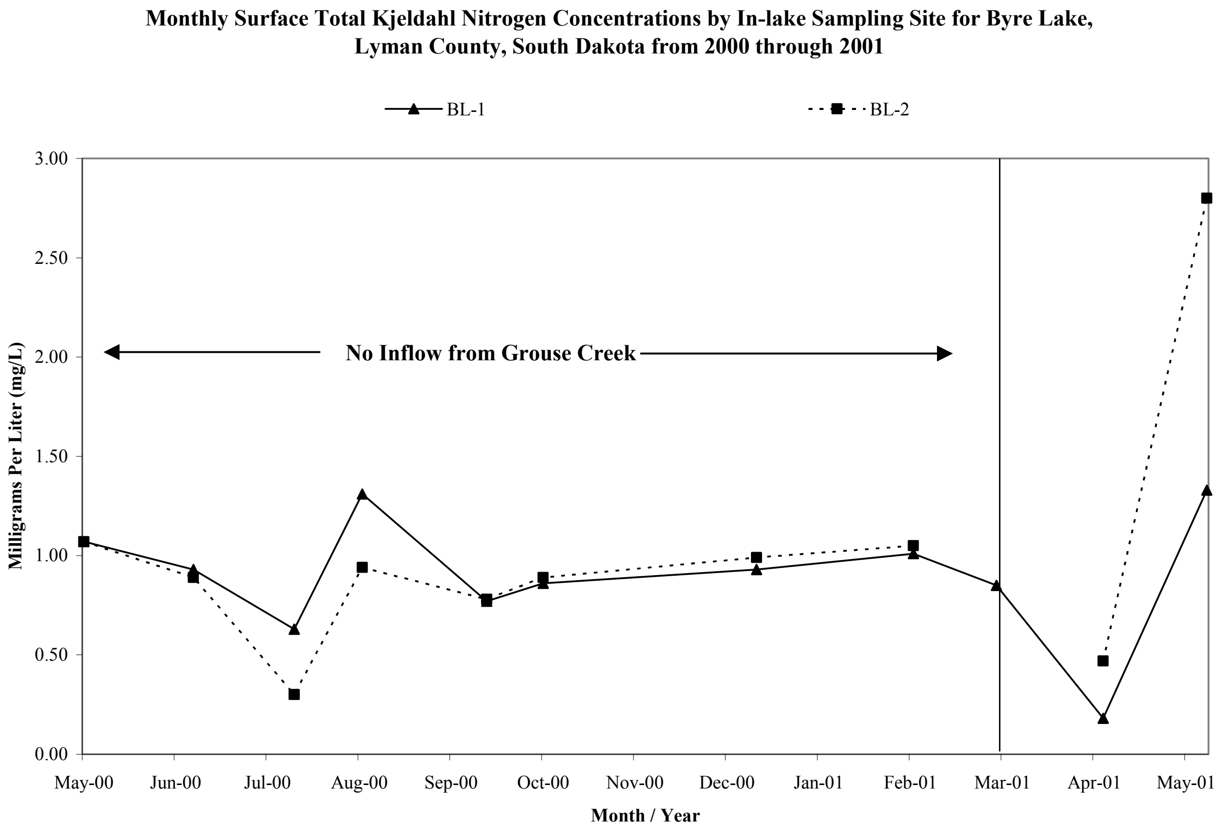


Figure 38. Monthly surface Total Kjeldahl Nitrogen (TKN) concentrations by date and sampling site for Byre Lake, Lyman County, South Dakota from 2000 through 2001.

The average and median TKN concentrations were 0.94 mg/L and 0.90 mg/L, respectively. Monthly average TKN concentrations were relatively steady during the 2000 sampling season (no input from Grouse Creek). There was a definite increase in the TKN concentrations at both BL-1 and BL-2 from April to May 2001 (Figure 38). Seasonally, average TKN concentrations were highest in the spring of 2001 at BL-2 (Table 30). Monthly in-lake TKN concentrations were not statistically different between in-lake sampling sites ($U_{0.05\,(2),\,11,\,17} = 90.00$, $p>0.05$).

Organic Nitrogen

The organic portion of TKN (TKN minus ammonia) is graphed on Figure 39. Organic nitrogen percentages (percent organic nitrogen in TKN) ranged from 90.6 percent to 99.6 percent and averaged 97.5 percent. The lowest organic percentage was in March 2001 at BL-1 (90.6 percent).

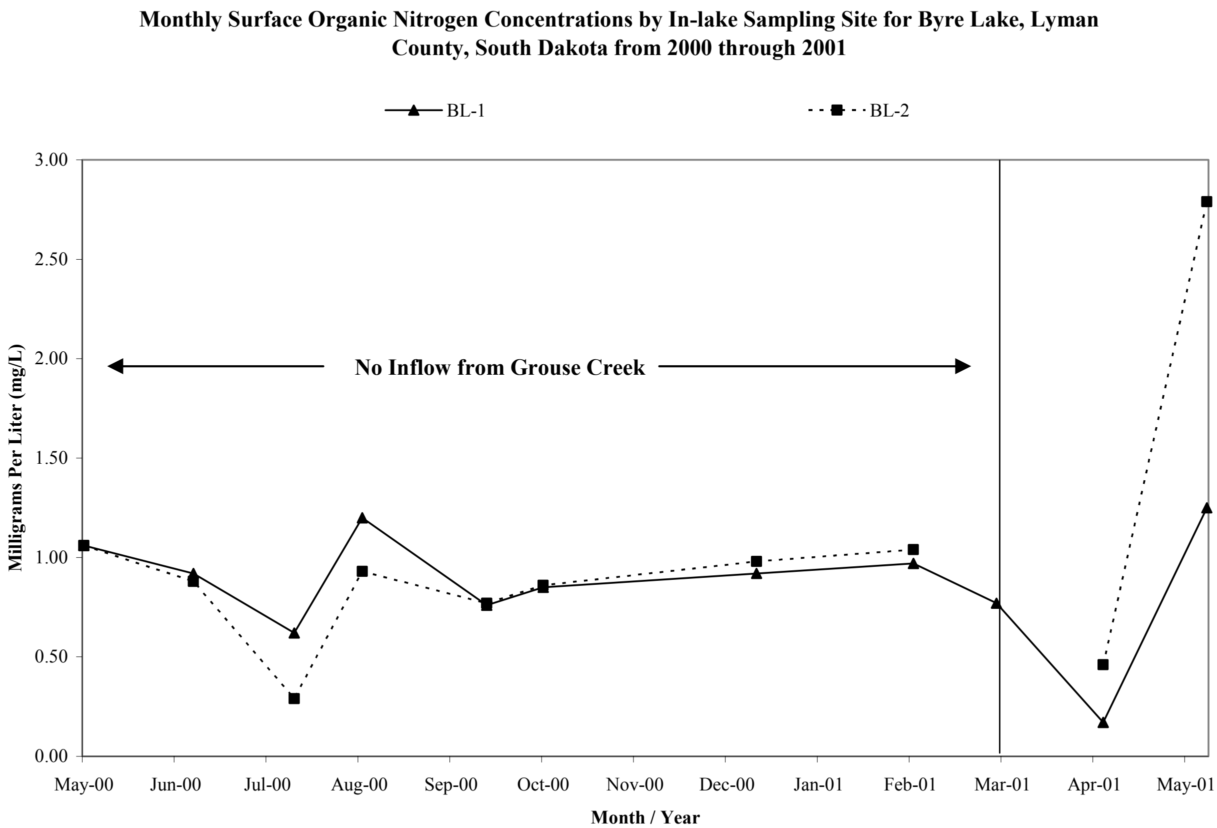


Figure 39. Monthly surface organic nitrogen concentrations by date and sampling site for Byre Lake, Lyman County, South Dakota from 2000 through 2001.

The average organic nitrogen concentration for Byre Lake was 0.88 mg/L (median 0.87 mg/L), with a maximum of 2.79 mg/L and a minimum concentration of 0.17 mg/L. Since organic nitrogen is a constituent of TKN, seasonal average organic nitrogen concentrations were similar (Table 30). Organic nitrogen concentrations peaked in the spring of 2001 and are similar to the TKN graph (Figure 38), because organic nitrogen incorporates TKN in the calculation (Figure 39). No significant differences in organic nitrogen concentrations were detected between in-lake sampling sites ($U_{0.05\,(2),\,11,\,17} = 89.00$, $p>0.05$).

Total Nitrogen

Total nitrogen is the sum of nitrate-nitrite and TKN concentrations. Total nitrogen is used to determine total nitrogen-to-total phosphorus ratios (limiting nutrient), and are discussed in the tributary section (3.1) and later in the in-lake section (3.1.1) of this report. The average total nitrogen concentration for Byre Lake was 1.16 mg/L (median 1.06 mg/L), with a maximum of 3.20 mg/L and a minimum concentration of 0.40 mg/L. Seasonally, average total nitrogen concentrations for Byre Lake were highest in the spring of 2001 at BL-2 (Table 30 and Figure 40). No significant differences in organic nitrogen concentrations were detected between in-lake sampling sites ($U_{0.05\ (2),\ 11,\ 17} = 82.00$, $p>0.05$).

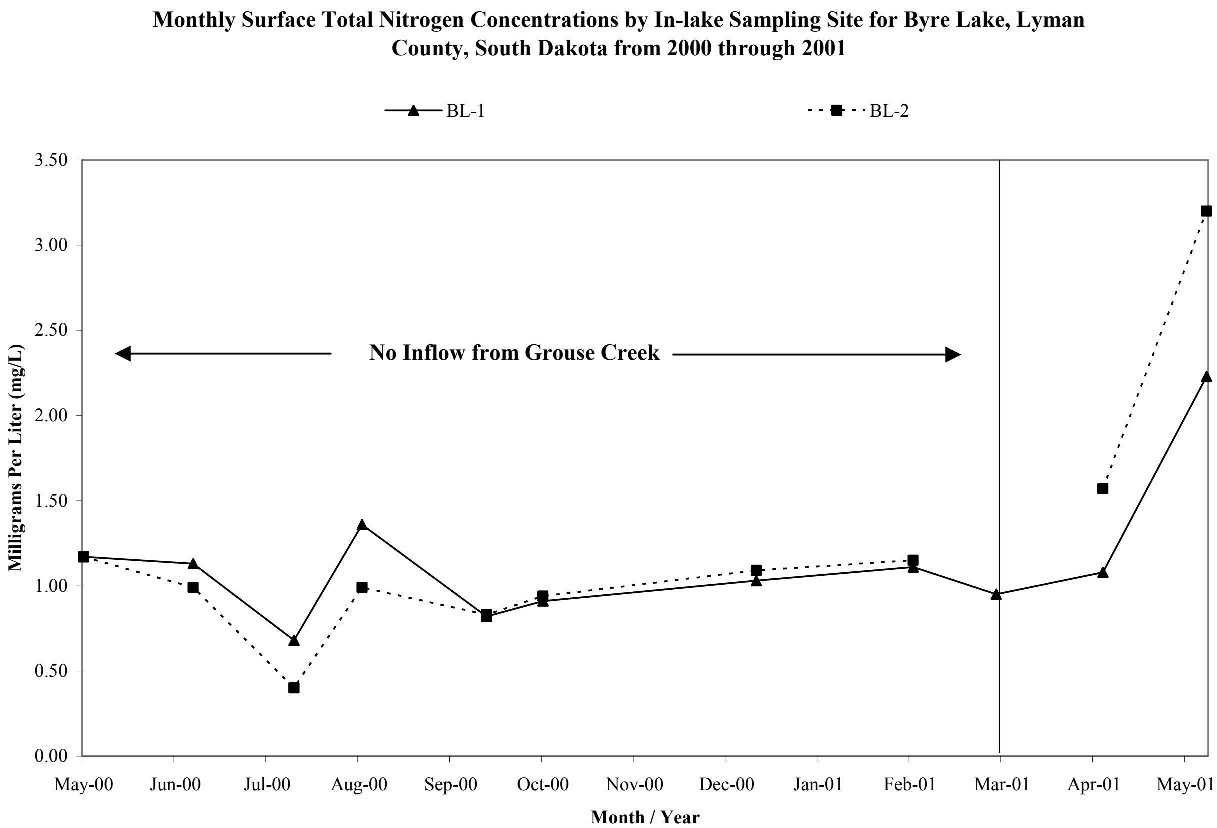


Figure 40. Monthly total nitrogen concentrations by date and sampling site for Byre Lake, Lyman County, South Dakota in 2000 and 2001.

Total Phosphorus

Typically, phosphorus is the single best chemical indicator of the condition of a nutrient-rich lake. Algae need as little as 0.02 mg/L of phosphorus for blooms to occur (Wetzel 1983). Phosphorus differs from nitrogen in that it is not as water-soluble and will sorb on to sediments and other substrates. Once phosphorus sorbs on to any substrate, it is not readily available for uptake by algae. Phosphorus sources can be natural from the geology and soil, from decaying organic matter, waste from septic tanks/systems or agricultural runoff. Once phosphorus enters a lake it may be used by the biota in the system or stored in lake sediment. Phosphorus will remain in the sediments unless released by wind and wave action re-suspending phosphorus into the water column, or by the loss of oxygen and the reduction of the redox potential in the microzone (sediment-water interface).

As dissolved oxygen levels are reduced, the ability of the microzone to hold phosphorus in the sediments is also reduced. The re-suspension of phosphorus into the water column of a lake is called internal loading and can be a large contributor of phosphorus available to algae (Zicker, 1956).

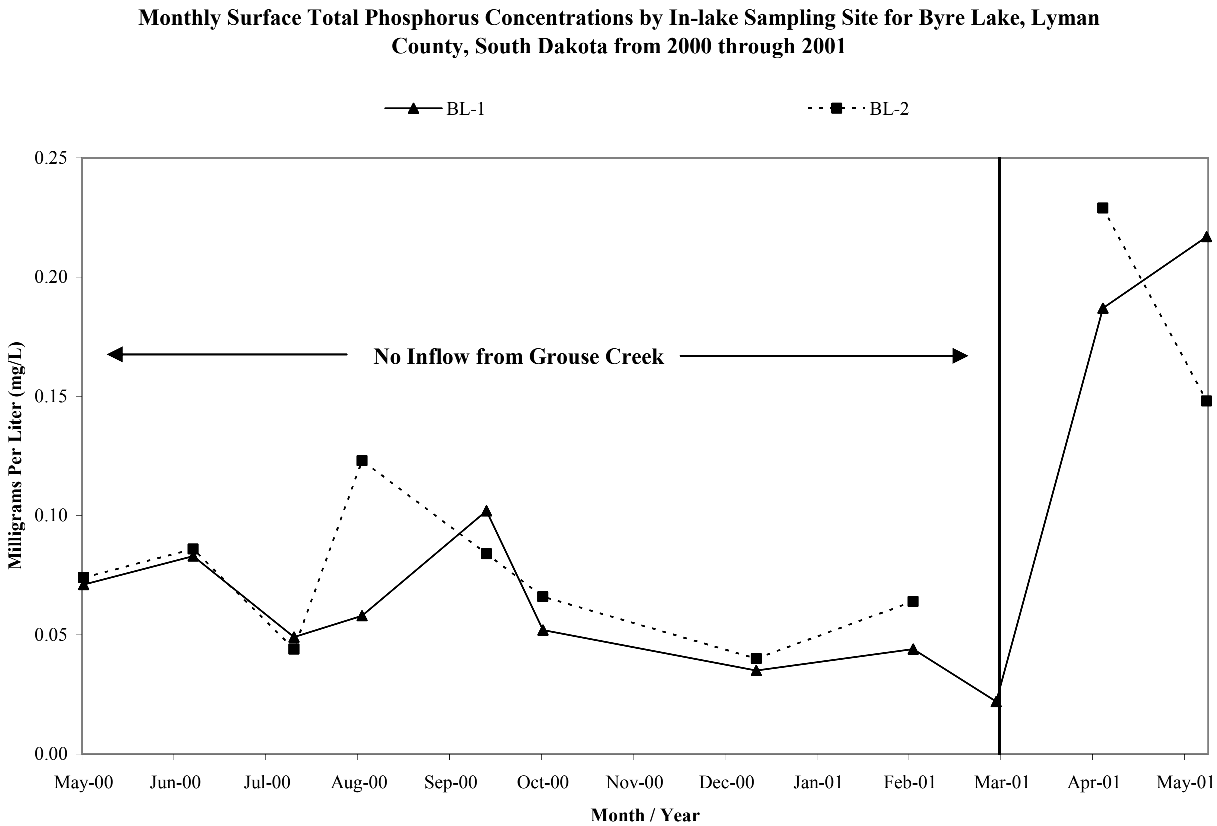


Figure 41. Monthly surface total phosphorus concentrations by date and sampling site for Byre Lake, Lyman County, South Dakota from 2000 through 2001.

The average concentration of total phosphorus throughout the study period was 0.092 mg/L (median 0.074 mg/L). The maximum sample concentration was collected at BL-2 in April (0.229 mg/L) (Figure 41). No significant differences in total phosphorus concentrations were detected between in-lake sampling sites ($U_{0.05\,(2),\,11,\,17} = 78.50$, $p>0.05$).

Seasonally, average total phosphorus concentrations were lower in the fall of 2000 and winter of 2001(Figure 41 and Table 30). On average, Byre Lake had 4.6 times more total phosphorus than the 0.02 mg/L needed to cause algal blooms (Wetzel, 1983). Based on total nitrogen-to–total phosphorus ratios relative to suggested in-lake criteria (10:1 TN:TP ratio, EPA 1990), during this study, monthly in-lake total phosphorus was generally limited (Figure 48). The highest densities of algae occurred in the spring of 2001 (May) with diatom blooms along with increased total phosphorus concentrations (Figure 41). Since excess phosphorus can cause algal blooms, reducing phosphorus loads in periods of increased tributary loading should over time promote better water quality.

Significant total phosphorus loading from Grouse Creek occurred from late March through May 2001 (Figure 18) and contributed to peak in-lake total phosphorus concentrations in May 2001. Increased in-lake concentrations were from tributary loading of total phosphorus to the lake. In-lake total phosphorus concentrations in May could have been higher if it were not for algal growth utilizing phosphorus during this time.

In-lake Trophic State Index (TSI) data (Table 37) indicate that a 79.6 percent reduction in in-lake total phosphorus is needed to meet current ecoregion targeted designated beneficial uses based on reference lake criteria for ecoregion 43. Every effort should be made to improve current management practices to control and reduce sediment and nutrient runoff in the Byre Lake watershed.

Total Dissolved Phosphorus

Total dissolved phosphorus is the fraction of total phosphorus that is readily available for use by algae and macrophytes. Dissolved phosphorus will sorb on to suspended materials (organic and inorganic) if present and not already saturated with phosphorus. In-lake total dissolved phosphorus and chlorophyll-*a* concentrations were averaged for each date because algae densities, which respond to available phosphorus concentrations, were also averaged for Byre Lake.

Generally, increased total suspended solids concentrations decrease concentrations of available total dissolved phosphorus; however, during this study total suspended solids showed a limited relationship to total dissolved phosphorus (R^2=0.25). The overall average percent phosphorus that was dissolved during the project was 41.8 percent. Percentages of total dissolved phosphorus ranged from 9.5 percent in the spring of 2000 to 76.9 percent in the fall of 2000. The average dissolved phosphorus concentration in Byre Lake was 0.043 mg/L (median 0.029 mg/L), with a maximum of 0.219 mg/L and a minimum concentration of 0.006 mg/L. Algae only need 0.02 mg/L of phosphorus to produce an algal bloom (Wetzel, 1983). Byre Lake averages 2.1 times that amount in available total dissolved phosphorus alone. No significant differences in total dissolved phosphorus concentrations were detected between in-lake sampling sites ($U_{0.05\ (2),\ 11,\ 17} = 83.00$, $p>0.05$).

Seasonal average total dissolved phosphorus concentrations were lowest in the winter of 2001 (less than 0.02 mg/L) and increased to the highest average concentration (0.118 mg/L) in the spring of 2001 at BL-1 (Figure 42 and Table 30).

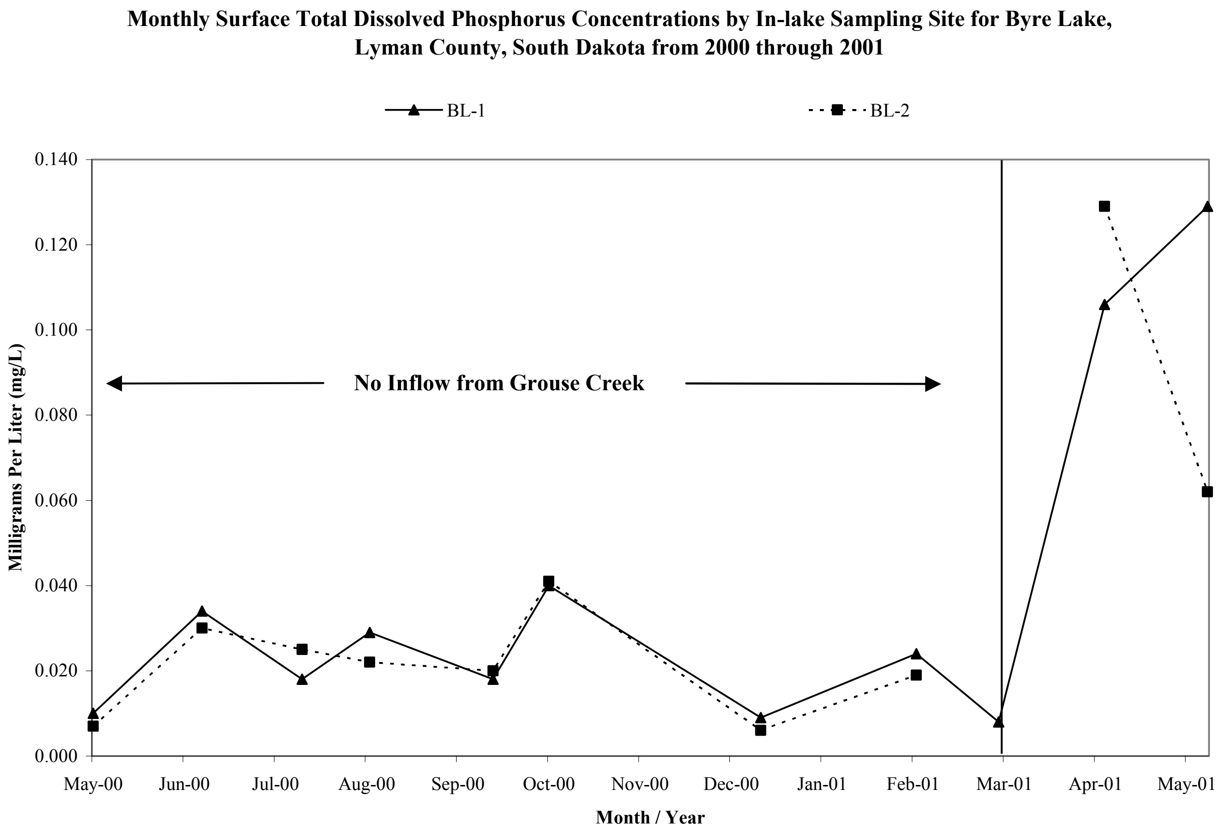


Figure 42. Monthly surface total dissolved phosphorus concentrations by date and sampling site for Byre Lake, Lyman County, South Dakota from 2000 through 2001.

Data indicate that while algal densities in Byre Lake were relatively high in spring of 2001, those densities did not produce thick floating mats of objectionable algal masses in Byre Lake. Since no nuisance algal blooms were reported by DENR personnel or the public during sampling, other conditions (light transparency, micronutrients, etc.) suppressed excessive productivity. Reducing tributary and in-lake phosphorus concentrations will, over time, reduce Carlson TSI values and increase water quality.

Fecal Coliform Bacteria

As was mentioned in the tributary section of this report, fecal coliform bacteria are found in the intestinal tract of warm-blooded animals and are used as indicators of waste and the presence of pathogens in a waterbody. Fecal coliform bacteria standards are in effect from May 1 through September 30 each year.

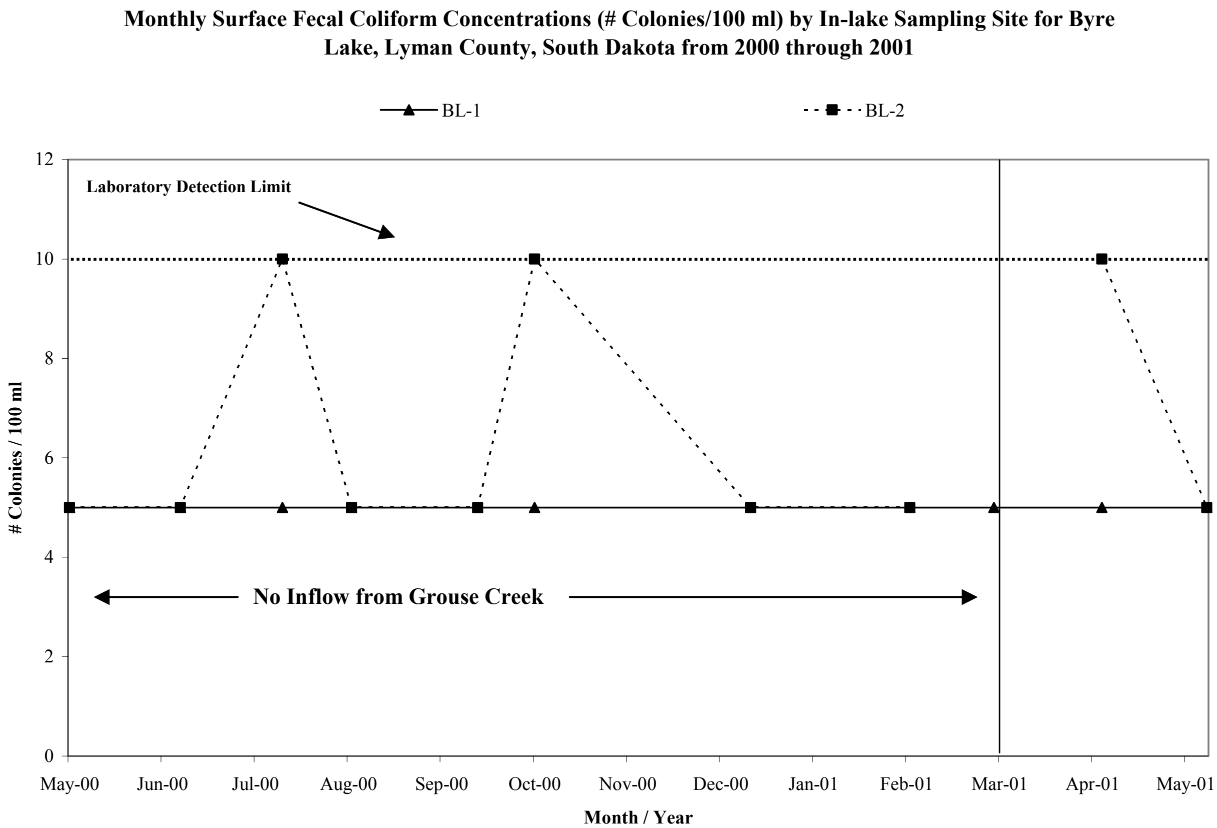


Figure 43. Surface fecal coliform bacteria colonies per 100 milliliters by date and sampling site for Byre Lake, Lyman County, South Dakota from 2000 through 2001.

In-lake fecal coliform concentrations are typically low because of exposure to sunlight and dilution of bacteria in a larger body of water. Of the 12 individual samples collected, 100 percent of fecal coliform concentrations were at or below detection limits (only three samples tested had fecal coliform counts at the detection limit) (Figure 43). The maximum concentrations (21 colonies/100 ml) were collected in May of 2000, October of 2000 and April of 2001 at BL-2; all other fecal coliform counts were below laboratory detection limits. Using a value of 5 (½ the detection limit) for those samples below laboratory detection limits, the average fecal coliform bacteria count was approximately 5.7 colonies/100 ml. No significant differences in fecal coliform counts were detected between in-lake sampling sites ($U_{0.05\,(2),\,11,\,17} = 73.50$, $p>0.05$).

Fecal coliform samples collected from Grouse Creek water quality sites upstream of Byre Lake had several elevated fecal coliform counts in excess of 1,000 colonies/100 ml (Table C-1 in Appendix C). Most high fecal coliform counts were collected during peak flow conditions in the early spring of 2001. Elevated fecal coliform values in April in Grouse Creek did not translate to elevated in-lake fecal coliform bacteria (Table C-1 in Appendix C and Figure 43). This is due in part to the natural variability of fecal coliform bacteria, increased exposure to sunlight and dilution in Byre Lake. Since high nutrient concentrations usually accompany elevated fecal bacteria counts, controlling animal waste would decrease both fecal coliform numbers and nutrient concentrations alike. In-lake fecal coliform concentrations do not indicate animal waste is a problem.

Chlorophyll-*a*

Chlorophyll-*a* is a major pigment in algae that may be used to estimate the biomass of algae found in a water sample (Brower, 1984). Chlorophyll-*a* samples were collected at both in-lake sampling sites during the project. Over all, the chlorophyll-*a* concentrations in Byre Lake were relatively high (Figure 44).

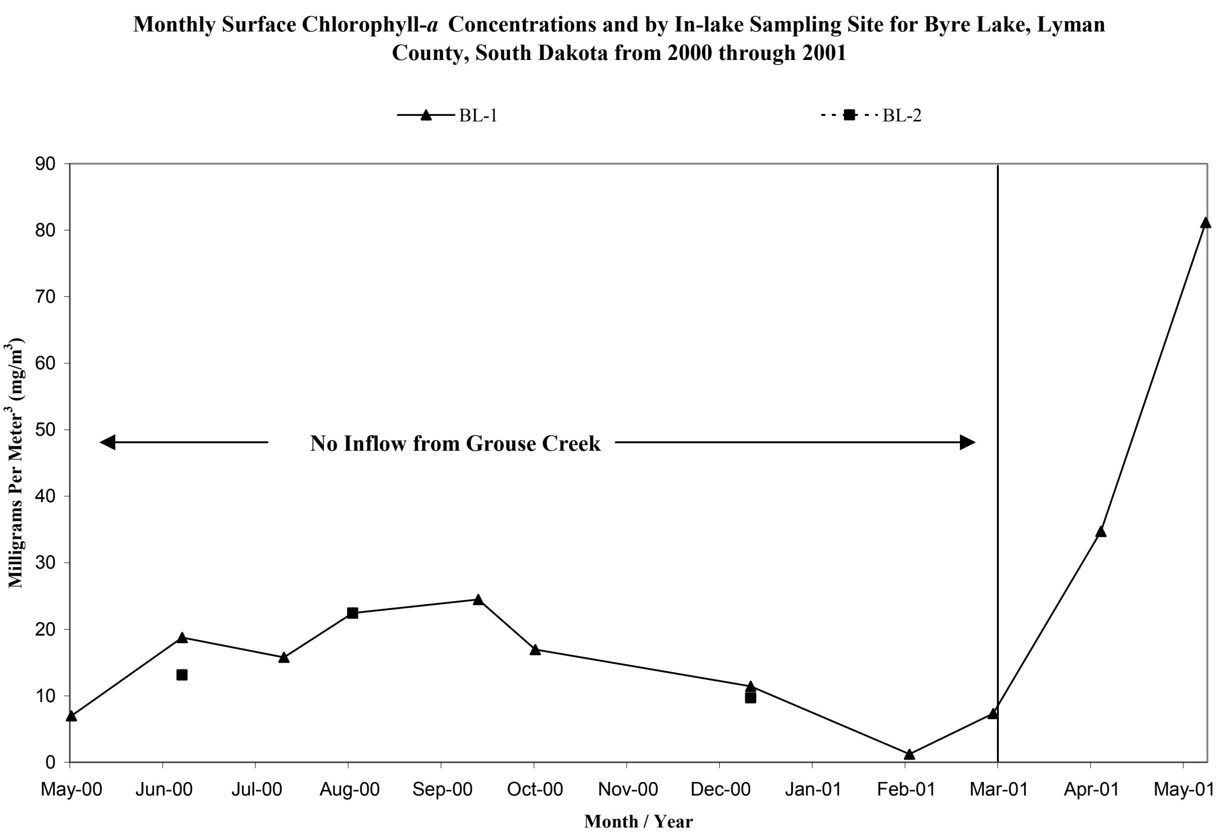


Figure 44. Monthly surface in-lake chlorophyll-*a* concentrations by date and sampling site for Byre Lake, Lyman County, South Dakota from 2000 through 2001.

The maximum in-lake chlorophyll-*a* concentration (81.2 mg/m^3) was collected on May 15, 2001 at BL-1 (Figure 44). The average chlorophyll-*a* concentration for the project was 20.5 mg/m^3 with a median concentration of 16.4 mg/m^3. Only three samples were collected on various dates at BL-2.

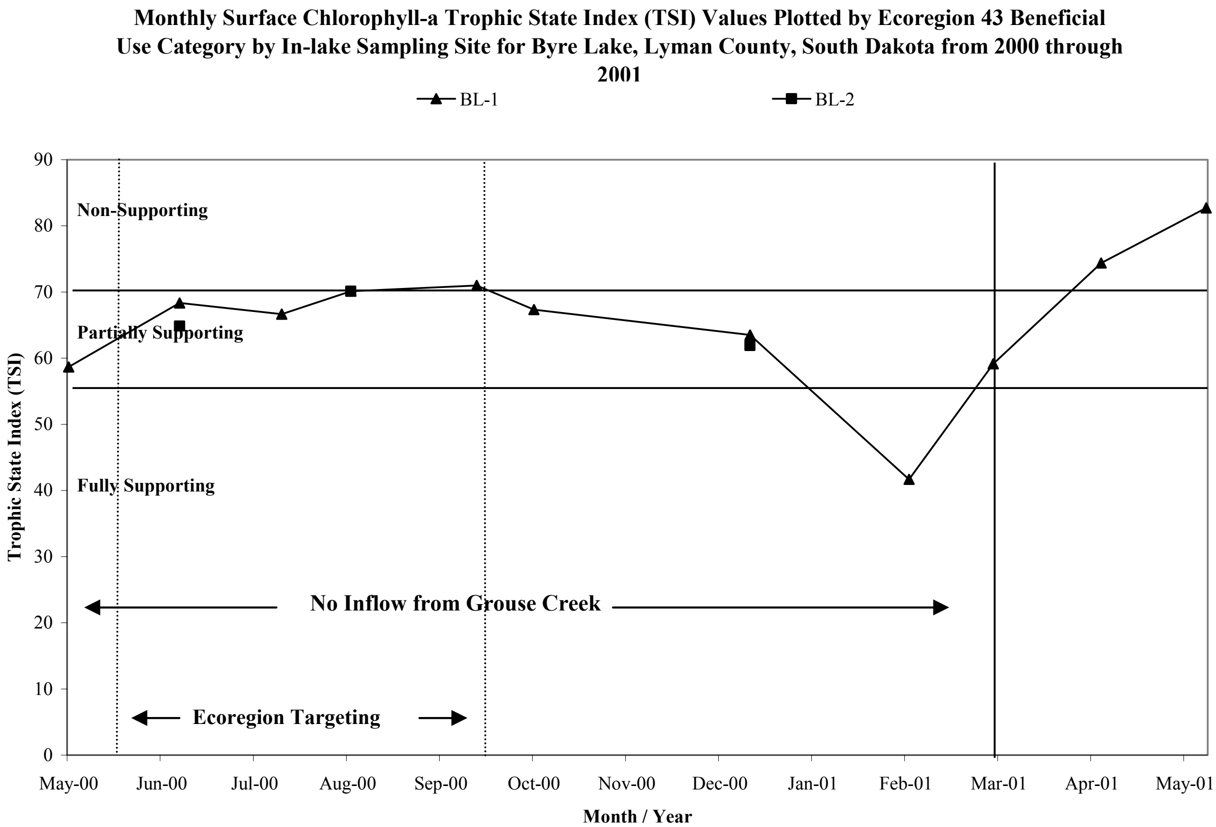


Figure 45. Monthly chlorophyll-*a* Trophic State Index (TSI) by beneficial use support categories, date and sampling site for Byre Lake, Lyman County, South Dakota from 2000 through 2001.

If chlorophyll-*a* was the only parameter used to estimate the trophic status of lakes, Byre Lake with an average TSI value of 65.75 would be rated hyper-eutrophic but partially-supporting for its ecoregion (Figure 45 and Figure 46) The ecoregion targeted mean TSI value for chlorophyll-*a* was 69.07 TSI which rated it at hyper-eutrophic but partially-supporting. Figure 45 indicates that three of the fourteen samples analyzed during the project had TSI values that were not supporting beneficial uses, and using Carlson's trophic categories, nine of the fourteen TSI values that were in the hyper-eutrophic range > 65.00 (Figure 46). No significant differences in chlorophyll-*a* concentrations were detected between in-lake sampling sites ($U_{0.05\ (2),\ 3,\ 10} = 11.50$, $p>0.05$).

Typically, chlorophyll-*a* and total phosphorus typically have direct relationships. As total phosphorus concentrations increase, so do chlorophyll-*a* concentrations. Variations in the relationship can be caused by many factors including, but not limited to: nutrient ratios, temperature, light, suspended sediment, and hydrologic residence time.

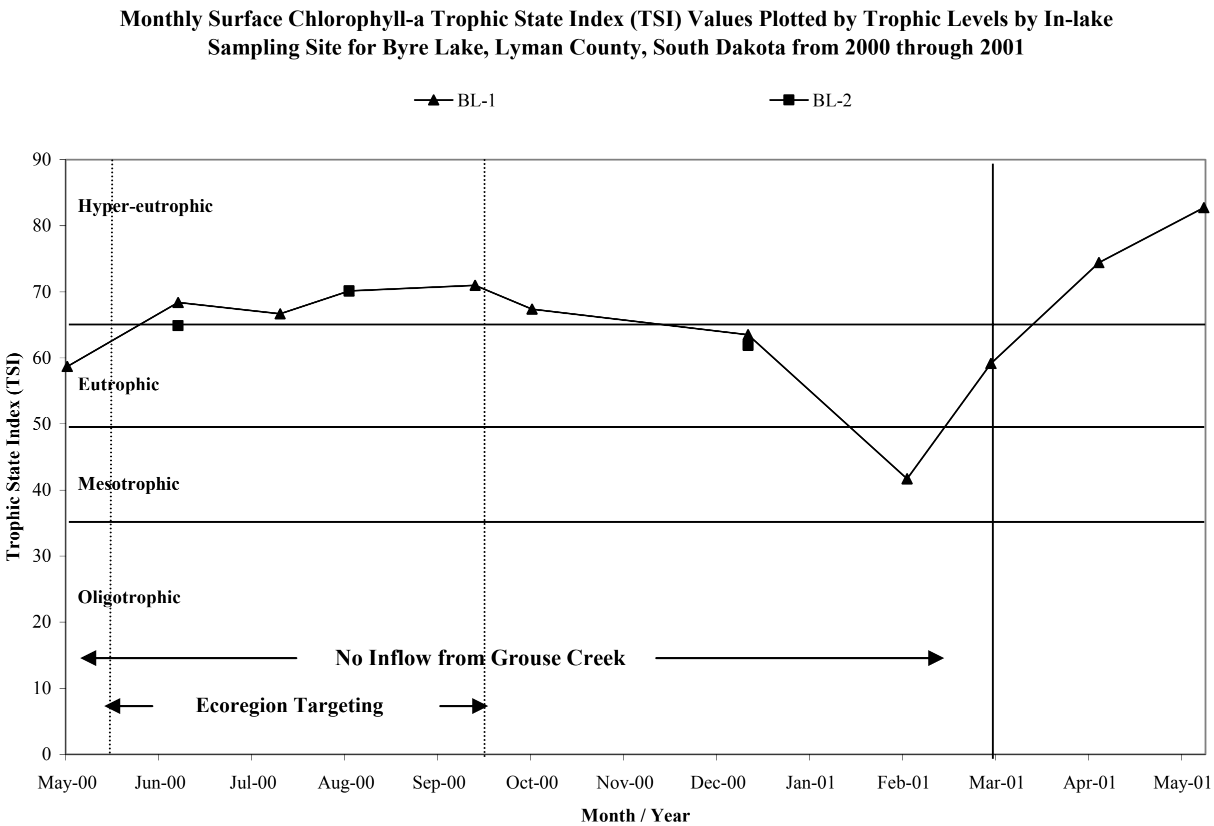


Figure 46. Monthly chlorophyll-*a* Trophic State Index (TSI) by Carlson trophic categories, date and sampling site for Byre Lake, Lyman County, South Dakota from 2000 through 2001.

Chlorophyll-*a* and total phosphorus concentrations for Byre Lake were transformed using Log(10) to linearize the data. Chlorophyll-*a* samples for the two sites were plotted against total phosphorus concentrations to determine their relationship in Byre Lake. A regression calculation was run on all data points to determine a regression equation and R^2 value to predict chlorophyll-*a* values from total phosphorus concentrations. The R^2 is a value given for a group of points with a statistically calculated line running through them.

The higher the R^2 value, the better the relationship, with a perfect relationship reached when R^2 = 1.0. The statistical chlorophyll-*a* to total phosphorus relationship for Byre Lake was calculated as having a R^2 = 0.6052 (Figure 47). This indicates that when availability of total phosphorus increases, chlorophyll-*a* concentrations also increase. The positive slope indicates that total phosphorus is a good predictor of chlorophyll-*a* concentrations (algal populations) in Byre Lake.

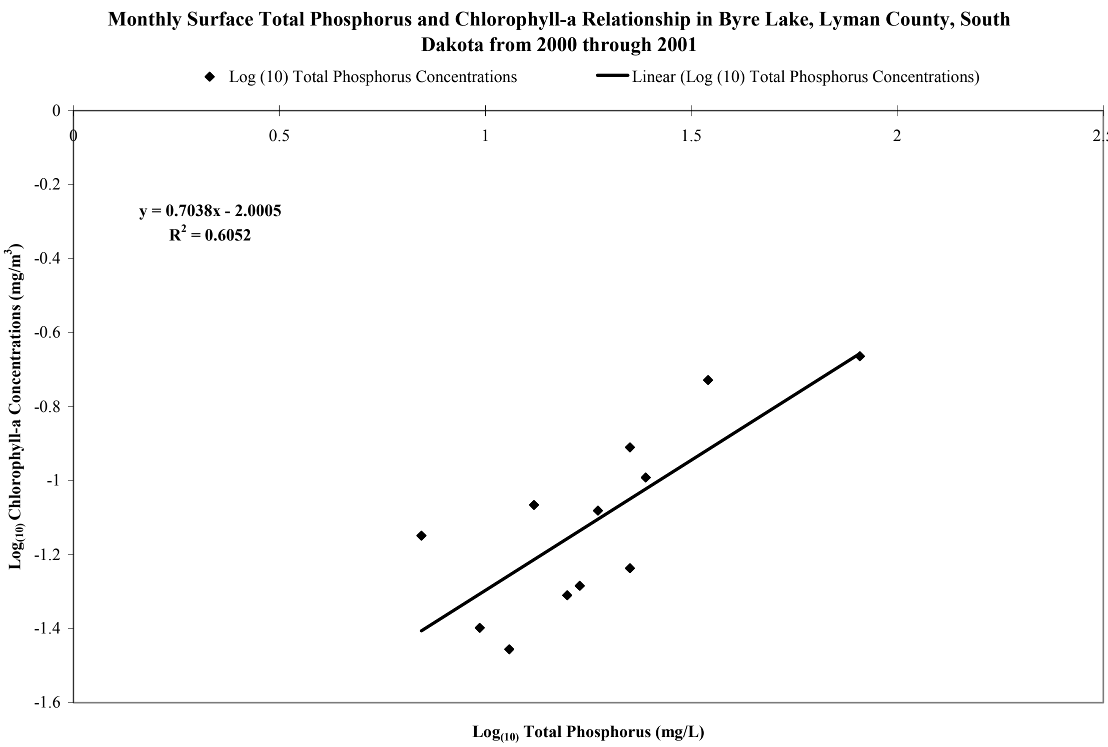


Figure 47. Log(10) chlorophyll-*a* concentrations vs. log (10) total phosphorus concentrations by date and in-lake sampling site for Byre Lake, Lyman County, South Dakota from 2000 through 2001.

In-lake Total Nitrogen-to-Total Phosphorus Ratios (Limiting Nutrient)

For an organism (algae) to survive in a given environment, it must have the necessary nutrients and environment to maintain life and successfully reproduce. If an essential life component approaches a critical minimum, this component will become the limiting factor (Odum, 1959). Nutrients such as phosphorus and nitrogen are most often the limiting factors in highly eutrophic lakes. Typically, phosphorus is the limiting nutrient for algal growth. However, in many highly eutrophic lakes with an overabundance of phosphorus, nitrogen can become the limiting factor.

In order to determine which nutrient is limiting in lakes, US EPA, (1990) has suggested an in-lake total nitrogen-to-total phosphorus ratio of 10:1. If the total nitrogen concentration divided by the total phosphorus concentration in a given sample is greater than 10, the lake is considered phosphorus-limited. If the ratio is less than 10, the waterbody is considered nitrogen-limited.

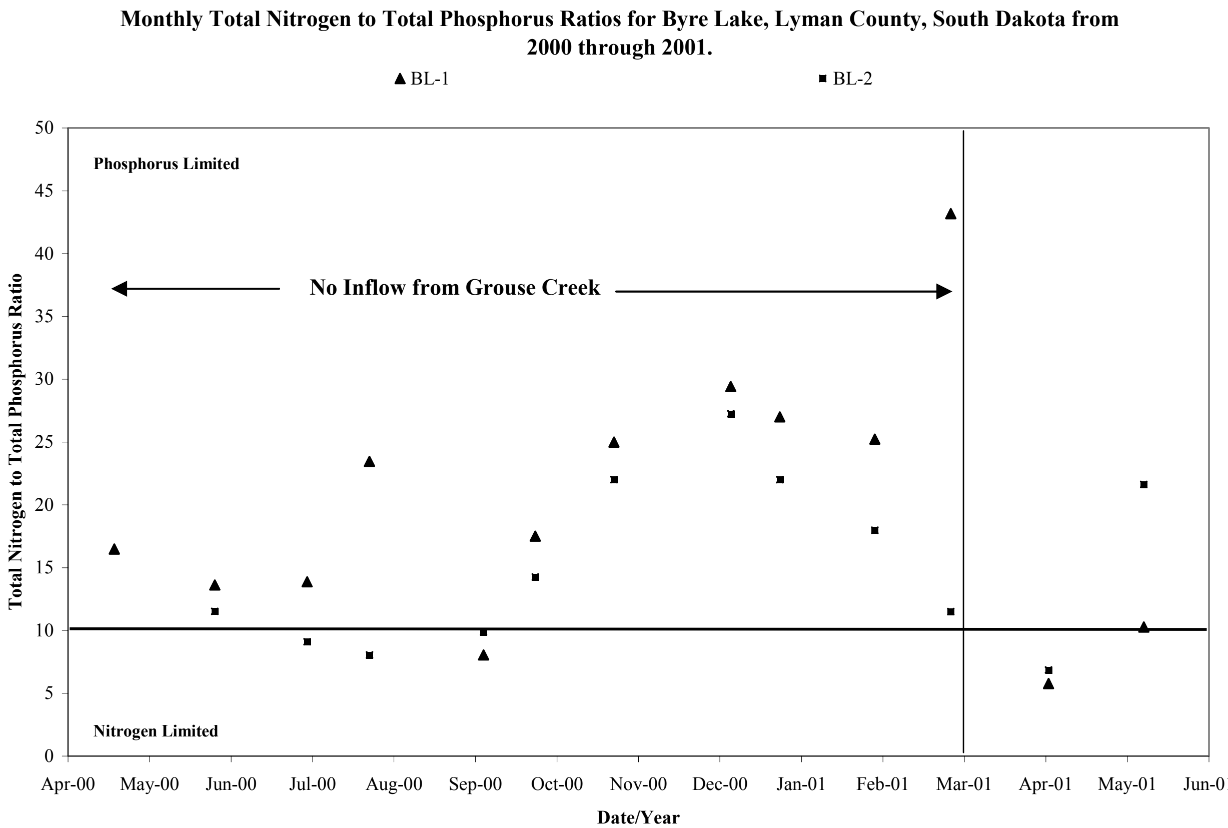


Figure 48. Surface total nitrogen-to-total phosphorus ratios by date and sampling site for Byre Lake, Lyman County, South Dakota from 2000 through 2001.

During the project, Byre Lake was generally phosphorus-limited (Figure 48). The average total nitrogen-to-total phosphorus ratio in Figure 48 was 15.4:1 (phosphorus-limited above 10) with a median of 13.96. Byre Lake was slightly nitrogen-limited in June and July of 2000 and April of 2001 at BL-2 and September of 2000 and April 2001 at BL-1. All total nitrogen-to-total phosphorus ratios between in-lake sampling sites (BL-1 and BL-2) were not statistically different ($U_{0.05\,(2),\,11,\,17} = 75.00$, $p>0.05$).

As stated earlier, limiting factors can be anything physical or chemical that limits the growth or production of organisms. Although phosphorus limitation was observed during most of the project, algal densities (cells/ml) increased from April through May 2001 in Byre Lake (Figure 48 and Figure 49).

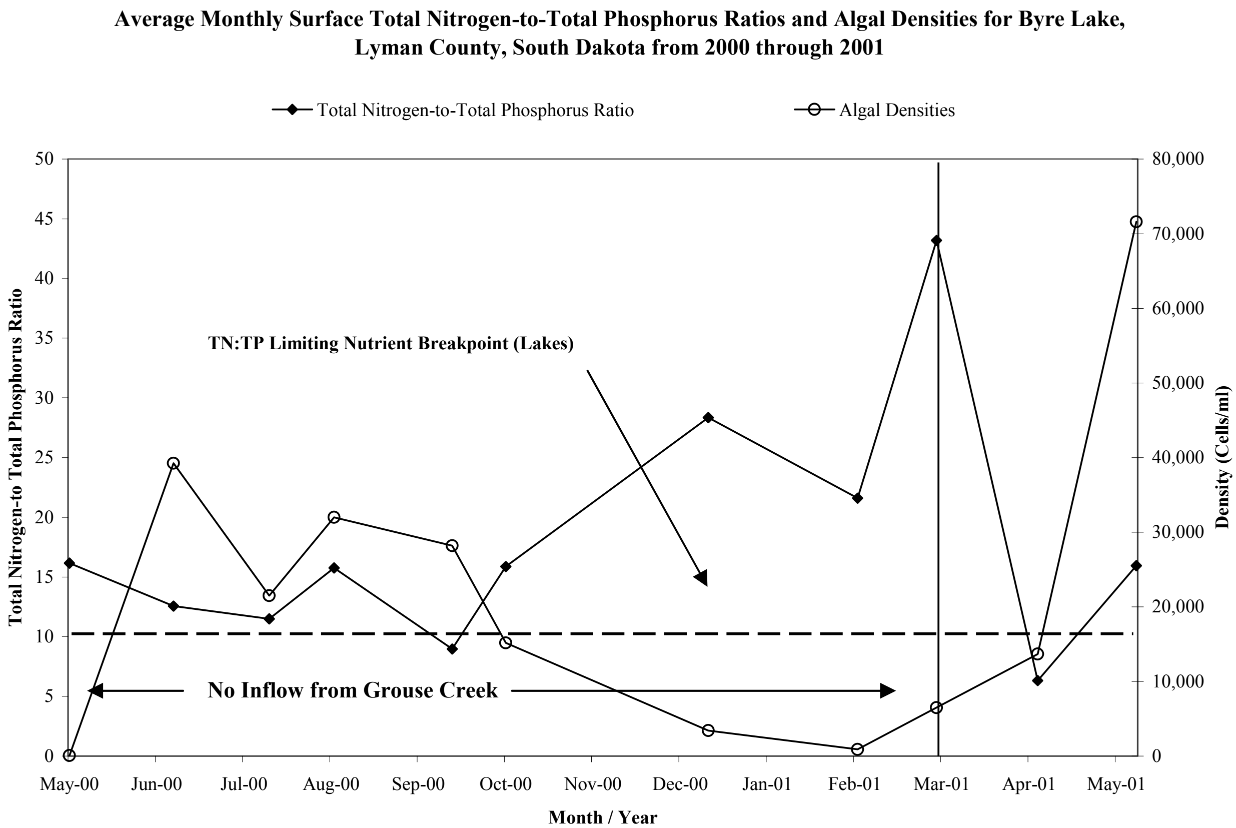


Figure 49. Average monthly surface total nitrogen-to-total phosphorus ratios and algal densities (cells/ml) for Byre Lake, Lyman County, South Dakota from 2000 through 2001.

Hydrologic, Sediment and Nutrient Budgets for Byre Lake

All budgets, hydrologic, sediment and nutrient, are based on watershed runoff/loading that occurred during the project period (May 2000 through May 2001). During the study, no runoff occurred in 2000 and runoff did not begin until the middle of March 2001 (spring runoff).

Hydrologic Budget

The hydrologic budget estimates how much water entered the lake and how much water left the lake. The hydrologic, sediment and nutrient budgets will be based on 2001 tributary sampling data. Sampling and gauging Grouse Creek began in the spring of 2000 and continued until ice up and began again when ice left the stream and continuous discharge measurements could be collected. Runoff did not occur in the watershed until March 2001

Hydrologic inputs to Byre Lake included precipitation, tributary runoff and both gauged and ungauged areas of the watershed. Hydrologic output from Byre Lake included the water leaving the lake over the spillway from the end of March through May 2001, evaporation and Kennebec drinking water withdrawals (Table 31 and Table 32). Precipitation data for Kennebec, South Dakota was acquired from the state climatologist in Brookings, South Dakota. Tributary sites were gauged when possible, and ungauged discharge was estimated using hydrologic export coefficients from the gauged sites.

In many projects, the volume of water above or below the level of the spillway at the beginning or end of the project is calculated as an input or output. During the study period, water was below the level of the spillway 330 days out of 393 days of monitoring (84 percent).

Table 31. Hydrologic budget for Byre Lake, Lyman County, South Dakota from 2000 through 2001.

Tributary	Input (acre-feet)	Tributary	Output (acre-feet)
Grouse Creek MCT-14 (Inlet)	5,929.46	**Outlet Discharge (MCT-15)**	4,736.92
Rainfall on Byre Lake	165.75	**Evaporation**	435.68
		Kennebec Withdrawals*	84.27
		Initial Volume Loss	838.34
Total	**6,095.21**		**6,095.21**

*** = Kennebec drinking water withdrawals from Byre Lake through May 2001**

The hydrologic budget for Byre Lake is provided in Table 31. Table 31 incorporates precipitation and evaporation in both the input and output calculations/estimations. The hydrologic budget was developed using output data from the FLUX model (Walker, 1996). Kennebec drinking water withdrawals were calculated using observed Kennebec withdrawal volume metered at Byre Lake (Table 32). One factor never directly measured in Byre Lake was the total volume of ground water that passed through the lake. Ground water in the area (based on alluvial wells (all are $\geq$ 30 feet)) is relatively deep and generally of poor drinking water quality. Ground water usually had little effect on the overall water quality of Byre Lake due to the low percentage contributed from this source. It was assumed that the same amount of ground water entered the lake as left the lake.

A major source of hydrologic input to Byre Lake was Grouse Creek at 97.3 percent of the total hydrologic load, followed by the rainfall on the lake contributing 2.7 percent. The hydraulic residence is the time between when water enters a reactor (lake) and the same water leaves the reactor. The hydraulic residence time when Byre Lake is full was estimated at 0.093 years or 33.9 days (calculated using BATHTUB (Walker, 1996)).

Table 32. Monthly drinking water withdrawals from Byre Lake by Kennebec, Lyman County, South Dakota from 2000 through 2002.

	Year		
Month	**2000**	**2001**	**2002**
January	1,401,800	1,083,400	1,845,100
February	1,486,700	1,232,700	1,404,800
March	1,435,000	1,358,400	1,853,400
April	1,163,400	1,506,400	1,858,800
May	1,969,300	2,166,100	2,462,700
June	2,223,600	2,053,400	4,135,300
July	2,720,300	3,878,300	2,192,000
August	2,844,700	3,960,100	2,112,000
September	2,464,800	2,319,000	WR/LJ*
October	1,917,200	1,771,100	WR/LJ
November	512,800	1,847,200	WR/LJ
December	0	1,689,700	WR/LJ
Yearly Total (gallons)	**20,139,600**	**24,865,800**	**17,864,100**

*** = Kennebec switched drinking water supply to West River / Lyman Jones Rural Water**

Suspended Solids Budget

As described in the tributary section of the report, overall suspended solids loads from the watershed did not appear to be significant during the sampling period. According to the data collected from Grouse Creek and the estimated amount from the ungauged portion of the watershed, Byre Lake received approximately 2,218.6 m^3 (1.8 acre-feet) of sediment, during this study. The volume of sediment was calculated by dividing the annual kilograms of sediment (4,797,761 kg) by 2,162.5 kg/m^3 (Stueven and Bren, 1999).

The calculation of total suspended solids at the outlet (MCT-15) found approximately 419,716 kg or 194.1 m^3 (0.16 acre-feet) of sediment leaving Byre Lake. An estimated 25,882 kg or 11.9 m^3 (0.009 acre-feet) of total suspended solids were removed from Byre Lake with drinking water withdrawals from Kennebec, South Dakota The amount of suspended solids retained in Byre Lake during this study was approximately 4,352,163 kg, which is 2,012.6 m^3 (1.6 acre-feet) or 90.7 percent of the total of suspended solids loading to the lake (Figure 50). This translates to an overall increase of 3.91 mm in sediment depth over the entire lake per year.

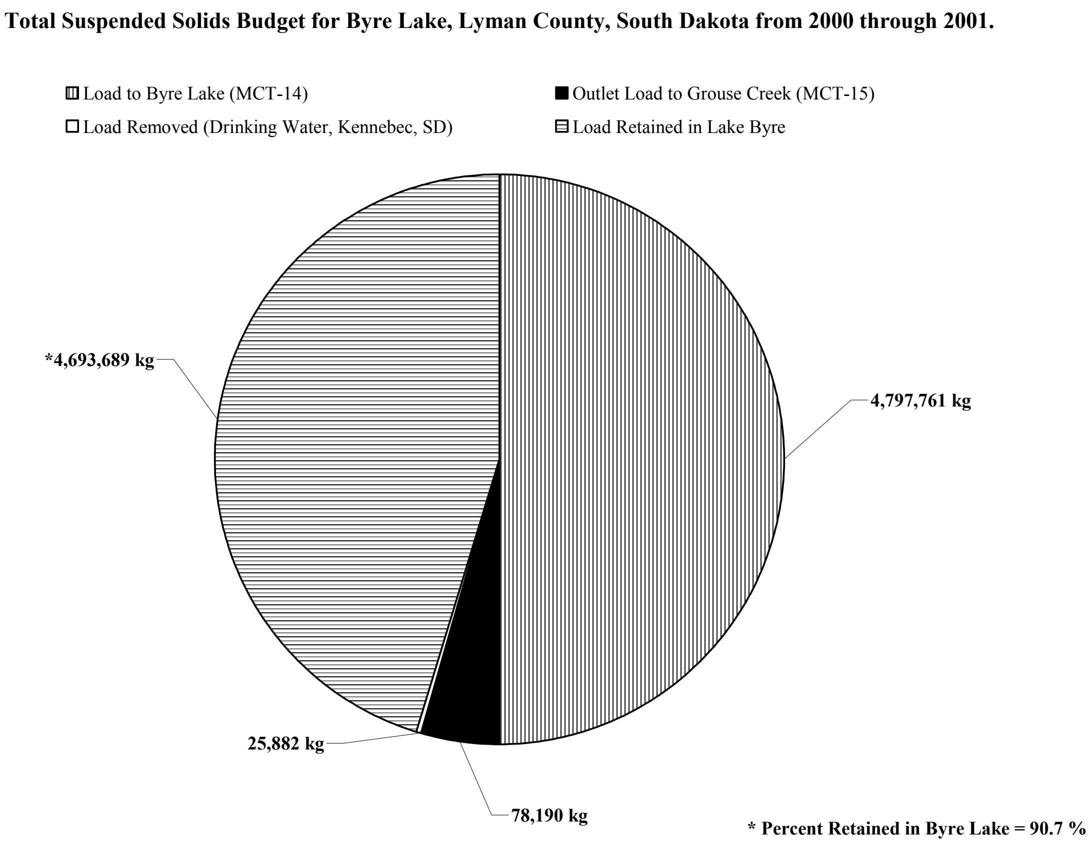


Figure 50. Percent total suspended solids budget for Byre Lake, Lyman County, South Dakota by source from 2000 through 2001.

To estimate the average organic portion of total suspended solids leaving Byre Lake, the total kilograms per year of volatile total suspended solids (VTSS) were divided by the total suspended solids to predict the percentage of organic suspended solids. The organic percentage of suspended solids measured at MCT-14 (Byre Lake inlet) during the project was 11.0 percent. In comparison, the overall average in-lake percentage of volatile total suspended solids at BL-1 was 24.0 percent while the percentage of volatile total suspended solids at BL-2 was 23.0 percent (Byre Lake average: 23.2 percent). An increase in organic composition of total suspended solids from tributary to in-lake percentages was observed in Byre Lake. A large portion of this increase may be attributed to in-lake algal populations. The estimated volatile total suspended solids percentage discharged from Byre Lake was 8.9 percent. Reducing total suspended solids concentrations in Byre Lake should be beneficial in reducing trophic state indices and the non-supporting (hyper-eutrophic) condition of the lake.

Nitrogen Budget

Tributary loadings were taken from the water quality data collected. Ground water loading was not considered in the overall input budget because there was no way to measure the input or fate of groundwater nitrate from the time it enters the lake until it leaves.

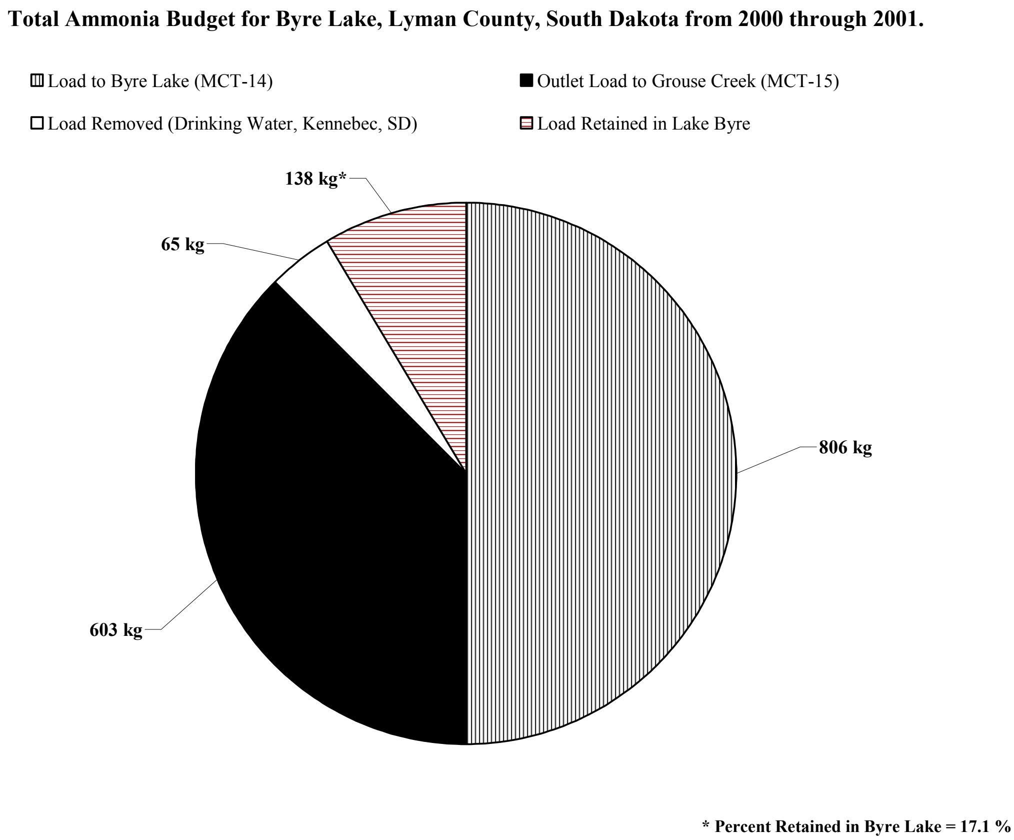


Figure 51. Percent ammonia budget for Byre Lake, Lyman County, South Dakota by source from 2000 through 2001.

Atmospheric nitrogen can enter a waterbody in many forms: as nitrogen, nitric acid, ammonia, nitrite, and as organic compounds either dissolved or particulate (Wetzel, 1983). It was not possible to know what ratio of inorganic to organic nitrogen entered the lake from the atmosphere. Blue-green algae are able to fix atmospheric nitrogen; however, the rate and amount at which atmospheric nitrogen was incorporated could not be determined given the scope of this project. Because no water quality data from precipitation was collected, the inputs from rainfall on the lake surface will be estimated as minimal and not considered in this report. The following charts show the percent of nitrogen loadings from different sources in the Byre Lake watershed (Figure 51 through Figure 54).

The ammonia (NH_3) budget for Byre Lake showed an increase in in-lake ammonia of 138 kg (304.2 lbs) or 17.1 percent of the total loading to the lake remained in the lake (Figure 51). The ammonia load remaining in the lake (138 kg) was readily available to and utilized by in-lake algae or converted to other forms of nitrogen. Ammonia is an inorganic form of nitrogen and is first used by algae for uptake and growth, followed by nitrate-nitrite (NO_3^- and NO_2^-) which must be reduced to NH_3 to be utilized by algae and plants.

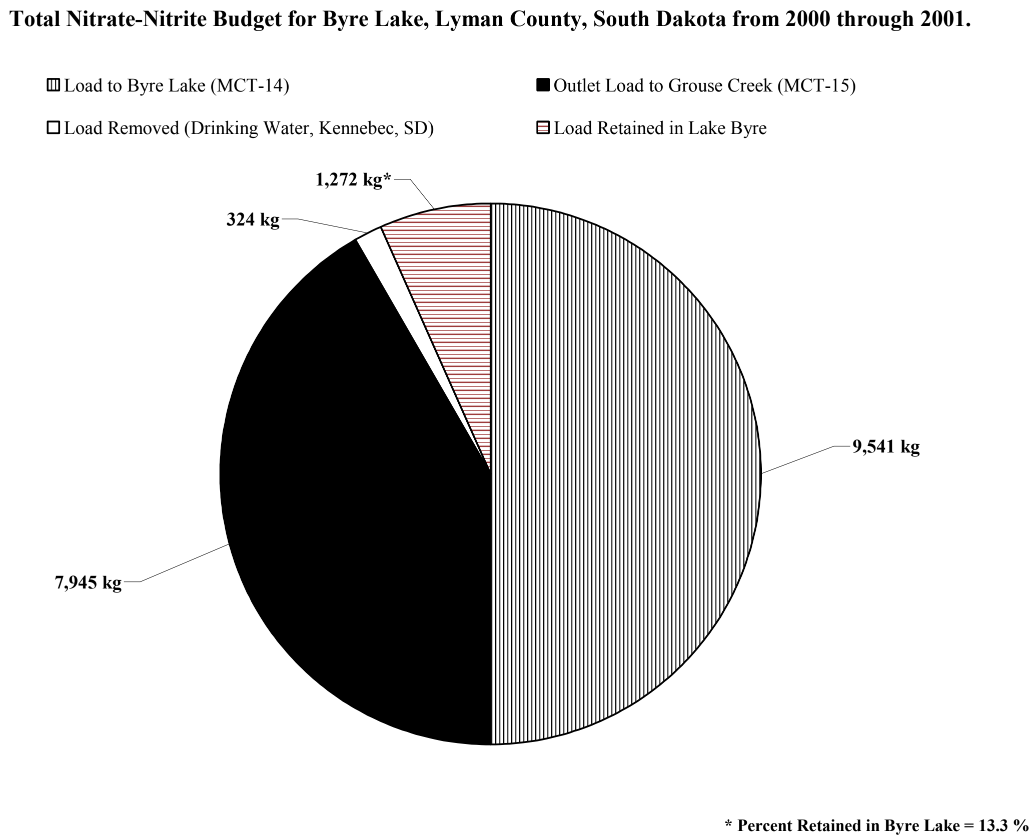


Figure 52. Percent nitrate-nitrite budget for Byre Lake, Lyman County, South Dakota by source from 2000 through 2001.

Another inorganic nitrogen parameter sampled was nitrate-nitrite (NO_3^- and NO_2^-). The nitrate-nitrite budget indicated an increase of nitrate in Byre Lake. An estimated 1,272 kg (1.4 tons) or 13.3 percent of the nitrate-nitrite load to Byre Lake was utilized by in-lake algae (converted to ammonia), aquatic macrophytes and/or sorbed on to the sediments. Algae can take up nitrate-nitrite nitrogen if available and convert it to ammonia for use through a nitrate reduction process. Approximately 7,945 kg (8.8 tons) of nitrate-nitrite was discharged from Byre Lake in 2001 (Figure 52).

Organic nitrogen can come in the form of animal waste, vegetation from the watershed or algae. If organic nitrogen is not dissolved, it can drop out of the water column once it reaches the lake. In the bottom sediments, organic nitrogen can be broken down into usable forms of nitrogen. Algae can then use the converted nitrogen for growth and leave the lake through the outlet or sink to the bottom at the end of their growth cycle. Figure 53 indicates Grouse Creek delivered a total organic nitrogen load of 7,574 kg (8.4 tons) to Byre Lake. Approximately 829 kg (0.91 tons) or 11.0 percent of the organic nitrogen load was retained in Byre Lake, increasing in-lake available nitrogen during the project.

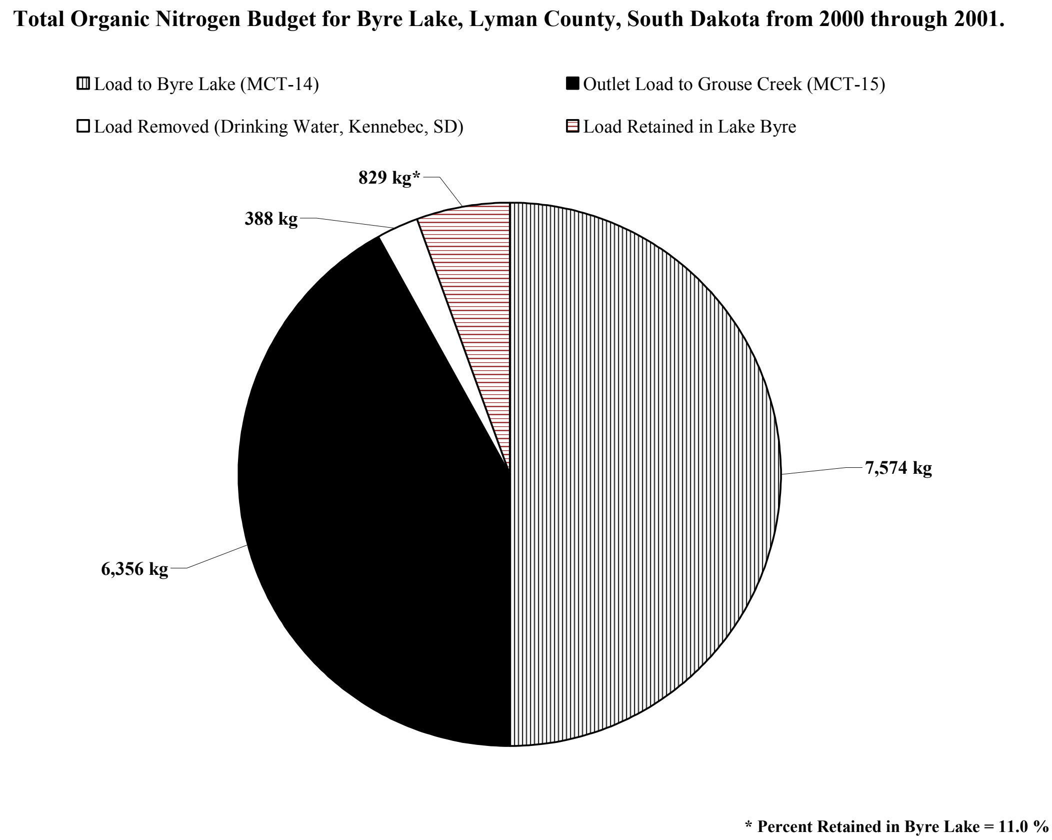


Figure 53. Percent organic nitrogen budget for Byre Lake, Lyman County, South Dakota by source from 2000 through 2001.

Total nitrogen concentrations are derived from adding TKN concentrations to nitrate–nitrite concentrations. Approximately 2,239 kg (2.5 tons) or 12.5 percent of the total nitrogen load was retained in Byre Lake during the project. Figure 54 indicates a total nitrogen load of 17,920 kg (19.8 tons) to Byre Lake. As was discussed previously, total nitrogen is used along with total phosphorus to determine limiting nutrients (ratio) which may affect algal metabolism for growth and chlorophyll-*a* production. Tributary total nitrogen-to-total phosphorus ratios indicated a nitrogen limited system, while in-lake ratios indicated a mostly a phosphorus-limited system from 2000 through 2001 (Figure 21 and Figure 48). All forms of nitrogen can eventually be broken down and reused for algal growth. Reducing the influx of nitrogen will be beneficial for reducing the hyper-eutrophic (non-supporting) condition found in Byre Lake.

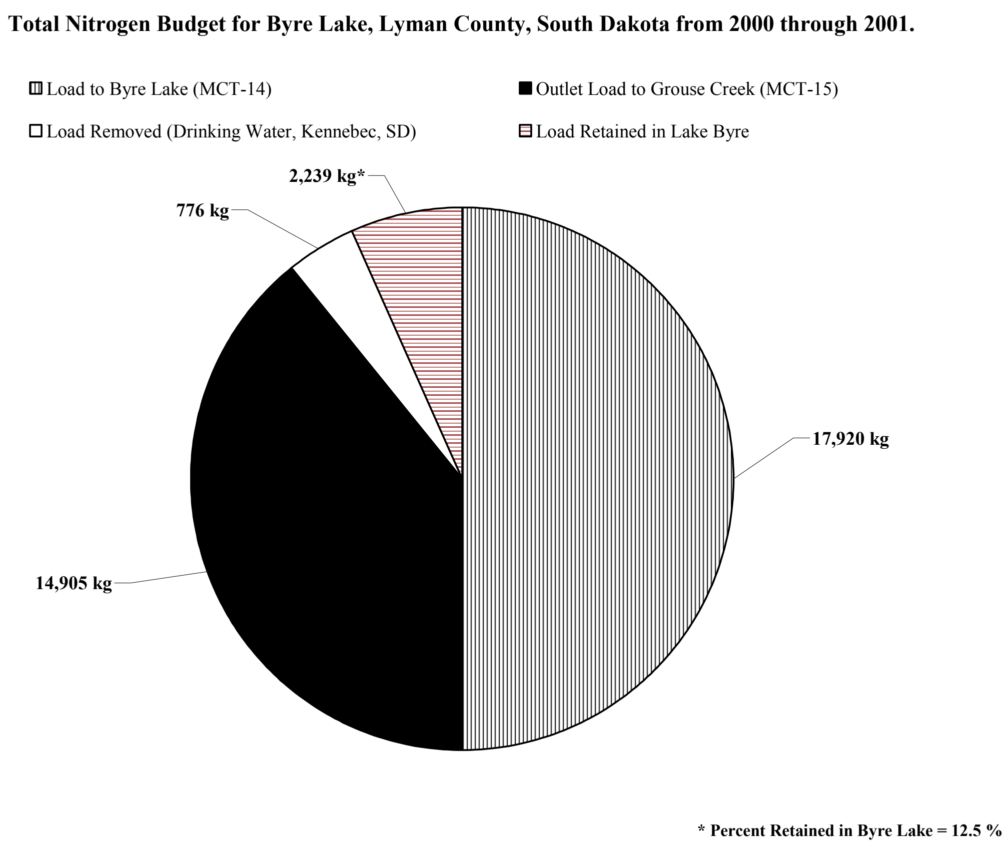


Figure 54. Percent total nitrogen budget for Byre Lake, Lyman County, South Dakota by source from 2000 through 2001.

Total Phosphorus Budget

Total phosphorus inputs during the 2000 through 2001 sampling season totaled approximately 9,391 kg (10.4 tons) to Byre Lake (Figure 55). The ground water portion of the phosphorus budget in most lakes is insignificant compared to tributary inputs. As with nitrogen, there is no way to know how much ground water entered the lake and how much left the lake. Phosphorus residence time for Byre Lake was calculated using BATHTUB (Walker, 1996) and was estimated to be 0.0169 years or 6.17 days.

The total load out of Byre Lake was approximately 2,719 kg (3.0 tons) this includes total phosphorus leaving Byre Lake over the spillway (MCT-15) and Kennebec, South Dakota drinking water withdrawal. During the 2000 through 2001 sampling season, there was an estimated 6,671 kg (7.4 tons), or 71.0 percent of the incoming total phosphorus that was retained in the lake could be utilized for metabolism and growth (algae and macrophytes). Increased in-lake concentrations of total phosphorus were observed throughout this study. Variable total phosphorus concentrations and total nitrogen concentrations contributed to the nutrient limitations (phosphorus) observed in Byre Lake from 2000 through 2001.

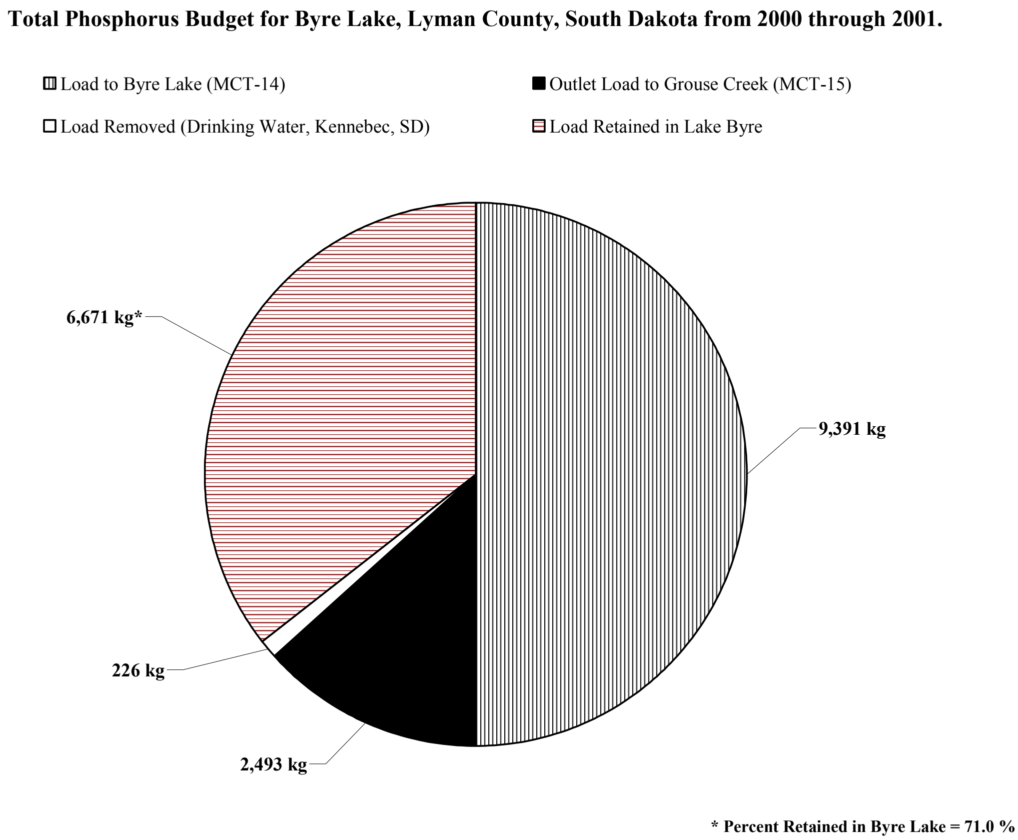


Figure 55. Percent total phosphorus budget for Byre Lake, Lyman County, South Dakota by source from 2000 through 2001.

Fluctuations in in-lake total phosphorus did not appear to be from the release of phosphorus from bottom sediments (internal loading) because surface water total phosphorus concentrations were not significantly different from bottom concentrations collected at the same time ($U_{0.05\ (2),\ 21,\ 7} = 53.00$, $p>0.05$); however, although on statistically significant, it is likely that to some extent internal loading does occur in Byre Lake. Reducing the influx of total phosphorus will improve the overall trophic state of the lake and increase the beneficial use status of Byre Lake.

Total Dissolved Phosphorus

The inputs (loads) of total dissolved phosphorus (Figure 56) to Byre Lake were estimated at 2,251 kg (2.5 tons). Byre Lake retained approximately 43.5 percent (980 kg) of the total dissolved phosphorus load. Tributary loading percentage of total dissolved phosphorus in total phosphorus was 23.9 percent while the outlet percentage of total dissolved phosphorus increased to 49.4 percent. The 25.5 percent difference may imply in-lake internal processing (loading) of total dissolved phosphorus or may represent a higher percentage of dissolved organic phosphorus compounds, which are utilized at a slower rate than inorganic forms (Wetzel, 2001). Reducing the influx of total dissolved phosphorus will improve the overall trophic state of Byre Lake.

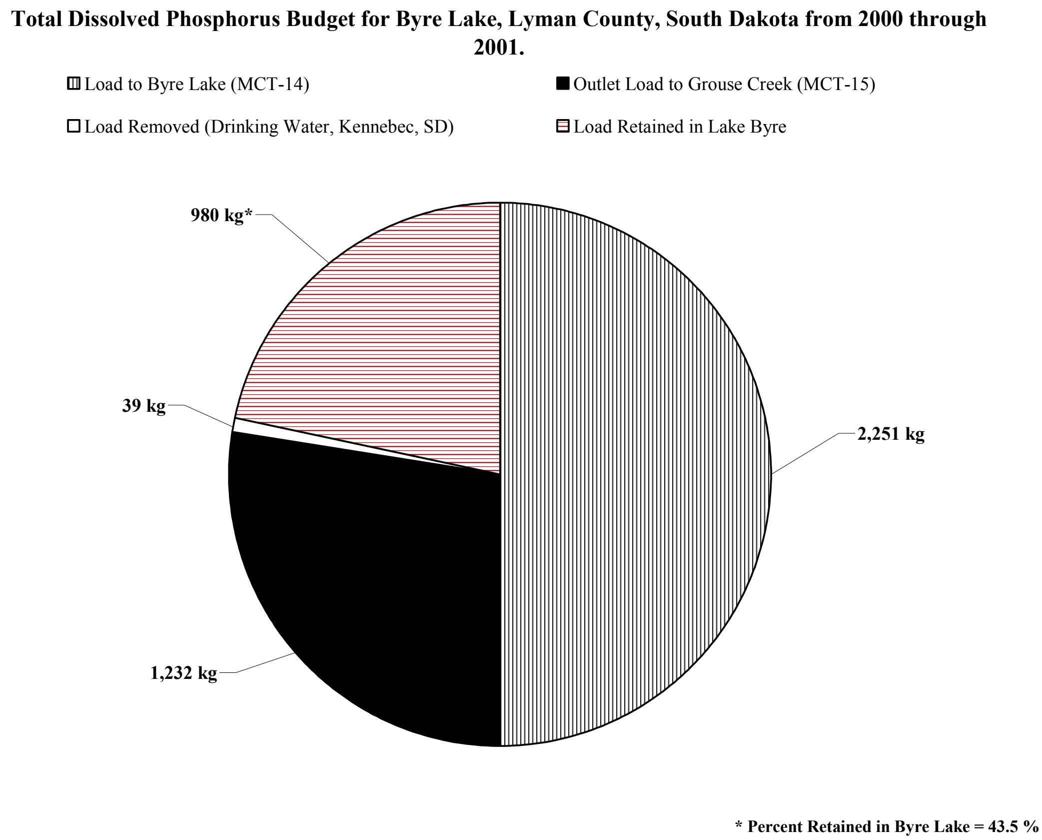


Figure 56. Percent total dissolved phosphorus budget for Byre Lake, Lyman County, South Dakota by source from 2000 through 2001.

Trophic State Index

Carlson's (1977) Trophic State Index (TSI) is one index that can be used to measure the relative trophic state of a waterbody. The trophic state estimates how much algal production occurs in lakes. The lower the nutrient concentrations are, the lower the trophic level (state), and the higher the nutrient concentrations, the more eutrophic (nutrient-rich) the lake. Trophic states range from oligotrophic (least productive) to hyper-eutrophic (excessive amounts of nutrients and productivity). Excessive or increased nutrient concentrations can impact aquatic communities, especially the algal community and can create excessive productivity. Overproduction creates algal blooms that adversely impact the structure and function of indigenous or intentionally introduced aquatic communities (ARSD § 74:51:01:12). Table 33 describes the different numeric limits applied to various levels of the Carlson Index.

Three different parameters are used to compare the trophic index of a lake: 1) total phosphorus, 2) Secchi disk, and 3) chlorophyll-*a*. The TSI trophic levels and numeric ranges applicable to Byre Lake are shown in Table 34 and a graph showing the TSI parameters for 2000 and 2001 is plotted on Carlson's trophic levels as shown in Figure 57.

Table 33. Carlson trophic levels and numeric ranges by category

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

In May 2000, SD DENR published *Ecoregion Targeting for Impaired Lakes in South Dakota* (SD DENR, 2000a). This document proposed ecoregion-specific targeted TSI values based on beneficial uses from May 15 through September 15. By October 2000, EPA had approved the use of ecoregion-specific targets to evaluate lakes using beneficial use categories. Generally, TSI values are now evaluated based upon ecoregion-specific beneficial use categories. This was done to evaluate lakes based upon other lakes within each level III Ecoregion instead of a statewide comparison as was formerly done. Byre Lake is in Ecoregion 43 and is categorized as non-supporting based on the document above. There are three beneficial use categories: non-supporting, partially supporting and fully supporting. Numeric ranges for beneficial use categories are shown in Table 34.

Table 34. Ecoregion 43 beneficial use category and Carlson TSI numeric ranges by beneficial use category.

Ecoregion (43) Beneficial Use Category	TSI Numeric Range
Non-Supporting	71 – 100
Partially Supporting	56 – 70
Fully Supporting	0 – 55

Trophic State Index values are plotted using beneficial use categories in Figure 58. Generally, most of the TSI values were in the partially supporting category. Based on ecoregion targeting (May 15 through September 15), the mean (69.44), total phosphorus (68.38) and chlorophyll-*a* (69.07) TSI values for Byre Lake were categorized as partially supporting (Table 36); while the Secchi TSI (71.01) was non-supporting. All mean TSI values for both the project and ecoregion targeted dates were hyper-eutrophic (Table 36 and Figure 57).

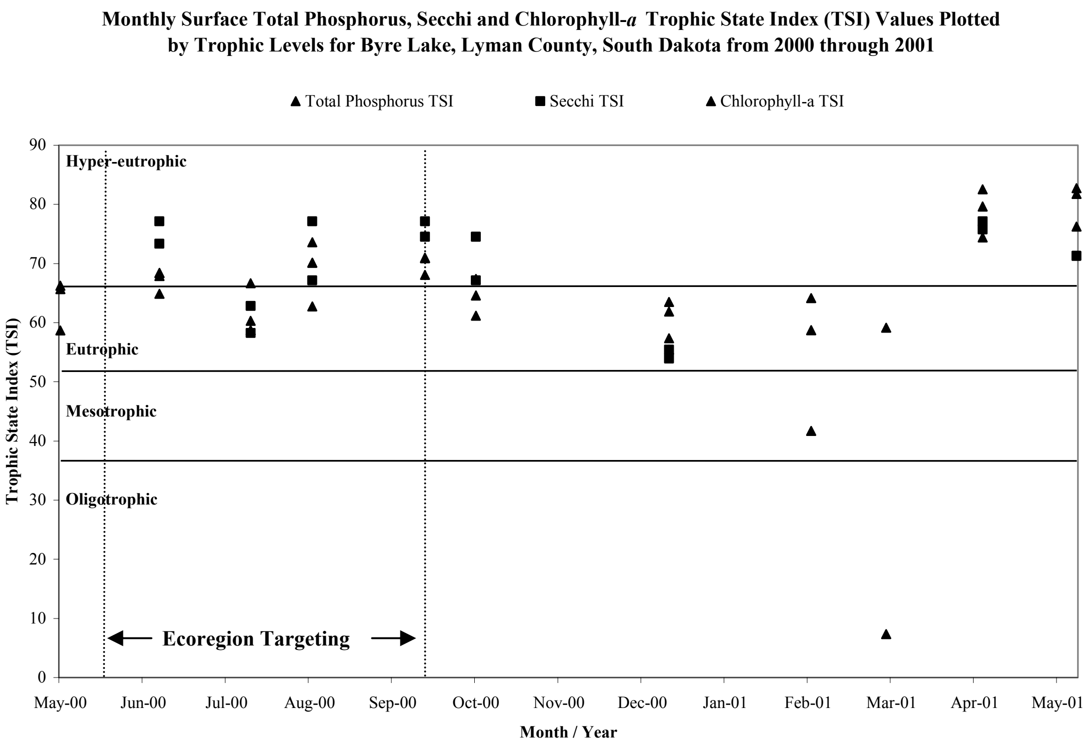


Figure 57. Monthly TSI values for total phosphorus, Secchi and chlorophyll-*a* TSI plotted by Carlson trophic level from Byre Lake, Lyman County, South Dakota by date from 2000 through 2001.

Excessive total phosphorus resulting in elevated TSI values is the result of elevated in-lake total phosphorus concentrations (Figure 55). Based on current data Byre Lake will not meet ecoregional beneficial use criteria. Unrealistic reductions in total phosphorus loads (83 percent) are needed to achieve ecoregion 43 criteria. Realistic criteria/goals for Byre Lake should be based on modified/alternative, county-specific criteria resulting in watershed-specific attainability (Table 35). Byre Lake attainability based on alternative criteria would require a 19.6 percent reduction to meet site specific TSI criteria. BMP reductions in total phosphorus will lower total phosphorus, Secchi and chlorophyll-*a* TSI values, improving water quality in Byre Lake and its watershed.

Table 35. Proposed alternative Lyman County Lakes (Byre Lake, Brakke and Fate Dams) beneficial use category.

Alternative Lyman County (Byre Lake, Brakke and Fate Dams) Lakes Beneficial Use Category	TSI Numeric Range
Non-Supporting	76 – 100
Partially Supporting	66 – 75
Fully Supporting	0 – 65

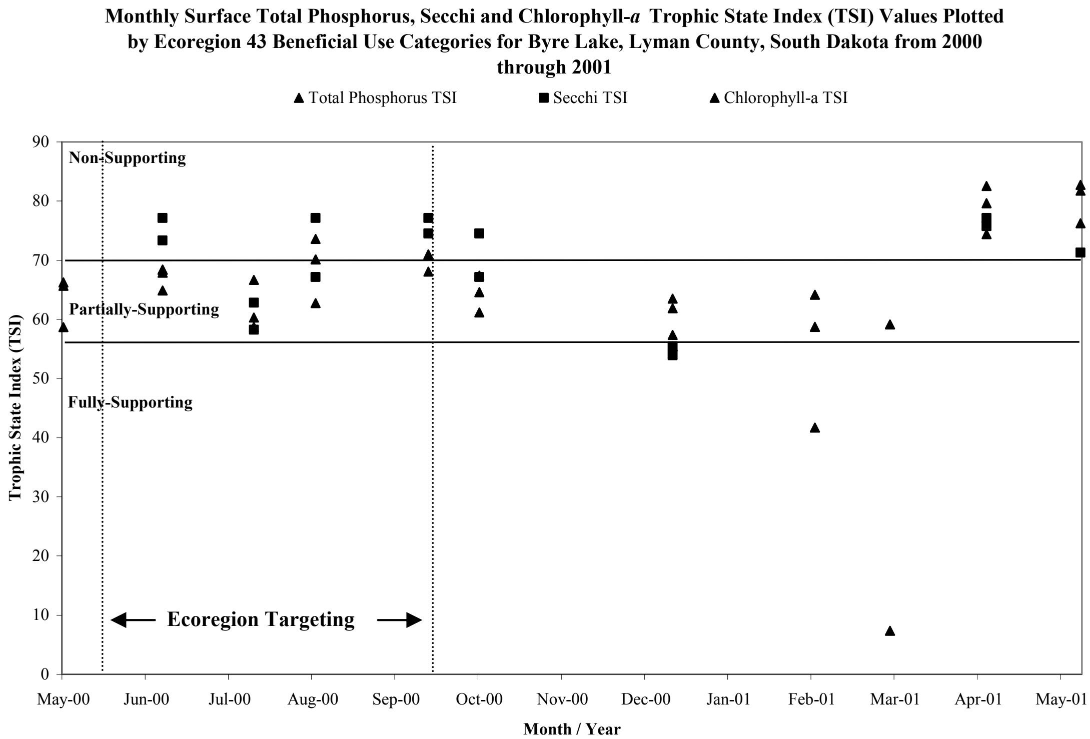


Figure 58. TSI values for total phosphorus, chlorophyll-*a* and Secchi TSI plotted by Ecoregion 43 beneficial use categories for Byre Lake, Lyman County, South Dakota by date from 2000 through 2001.

Table 36. Descriptive statistics for all observed Trophic State Index and ecoregion targeted values collected in Byre Lake, Lyman County, South Dakota in 2000 through 2001.

Parameter	Total Phosphorus	Secchi Depth	Chlorophyll-*a*	Parameters Combined
Mean TSI	64.36	69.63	65.75	66.39
Median TSI	65.65	72.32	67.02	67.37
Standard Deviation	15.26	8.03	9.33	11.84
Ecoregion Targeted (May 15 through September 15)	68.38	71.01	69.07	69.44

Biomass-Based Spatial Comparisons

Carlson 1992 describes a way to determine identify limitation factors based on chlorophyll-*a*. Byre Lake TSI data from 2000 through 2001 indicate total phosphorus and Secchi depth were relatively balanced and were not limiting biomass (chlorophyll-a); based on spatial position with TSI data points oscillating around zero for both the X (phosphorus-limited above the X-axis and something other than phosphorus limitation below the X-axis) and Y-axis (transparency greater than predicted from the chlorophyll-*a* index right of the Y-axis (algal factors) and transparency less than predicted suggesting (organic matter or suspended sediment) left of the Y-axis). Observed oscillations (spread) maybe related to yearly or seasonal variations in hydrologic, nutrient and internal loading (Figure 59). This scenario related well with in-lake total phosphorus concentrations and algal densities. Data indicate that Byre Lake is relatively balanced and tends to be phosphorus limited most of the year (Figure 59 and Figure 48).

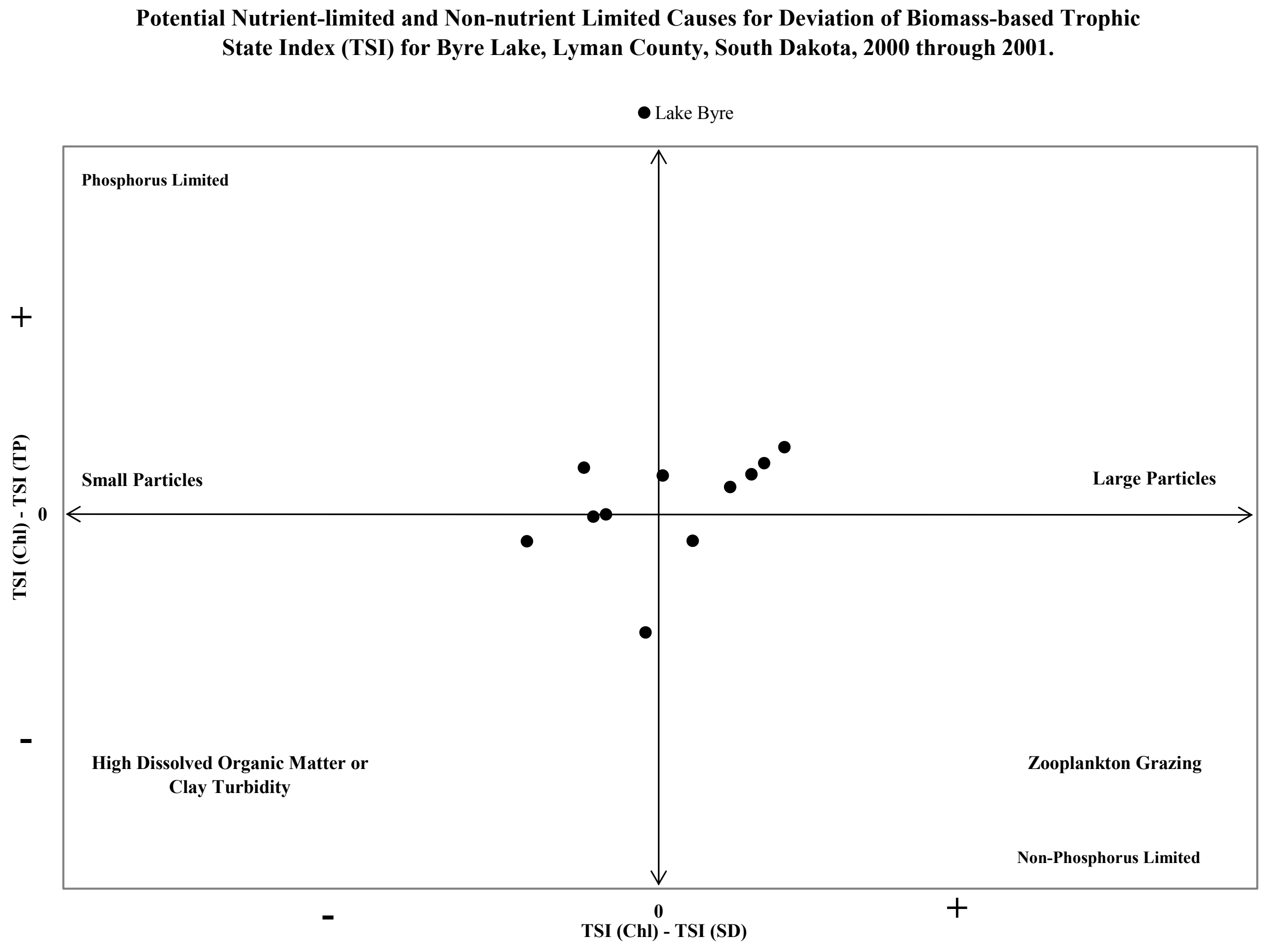


Figure 59. Potential nutrient-limited and non-nutrient limited causes for deviation of biomass-based Trophic State Index (TSI) for Byre Lake, Lyman County, South Dakota in 2000 and 2001.

As part of the Medicine Creek watershed assessment (2000 through 2001), data was also collected on Fate and Brakke Dams for separate evaluation and analysis. Byre Lake, Fate, and Brakke Dams TSI adjusted values using chlorophyll-*a* are provided in Figure 60 for evaluation and regional comparison.

Similar to Byre Lake, both Fate and Brakke Dams data oscillated (around zero (0)) around both the X and Y-axis (Figure 60). All three lakes were relatively similar in seasonal phosphorus (generally oscillating around the X-axis) and seasonal variations in Secchi transparency (generally oscillating around the Y-axis) affecting biomass. Part of the seasonal similarity in biomass-based TSI data is that all three lakes are in the same (Medicine Creek) watershed with similar agricultural disturbances.

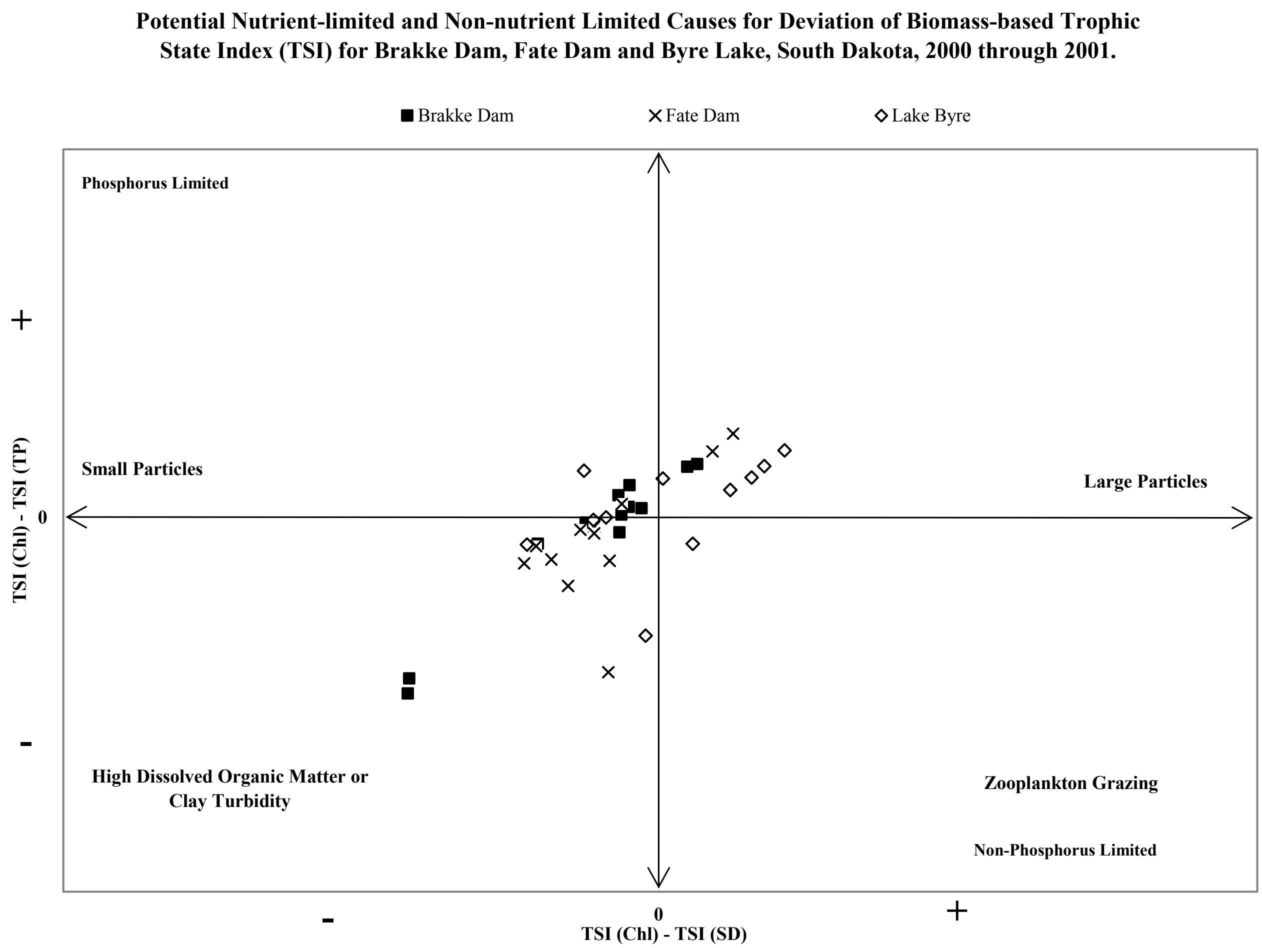


Figure 60. A comparison of potential nutrient-limited and non-nutrient limited causes for deviation of biomass-based Trophic State Index (TSI) between Byre Lake, Fate Dam, and Brakke Dam, Lyman County, South Dakota.

Reduction Response Model (BATHTUB)

The reduction response model used to predict in-lake response to reductions in tributary input was BATHTUB (Walker, 1996). BATHTUB is predictive in that it will assess impacts of changes in water and/or nutrient loadings, and estimate nutrient loadings consistent with given water quality management objectives. In-lake and tributary data collected from this project was used to calculate existing conditions and to predict parameter-specific and mean TSI values based on general reductions in loadings from Grouse Creek (Byre Lake watershed) for 2000 and 2001 (Table 37).

Table 37. Existing and predicted tributary reductions in nitrogen and phosphorus concentrations and predicted in-lake mean TSI values using the BATHTUB model.

	Percent Phosphorus Reduction											
Parameter	**0%**	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**95%**	**99%**
Total Phosphorus (mg/m^3)	94.63	89.29	83.64	77.63	71.19	64.33	56.63	47.92	37.66	24.55	15.65	5.31
Total Nitrogen (mg/m^3)	1607.16	1607.16	1607.16	1607.16	1607.16	1607.16	1607.16	1607.16	1607.16	1607.16	1607.16	1607.16
Composite Nutrient (mg/m^3)	74.64	71.93	68.88	65.41	61.41	56.85	51.32	44.57	35.97	24.06	15.52	5.31
Chlorophyll-*a* (mg/m^3)	21.31	20.65	19.9	19.02	17.97	16.73	15.17	13.18	10.51	6.67	3.93	0.99
Secchi (Meters)	0.56	0.59	0.62	0.65	0.7	0.75	0.83	0.94	1.13	1.56	2.2	5
Organic Nitrogen (mg/m^3)	727	712.16	694.99	674.89	651.03	622.79	587.19	541.73	480.96	393.29	330.77	263.92
Total Phosphorus-Total Dissolved Phosphorus (mg/m^3)	60.34	59.18	57.84	56.27	54.41	52.2	49.42	45.87	41.13	34.29	29.4	24.19
Antilog PC-1 (Principle Components)	942.7	881.53	815.26	743.12	664.2	579.19	483.3	376.64	257.67	126.29	58.29	9.11
Antilog PC-2 (Principle Components)	6.68	6.77	6.86	6.95	7.03	7.12	7.18	7.22	7.16	6.86	6.38	5.18
(Total Nitrogen - 150) / Total Phosphorus	15.4	16.32	17.42	18.77	20.47	22.65	25.73	30.41	38.69	59.36	93.09	274.18
Inorganic Nitrogen / Phosphorus	25.66	29.73	35.35	43.64	56.98	81.14	141.59	521.76	1126.2	1213.87	1276.4	1343.24
Turbidity 1/M (1/Secchi – 0.025* Chlorophyll-*a*)	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12
Mixed layer Depth * Turbidity	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05
Mixed layer Depth / Secchi	3.26	3.12	2.97	2.81	2.63	2.43	2.21	1.94	1.62	1.17	0.83	0.37
Chlorophyll-*a* * Secchi	11.94	12.1	12.25	12.39	12.51	12.58	12.57	12.39	11.87	10.42	8.64	4.97
Mean Chlorophyll-*a* / Total Phosphorus	0.23	0.23	0.24	0.24	0.25	0.26	0.27	0.28	0.28	0.27	0.25	0.19
Frequency (Chlorophyll-*a* >10) %	81.86	80.51	78.82	76.64	73.75	69.87	64.16	55.39	40.93	16.76	3.45	0
Frequency (Chlorophyll-*a* >20) %	41.75	39.81	37.52	34.78	31.47	27.5	22.49	16.28	8.89	1.87	0.17	0
Frequency (Chlorophyll-*a* >30) %	19.43	18.08	16.55	14.8	12.79	10.53	7.93	5.08	2.27	0.31	0.02	0
Frequency (Chlorophyll-*a* >40) %	9.24	8.44	7.55	6.56	5.47	4.31	3.05	1.78	0.69	0.07	0	0
Frequency (Chlorophyll-*a* >50) %	4.59	4.13	3.63	3.08	2.5	1.9	1.28	0.69	0.24	0.02	0	0
Frequency (Chlorophyll-*a* >60) %	2.39	2.12	1.83	1.53	1.21	0.89	0.58	0.29	0.09	0.01	0	0
Carlson TSI-(Phosphorus)	69.76	68.92	67.98	66.91	65.66	64.2	62.36	59.95	56.48	50.3	43.81	28.24
Carlson TSI-(Chlorophyll-*a*)	60.61	60.3	59.94	59.5	58.94	58.24	57.28	55.9	53.68	49.21	44.02	30.55
Carlson TSI-(Secchi)	68.34	67.7	66.99	66.17	65.22	64.11	62.72	60.89	58.25	53.56	48.63	36.8
Mean TSI	66.24	65.64	64.97	64.19	63.27	62.18	60.79	58.91	56.14	51.02	45.49	31.86

Existing average tributary phosphorus concentrations (0.499 mg/L) were reduced by 10 percent successively (10 percent increments) and modeled to create an in-lake reduction curve. Reductions in each TSI category (Secchi, total phosphorus and chlorophyll-*a*) are plotted by Ecoregion 43 beneficial use categories separately in Figure 61.

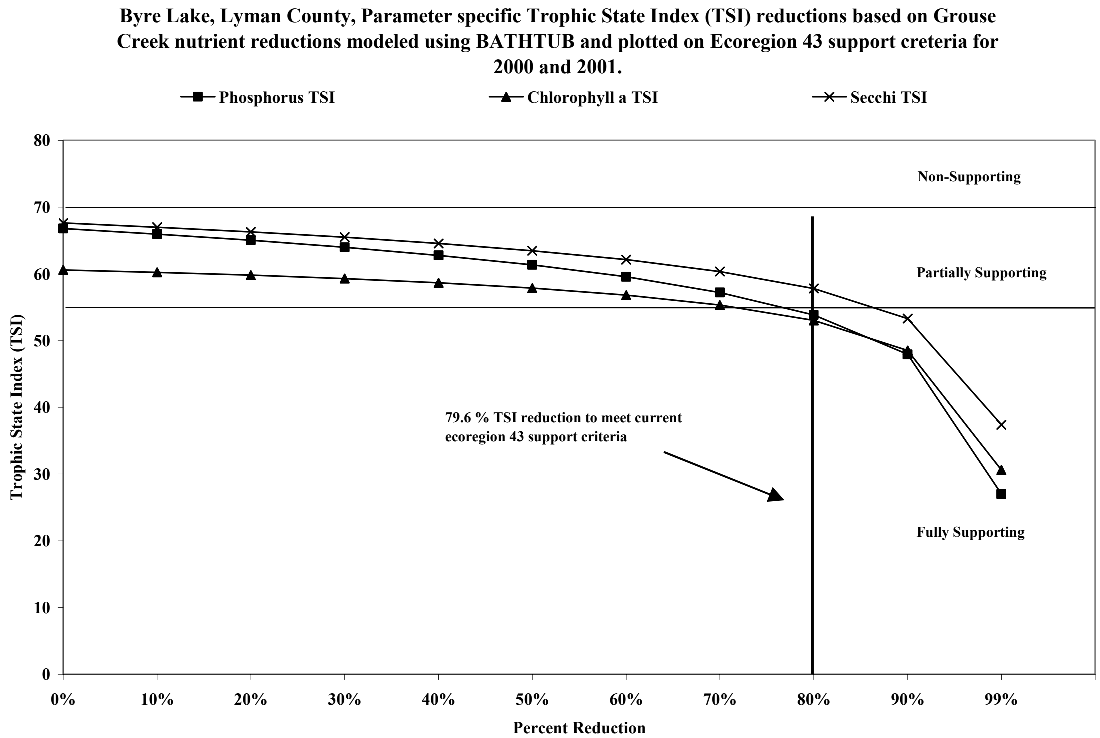


Figure 61. Predicted Trophic State Index (TSI) reductions using the BATHTUB reduction model ranked by Ecoregion 43 beneficial use categories for Byre Lake, Lyman County, South Dakota using 2000 through 2001 loading data.

Initial Secchi, and total phosphorus Trophic State Index (TSI) reduction values begin in the partially supporting category based on ecoregion 43 beneficial use categories. Secchi and Chlorophyll-*a* TSI reduction values declined at a similar rate within the partially supporting category; however, predicted total phosphorus TSI values declined faster in the partially supporting category. Predicted TSI began to markedly trend downward only after a 79.6 percent phosphorus load reduction (Figure 61). This suggests that tributary total phosphorus concentrations and overall loading must be reduced approximately 80 percent before they significantly affect changes in Secchi and chlorophyll-*a* TSI values.

Mean TSI values were calculated for each reduction and plotted by beneficial use categories (Figure 62). Current mean TSI values for 2000 and 2001 were calculated using "BATHTUB" and found to be partially supporting. Again, using predicted TSI reductions based on 2000 through 2001 tributary water quality data, a 79.6 percent reduction in total phosphorus loading will bring mean TSI values the lake into fully supporting status (Figure 61 and Figure 62).

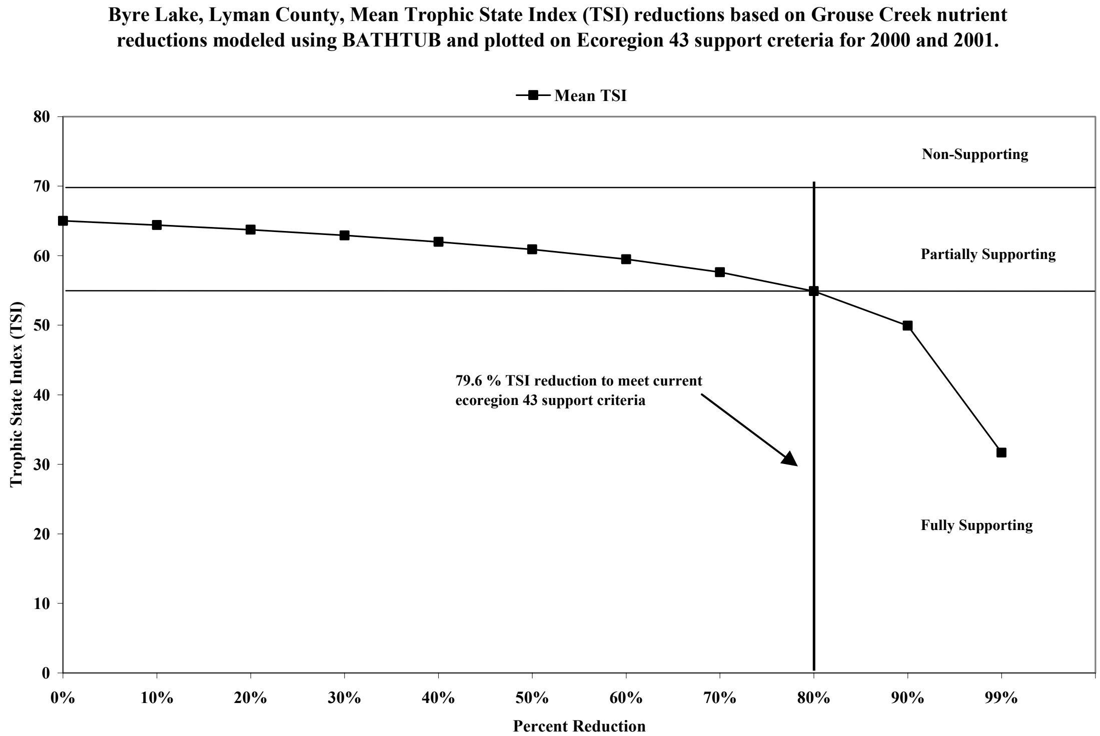


Figure 62. Predicted mean Trophic State Index (TSI) reductions using the BATHTUB reduction model ranked by Ecoregion 43 beneficial use categories for Byre Lake, Lyman County, South Dakota using 2000 through 2001 loading data.

The current phosphorus load to Byre Lake based on 2000 through 2001 data is 9,391 kg/yr (total phosphorus budget, pages 95 trough 96). Current phosphorus loading would have to be reduced by 7,475 kg/yr (79.6 percent) to fully support beneficial uses based on phosphorus TSI values. Reduction in in-lake phosphorus may also be realized by reducing what internal loading there is in Byre Lake. To fully support beneficial uses based on phosphorus TSI the TMDL would be 1,916 kg/yr.

Mean TSI values were originally used to set current ecoregional beneficial use criteria for lakes in South Dakota (SD DENR, 2000a). Currently, the target for full support in ecoregion 43 is a mean TSI value ≤ 55.00. However, current ecoregional (ecoregion 43) target criteria appear not to fit Byre Lake based on AnnAGNPS watershed loading and BATHTUB in-lake eutrophication modeling. AnnAGNPS model was used to estimate watershed loading under ideal conditions (entire watershed converted to grassland with a minimum grass height of 10.2 cm (4 inches)) indicate the maximum phosphorus reduction in this watershed would be 28.1 percent (Appendix B). BATHTUB was then used to model AnnAGNPS phosphorus reduction to in-lake trophic response under ideal conditions. Data indicate under ideal conditions (mean TSI 64.16); Byre Lake could not meet ecoregional-based beneficial use criteria based on current targets (Appendix B).

Current watershed conditions (loading) as modeled through BATHTUB result in a mean in-lake TSI value of 66.24 (Table 48). The Byre Lake/Grouse Creek watershed can not meet current ecoregional-based beneficial use criteria which are unrealistic and unachievable in the Byre Lake watershed. Alternative site-specific (watershed-specific) evaluation criteria (fully supporting, mean TSI $\leq$ 65.00) are proposed based on AnnAGNPS modeling, BMPs and watershed-specific phosphorus reduction attainability (Figure 63).

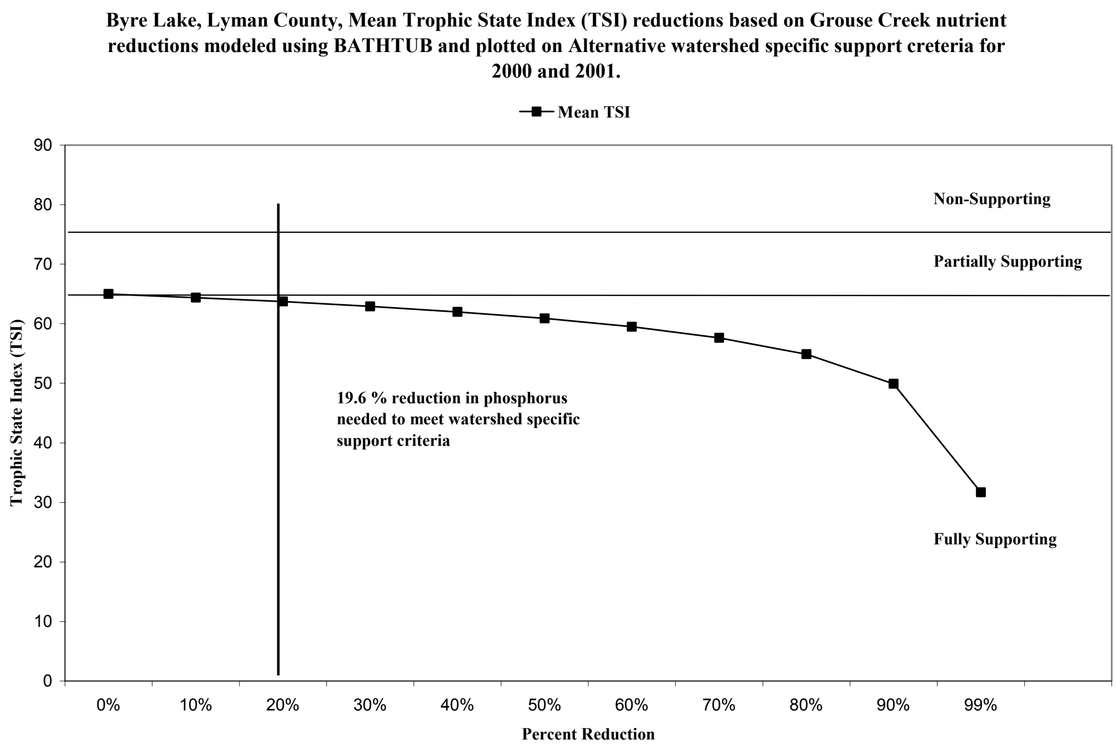


Figure 63. Mean Trophic State Index (TSI) reductions plotted on alternative watershed specific support criteria for Byre Lake, Lyman County, South Dakota based on 2000 through 2001 data.

Based on site-specific criteria and under current conditions (mean TSI 66.24), Byre Lake only partially supports beneficial uses using this evaluation criteria. The site (watershed) specific criteria/goals are more realistic and attainable based on AnnAGNPS modeling and BMP reductions within the Byre Lake watershed. BMP-based reduction criteria for Byre Lake was estimated based on a 19.6 percent reduction (1,841 kg/yr) in total phosphorus loads resulting in a phosphorus TMDL of 7,550 kg/yr resulting in a mean TSI of 65.00.

Thus, reductions in total phosphorus loading are crucial to any long-term watershed improvement scenario. Realistic criteria/goals for Byre Lake should be based on BMP reductions within the Byre Lake watershed resulting in watershed-specific criteria.

3.2 Groundwater Monitoring

Groundwater was not monitored during the Byre Lake watershed assessment, part of the Medicine Creek Watershed Assessment Project.

3.3 Biological Monitoring (In-lake)

Byre Lake Phytoplankton

Composite surface algae samples were collected monthly at two in-lake water quality monitoring sites, from May 1, 2000 through December 14, 2000, and February 5, 2001 through May 15, 2001 (Figure 22). Samples were not collected in November 2000. A total of 89 algal taxa (genera or species) including two 'unidentified' categories were collected in 18 samples from this small 127-acre reservoir during this survey (Table 38). Algae species richness (the number of taxa observed) was rated as 'high' compared to other recently monitored small (< 200 ac.) eutrophic state lakes (mean: 73 taxa). However, the relative abundance of those taxa was uneven, with 64 percent of taxa each contributing less than 0.1 percent to total algal abundance, and only three species comprising more than 73 percent of total density for the survey (Appendix E, Table E-1). A similar algal distribution was observed in Corsica Lake, a small eutrophic impoundment in Douglas County, South Dakota.

Table 38. Algae species collected from Byre Lake, Lyman County, South Dakota from 2000 through 2001.

Species	Algae Type
Achnanthes minutissima	Diatom
Actinastrum hantzschii	Non-Motile Green Algae
Amphiprora ornata	Diatom
Anabaena flos-aquae	Blue-Green Algae
Anacystis marina	Blue-Green Algae (colonial)
Ankistrodesmus falcatus	Non-Motile Green Algae
Ankistrodesmus sp.	Non-Motile Green Algae
Aphanizomenon flos-aquae	Blue-Green Algae
Aphanocapsa sp.	Blue-Green Algae
Asterionella formosa	Diatom
Carteria sp.	Flagellated Algae (Green Algae)
Characium limneticum	Non-Motile Green Algae
Chlamydomonas sp.	Flagellated Algae (Green Algae)
Chromulina sp.	Flagellated Algae (Yellow-Brown Algae)
Chroomonas sp.	Flagellated Algae (cryptophyte)
Chrysochromulina parva	Flagellated Algae (Yellow-Brown Algae)
Closteriopsis longissima	Non-Motile Green Algae
Closterium sp.	Green Algae (desmid)
Cocconeis pediculus	Diatom
Cocconeis placentula	Diatom
Coelastrum microporum	Non-Motile Green Algae
Cryptomonas erosa	Flagellated Algae (cryptophyte)
Cryptomonas sp.	Flagellated Algae (cryptophyte)
Cyclotella meneghiniana	Diatom
Cyclotella pseudostelligera	Diatom
Cyclotella stelligera	Diatom
Cymatopleura elliptica	Diatom
Cymatopleura solea	Diatom
Diatoma tenue v. *elongatum*	Diatom
Dictyosphaerium pulchellum	Non-Motile Green Algae
Dinobryon sertularia	Flagellated Algae (Yellow-Brown Algae)
Diploneis smithi	Diatom
Diplostauron sp.	Flagellated Algae (Green Algae)
Euglena sp.	Flagellated Algae (euglenoid)
Glenodinium sp.	Flagellated Algae (Dinoflagellate)
Gymnodinium sp.	Flagellated Algae (Dinoflagellate)
Gyrosigma sp.	Diatom
Kirchneriella sp.	Non-Motile Green Algae
Mallomonas pseudocoronata	Flagellated Algae (Yellow-Brown Algae)
Mallomonas sp.	Flagellated Algae (Yellow-Brown Algae)
Melosira granulata	Diatom
Melosira granulata v. *angustissima*	Diatom
Micractinium pusillum	Non-Motile Green Algae
Micractinium quadrisetum	Non-Motile Green Algae
Micractinium sp.	Non-Motile Green Algae
Microcystis aeruginosa	Blue-Green Algae
Navicula capitata	Diatom
Navicula minima	Diatom

Table 38 (continued). Algae species collected from Byre Lake, Lyman County, South Dakota from 2000 through 2001.

Species	Algae Type
Navicula sp.	Diatom
Nitzschia acicularis	Diatom
Nitzschia capitellata	Diatom
Nitzschia palea	Diatom
Nitzschia paleacea	Diatom
Nitzschia sp.	Diatom
Nitzschia vermicularis	Diatom
Ochromonas sp.	Non-Motile Green Algae
Oocystis lacustris	Non-Motile Green Algae (colonial)
Oocystis pusilla	Non-Motile Green Algae (colonial)
Oocystis sp.	Non-Motile Green Algae (colonial)
Oscillatoria agardhii	Blue-Green Algae
Pandorina morum	Flagellated Algae (Green Algae)
Pascheriella tetras	Flagellated Algae (Green Algae)
Pediastrum duplex	Non-Motile Green Algae (colonial)
Peronia sp.	Diatom
Phacus pseudonordstedtii	Flagellated Algae (euglenoid)
Phacus sp.	Flagellated Algae (euglenoid)
Rhodomonas minuta	Flagellated Algae (cryptophyte)
Scenedesmus acuminatus	Non-Motile Green Algae
Scenedesmus quadricauda	Non-Motile Green Algae
Selenastrum gracile	Non-Motile Green Algae
Selenastrum minutum	Non-Motile Green Algae
Sphaerocystis schroeteri	Non-Motile Green Algae
Staurastrum sp.	Non-Motile Green Algae
Stephanodiscus astraea minutula	Diatom
Stephanodiscus hantzschii	Diatom
Stephanodiscus minutus	Diatom
Surirella ovalis	Diatom
Syncrypta volvox	Flagellated Algae (Yellow-Brown Algae)
Synedra acus	Diatom
Synedra sp.	Diatom
Synedra ulna	Diatom
Synura uvella	Flagellated Algae (Yellow-Brown Algae)
Trachelomonas hispida	Flagellated Algae (euglenoid)
Trachelomonas sp.	Flagellated Algae (euglenoid)
Trachelomonas volvocina	Flagellated Algae (euglenoid)
Unidentified algae	Algae
Unidentified flagellates	Flagellated Algae
Unidentified pennate diatoms	Diatom
Uroglena sp.	Flagellated Algae (Yellow-Brown Algae)
Total Species	**89**

Diatoms (Bacillariophyceae) represented the most diverse group of algae in Byre Lake with 33 taxa (37 percent of all species collected) followed by five phyla of motile (flagellated) algae with 26 taxa, including an 'unidentified flagellates' category, and by non-motile green algae (Chlorophyta) with 23 taxa. As occurred frequently in monitored small lakes, blue-green algae (Cyanophyta) were the least diverse but often the most abundant algal group collected. Byre Lake had only 6 species identified during the present survey (Appendix E, Table E-1). A single blue-green species, *Aphanizomenon flos-aquae*, comprised half of total algal abundance (density in algal cells per milliliter of water) and one-third of the biovolume during this study (Appendix E, Table E-1 and Table E-2).

Yellow-brown (or, golden-brown) flagellates (Chrysophyta) were the most diverse phylum of motile algae in Byre Lake comprising 9 taxa, followed by euglenoid flagellates (Euglenophyta) with 6 species. Other phyla were less diverse, including green flagellates (Chlorophyta) and cryptomonads (Cryptophyta) with 4 taxa each, and dinoflagellates (Pyrrhophyta) represented by only two species.

Byre Lake algal density and biovolume (a relative expression of biomass) showed a high seasonal variability during the study period, ranging over more than three magnitudes. Algal density (abundance) ranged from 66 cells/ml on May 1, 2000 to 71,606 cells/ml on May 15, 2001 with the corresponding range of biovolume from 16,545 μm^3/ml to 17,457,290 μm^3/ml. (Table 39). The extremely small algae population recorded on the former date is unusual for a eutrophic lake in mid-spring. Perhaps, this low density is a sampling artifact. The mean algae biovolume for this assessment amounted to 3,761,659 µm3/ml for an average algal density of 21,107 cells/ml. Considering the above anomaly, this probably places the algae productivity of Byre Lake in the mid-range of recently monitored small eutrophic state lakes.

The Byre Lake phytoplankton during this survey consisted primarily of blue-green algae (almost all *Aphanizomenon*) and diatoms which together made up 80 percent of the algae population, both in terms of number of cells and biovolume. Flagellated algae were of secondary importance, contributing slightly more than 13% of algal abundance and nearly 18% of total biovolume. Moreover, dinoflagellates that are important constituents of the summer plankton in a number of eutrophic state lakes, occurred only in trace densities in Byre Lake during this investigation (< 0.1 percent). Non-motile green algae represented the least important major algae group in the lake, accounting for 3 percent of density and slightly more than 2 percent of biovolume.

Table 39. Byre Lake algal density (cells/ml), biovolume (μm^3/ml) and percentage by algal group from 2000 through 2001.

Date	Algae Group	Density	Density %	Biovolume	Biovolume %
01-May-00	Flagellated Algae	17	25.8%	3,660	22.1%
	Blue Green Algae	0	0.0%	0	0.0%
	Diatom	44	66.7%	12,770	77.2%
	Non-Motile Green Algae	5	7.6%	115	0.7%
	Unidentified Algae	0	0.0%	0	0.0%
Total		**66**		**16,545**	
07-Jun-00	Flagellated Algae	546	1.4%	34,580	0.7%
	Blue Green Algae	37,515	95.6%	4,376,601	94.6%
	Diatom	0	0.0%	0	0.0%
	Non-Motile Green Algae	1,185	3.0%	215,908	4.7%
	Unidentified Algae	0	0.0%	0	0.0%
Total		**39,246**		**4,627,089**	
11-Jul-00	Flagellated Algae	443	2.1%	132,726	5.1%
	Blue Green Algae	20,801	96.8%	2,433,717	94.0%
	Diatom	0	0.0%	0	0.0%
	Non-Motile Green Algae	213	1.0%	22,149	0.9%
	Unidentified Algae	23	0.1%	690	0.0%
Total		**21,480**		**2,589,282**	
03-Aug-00	Flagellated Algae	994	3.1%	148,276	3.9%
	Blue Green Algae	30,486	95.3%	3,555,354	93.2%
	Diatom	353	1.1%	106,166	2.8%
	Non-Motile Green Algae	154	0.5%	6,567	0.2%
	Unidentified Algae	0	0.0%	0	0.0%
Total		**31,987**		**3,816,363**	
14-Sep-00	Flagellated Algae	220	0.8%	114,241	2.2%
	Blue Green Algae	20,927	74.2%	2,273,422	43.8%
	Diatom	5,845	20.7%	2,493,393	48.0%
	Non-Motile Green Algae	1,206	4.3%	312,740	6.0%
	Unidentified Algae	0	0.0%	0	0.0%
Total		**28,198**		**5,193,796**	
03-Oct-00	Flagellated Algae	1,455	9.6%	286,392	14.4%
	Blue Green Algae	10,114	66.7%	1,183,338	59.5%
	Diatom	731	4.8%	193,825	9.7%
	Non-Motile Green Algae	2,864	18.9%	325,251	16.4%
	Unidentified Algae	0	0.0%	0	0.0%
Total		**15,164**		**1,988,806**	

Table 39 (continued). Byre Lake algal density (cells/ml), biovolume (µm^3/ml) and percentage by algal group from 2000 through 2001.

Date	Algae Group	Density	Density %	Biovolume	Biovolume %
14-Dec-00	Flagellated Algae	3,269	95.9%	627,973	96.0%
	Blue Green Algae	0	0.0%	0	0.0%
	Diatom	92	2.7%	25,185	3.8%
	Non-Motile Green Algae	46	1.4%	1,110	0.2%
	Unidentified Algae	0	0.0%	0	0.0%
Total		**3,407**		**654,268**	
05-Feb-01	Flagellated Algae	587	66.5%	106,830	77.9%
	Blue Green Algae	13	1.5%	52	0.0%
	Diatom	12	1.4%	22,110	16.1%
	Non-Motile Green Algae	1	0.1%	25	0.0%
	Unidentified Algae	270	30.6%	8,100	5.9%
Total		**883**		**137,117**	
05-Mar-01	Flagellated Algae	2,339	36.1%	297,655	92.6%
	Blue Green Algae	3,854	59.4%	15,416	4.8%
	Diatom	0	0.0%	0	0.0%
	Non-Motile Green Algae	20	0.3%	360	0.1%
	Unidentified Algae	270	4.2%	8,100	2.5%
Total		**6,483**		**321,531**	
10-Apr-01	Flagellated Algae	12,214	89.4%	4,430,219	96.8%
	Blue Green Algae	0	0.0%	0	0.0%
	Diatom	239	1.7%	109,563	2.4%
	Non-Motile Green Algae	86	0.6%	2,780	0.1%
	Unidentified Algae	1,120	8.2%	33,600	0.7%
Total		**13,659**		**4,576,162**	
15-May-01	Flagellated Algae	8,943	12.5%	1,072,261	6.1%
	Blue Green Algae	311	0.4%	14,928	0.1%
	Diatom	55,350	77.3%	16,109,966	92.3%
	Non-Motile Green Algae	1,522	2.1%	95,735	0.5%
	Unidentified Algae	5,480	7.7%	164,400	0.9%
Total		**71,606**		**17,457,290**	

In the relative abundance of the various algal divisions discussed above, Byre Lake resembled typical larger Midwestern hardwater eutrophic lakes as described by Prescott (1962). Those waterbodies are described as being frequently dominated by blue-green algae and diatoms with green algae comprising a small percentage of the total algae community. Most other monitored small (< 200 ac.) eutrophic state lakes did not fit this description, often having larger populations of green algae and flagellated algae and comparatively smaller populations of diatoms and blue-green algae. The reasons for this difference can not be readily explained at this time. Perhaps the other waterbodies contained a greater abundance of nitrogenous and other organic compounds and dissolved CO_2 that would favor green and motile algae (Shapiro 1973, Prescott 1962).

The seasonal distribution of algal abundance in Byre Lake for the study period consisted of two peaks, a small peak in early June 2000 consisting primarily of the blue-green alga *Aphanizomenon* and a large spring diatom pulse in mid-May 2001 primarily composed of *Stephanodiscus minutus* (= S. *astraea minutula*) and *Stephanodiscus hantzschii*. The seasonal changes in algal biovolume generally paralleled those for total algal abundance (Figure 64).

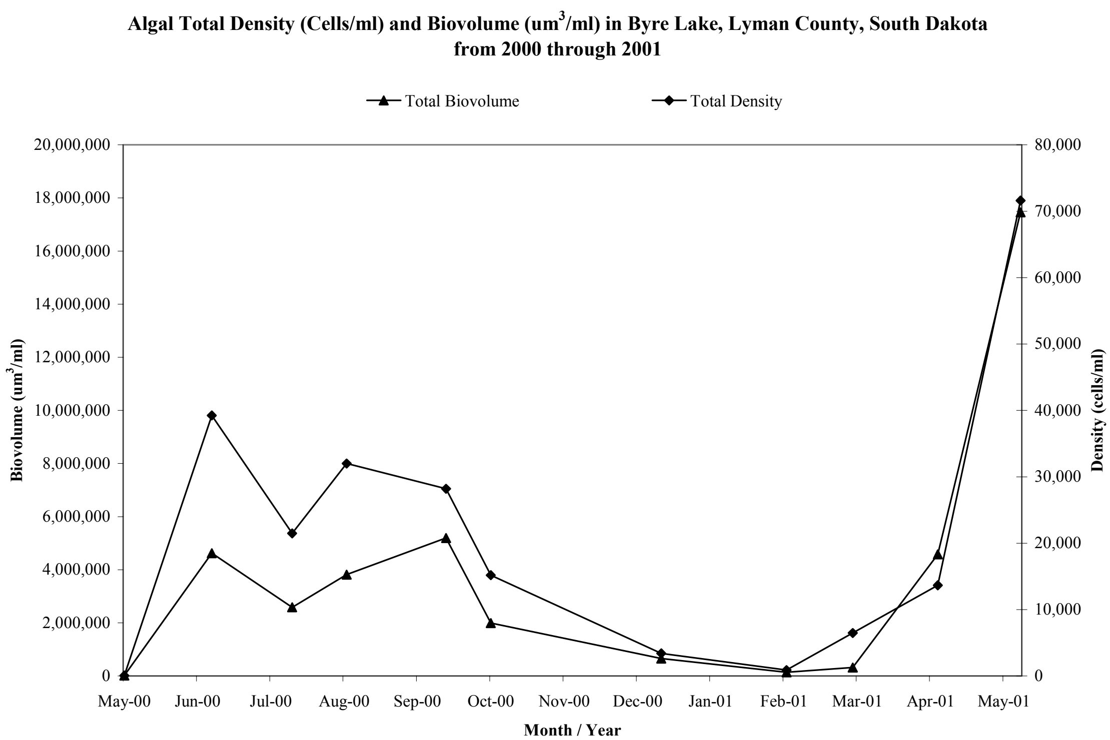


Figure 64. Total algal density (cells/ml) and biovolume (μm^3/ml) for Byre Lake, Lyman County, South Dakota from 2000 through 2001.

The seasonal succession of major algae groups in Byre Lake seemed to follow a typical pattern noted for eutrophic lakes (Wetzel 2001). Flagellated algae made up more than 90 percent of the algae population in winter and early spring, followed by a mid-spring diatom pulse and a moderate to moderately-large bloom of blue-green algae (mainly *Aphanizomenon*) from late spring to early autumn (Figure 65 and Figure 66). *Aphanizomenon*, a nuisance blue-green, ranged in abundance from 37,173 cells/ml to 8,100 cells/ml when it was present in the plankton from June 7 to October 3, 2000. Mean density of this species for the project period was 22,050 cells/ml when present in the lake. This is considered a relatively moderate density for a eutrophic waterbody.

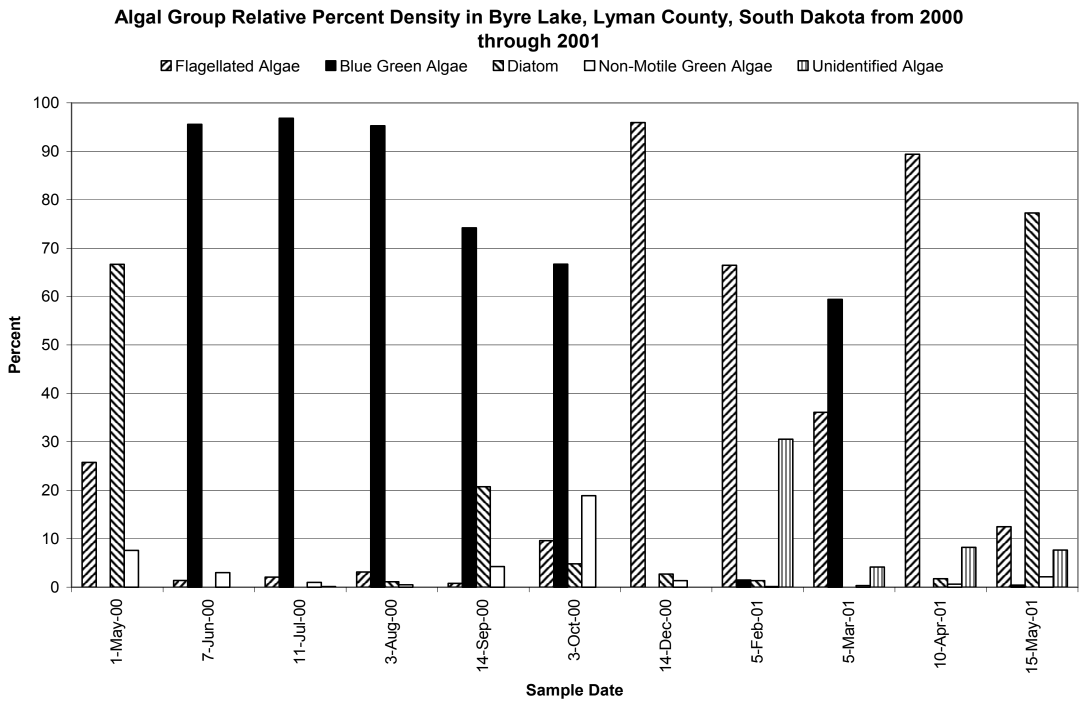


Figure 65. Relative percent density by algal group for Byre Lake, Lyman County, South Dakota from 2000 through 2001.

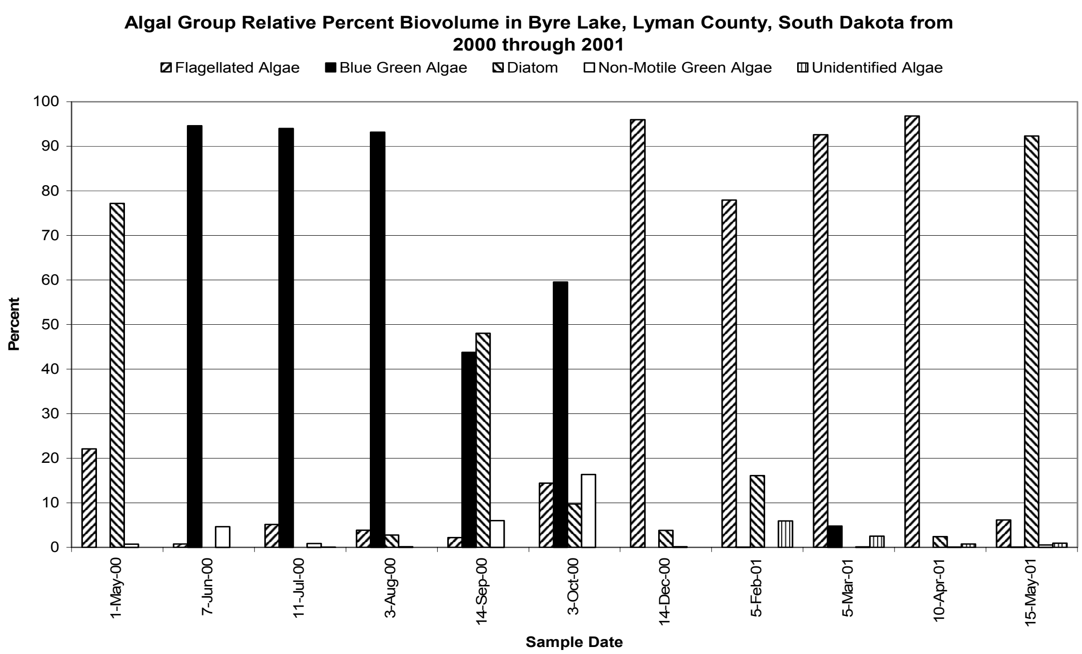


Figure 66. Relative percent biovolume by algal group for Byre Lake, Lyman County, South Dakota from 2000 through 2001.

Aquatic Macrophyte Survey

An aquatic macrophyte survey of Byre Lake was conducted on August 21, 2001. The survey consisted of surveying 15 transects, quantify and identifying the submergent plant community (Figure 67). Each transect had one survey point with four plant retrieves to evaluate the macrophyte community (approximately ten meters from shore). Sampling at each survey point consisted of casting a plant grapple approximately six meters in four separate directions (north, south, east and west), slowly retrieving the grapple and identifying plant species retained on the grapple.

The survey also identified bank stability, vegetative protection and riparian vegetative zone width using a rating scale ranging from zero through ten. These were used to identify potential erosional areas around Byre Lake. Aquatic plant species were identified using Fassett (1957) and Crow and Hellquist (2000) and are listed in Table 40. floating-leaf pondweed (*Potamogeton natans*) and sago pondweed (*Stuckenia pectinata*) were the most abundant submerged species in Byre Lake in 2001.

Table 40. Submergent plant species identified in Byre Lake, Lyman County, South Dakota in 2001.

Number		Scientific Name
	Transect Submerged Species	
1	Floating-Leaf Pondweed	*Potamogeton natans*
2	Sago Pondweed	*Stuckenia pectinata*
3	Bushy Pondweed	*Najas* sp.
4	Flat-Stemmed Pondweed	*Potamogeton zosteriformis*
5	Unidentified	-

Submergent macrophyte species were sampled using 15 transects (Figure 67) with 60 survey points throughout the lake. Four separate transect species were identified during the survey and are listed on Table 40. One species (unidentified grass species) was encountered at two transect locations (transect 1 and 15). All four identified macrophyte species, sago pondweed (*Stuckenia pectinata*), floating-leaf pondweed (*Potamogeton natans*), bushy pondweed (*Najas* sp.) and flat-stemmed pondweed (*Potamogeton zosteriformis*) are relatively ubiquitous and commonly found in other lakes in South Dakota. Eleven of the fifteen (73.3 percent) transects yielded submerged vegetation (Table 41).

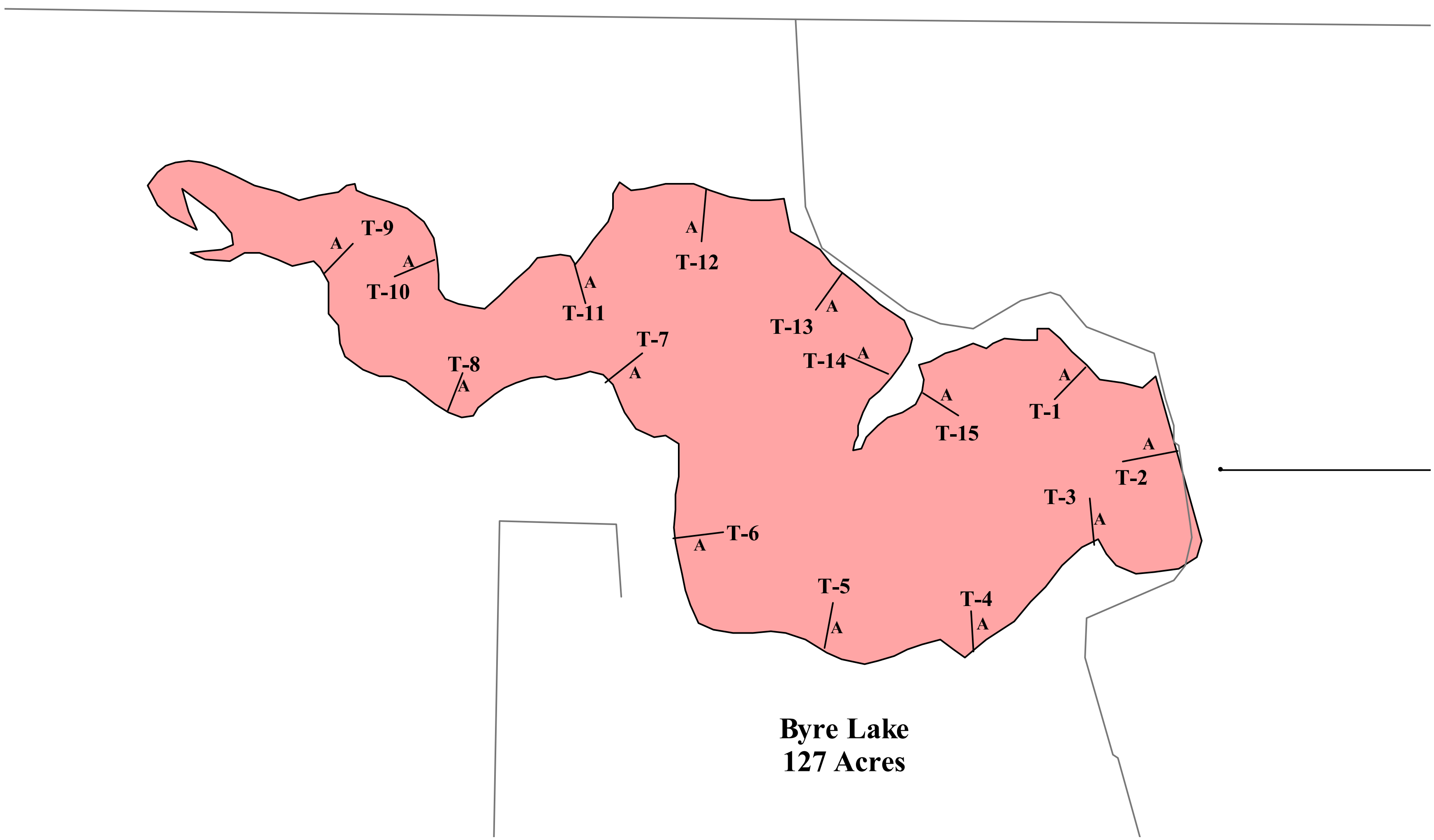


Figure 67. Submergent macrophyte transect locations at Byre Lake, Lyman County, South Dakota in 2001.

Table 41. Shoreline and transect submergent plant species sampled from Byre Lake, Lyman County, South Dakota in 2001.

					Habitat Parameter Score			
Transect and Station	Total Depth (m)	Secchi Depth (m)	Transect Submergent Species	Transect Density	Vegetative Protection	Riparian Vegetative Zone Width	Bank Stability	Total Out of (30 Points)
1A	1.10	0.15	*Potamogeton natans*	1	8	8	9	25
			Stuckenia pectinata	3				
			Najas sp.	1				
			Potamogeton zosteriformis	2				
			Unidentified	1				
2A	2.60	0.10	None	0	1	1	9	11
3A	2.40	0.10	*Potamogeton natans*	1	7	5	8	20
4A	1.20	0.10	*Stuckenia pectinata*	3	9	7	9	25
5A	0.65	0.10	None	0	1	4	0	5
6A	1.00	0.15	*Stuckenia pectinata*	1	4	6	3	13
7A	0.80	0.15	*Potamogeton natans*	1	7	6	9	22
			Stuckenia pectinata	1				
8A	0.45	0.10	*Potamogeton natans*	1	7	6	8	21
			Stuckenia pectinata	1				
9A	0.25	0.10	*Stuckenia pectinata*	3	7	7	9	23
10A	0.85	0.15	*Potamogeton natans*	1	5	5	4	14
11A	0.70	0.20	None	0	9	4	9	22
12A	0.80	0.20	None	0	6	1	3	10
13A	0.70	0.15	*Potamogeton natans*	3	5	1	5	11
14A	1.20	0.10	*Stuckenia pectinata*	1	8	1	9	18
			Najas sp.	2				
15A	0.90	0.15	*Potamogeton natans*	2	8	2	9	19
			Najas sp.	2				
			Unidentified	1				

Canfield et al. (1985) proposed a model to determine maximum depth of colonization (MDC) for submerged macrophytes. The model is influenced by regional differences in plant response, changes in available light and seasonal characteristics (Equation 3). The model equation is as follows:

Equation 3. Maximum depth of colonization equation

$$\text{Log MDC} = 0.61(\log \text{SD}) + 0.26$$

MDC = Maximum depth of colonization
SD = Secchi depth

The calculated maximum depth of colonization in Byre Lake was 0.53 meter (1.75 feet). Calculations were based upon the average measured Secchi depth in meters during the aquatic macrophyte survey (Table 41). The scarcity of submerged vegetation in Byre Lake appears to be a result of decreased light penetration due to organic and inorganic turbidity. Reductions in sediment and nutrient loads to the lake should improve Secchi depth and transparency.

Improving Secchi depth will allow increased littoral colonization of submerged macrophytes in regions of Byre Lake conducive to colonization, which will increase the uptake of nutrients and increase habitat for fish and macroinvertebrates.

3.4 Other Monitoring

Byre Lake Sediment Survey

A sediment survey was completed on Byre Lake in January 2003. Sampling entailed drilling holes through the ice and recording the depth of the water column. A long steel probe was then pushed into the sediment until solid substrate was encountered and the depth of the sediment recorded. One hundred six survey sites were recorded by GPS (Global Positioning System) (Figure 68).

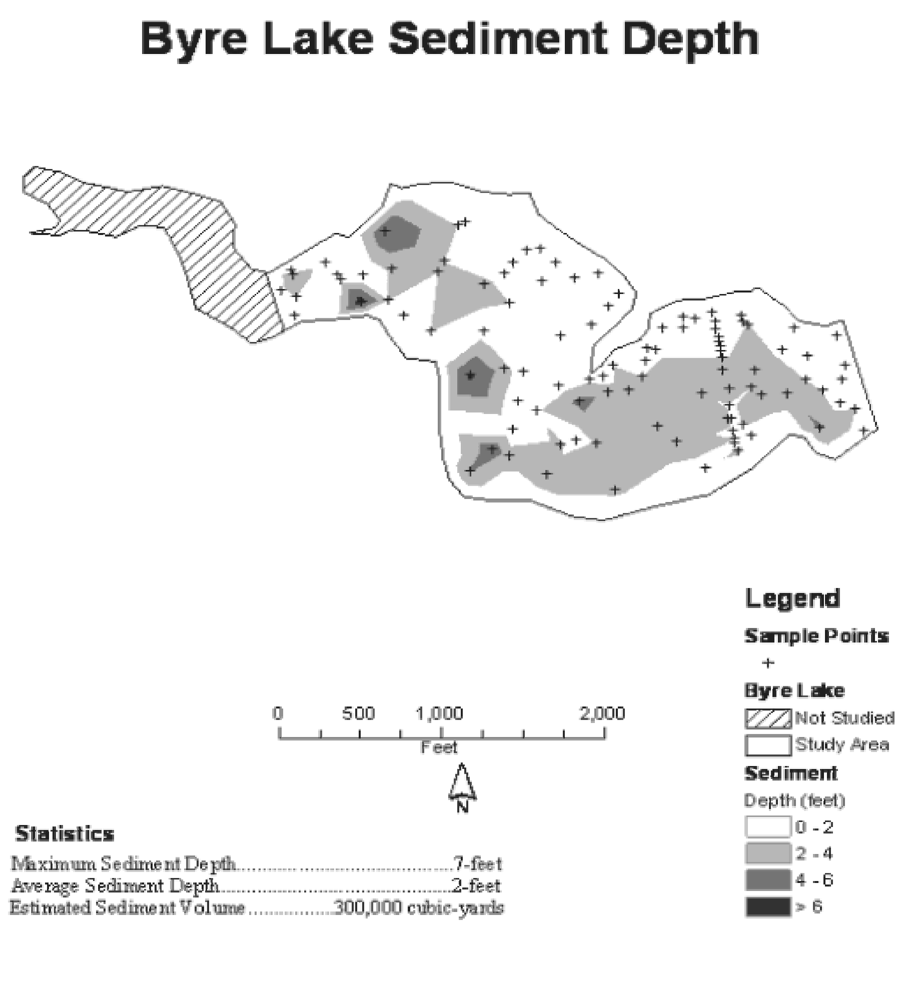


Figure 68. Sediment survey sampling points and sediment depth for Byre Lake, Lyman County, South Dakota for January 2003.

Sediment depths ranged from 0.15 to 2.13 meters (Figure 68). At the time of this survey, the average depth of sediment in Byre Lake was approximately 0.58 meters (1.91 feet). Total sediment volume accumulated within Byre Lake was estimated at 229,365 m^3 (300,000yd^3). The total loss in water volume due to sedimentation was estimated at 185.8 acre-feet; while the water volume loss due to sedimentation during this study (May 2000 through May 2001) was 1.6 acre-feet.

The estimated load (Grouse Creek) to Byre Lake for 2001 was 4,797,761 kg. Adjusting the load for sediment leaving the lake, based on FLUX loading, via the outlet (MCT-15) was approximately 419,716 kg or 194.1 m^3 (0.16 acre-feet) and an estimated 25,882 kg or 11.9 m^3 (0.009 acre-feet) of total suspended solids were removed from Byre Lake with drinking water withdrawals. The corrected amount of suspended solids retained in Byre Lake during this study was approximately 4,352,163 kg, which is 2,012.6 m^3 (1.6 acre-feet) or 90.7 percent of the total of suspended solids loading to the lake. Dividing cubic meters by the total acres of Byre Lake (127.3 acres) estimates cubic meters per acre (15.8 m^3/acre) and multiplying by 0.00081 derives acre-feet (0.0128 acre-feet/acre). Finally, multiplying feet by 304.8 yields an overall increase of 3.90 mm of sediment depth over the entire lake during this study.

Elutriate Analysis (Sediment Analysis)

Elutriate samples are used to determine chemical substances (contaminants) in sediment samples. In general, contaminants are composed of various metals, pesticides and herbicides (Table 42). A typical sample set is composed of sediment and receiving water (overlying water). Receiving water is typically analyzed before being mixed with the sediment to detect existing contamination. The sediment and receiving water are mixed for a predetermined amount of time at the laboratory and then the homogenous sample is separated again using a centrifuge. The overlying water is collected from the centrifuge bottles, extracted and analyzed for contaminants.

All water quality standards for toxic pollutants for human health and aquatic life values in South Dakota are based on beneficial use categories (ARSD § 74:51:01). Elutriate samples were collected from Byre Lake on August 8, 2001. Sediment and receiving water samples were collected from both in-lake sampling sites and composited. All sediment samples were collected using a stainless steel Petite Ponar dredge and receiving water samples were collected using a Van Dorn type sampler. All samples were preserved and transported to the laboratory at 4° C.

Composite receiving water and elutriate samples collected at Byre Lake were analyzed at the South Dakota State Health Laboratory in Pierre. Data indicate both receiving water and elutriate samples were below laboratory detection limits for PCBs, herbicide and pesticide parameters and were relatively low or below laboratory detection limits for metals and nutrient parameters. Based on these data, there does not appear to be a contaminate problem in Byre Lake.

Table 42. Byre Lake receiving water and elutriate chemical concentrations collected in August 2001.

Parameter	Receiving Water Byre Lake	Elutriate Sample Byre Lake	Actual in Sediment Byre Lake	Unit
COD	27.8	38.0	10.2	mg/L
Phosphorus, total	0.019	0.042	0.023	mg/L
TKN	1.14	5.46	4.32	mg/L
Hardness	200	200	0	mg/L
Nitrate	0.1	0.1	0	mg/L
Nitrite	< 0.02	< 0.02	< 0.02	mg/L
Aluminum	11.7	4.4	-7.3	µg/L
Zinc	3.0	5.8	2.8	µg/L
Silver	< 0.2	< 0.2	< 0.2	µg/L
Selenium	1.5	1.2	-0.3	µg/L
Nickel	5.6	5.5	-0.1	µg/L
Mercury, total	0.2	< 0.2	-0.2	µg/L
Lead	0.1	< 0.1	-0.1	µg/L
Copper	< 0.02	< 0.02	< 0.02	µg/L
Cadmium	< 0.2	< 0.2	< 0.2	µg/L
Arsenic	8.7	18.1	9.4	µg/L
Ammonia	< 0.02	4.03	4.01	mg/L
Endosulfan II	< 0.500	< 0.500	0	µg/L
Atrazine	< 0.500	< 0.500	0	µg/L
Endrin	< 0.500	< 0.500	0	µg/L
Heptachlor	< 0.400	< 0.400	0	µg/L
Heptachlor Epoxide	< 0.500	< 0.500	0	µg/L
Methoxychlor	< 0.500	< 0.500	0	µg/L
Toxaphene	ND	ND	0	-
Aldrin	< 0.500	< 0.500	0	µg/L
Dieldrin	< 0.500	< 0.500	0	µg/L
Aroclor 1016	< 0.100	< 0.100	0	µg/L
Aroclor 1221	< 0.100	< 0.100	0	µg/L
Aroclor 1232	< 0.100	< 0.100	0	µg/L
Aroclor 1242	< 0.100	< 0.100	0	µg/L
Aroclor 1248	< 0.100	< 0.100	0	µg/L
Aroclor 1254	< 0.100	< 0.100	0	µg/L
Aroclor 1260	< 0.100	< 0.100	0	µg/L
Diazinon	< 0.500	< 0.500	0	µg/L
DDD	< 0.500	< 0.500	0	µg/L
DDT	< 0.500	< 0.500	0	µg/L
DDE	< 0.500	< 0.500	0	µg/L
BETA BHC	< 0.500	< 0.500	0	µg/L
GAMMA BHC	< 0.500	< 0.500	0	µg/L
ALPHA BHC	< 0.500	< 0.500	0	µg/L

Fisheries Data

The most recent fisheries survey data was collected by South Dakota Game, Fish and Parks from July 24 through July 26, 2000. That report is summarized below and is presented in Appendix G. Byre Lake is being managed using the latest management plan (F-21-R-29) 1996. The lake is classified as a warm-water permanent fishery and supports fifteen species of fish.

Fish collection consisted of setting eight 19 mm (¾ inch) and two baby frame nets for three 24-hour periods from July 24 through July 26, 2000 and six 10-minute electrofishing transects on October 18, 2000. All fish captured by net and electrofishing methods were measured (total length in millimeters), weighed (grams) and identified to species. Six 10-minute electrofishing transects yielded 29 largemouth bass and 19 walleye. Eight 24-hour frame nets yielded black bullhead, 83 bluegill, 4 largemouth bass, 13 northern pike, 9 walleye and 1 yellow perch. Scales were also collected from largemouth bass and walleye to back-calculate length by year-class (age). Largemouth bass age-class structure was good with 25 fish representing seven age classes. Largemouth bass growth and condition was excellent with bass reaching a preferred length in less than five years and a condition factor (Wr) greater than 100 (Byre Lake Wr = 112). Walleye numbers were lower than in the 1997 survey; however, 17 walleye taken in the 2000 survey represented four age classes that showed good growth for a small impoundment. Walleye seasonal condition factors (Wr) varied from a low of 80.9 in the summer of 2000 to 99.3 in the fall. This indicates walleye predation on young-of-the-year forage fish during the summer. The fisheries survey indicated that natural reproduction in walleye was occurring since several year classes were present since the last walleye stocking in 1995 (Appendix G).

South Dakota Game, Fish and Parks (SD GF&P) recommended that Byre Lake looks great and should be resampled in 2001 to sample all fish populations. The 2001 sampling data on Byre Lake had not been published by the completion of this report (April 2003).

Endangered Species

The South Dakota Natural Heritage Database identified one species, the whooping crane, as being endangered in the project study area. This database contains documented identifications of rare, threatened or endangered species across the state and is listed in Appendix H. The whooping crane (*Grus americana*), a federally-listed endangered species, has been recorded in the Grouse Creek/ Byre Lake watershed. Two observations were recorded in the watershed, the first observation (October 29, 1997) indicated 3 cranes flying over and another on May 7, 1998 where a crane was on the ground for five days. The State of South Dakota lists the whooping crane as SZN, nonbreeding, no definable occurrences for conservation purposes, a category usually assigned to migrants. There are no other threatened or endangered species documented in the Grouse Creek watershed; however, six species are identified as being rare in this part of their range. Species identified as rare in the Byre Lake watershed were five bird species, Swainson's hawk (*Buteo swainsoni*), ferruginous hawk (*Buteo regalis*), burrowing owl (*Athene cunicularia*), Baird's sparrow (*Ammodramus* bairdii) and Sprague's pipit (*Anthus spragueii*). The Baird's sparrow (*Ammodramus* bairdii) and Sprague's pipit (*Anthus spragueii*) are state listed as S2B as imperiled because of rarity or because of some other factor(s) making it very vulnerable to extinction throughout its range. One mammal species was also listed as rare, plains spotted skunk (*Spilogale putorius interrupt)*. The US Fish and Wildlife Service lists the bald eagle, and western prairie fringed orchid as species that could potentially be found in the area. None of these species were encountered during this study; however, care should be taken when conducting mitigation projects in the Byre Lake/Grouse Creek watershed.

3.5 Quality Assurance Reporting

Eleven quality assurance and quality control (QA/QC) samples were collected throughout the 2000 and 2001 sampling periods for both tributary and in-lake sampling sites. Standard chemical analysis was performed on all blank and replicate samples collected. Analyses followed both the tributary and in-lake standard routine chemical parameters for analysis and are listed in Table 2 for tributary samples and Table 25 for in-lake samples.

Replicate samples were compared to the original samples using the industrial statistic (Equation 4). The value given is the absolute difference between the original and the duplicate sample in percent. The equation used was:

Equation 4. Industrial statistic equation.

$$\%I = (A-B) / (A+B) \times 100$$

%I = Industrial Statistic
(A-B) = Absolute difference
(A+B) = Absolute sum

Blank samples were evaluated by calculating the mean and standard deviation of all blank samples for both tributary and in-lake samples. The criterion for compliance was that the standard deviation be less than the mean of all blank samples.

Three tributary quality assurance / quality control samples were collected for watershed tributary monitoring samples. Eleven tributary samples were collected at both MCT-14 and MCT-15 for an overall quality assurance / quality control percentage of 27.3 percent. One tributary duplicate sample parameter (volatile total suspended solids) had an industrial statistic (%I) greater than 10 percent (absolute percent). All other reduplicate parameter samples were within 10 percent from the original samples. Volatile total suspended solids concentrations is the organic portion of total suspended solids and can vary considerably because of variations in sample collection and processing. Variations in field sampling techniques and preparation may be some reasons for differences. Over all, 92.3 percent of all tributary industrial statistics values were less than 10 percent different (Table 43).

All blank quality assurance / quality control tributary samples were in compliance with criterion proposed above with the standard deviation being less than the mean for each chemical parameter.

Table 43. Grouse Creek tributary quality assurance / quality control samples collected in Grouse Creek, Lyman County, South Dakota from 2000 and 2001.

Sample Type	Site	Time	Date	Fecal Coliform (#/100 ml)	Alkalinity (mg/L)	Total Solids (mg/L)	Total Dissolved Solids (mg/L)	Total Suspended Solids (mg/L)	TKN (mg/L)	Ammonia (mg/L)	Nitrate (mg/L)	Organic Nitrogen (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	Total Dissolved Phosphorus (mg/L)	Volatile Total Suspended Solids (mg/L)
Blank	MCT-15	1700	05/13/01	5	3	3	3	0.5	0.36	0.01	0.1	0.26	0.46	0.002	0.003	1
Blank	MCT-15	1700	05/13/01	5	3	3	3	0.5	0.36	0.01	0.1	0.26	0.46	0.002	0.002	1
Mean				5.0	3.0	3.0	3.0	0.50	0.36	0.01	0.1	0.26	0.46	0.002	0.0025	1.0
Standard Deviation				0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0007	0.00
Replicate	MCT-15	1700	05/13/01	5	113	372	331	41.0	1.08	0.02	1.00	1.06	2.08	0.236	0.155	4.0
Routine	MCT-15	1700	05/13/01	5	105	373	334	39.0	0.95	0.02	1.00	0.94	1.95	0.249	0.157	7.0
Industrial Statistic (%I)				0.00%	3.67%	0.13%	0.45%	2.50%	6.40%	0.00%	0.00%	6.00%	3.23%	2.68%	0.64%	**27.27%**

Table 44. In-lake quality assurance/quality control samples collected in Byre Lake, Lyman County, South Dakota from 2000 through 2001.

Sample	Site	Sample Date	Time	Depth	Water Temp	Fecal Coliform	Alkalinity	Total Solid	Total Dissolved Solids	Total Suspended Solids	TKN	Ammonia	Nitrate	Organic Nitrogen	Total Nitrogen	Total Phosphorus	Total Dissolved Phosphorus	Volatile Total Suspended Solids
					(° C)	(#/100 ml)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Blank	BL	05/15/01	1200	-	-	5	3	8	7.00	0.5	0.36	0.01	0.10	0	0.46	0.002	0.002	0.5
Blank	BL	05/15/01	1200	-	-	5	3	9	8.00	0.5	0.36	0.01	0.10	0	0.46	0.002	0.002	0.5
Mean						5.0	3.0	8.5	7.5	0.5	0.36	0.01	0.10	0.0	0.46	0.002	0.002	0.5
Standard Deviation						0.00	0.00	0.71	0.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Routine	BL-2	12/14/00	13:50	Surface	-	5	187	550	546	4.0	0.99	0.01	0.10	0.98	1.09	0.040	0.006	0.5
Replicate	BL-2	12/14/00	13:50	Surface	-	5	187	546	541	5.0	0.89	0.01	0.10	0.88	0.99	0.045	0.006	1.0
Industrial Statistic (%I)						0.00%	0.00%	0.36%	0.46%	**11.11%**	5.32%	0.00%	0.00%	5.38%	4.81%	5.88%	0.00%	**33.33%**
Routine	BL-2	04/10/01	9:00	Surface	-	10	117	446	426	20.0	0.47	0.01	1.10	0.46	1.57	0.229	0.129	4.0
Replicate	BL-2	04/10/01	9:00	Surface	-	10	116	453	432	21.0	0.71	0.01	1.10	0.70	1.81	0.215	0.128	2.0
Industrial Statistic (%I)						0.00%	0.43%	0.78%	0.70%	2.44%	20.34%	0.00%	0.00%	**20.69%**	7.10%	3.15%	0.39%	**33.33%**
Routine	BL-1	06/07/00	12:15	Surface	17.80	5	167	459	444	15.0	0.93	0.01	0.20	0.92	1.13	0.083	0.034	3.0
Replicate	BL-1	06/07/00	12:15	Surface	-	5	170	462	450	12.0	1.12	0.08	0.20	1.04	1.32	0.079	0.028	2.0
Industrial Statistic (%I)						0.00%	0.89%	0.33%	0.67%	**11.11%**	9.27%	**77.78%**	0.00%	6.12%	7.76%	2.47%	9.68%	**20.00%**
Routine	BL-1	12/14/00	13:00	Surface	7.22	5	184	537	534	3.0	0.84	0.01	0.10	0.83	0.94	0.028	0.007	0.5
Replicate	BL-1	12/14/00	13:00	Surface	-	5	185	542	534	8.0	0.93	0.01	0.10	0.92	1.03	0.035	0.009	1.0
Industrial Statistic (%I)						0.00%	0.27%	0.46%	0.00%	**45.45%**	5.08%	0.00%	0.00%	5.14%	4.57%	**11.11%**	**12.50%**	**33.33%**
Routine	BL-1	02/05/01	10:00	Surface	3.86	5	194	586	572	14.0	1.01	0.04	0.10	0.97	1.11	0.044	0.024	4.0
Replicate	BL-1	02/05/01	10:00	Surface	-	5	200	612	585	27.0	0.97	0.02	0.20	0.95	1.17	0.066	0.030	5.0
Industrial Statistic (%I)						0.00%	1.52%	2.17%	1.12%	**31.71%**	2.02%	**33.33%**	**33.33%**	1.04%	2.63%	**20.00%**	**11.11%**	**11.11%**
Routine	BL-1	05/15/01	8:30	Surface	16.86	5	115	355	332	23.0	1.33	0.08	0.90	1.25	2.23	0.217	0.129	4.0
Replicate	BL-1	05/15/01	8:30	Surface	-	5	114	359	328	31.0	1.23	0.01	0.50	1.22	1.73	0.189	0.065	10.0
Industrial Statistic (%I)						0.00%	0.44%	0.56%	0.61%	**14.81%**	3.91%	**77.78%**	**28.57%**	1.21%	**12.63%**	6.90%	**32.99%**	**42.86%**

Eight tributary quality assurance / quality control samples were collected for in-lake monitoring samples. Twenty-eight in-lake samples were collected in Byre Lake for an overall quality assurance/quality control percentage of 28.6 percent. Eight tributary replicate sample parameters (total suspended solids (five of six samples), volatile total suspended solids (six of six samples), ammonia, nitrate, organic nitrogen, total nitrogen, total phosphorus and total dissolved phosphorus) had at least one industrial statistic (%I) greater than 10 percent (absolute percent). Sampling parameters, total suspended solids (five of six samples) and volatile total suspended solids (six of six samples) had the most instances of exceeding the 10 percent threshold. Variations in field sampling and preparation techniques may be some reasons for differences. All other replicate parameter samples were within 10 percent of the original samples. Over all, 38.5 percent of sampling parameters had all in-lake industrial statistics values less than 10 percent different (Table 44).

All quality assurance/quality control blank in-lake samples were in compliance with the criterion proposed above, with the standard deviation being less than the mean for each chemical parameter.

3.6 Monitoring Summary and Recommendations

Monitoring Summary

Tributary

Grouse Creek was monitored for tributary loading to Byre Lake from April 2000 through May 2001. Approximately 5,929 acre-feet of water flowed into Byre Lake from the gauged portion of the watershed (22,946 acres) in 2000 and 2001. The export coefficient (water delivered per acre) for the Byre Lake/Grouse Creek watershed was 0.27 acre-foot. Peak hydrologic load for the watershed occurred in the spring. Because of dry conditions in Lyman County, no runoff was recorded in the 2000 sampling season. Approximately 96 percent of the total hydrologic load delivered to Byre Lake was delivered in the spring of 2001.

Grouse Creek was monitored using nineteen water quality parameters, a large percent of which (68.4 percent) had the highest average concentrations and values for both tributaries (Grouse Creek inlet (MCT-14) and outlet (MCT-15)) in the spring of 2001. The remaining six water quality parameters (31.6 percent) had the highest average concentrations and values in the winter of 2001. Twenty-nine samples exceeded water quality standards during the project period.

No fecal coliform standards violations were observed in the Grouse Creek watershed during this study (bacteria standards in effect from May 1 through September 30). Although no violations occurred, elevated fecal coliform counts were collected from both tributary sampling sites in April 2001. Most high fecal coliform counts (> 1,000 colonies/100 ml) were collected during peak flow conditions in late April of 2001 (Appendix C). Runoff from land-applied manure may be responsible for the sporadic high fecal concentrations. Since the majority of the Byre Lake/Grouse Creek watershed is agricultural, most elevated fecal coliform counts can be attributed to agricultural runoff.

Byre Lake/Grouse Creek was not included in South Dakota's impaired waterbodies list for increasing TSI trend; however, water quality data from this study identify Byre Lake as partially supporting assigned beneficial uses based upon current Ecoregion 43 criteria (mean TSI ≤ 55.00). Based on the alternative site-specific (watershed-specific) evaluation criteria (full support = mean TSI ≤ 65.00), Byre Lake still only partially supports beneficial uses. Data indicate increased nutrient (phosphorus) loading from the watershed (Grouse Creek) to Byre Lake resulting in elevated TSI values. AnnAGNPS modeling identified priority areas and critical cells within the watershed for mitigation (treatment). Priority areas and critical cells were listed in the tributary recommendations section of this report and in Appendix B. All watershed nutrient parameters eventually affect in-lake concentrations and TSI values in Byre Lake. Reductions in any or all of these parameters may lower in-lake TSI values.

Total phosphorus loading to Byre Lake is 9,391 kg/yr; all recommended Best Management Practices (BMPs) should be implemented in the watershed to reduce the nutrient (phosphorus) loading to Byre Lake. Based on site-specific standards for Byre Lake, a 19.6 percent reduction in total phosphorus (1,841 kg/yr) is needed to fully support adjusted beneficial use criteria and meet the total phosphorus TMDL of 7,550 kg/yr. AnnAGNPS modeling indicates a 19.6 percent reduction in total phosphorus is attainable in the Byre Lake watershed.

In-lake

Byre Lake is a 51.5 ha (127.3 acre) impoundment located in Lyman County, South Dakota and was not included in the South Dakota's impaired waterbodies list. However, current data indicate Byre Lake exceeded Ecoregion 43 beneficial use standards based on mean TSI and is in need of a TMDL.

The surface samples at site BL-1 and BL-2 in Byre Lake exceeded in-lake water quality standards for pH on May 15, 2001. Surface pH in Byre Lake in May of 2001 was the highest pH values recorded during the project. These violations were in conjunction with the largest algal bloom during the project. Algal blooms are known to increase pH in lakes; by reducing and controlling in-lake phosphorus concentrations the frequency of nuisance algal blooms will be reduced, mitigating in-lake pH concerns.

Current data indicate that a reduction in total phosphorus is needed in both the watershed and in Byre Lake to meet proposed site-specific designated beneficial uses based on modeled attainability criteria. Every effort should be made to improve current management practices to control and reduce sediment and nutrient runoff in the Byre Lake watershed.

Decreasing tributary sediment, nitrogen and phosphorus inputs from Grouse Creek will improve (lower) Byre Lake TSI values. Tributary reductions in these parameters will reduce Secchi, total phosphorus and chlorophyll-*a* TSI values and increase transparency. Increasing transparency (algal and non-algal turbidity) should increase the growth of submerged macrophytes, which would increase the uptake of nitrogen and phosphorus, reducing available nutrients that cause algal blooms. Increasing densities of submerged macrophytes will also create littoral zone cover for macroinvertebrates and forage fish, and ambush points for predator species

Mean TSI values were originally used to set current ecoregional beneficial use criteria for lakes in South Dakota (SD DENR, 2000a). Currently, the target for full support in Ecoregion 43 is a mean TSI value of ≤ 55.00. However, current ecoregional (Ecoregion 43) target criteria appear not to fit Byre Lake based on AnnAGNPS watershed loading and BATHTUB in-lake eutrophication modeling. AnnAGNPS data indicate under ideal conditions (converting the entire watershed to all grass would produce a total phosphorus reduction of 28.1 percent resulting in a mean TSI value of 64.16), Byre Lake still could not meet ecoregional-based beneficial use criteria based on current targets. Alternative site specific (watershed-specific) evaluation criteria (fully supporting, mean TSI ≤ 65.00) was proposed based on AnnAGNPS modeling, BMPs and watershed-specific phosphorus reduction attainability.

Based on site-specific criteria and under current conditions (mean TSI 66.24), Byre Lake only partially supports beneficial uses using this evaluation criteria. The site (watershed) specific criteria/goals are more realistic and attainable based on AnnAGNPS modeling and BMP reductions within the Byre Lake watershed. BMP based reduction criteria for Byre Lake were estimated based on a 19.6 percent reduction in total phosphorus loads (1,841 kg/yr) resulting in a phosphorus TMDL of 7,550 kg/yr resulting in a mean TSI of 65.00.

Tributary Recommendations

Tributary recommendations are based on Best Management Practices (BMPs) and best professional judgment. All reductions were modeled or calculated using water quality and/or AGNPS data collected during this study. Reduction percentages given in Table 45 are the expected percent reduction in sediment and nutrients delivered to Byre Lake based on 2000 and 2001 loading data. BMP recommendations, streambank stabilization and conversion of highly erodible land to grass were not modeled due to insufficient data but should be considered in any phase II implementation plan. Total acreage and total percentage of the watershed by priority ranking for combined and phosphorus-only critical cells are provided in Table 46.

No Tillage

Sediment and nutrient reductions were assessed by converting specific minimum tillage operations to no-tillage operations were predicted using the AnnAGNPS model. Reductions in sediment, nitrogen and phosphorus were based on mitigating 4 of 17 minimum tillage operations to no-tillage. Reduction percentage estimates are conservative for each parameter and are presented in Table 45.

Streambank Stabilization

Sloughing banks and eroding areas were observed in the Grouse Creek watershed, however, data specific to these areas were not available to estimate reductions. These areas contribute to the overall sediment and nutrient input to Byre Lake and should be included in any implementation plan. Models are available (Pollutants Controlled Calculation and Documentation manual (MI DEQ 1999), Annualized Agricultural Non Point Source model (AnnAGNPS) and Hydrologic Simulation Program Fortran (HSPF), etc.) to determine sediment and nutrient contributions and can be used to predict/estimate reductions. Field variables such as soil type, total linear distance of impacted areas (left and right streambanks) and bank height and others are used in the models. Restoration alternatives could include, but are not limited to, laying-back steep banks and re-vegetating, riprapping selected areas, replanting barren and susceptible areas and willow planting.

Conversion of Highly Erodible Cropland to Rangeland

Conversion of highly erodible cropland to rangeland will reduce sediment and nutrient loading to Grouse Creek and Byre Lake, however, reduction estimations for the conversion of highly erodible land to grass were not modeled due to insufficient data. This Best Management Practice (BMP) should be considered for the phase II implementation project.

Fertilizer Application

Reducing fertilizer and manure application rates and/or altering temporal applications (time of application) could reduce nutrient loading (phosphorus) to Byre Lake 4.3 percent (Table 45). Nutrient reductions were estimated using the AnnAGNPS model with critical cell numbers and locations provided in Appendix B. Altering (reducing) fertilizer application rates (pounds/acre) and applying fertilizers based on seasonal (hydrological) considerations will limit nutrient runoff and loading. Applying less fertilizer during seasons with lower potentials for heavy sustained rains will be more cost effective and reduce the annual nutrient load to Byre Lake.

Buffer Strips

Buffer strips have been shown to stabilize streambanks, reduce sediment delivery up to 93 percent and remove up to 50 percent of the nutrient and pesticides runoff (CTIC 1999). Personnel from the ACCD office in Kennebec, South Dakota, estimated public participation in constructing buffer strips on Grouse Creek. Combined and phosphorus priority-one critical cells were treated and calculated reduction percentages were modeled using AnnAGNPS. Buffer strip reductions in the overall annual loading to Byre Lake were estimated and are provided in Table 45.

Table 45. Estimated delivered reduction percentages for select Best Management Practices for Grouse Creek, Lyman County, South Dakota.

Best Management Practice	Parameter (Percent Reduction) Sediment	Nitrogen	Phosphorus
Fertilizer Reduction	0	0.1	4.3
Grazing Management	4.1	+0.7	7.9
Conservation Tillage Reduction (minimum tillage)	6.7	2.2	3.1
Buffer strips (all priority 1 - combined and phosphorus)[4]	6.1	0.5	4.3
Streambank stabilization (eroded areas)[1]	-	-	-
Conversion of highly erodible cropland to rangeland[2]	-	-	-
Riparian Management[3]	-	-	-
Overall Watershed Percent Reduction	16.9	2.1	19.6

[1] = Insufficient data to calculate/estimate reductions, however, sloughing banks and eroding areas were observed throughout the watershed and contribute to sediment and nutrient loading.
[2] = Reduction estimations for the conversion of highly erodible land to grass were not modeled/calculated/estimated due to insufficient data, however, this BMP should be considered for implementation.
[3] = Riparian management reductions were not modeled due to insufficient data; however, this BMP should be considered for implementation.
[4] = Modeled by AnnAGNPS reducing combined and phosphorus-only priority-1 critical cells.

Table 46. Priority acres and percentage of the watershed, based on AnnAGNPS-derived loading for Grouse Creek and Byre Lake, Lyman County, South Dakota in 2000 through 2001.

Priority Ranking	Combined Critical Cells	Percentage of Watershed	Phosphorus Critical Cells	Percentage of Watershed
1	116.8	0.5	1,637.4	7.1
2	689.2	3.0	794.9	3.5
3	2,365.1	10.3	1,713.6	7.5
Total	**3171.1**	**13.8**	**4,145.9**	**18.1**

In-lake Recommendations

In-lake recommendations are based on Best Management Practices (BMPs) and best professional judgment. Reductions were estimated or calculated using water quality data collected during this study. Reduction percentages given in Table 47 are the expected percent reduction in in-lake nutrients based on 2000 through 2001 data.

Aluminum Sulfate Treatment (Alum)

Alum treatment uses an aluminum sulfate slurry that, when applied to water, creates a aluminum hydroxide precipitate (floc). The aluminum hydroxide (Al_3O_2) floc removes phosphorus and suspended solids, both organic and inorganic, from the water column by reacting with the assimilated phosphorus to create aluminum phosphate that settles to the bottom. By collecting and settling out suspended particles including algae, alum leaves the lake noticeably clearer. (improving Secchi depth). Once on the bottom of the lake, floc forms a layer that acts as a phosphorus barrier by combining with phosphorus as it is released from the sediment. The aluminum phosphate compound will not release phosphorus to the water column unless disturbed (Sweetwater, 2000).

The treatment can last ten years or more and is dependent upon the amount of alum applied, total suspended solids sedimentation rate and external phosphorus loading. Byre Lake received approximately 9,391 kg (10.4 tons) of phosphorus in 2000 through 2001. Watershed BMP techniques would have to be implemented to reduce sediment and phosphorus loading before attempting an alum treatment to attain long-term success. If tributary BMP reduction percentages are not realized, an alum drip system could be installed on the tributary inlet to further reduce the phosphorus loading to Byre Lake.

Welch and Cooke (1995) studied lakes treated with alum and found that phosphorus concentrations were reduced from 30 percent to 90 percent after application. If long-term disturbance and tributary loadings are significantly reduced, a significant reduction in in-lake phosphorus is estimated, based upon in-lake concentrations prior to application. If alum treatment is initiated, it is suggested that approximately the lower 16.2 hectares (40 acres, downstream third) be treated because of favorable water depth ($\geq$ 3.05 m, 10 feet). The percent reductions for alum treatment in Table 47 were calculated using a conservative percent reduction in in-lake phosphorus concentrations (30 percent). BATHTUB modeled reductions were 4.1 percent in phosphorus TSI, 3.2 percent in Secchi TSI and 1.9 percent in chlorophyll-*a* TSI (mean TSI reduction of approximately 3.0 percent).

Aquatic Macrophytes

As lake transparency improves, the maximum depth of macrophyte colonization increases, allowing submerged vegetation to re-colonize littoral zones within Byre Lake naturally. It is estimated that because of the bathymetric morphology (subsurface shape or contour) of Byre Lake, submerged vegetation should not dominate the lake, even with increased transparency. If submergent vegetation does not re-colonize littoral zones, manual planting of desirable aquatic species (indigenous species or other species common to lakes in Ecoregion 43) might be initiated. Because the success of submerged macrophyte plantings is not predictable, estimated TSI reductions as a result of those plantings were not included in this report (Table 47).

Shoreline Stabilization

Sloughing banks and eroding areas were observed in Byre Lake especially on the southwestern shoreline (one to 3 meter banks), however, data specific to these areas were not available to estimate reductions. These areas contribute to the overall sediment and nutrient input to Byre Lake and should be included in any implementation plan. Models are available (Pollutants Controlled Calculation and Documentation manual (MI DEQ 1999) and Hydrologic Simulation Program Fortran (HSPF), etc.) to determine sediment and nutrient contributions and can be used to predict/estimate reductions. Field variables such as soil type, total linear distance of impacted areas, bank height and others are used in the models. Restoration alternatives could include, but are not limited to, laying-back steep banks and re-vegetating, riprapping selected areas, replanting barren and susceptible areas and willow planting.

Table 47. Estimated reduction percentages using BATHTUB for select in-lake Best Management Practices for Byre Lake, Lyman County, South Dakota in 2000 and 2001.

Best Management Practice (BMP)	Estimated In-lake Percent Phosphorus Reduction	Estimated TSI Percent Reduction [2]		
		Phosphorus	Secchi	Chlorophyll-*a*
Aluminum Sulfate Application	30 to 90	4.1	3.2	1.8
Submerged Aquatic Macrophytes	Variable	I [1]	I	I
Shoreline stabilization (eroded areas)[3]	Variable	I	I	I
Estimated In-lake Total Reduction in Byre Lake	**30**	**4.1**	**3.2**	**1.8**

[1] = Conditions should improve but data was unavailable to calculate a viable response.
[2] = Percent TSI reductions was estimated using predicted tributary TSI values based on BATHTUB modeling (Table 37).
[3] = Insufficient data to calculate/estimate reductions, however, sloughing banks and eroding areas were observed especially on the southwestern shoreline of Byre Lake and contribute to sediment and nutrient loading.

Implementing any or all in-lake Best Management Practices will augment tributary mitigation and have an overall positive impact on Byre Lake over time.

Targeted Reduction and TMDL

Targeted reductions for specific parameters and mean TSI values were modeled through the BATHTUB reduction model. All reductions were modeled or calculated using water quality and/or AGNPS data collected during this study. Parameter-specific and mean TSI values were plotted on Ecoregion 43 beneficial use categories and are shown in Figure 69 and Figure 70. Tributary and in-lake TSI reductions were based on Best Management Practices and best professional judgment. Reductions in TSI were based on tributary and in-lake BMP recommendations outlined on pages 127 through 131 of this report. Background loading was estimated as the total phosphorus load minus the estimated load reduction based on BMP and best professional judgment. The margin of safety for phosphorus is implicit. Implicit, in that, all reduction estimations for tributary and in-lake reductions were calculated using extremely conservative reduction values/percentages (Appendix I).

Based upon 2000 and 2001 loading data, both phosphorus TSI (69.76) and Secchi TSI values were partially supporting; however chlorophyll-*a* TSI values (60.61) were fully supporting based on previously defined watershed-specific beneficial use criteria (Figure 69). SD DENR-recommended targets for specific TSI parameters for Byre Lake based on watershed-specific criteria and tributary BMP attainability. They are 68.02 for phosphorus, 59.96 for chlorophyll-*a* and 67.02 for Secchi visibility (Table 48). To reach these goals, tributary total phosphorus loads will have to be reduced by 19.6 percent. Reductions should improve phosphorus TSI by 2.5

percent, chlorophyll-*a* TSI by 1.1 percent and Secchi TSI by 2.9 percent, which will improve in-lake water quality. Both during and after implementing BMPs to reduce sediment, nitrogen and phosphorus loads to the lake, long-term tributary and in-lake monitoring should be conducted to evaluate BMPs' effectiveness and determine if in-lake TSI targets have been met.

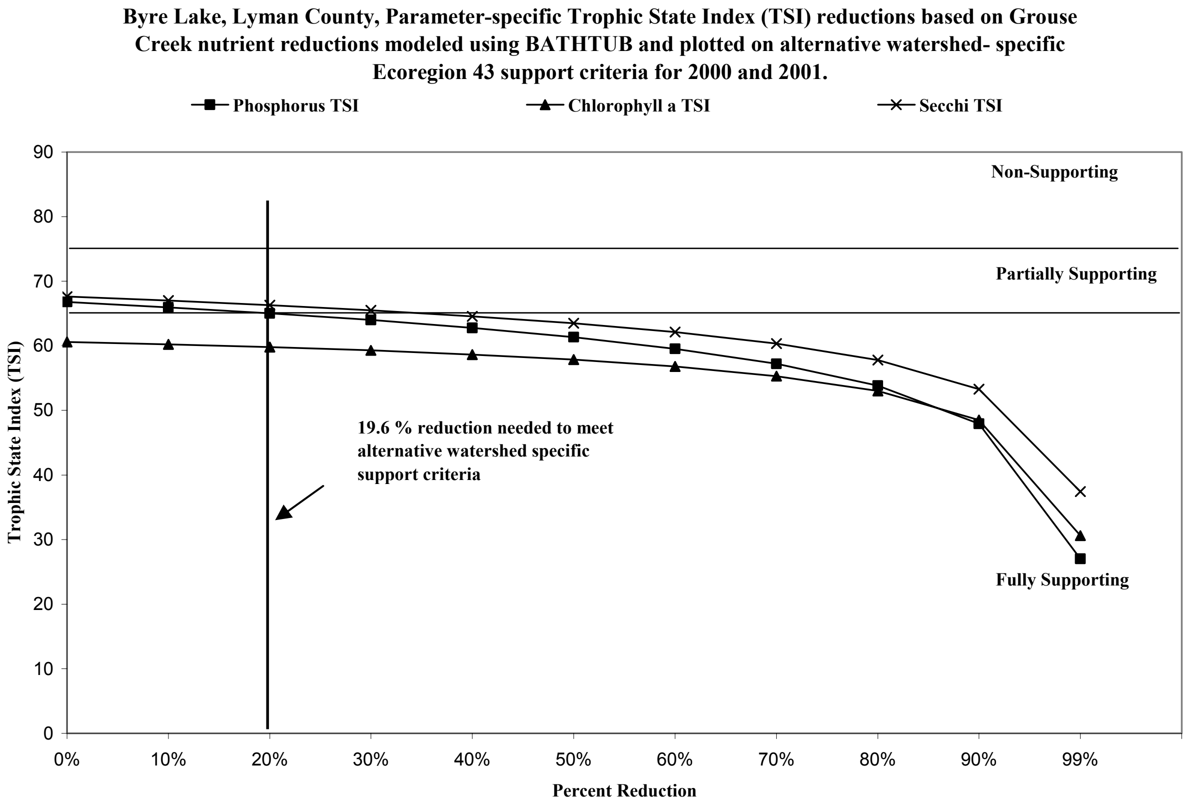


Figure 69. TMDL-predicted parameter specific Trophic State Index (TSI) reductions using the BATHTUB reduction model based on tributary BMPs reductions and ranked by watershed-specific beneficial use categories for Byre Lake, Lyman County, South Dakota using 2000 and 2001 data.

The average TSI values for phosphorus, chlorophyll-*a* and Secchi combined (66.24) as modeled by BATHTUB were also in the partially supporting category (Figure 70). The recommended target for an average TSI value in Byre Lake is 65.00 (Table 49). Implementing tributary BMPs in priority 1 and 2 critical cells in the watersheds will decrease the in-lake mean TSI value by 1.9 percent and fully support new site-specific beneficial use criteria.

If an in-lake alum treatment is considered, all tributary BMPs should be in place and implemented before alum treatment begins. In-lake BMPs will improve TSI values (an estimated 4.9 percent, based on modeled tributary TSI reductions); however, the Total Maximum Daily Load (TMDL) is based on attainable tributary BMP reductions using conservative targeted reduction estimates.

An appropriate TMDL for total phosphorus in Byre Lake is 7,550 kg/yr, producing a mean TSI of 65.00 (Equation 5). The load allocation for phosphorus is 1,841 kg/yr and the background load for phosphorus is 5,709 kg/yr based on 2000 through 2001 total phosphorus and hydrologic loads to Byre Lake (Appendix I, Table 49 and Equation 5).

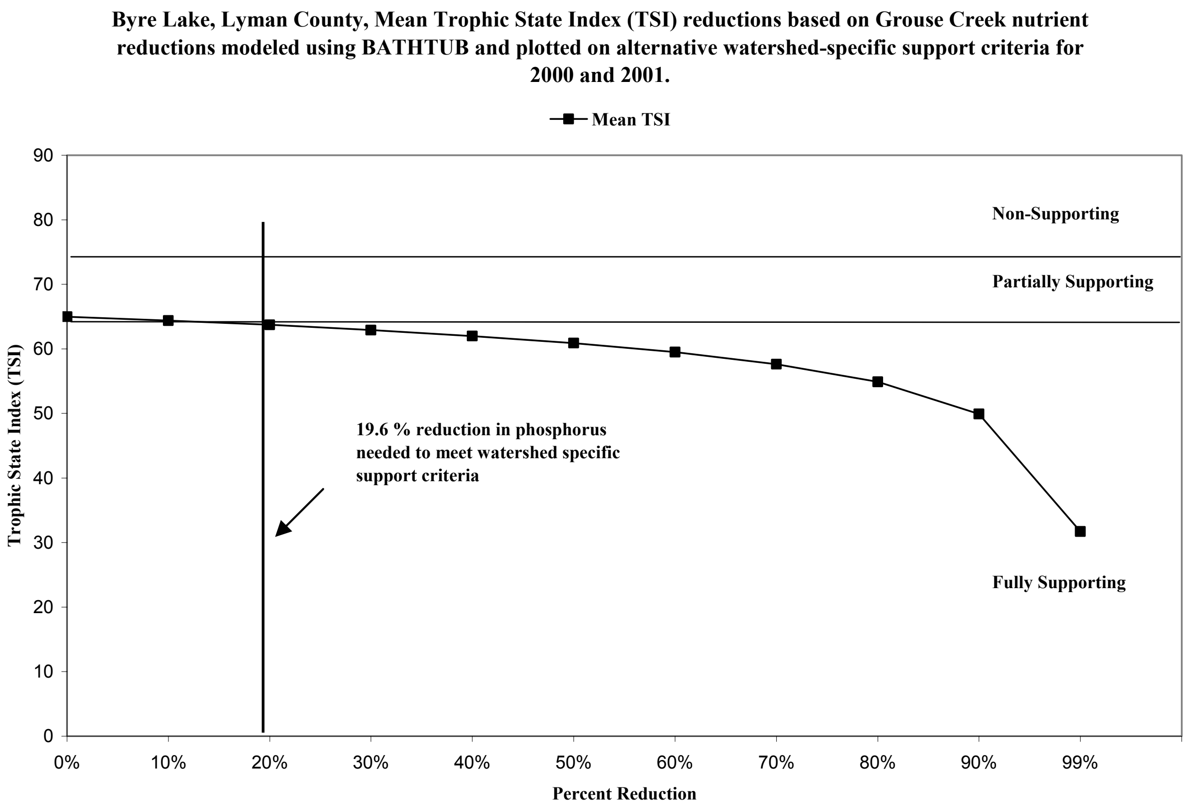


Figure 70. TMDL-predicted mean Trophic State Index (TSI) reduction using the BATHTUB reduction model based on tributary BMPs reductions ranked by Ecoregion 43 watershed-specific beneficial use categories for Byre Lake, Lyman County, South Dakota based on 2000 and 2001 data.

Over all, average TSI values will be reduced by 1.9 percent for tributary BMPs. In-lake BMPs (alum treatment) should be implemented to achieve additional reductions (approximately 3.0 percent) after tributary BMPs to achieve maximum benefit.

Table 48. Current, targeted and percent reduction based on BATHTUB for parameter-specific and mean TSI values based on 2000 and 2001 water quality data for Byre Lake, Lyman County, South Dakota.

TSI Parameter	2001 Estimated TSI Values (BATHTUB)	TMDL Targeted TSI Value	Percent TSI Reduction
Total Phosphorus	69.76	68.02	2.5
Chlorophyll-*a*	60.61	59.96	1.1
Secchi	68.34	67.02	1.9
Average	**66.24**	**65.00**	**1.9**

Table 49. Total phosphorus TMDL target and background loading for Byre Lake, Lyman County, South Dakota in 2000 and 2001.

Parameter	Best Management Practice	Margin of Safety	TMDL	Background
Total Phosphorus	Tributary and In-lake BMPs	Implicit (conservative estimations)	Total Phosphorus TSI 68.02 (7,550 kg/year) (Mean TSI 65.00)	5,709 kg/year

[1] = Calculated based on 2000 through 2001 in-lake and tributary loading/concentration data

Equation 5. TMDL equation for Byre Lake, Lyman County, South Dakota, based on 2000 and 2001 data.

Component	Maximum Load
Waste Load Allocation (WLA):	0 (kg/yr)
+ Load Allocation (LA)	1,841 (kg/yr)
+ Background:	5,709 (kg/yr)
+ Margin of Safety:	Implicit
TMDL[1]	**7,550 (kg/yr)**

[1] = Represents a total phosphorus tributary load reduction of 19.6 percent, based upon BMP attainability.

4.0 Public Involvement and Coordination

Public involvement and coordination were the responsibility of American Creek Conservation District. As local sponsor for the project, they were responsible for issuing press releases and/or news bulletins. The project was discussed at monthly meetings of the American Creek Conservation District Board, which is also a public setting where the public is invited to attend. The project was also discussed at County Commission meetings (Lyman and Jones counties)

The American Creek County Conservation District was the appropriate lead project sponsor for this project. The Conservation District was important to this project because of its working relationship with the stakeholders within the watershed.

4.1 State Agencies

Because the South Dakota Department of Environment and Natural Resources (SD DENR) is the statewide pollution control agency, it was the appropriate lead state agency for this project. SD DENR is responsible for tracking Section 319 funds and state and local match for federal funding. The Department (SD DENR) is also responsible for coordination and data collection for all assessment and implementation projects throughout the State of South Dakota.

South Dakota Department of Agriculture (SD DOA) provided conservation commission funds for this project.

South Dakota Game, Fish and Parks (SD GF&P) provided current and long-term fisheries data, reports and endangered species list (Heritage List) for Byre Lake. SD GF&P should be contacted and consulted during the planning and implementation phases of this project.

4.2 Federal Agencies

Natural Resources Conservation Service (NRCS) provided office space and technical assistance for the project. NRCS is the contact for local landowners involved with conservation plans and practices. NRCS needs to be involved up front during all phases of the implementation process.

The United States Environmental Protection Agency (US EPA) provided financial assistance for the project. The US EPA provided $101,796 of Section 319 funds to cover project costs for the Medicine Creek watershed assessment in which the Byre Lake watershed was assessed. EPA will also review and approve this assessment and TMDL.

The United States Fish and Wildlife Service (US FWS) did not provide financial or technical assistance during the assessment project. However, they should be contacted prior to the implementation project regarding their role in the implementation of the TMDL and the potential impact on any endangered species (consultation process).

4.3 Local Governments, Industry, Environmental, and Other Groups; Public-at-Large

The American Creek County Conservation Districts within the Byre Lake watershed will need to take a leading role in the planning and implementation of this project. This was evident during the assessment phase and becomes more important during the implementation phase when conservation practices need to be implemented with local landowners.

4.4 Other Sources of Funds

The Byre Lake Watershed Assessment project was funded with Section 319 and local funds. Conservation Commission funds along with funds from Lyman and Jones Counties were also secured for this project.

Funding Category	Source	Total
EPA Section 319 Funds	US EPA	$101,796
Conservation Commission	Local	$47,864
Counties	Local	$20,000
Total Budget		**$169,660**

5.0 Aspects of the Project That Did Not Work Well

After the project implementation plan (PIP) was approved the funding was not released until early June 1999 which resulted in a setback for the data collection phase of this project. Fortunately, there was enough funding at the end of the first year so that the water quality data could be collected the following spring (2000). This delay could have been avoided had the funding been released in early March of 1999. The deadlines identified in the objectives/tasks and the milestone schedule would have had an increased chance of being met.

Another aspect of the project that provided some difficulty was that AGNPS modeling was outlined as the watershed model; however, after the project was started a decision was made to change the watershed model from AGNPS to an updated annualized version (AnnAGNPS). This change required different data requirements and a steep learning curve to transition from AGNPS to AnnAGNPS. This increased the modeling and analysis time required for relating AnnAGNPS data to water quality monitoring data. However, this change increased resolution and identification of critical cells within the Byre Lake watershed.

6.0 Future Activity Recommendations

The Byre Lake watershed is an estimated 9,286.2 ha (22,946 acres) in size. This assessment project documented priority and critical areas for erosion, total nitrogen and total phosphorus in the watershed (Appendix B). As indicated in the report, certain areas in the Byre Lake watershed have been identified as areas of concern. Implementation efforts should be undertaken to implement/install BMPs on critical areas in the Byre Lake watershed.

The Byre Lake/Grouse Creek watershed can not meet current ecoregional based beneficial use criteria which are unrealistic and unachievable in the Byre Lake watershed. An alternative site-specific (watershed-specific) evaluation criterion (fully supporting, mean TSI < 65.00) is proposed based on AnnAGNPS modeling, BMPs and watershed-specific phosphorus reduction attainability. The watershed-specific beneficial use target criteria and TMDL based on realistic and attainable goals is recommended for the Byre Lake/Grouse Creek watershed. Implementation of select BMPs in the Byre Lake/Grouse Creek watershed will reduce nutrient loading, allowing Byre Lake, based on watershed-specific criteria, to fully support beneficial uses.

Current data indicate that a 19.6 percent reduction in phosphorus can be achieved in this watershed to meet the TMDL goal of 7.550 kg/yr for a mean in-lake TSI of 65.00. The recommended reductions will improve compliance with South Dakota's narrative criteria and the designated beneficial uses of the watershed, specifically, domestic water supply, warmwater permanent fish life propagation water, immersion recreation water, limited contact recreation water, fish and wildlife propagation, recreation, and stock watering water and irrigation water. Based upon data from this assessment, a phase II implementation project should be designed and initiated in this watershed to achieve this goal.

An implementation project should be initiated to reduce sediment, total nitrogen and total phosphorus loading to meet the TMDL set for Byre Lake (7,550 kg/year of phosphorus). Critical cells by priority ranking are outlined in Byre Lake/Grouse Creek AnnAGNPS final report (Appendix B and Attachment A). Implementing all modeled tributary BMPs outlined in this report will reduce sediment, nitrogen and phosphorus loading and improve the trophic status of Byre Lake.

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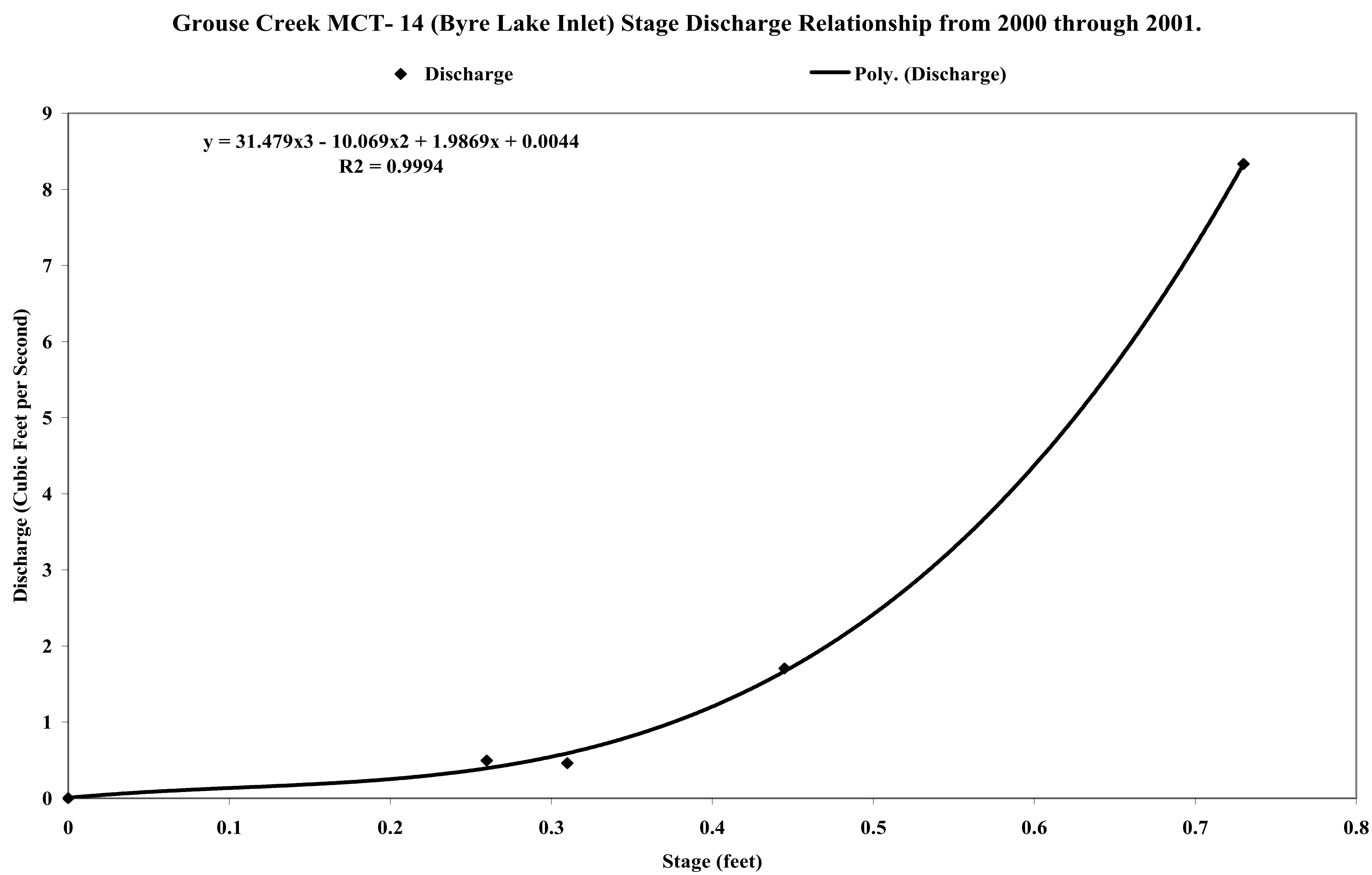
APPENDIX A

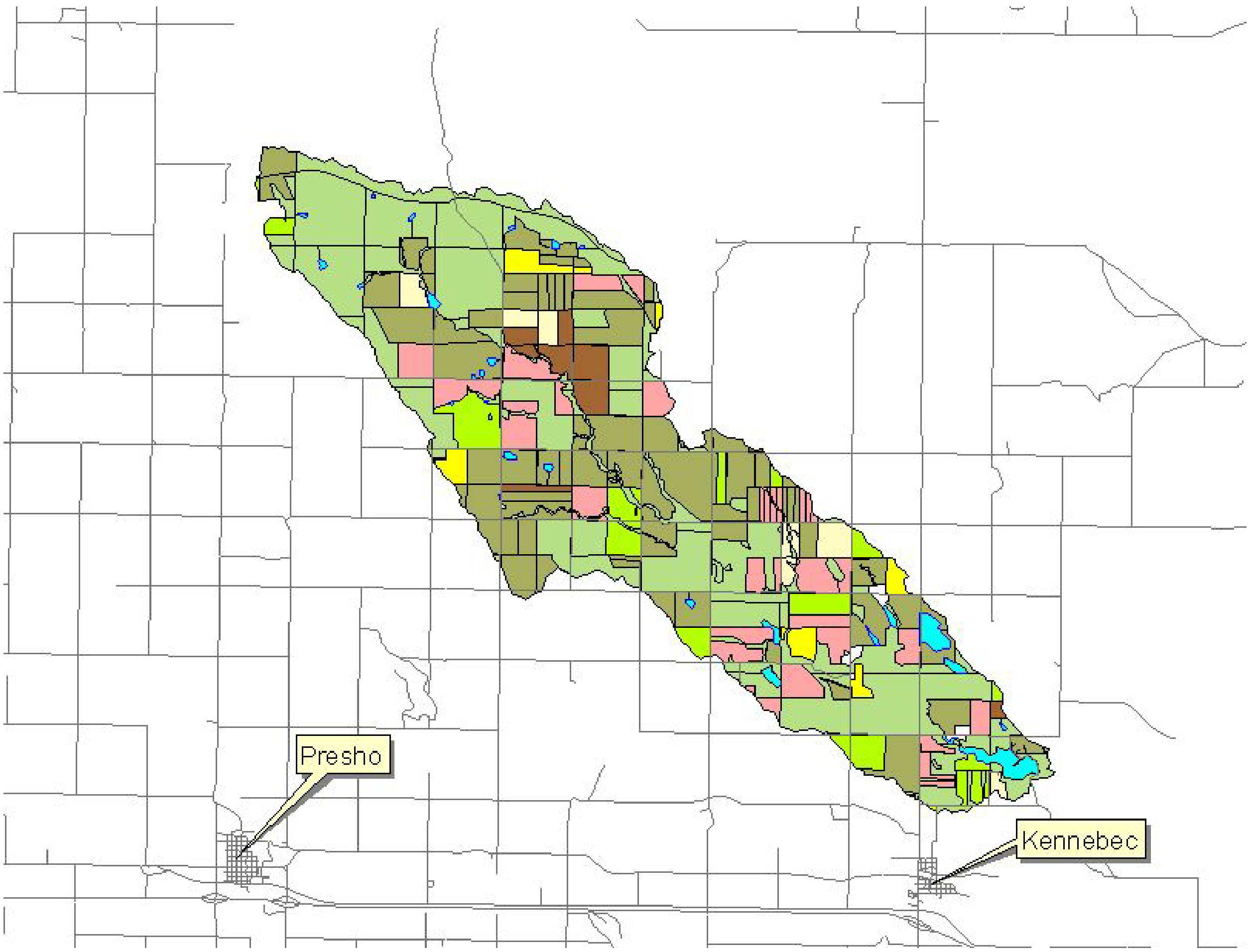
Grouse Creek Tributary Stage Discharge Regression Graphs and Equations from 2000 through 2001


Grouse Creek MCT- 14 (Byre Lake Inlet) Stage Discharge Relationship from 2000 through 2001.
Discharge
Poly. (Discharge)
y = 31.479x3 - 10.069x2 + 1.9869x + 0.0044
R2 = 0.9994
Discharge (Cubic Feet per Second)
Stage (feet)
0
1
2
3
4
5
6
7
8
9
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8

APPENDIX B

Annual Agricultural Non-Point Source Pollution Model (AnnAGNPS) Final Report

ANNUALIZED AGRICULTURAL NON-POINT SOURCE (AnnAGNPS) ANALYSIS OF BYRE LAKE / GROUSE CREEK WATERSHED, LYMAN COUNTY, SOUTH DAKOTA



Prepared by:
Robert L. Smith
Environmental Program Scientist

SOUTH DAKOTA DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES
DIVISION OF FINANCIAL AND TECHNICAL ASSISTANCE
WATER RESOURCES ASSISTANCE PROGRAM

APRIL 2003

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INTRODUCTION

Water quality is a major concern, especially in the agricultural states of the Midwest United States. Several common water quality problems have been noted in lakes and reservoirs of the Central Plains. There have been reports of elevated plant nutrient levels, with concurrent elevations in plant biomass (Smith, 1998). Suspended solids and siltation have increased, and increases in these factors reduce light penetration, aesthetics, lake depth and volume, leading to alteration of aquatic habitats (deNoyelles et al., 1999). Water quality assessments have shown elevated levels of pesticides and other toxic chemicals (Scribner et al., 1996). Further, local and state regulatory agencies have fielded complaints regarding objectionable taste and odor conditions (e.g., KDHE, 1999). All these problems contribute to or are symptomatic of water quality degradation. However, excess nutrients and siltation, both of which result from intensive agricultural activities, are the water quality factors that contribute most to eutrophication (Carpenter et al., 1998). Eutrophication is itself a serious and widespread problem in the Midwest. According to the National Water Quality Report to Congress, 50% of assessed U.S. lakes and a higher percentage of reservoirs in the agriculturally dominated Midwest were considered eutrophic (USEPA, 2000).

A vital key to the development of a lake/reservoir management strategy is to identify nutrient loading that describes associated eutrophic conditions in lakes and reservoirs. Annualized Agricultural Nonpoint Source (AnnAGNPS 2.22) is a batch-process, continuous-simulation, watershed-scale model designed for agriculturally dominated watersheds, which was developed jointly by U.S. Department of Agriculture's Agricultural Research Service and Natural Resource Conservation Service (Bosch et al., 1998; Cronshey and Theurer, 1998; Geter and Theurer, 1998; Theurer and Cronshey, 1998; Johnson et al., 2000).

AnnAGNPS requires more than 400 parameters in 34 data categories, including land use, topography, hydrology, soils, feedlot operation, field management, and climate. AnnAGNPS uses up-to-date technologies that expand the original modeling capabilities of AGNPS. For example, soil loss from each field is predicted based on the Revised Universal Soil Loss Equation (RUSLE) (Renard et al, 1997) and the sediment yield leaving each field is based on the Hydrogeomorphic Universal Soil Loss Equation (HUSLE) (Theurer and Clarke, 1991).

AnnAGNPS is an effective tool for watershed assessment. However, the complexity of modeling procedures and massive data preparation render its application tedious and time consuming. Therefore, automation of the preparation and processing of repetitive data is required. ArcView® Spatial AnnAGNPS interface is a user-friendly tool developed to assist decision-makers to conduct easier, effective watershed assessments. The Spatial AnnAGNPS interface not only assists users to extract the required soil data from the National Soil Survey Geographic Database (SSURGO) but also helps users organize input files, run the model, and visualize modeling results.

AnnAGNPS is a data-intensive watershed model that routes sediment and nutrients through a watershed by utilizing land uses and topography. The watershed is broken up into cells of varying sizes based on topography. Each cell is then assigned a primary land use and soil type. Best

Management Practices (BMPs) are then simulated by altering the land use in the individual cells and reductions in sediment and nutrient yield are calculated at the outlet to the watershed.

METHODS

The Byre Lake / Grouse Creek watershed (Figure B-1) was modeled and analyzed using AnnAGNPS modeling program.

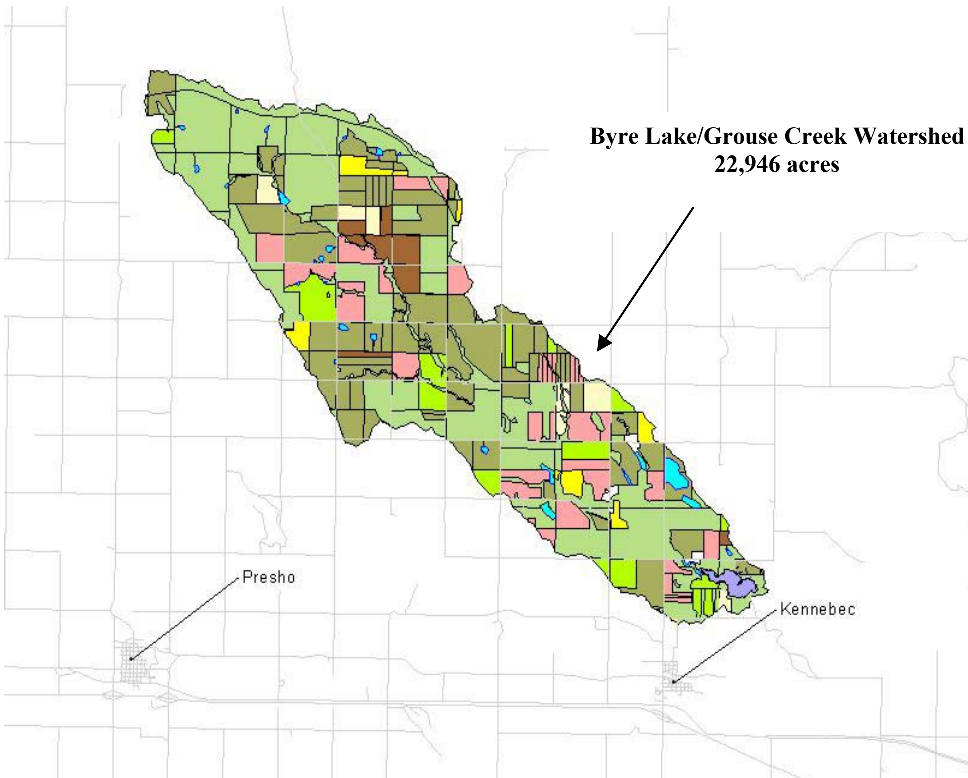

Figure B-1. Byre Lake / Grouse Creek watershed, Lyman County, South Dakota in 2002.

ArcView® data layers for AnnAGNPS were acquired from various governmental agencies. Digital Elevation Model layers (DEMs) were downloaded from a United States Geological Survey website, soil layers were downloaded from a United States Department of Agricultural, Natural Resource Conservation Service (USDA-NRCS) website and digital NASIS (National Soil Information System) data were obtained from the NRCS office in Huron, South Dakota. AnnAGNPS field data and field digitizing in ArcView® for the Byre Lake/Grouse Creek watershed analysis was performed by personnel from the American Creek Conservation District in 2002. Field history, planting and crop rotation data was obtained from the Farm Service Agency in Kennebec. Tillage, fertilization and feedlot data for the Byre Lake/Grouse Creek watershed was acquired through the use of stakeholder surveys. Planting dates for specific crops and tillage practices were acquired for this region using RUSLE data provided by NRCS. All AnnAGNPS data modification and entry was preformed by South Dakota Department of Environment and Natural Resources (SD DENR) Water Resources Assistance Program (WRAP).

Climate/weather data from Pierre, South Dakota was used to generate simulated weather data. Model results are based on 10 years of climate data for initializing variables prior to 25-year watershed simulation. Simulated precipitation based on climate data ranged from 13 to 29 inches per year. Mean annual precipitation for this watershed is around 17 inches.

Impoundment data was obtained from ArcView® Digital Ortho Quad layers (DOQs). DOQs were used to identify and quantify impoundments greater than 10 acres. Average depths were estimated based on best professional judgment using known waterbodies of similar size. Coefficients were calculated based on surface area and depth, with a equation based upon impoundment morphology.

Initial critical cells for sediment, nitrogen and phosphorus were determined using simulated cell specific runoff values (kg/acre), with threshold values based on runoff values greater than one standard deviation from the mean. Sediment, nitrogen and phosphorus critical cells were converted to a grid system and prioritized based upon critical cells similarity. Cells critical for all three categories (sediment, nitrogen and phosphorus) received a priority ranking of one (1), cells critical for two categories received a priority ranking of two (2) and critical cells with only one critical category received a priority three (3) ranking.

Byre Lake was identified in the Byre Lake/Grouse Creek assessment report as having increased phosphorus loading resulting in elevated Trophic State Index (TSI) values based on Ecoregion 43 criteria. Since phosphorus is a major concern, critical cells by priority rank based on one, two and three standard deviations from the mean for phosphorus loading are provided in Attachment A.

The existing field conditions, three-year crop rotation and fertilizer applications were modeled through AnnAGNPS to obtain initial (current) loading values at the outlet of each cell. Specific AnnAGNPS parameters would then be manipulated (conventional tillage converted to no-till, high and moderate fertilization application converted to low fertilization applications, etc.) to represent specific BMPs applied to the watershed. The AnnAGNPS model was re-run with manipulated values, the modified loading values were compared to the initial values to estimate/calculate sediment and nutrient reduction percentages.

RESULTS AND DISCUSSION

Critical Cells

Critical cells for the Byre Lake/Grouse Creek watershed based on AnnAGNPS modeling appear in Figure B-2. AnnAGNPS model identified approximately 3,171 acres of critical areas, or 13.8 percent of the watershed, within the Byre Lake/Grouse Creek watershed, based on the above criteria (Table B-1). Byre Lake watershed has been identified as contributing increased nutrients (phosphorus) to Byre Lake, increasing in-lake TSI values above ecoregional targets (Ecoregion 43 -

mean TSI $\leq$ 55.00). Attachment A lists critical phosphorus cells by priority rank for the Byre Lake / Grouse Creek watershed.

Table B-1. Critical cell acreage by priority ranking for the Byre Lake / Grouse Creek watershed, Lyman County, South Dakota for 2002.

Priority Ranking	Acres	Percentage of the watershed
1	116.8	0.5
2	689.2	3.0
3	2,365.1	10.3
Total	**3,171.1**	**13.8**

Spatially, approximately two-thirds of the critical cells are in the northern half of the watershed (Figure B-2). Table B-1 indicates approximately 0.5 percent of the total acres in the Byre Lake / Grouse Creek watershed were priority one (3.7 percent of the identified critical cells), 3.0 percent of the watershed were priority two (21.7 percent of the identified critical cells) and 10.3 percent of the watershed were priority three (74.6 percent of the identified critical cells). All priority cells should be field verified prior to BMP implementation.

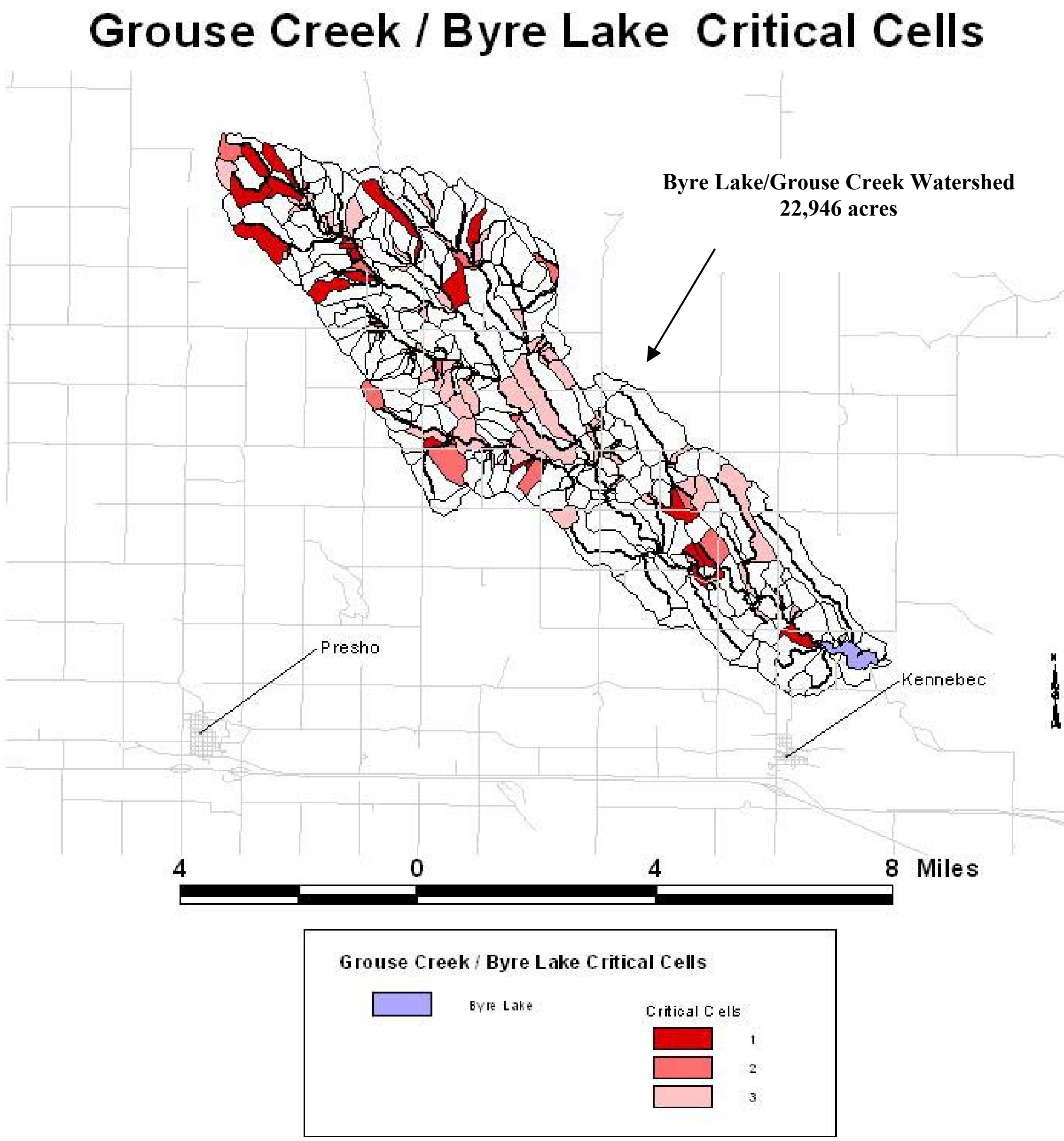

Figure B-2. AnnAGNPS Byre Lake / Grouse Creek critical cells by priority ranking.

Table B-2. Critical cells by priority ranking for the Byre Lake / Grouse Creek watershed, Lyman County, South Dakota in 2002.

			Location (Critical Cell (Centroid))			
			UTM Coordinates		Decimal Degrees	
Critical Cell Number	Priority Rank	Cell Size (Acres)	X-Coordinates	Y-Coordinates	X-Coordinates	Y-Coordinates
332	1	3.645	424104.99252	4869539.48301	-99.94623	43.97507
342	1	6.969	423766.02048	4869375.62076	-99.95043	43.97356
842	1	14.327	419095.91027	4875134.43721	-100.00953	44.02491
852	1	3.464	418944.08218	4875195.19514	-100.01143	44.02544
853	1	12.291	418870.01216	4875346.10375	-100.01238	44.02679
872	1	8.611	418810.50476	4875505.93979	-100.01314	44.02822
1463	1	33.816	428261.46957	4866991.44302	-99.89407	43.95255
1472	1	33.717	428574.89300	4866951.60178	-99.89016	43.95222
321	2	84.786	423821.99542	4869034.50382	-99.94969	43.97050
442	2	186.083	421570.45778	4869417.11551	-99.97781	43.97371
481	2	76.374	419560.28560	4871294.44767	-100.00315	43.99039
483	2	13.142	420190.17052	4870770.17032	-99.99522	43.98574
503	2	4.006	421719.47271	4870290.36096	-99.97608	43.98158
542	2	8.517	423429.14043	4870650.70371	-99.95482	43.98501
612	2	13.631	421402.51521	4872045.92035	-99.98029	43.99735
712	2	5.923	419755.37411	4873200.90530	-100.00100	44.00757
722	2	2.446	419574.81734	4873230.00162	-100.00326	44.00781
742	2	4.183	421516.54336	4872479.74416	-99.97893	44.00127
822	2	31.562	419291.48234	4874746.81027	-100.00703	44.02144
833	2	1.112	419034.99298	4874939.44845	-100.01026	44.02314
862	2	4.823	418945.72937	4875479.43831	-100.01145	44.02799
902	2	2.592	417309.81197	4875180.00233	-100.03182	44.02512
981	2	75.230	415727.62364	4877981.30731	-100.05200	44.05015
1012	2	7.175	417728.86656	4877024.07915	-100.02687	44.04176
1112	2	3.220	421329.99861	4874819.99955	-99.98161	44.02232
1152	2	4.741	422214.95973	4874771.60649	-99.97056	44.02198
1153	2	3.558	422395.17976	4874865.35014	-99.96832	44.02284
1162	2	31.055	421959.64866	4875031.30313	-99.97378	44.02429
1202	2	6.719	422021.77130	4876289.97893	-99.97319	44.03562
1222	2	2.224	422499.46788	4874894.65425	-99.96703	44.02311
1262	2	1.727	423567.97637	4874324.79190	-99.95361	44.01810
1272	2	51.162	424423.03017	4874743.07205	-99.94301	44.02195
1453	2	31.926	428019.58841	4868498.15901	-99.89729	43.96609
1473	2	118.291	428830.31018	4867184.83446	-99.88701	43.95435
1512	2	6.199	430610.61008	4865789.57361	-99.86464	43.94196
122	3	15.428	430089.67255	4865354.55495	-99.87107	43.93799
152	3	7.928	428829.66901	4866179.35825	-99.88688	43.94530

Table B-2. Critical cells by priority ranking for the Byre Lake / Grouse Creek watershed, Lyman County, South Dakota in 2002 (continued).

			Location (Critical Cell (Centroid))			
			UTM Coordinates		Decimal Degrees	
Critical Cell Number	Priority Rank	Cell Size (Acres)	X-Coordinates	Y-Coordinates	X-Coordinates	Y-Coordinates
221	3	77.686	424747.44525	4867995.54003	-99.93800	43.96124
283	3	4.080	425470.34472	4869465.67152	-99.92920	43.97455
322	3	3.258	424223.96969	4869360.01154	-99.94472	43.97347
333	3	13.957	424105.85845	4869674.98948	-99.94624	43.97629
352	3	50.502	423564.26804	4869642.05821	-99.95299	43.97594
353	3	57.994	423655.69308	4870005.68201	-99.95190	43.97922
363	3	7.255	423114.48011	4869990.35449	-99.95864	43.97903
373	3	7.316	423115.92464	4869554.29088	-99.95856	43.97510
393	3	5.369	422681.05137	4869629.98757	-99.96399	43.97574
422	3	51.028	422229.07182	4869896.83165	-99.96967	43.97809
423	3	92.938	422263.19892	4870308.12601	-99.96930	43.98180
472	3	59.793	421030.70713	4870260.33276	-99.98466	43.98124
532	3	170.605	424264.80017	4870096.29564	-99.94432	43.98010
543	3	3.239	423339.81354	4870783.95845	-99.95595	43.98620
553	3	125.738	423445.50561	4871325.34033	-99.95471	43.99108
571	3	74.853	422169.86219	4871234.99976	-99.97060	43.99013
572	3	7.785	422244.47626	4871715.35854	-99.96974	43.99447
573	3	3.336	422154.82846	4871790.35449	-99.97087	43.99513
591	3	76.685	421901.58599	4871010.15822	-99.97391	43.98808
593	3	63.559	421613.95801	4871610.76074	-99.97759	43.99346
602	3	24.181	421698.89882	4872057.76041	-99.97660	43.99749
622	3	30.020	421321.71687	4871729.91983	-99.98125	43.99450
623	3	32.068	421061.42534	4871864.44334	-99.98452	43.99568
633	3	14.151	420985.70882	4872494.80917	-99.98555	44.00135
642	3	3.571	420685.53715	4872359.81359	-99.98928	44.00010
643	3	1.557	420625.00188	4872450.18002	-99.99005	44.00091
663	3	6.013	420430.64386	4872488.46503	-99.99248	44.00123
682	3	4.303	419830.12838	4872930.18026	-100.00003	44.00514
683	3	4.160	419769.80403	4873108.90945	-100.00081	44.00675
693	3	4.378	419695.90908	4872899.80659	-100.00170	44.00486
723	3	3.385	419574.98587	4873348.90452	-100.00328	44.00888
772	3	16.939	420940.90919	4873501.24413	-99.98626	44.01040
802	3	3.594	419725.18181	4874414.99779	-100.00157	44.01850
803	3	2.112	419790.14165	4874459.93729	-100.00076	44.01891
813	3	16.179	418645.00000	4874631.80394	-100.01507	44.02033
843	3	10.660	419274.66310	4875167.58405	-100.00730	44.02522

Table B-2. Critical cells by priority ranking for the Byre Lake / Grouse Creek watershed, Lyman County, South Dakota in 2002 (continued).

			Location (Critical Cell (Centroid))			
			UTM Coordinates		Decimal Degrees	
Critical Cell Number	Priority Rank	Cell Size (Acres)	X-Coordinates	Y-Coordinates	X-Coordinates	Y-Coordinates
863	3	9.055	419139.99948	4875405.18243	-100.00902	44.02735
873	3	7.118	418870.54918	4875674.80899	-100.01242	44.02975
903	3	6.041	417193.98530	4875119.94990	-100.03325	44.02456
922	3	4.506	418524.43310	4875614.08133	-100.01673	44.02916
923	3	12.113	418556.08005	4875822.65398	-100.01637	44.03104
942	3	13.080	417366.34105	4876245.23241	-100.03128	44.03471
943	3	14.189	417504.97993	4876528.87273	-100.02959	44.03728
952	3	8.746	417715.93363	4876589.98826	-100.02697	44.03786
953	3	9.942	417818.33377	4876621.14005	-100.02570	44.03815
971	3	76.936	415595.37360	4877264.48155	-100.05354	44.04369
993	3	3.973	417789.98982	4876814.25267	-100.02608	44.03988
1022	3	12.109	418270.56057	4875945.54940	-100.01995	44.03212
1023	3	17.983	418387.41806	4876050.95796	-100.01851	44.03308
1042	3	89.325	419089.24211	4876139.33498	-100.00976	44.03395
1052	3	32.532	421510.53606	4873891.05872	-99.97922	44.01397
1072	3	13.718	420339.85136	4874777.52996	-99.99395	44.02183
1092	3	18.264	420243.34513	4875196.16210	-99.99522	44.02559
1122	3	267.998	424152.13374	4871238.03376	-99.94588	43.99037
1133	3	20.014	423923.62777	4872675.53146	-99.94894	44.00329
1172	3	26.313	421447.55697	4875535.75114	-99.98025	44.02877
1192	3	25.949	421135.84454	4876364.45123	-99.98426	44.03620
1203	3	6.719	422019.11538	4875945.01029	-99.97317	44.03252
1213	3	42.910	422475.77457	4875451.51010	-99.96740	44.02812
1223	3	1.112	422649.99984	4874924.99958	-99.96515	44.02340
1232	3	28.589	423609.03360	4873185.53052	-99.95294	44.00784
1282	3	6.570	423998.90707	4872569.32219	-99.94799	44.00234
1292	3	10.025	424150.51290	4872734.64946	-99.94612	44.00384
1293	3	10.051	424271.02598	4872599.64323	-99.94460	44.00264
1301	3	73.552	424660.17497	4871866.53322	-99.93964	43.99608
1302	3	25.802	424360.14051	4872387.66211	-99.94346	44.00074
1303	3	10.839	424179.99660	4872254.99912	-99.94568	43.99953
1312	3	12.360	425621.17292	4869689.31211	-99.92735	43.97658
1322	3	14.423	425545.17166	4870065.84102	-99.92835	43.97996
1332	3	7.783	425395.16588	4870409.82895	-99.93027	43.98304
1333	3	10.344	425562.13641	4870529.97581	-99.92820	43.98414
1342	3	16.778	425679.65206	4870634.32943	-99.92675	43.98509
1352	3	6.070	425965.00216	4869869.99893	-99.92309	43.97824

Table B-2. Critical cells by priority ranking for the Byre Lake / Grouse Creek watershed, Lyman County, South Dakota in 2002 (continued).

			Location (Critical Cell (Centroid))			
			UTM Coordinates		Decimal Degrees	
Critical Cell Number	Priority Rank	Cell Size (Acres)	X-Coordinates	Y-Coordinates	X-Coordinates	Y-Coordinates
1353	3	7.459	425890.51991	4869661.50463	-99.92399	43.97635
1362	3	5.100	426145.32923	4869974.32611	-99.92086	43.97920
1363	3	3.980	426174.83404	4869900.00081	-99.92048	43.97853
1373	3	12.968	426174.65708	4869569.50148	-99.92043	43.97555
1382	3	10.110	426204.83195	4868939.66571	-99.91997	43.96989
1383	3	2.458	426090.39974	4868670.27461	-99.92136	43.96745
1402	3	15.536	427015.33841	4868490.98721	-99.90981	43.96593
1403	3	5.605	427150.00015	4868535.16495	-99.90813	43.96634
1442	3	22.128	427885.17701	4869705.32258	-99.89913	43.97695
1443	3	5.017	427645.00974	4869375.98321	-99.90208	43.97396
1451	3	104.981	428556.94890	4868638.41222	-99.89061	43.96741
1452	3	44.784	428028.46919	4868822.35048	-99.89722	43.96901
1462	3	11.133	428155.00341	4866885.64936	-99.89538	43.95159
1482	3	36.269	429639.00661	4866301.44009	-99.87681	43.94647
1503	3	277.327	429716.41922	4868082.26670	-99.87608	43.96251
1522	3	13.803	430991.08605	4865444.05073	-99.85985	43.93888
1523	3	6.007	431079.53298	4865355.00405	-99.85874	43.93809
1532	3	2.445	432205.15417	4864605.15166	-99.84462	43.93144
1533	3	6.798	432294.69889	4864725.46246	-99.84352	43.93253

AnnAGNPS Load Reduction Estimates

Existing conditions for year 2002, including row crop, pasture, fertilizer application rates, buffers and tillage practices were modeled using AnnAGNPS. Initial conditions were modeled and loads were estimated at the outlet cell of the watershed (Table B-3). To model the best possible condition the watershed could attain, all land use in the Byre Lake/Grouse Creek watershed was switched to all grass in good condition (4 to 6 inches high).

Table B-3. Modeled initial condition and best possible condition for the Byre Lake / Grouse Creek watershed, Lyman County, South Dakota using AnnAGNPS 2002 data.

Best Management Practice	Sediment (tons)	Nitrogen (tons)	Carbon (tons)	Phosphorus (tons)
Initial Condition	9,767.9	23,211.5	158.9	178.5
Entire Watershed All Grass[1]	4.3	24,082.9	0.03	128.4
Percent Reduction	**99.9**	**+ 3.8**	**99.9**	**28.1**

+= Modeled increase in nitrogen
[1] = Entire watershed to grass four to six inches high

Data indicate under ideal conditions, sediment and carbon would be drastically reduced while nutrient reductions were mixed (increase in nitrogen and decrease in phosphorus). The increase in nitrogen was assumed to be the result of row crops utilizing more nitrogen than grass, or, grass having more residue, breaking down and releases more nitrogen than row crops after harvest.

Byre Lake/Grouse Creek watershed has been identified as producing considerable nutrient (phosphorus) loading resulting in increased Trophic State Index (TSI) values in Byre Lake. AnnAGNPS estimated by converting current conditions to all grass in good condition (best possible condition) a phosphorus reduction of 28.1 percent. A 28.1 percent reduction in current phosphorus loading would result in a phosphorus TSI of 66.86 and a mean TSI of 64.16 for Byre Lake (4.0 percent TSI reduction).

Table B-4. Modeled initial condition and fertilizer reduction for the Byre Lake / Grouse Creek watershed, Lyman County, South Dakota using AnnAGNPS 2002 data.

Best Management Practice	Sediment (tons)	Nitrogen (tons)	Carbon (tons)	Phosphorus (tons)
Initial Condition	9,767.9	23,211.5	158.9	178.5
Fertilizer Reduction[1]	9,767.9	23,168.5	158.9	170.9
Percent Reduction	**0**	**0.1**	**0**	**4.3**

[1] = Reduced selected fertilizer application rates from high or moderate to low

AnnAGNPS was used to predict/estimate phosphorus load reduction with reduced fertilizer application rates. Fertilizer reduction modeling was done on select locations in the Byre Lake/Grouse Creek watershed using 2002 field application rates. Application rates varied in the type and amount of fertilizer applied throughout the watershed. Both nitrogen and phosphorus may be applied, nitrogen only or phosphorus only, depending upon field, crop and/or tillage practice. Forty-four separate field operations were identified in the Byre Lake / Grouse Creek watershed, four (9.1 percent) applied nitrogen and phosphorus, six (13.6 percent) applied phosphorus only and thirty-four (77.2 percent) applied nitrogen fertilizer only. Applications rates also varied from high to low in pounds/acre.

Reductions were modeled by reducing phosphorus application rates in fields where phosphorus application rates were at high or moderate levels. Critical cell priority rating for phosphorus appeared to be related to areas in the watershed with increased phosphorus fertilization rates. By reducing phosphorus application rates in selected fields, overall estimated phosphorus loading was reduced by 4.3 percent (Table B-4).

AnnAGNPS was used to predict/estimate phosphorus load reduction based on grazing management. Field data on pastures in Byre Lake/Grouse Creek watershed indicated pasture locations but did not delineate specific grass conditions by pasture. The district manager for the American Creek Conservation District (ACCD) indicated that the majority of the pasture in this watershed was in reasonably good condition. Based upon this, the rating of the existing condition used in the model for all pastures was "fair". Phosphorus reductions were modeled by switching existing pasture from fair (grass two to four inches in height) to "good" (grass four to six inches in height).

Phosphorus reductions based on grazing management improvements on all pasture indicated an overall estimated phosphorus reduction of 7.9 percent (Table B-5).

Table B-5. Modeled initial condition and grazing management improvements for the Byre Lake / Grouse Creek watershed, Lyman County, South Dakota using AnnAGNPS 2002 data.

Best Management Practice	Sediment (tons)	Nitrogen (tons)	Carbon (tons)	Phosphorus (tons)
Initial Condition	9,767.9	23,211.5	158.9	178.5
Grazing Management[1]	9,368.9	23,390.1	154.7	164.3
Percent Reduction	**4.1**	**+0.7**	**2.6**	**7.9**

+= Modeled increase in nitrogen
[1] = Modeled all pastures from fair condition (grass two to four inches high) to good condition (grass four to six inches high).

Operational data (field practices) collected by the project sponsors indicated 17 of the 44 field operations (38.6 percent) used minimum tillage practices. The district manager for the ACCD indicated that stakeholder participation during BMP implementation can be expected to be approximately 20 percent. Approximately 35 percent of the 17 minimum tillage operations (six operations) were modeled as converted to no tillage and phosphorus reductions were estimated. AnnAGNPS predicted a 3.1 percent phosphorus reduction converting 35.3 percent of the minimum tillage practices to no tillage (Table B-6).

Table B-6. Modeled initial condition and conservation tillage for the Byre Lake / Grouse Creek watershed, Lyman County, South Dakota using AnnAGNPS 2002 data.

Best Management Practice	Sediment (tons)	Nitrogen (tons)	Carbon (tons)	Phosphorus (tons)
Initial Condition	9,767.9	23,211.5	158.9	178.5
Conservation Tillage Reduction[1]	9,114.9	22,859.3	146.9	172.9
Percent Reduction	**6.7**	**1.5**	**7.6**	**3.1**

[1] = Modeled selected fields that are currently minimum tillage to no tillage.

AnnAGNPS was also used to predict/estimate phosphorus load reduction based on buffer management. Combined and phosphorus priority-one critical cells for Byre Lake / Grouse Creek were converted from current crops to all grass and modeled using AnnAGNPS. Parameter specific reduction results were again reduced by 50 percent to better simulate buffer reductions. AnnAGNPS predicted a 4.3 percent phosphorus reduction by applying buffer strips to both combined and phosphorus priority-one critical cells (Table B-7).

Table B-7. Modeled initial condition and buffer strips for the Byre Lake / Grouse Creek watershed, Lyman County, South Dakota using AnnAGNPS 2002 data.

Best Management Practice	Sediment (tons)	Nitrogen (tons)	Carbon (tons)	Phosphorus (tons)
Initial Condition	9,767.9	23,211.5	158.9	178.5
Buffer Strips[1]	9,172.1	23,095.4	158.9	170.9
Percent Reduction	**6.1**	**0.5**	**0**	**4.3**

[1] = Modeled for phosphorus and combined priority-one critical cells.

CONCLUSION

Modeled BMP reductions were: minimum tillage to conservation tillage (no tillage), grazing management and fertilizer reduction (Table B-8). The combination of increased implementation of conservation tillage, grazing management, fertilizer reduction and buffer strips will result in reductions in sediment and phosphorus. Installing these practices on priority critical cells will reduce the amount of nitrogen entering Byre Lake / Grouse Creek annually by 2.1 percent from 21,057,118.6 kilograms (23,211.5 tons) to 20,614,919.1 kilograms (22,724.1 tons) and phosphorus by 19.6 percent from 161,932.5 kilograms (178.5 tons) to 130,193.7 kilograms (143.5 tons). A 19.6 percent reduction in phosphorus loading would result in a phosphorus TSI of 68.02 and a mean TSI of 65.00 (a 1.9 percent mean TSI reduction).

The suspected source of the elevated nutrient levels found within the Byre Lake / Grouse Creek watershed is probably runoff from fertilized cropland. Therefore, it is recommended that efforts to reduce nutrients should be focused within the identified critical nutrient cells.

Table B-8. AnnAGNPS modeled overall BMP reduction percentages for the Byre Lake / Grouse Creek watershed, Lyman County, South Dakota for 2002.

Best Management Practice	Sediment (tons)	Nitrogen (tons)	Carbon (tons)	Phosphorus (tons)
Fertilizer Reduction	**-**	**0.1**	**-**	**4.3**
Grazing Management Reduction	**4.1**	**+0.7**	**2.6**	**7.9**
Conservation Tillage Reduction	**6.7**	**2.2**	**7.6**	**3.1**
Buffer Strips	**6.1**	**0.5**	**-**	**4.3**
Overall Watershed Percent Reduction	**16.9**	**2.1**	**10.2**	**19.6**

+= Modeled increase in nitrogen

It is recommended that efforts to reduce sediment and nutrients be targeted to the installation of appropriate BMPs that include no-tillage on cropland, buffer and filter strips, conversion of highly erodible cropland to rangeland, pasture or CRP; improvement of land surface cover (C-factor) on cropland and rangeland. Riparian management should also be implemented/installed in the top priority-one and two critical cells in the Byre Lake / Grouse Creek watershed.

The implementation of appropriate BMPs, targeting field verified critical cells in priority sub-watersheds, should produce the most cost-effective treatment plan for reducing sediment and nutrient yields from the Byre Lake / Grouse Creek watershed.

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ATTACHMENT A

Table A-1. Phosphorus critical cells for Byre Lake / Grouse Creek watershed, Lyman County, South Dakota in 2002.

Critical Cell Number	Priority Rank	Area (Acres)	Phosphorus Load
1122	1	268.22	18709.2
1272	1	52.64	15615.2
532	1	170.83	9769.5
52	1	84.53	9686.1
1142	1	276.60	9169.5
82	1	70.35	8400.7
222	1	186.38	7274.4
1542	1	236.51	6943.5
213	1	247.96	6496.8
1213	1	43.35	5825.8
962	2	73.06	4369.1
892	2	88.44	4399.4
672	2	88.06	4425.6
1212	2	61.80	4487.4
22	2	164.46	4519.6
1273	2	97.61	4815.3
73	2	93.08	4852.7
422	2	51.25	5234.9
1341	2	77.10	5749.2
132	3	110.45	4157.0
661	3	74.69	3731.8
262	3	11.94	3653.3
552	3	130.51	3442.8
1202	3	8.72	2656.3
1452	3	45.01	2562.2
1242	3	68.11	2307.8
1052	3	32.75	2190.5
343	3	12.11	2176.1
92	3	38.82	2088.5
1013	3	38.01	2084.2
472	3	60.24	1985.5
822	3	32.23	1960.1
1183	3	68.89	1735.3
762	3	62.97	1717.8
782	3	112.31	1687.6
1492	3	53.87	1628.3
632	3	43.39	1616.4

Table A-1. Phosphorus critical cells for Byre Lake / Grouse Creek watershed, Lyman County, South Dakota in 2002 (continued).

Critical Cell Number	Priority Rank	Area (Acres)	Phosphorus Load
162	3	26.18	1608.2
942	3	13.52	1517.3
1132	3	48.24	1330.4
1093	3	30.14	1297.8
1172	3	26.54	1271.9
1352	3	6.88	1201.8
523	3	45.26	1190.5
562	3	39.48	1159.7
142	3	18.27	1108.1
1392	3	104.62	1003.4
302	3	13.83	998.3
943	3	14.86	989.2
382	3	20.50	974.5
1092	3	0.22	891.9
932	3	99.78	875.2
702	3	18.62	838.8
582	3	28.20	830.9
652	3	20.59	819.6
872	3	8.83	804.0
642	3	4.24	800.0
1203	3	7.16	797.2
862	3	5.49	792.0
522	3	24.93	790.8
1312	3	12.80	781.7
362	3	69.37	611.0

APPENDIX C

Grouse Creek Tributary Chemical Data for 2000 through 2001

Table C-1. Chemical Data for Grouse Tributary Creek, Lyman County, South Dakota from 2000 through 2001

Site	Date	Temperature (°C)	Dissolved Oxygen (mg/L)	pH (su)	Conductivity $\mu S/cm^3$	Fecal Coliform (Colonies/100 ml)	Alkalinity (mg/L)	Total Solids (mg/L)	Total Dissolved Solids (mg/L)	Total Suspended Solids (mg/L)	Volatile Total Suspended Solids (mg/L)	Ammonia (mg/L)	Un-ionized Ammonia (mg/L)	Nitrate - Nitrite (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Total Nitrogen (mg/L)	Organic Nitrogen (mg/L)	Inorganic Nitrogen (mg/L)	Total Phosphorus (mg/L)	Total Dissolved Phosphorus (mg/L)	Total Nitrogen : Total Phosphorus (mg/L) Ratio
MCT-14	03/13/01	0.19	7.47	8.37	827	5	70	582	578	4.0	2.0	0.20	0.00386	0.70	1.41	2.11	1.21	0.90	0.268	0.212	7.87
MCT-14	03/19/01	0.62	11.01	7.95	267	10	51	277	205	72.0	10.0	0.35	0.00270	1.00	1.27	2.27	0.92	1.35	0.510	0.306	4.45
MCT-14	03/26/01	0.58	8.01	7.97	629	5	87	486	467	19.0	0.5	0.14	0.00113	2.30	0.73	3.03	0.59	2.44	0.380	0.327	7.97
MCT-14	04/05/01	6.44	8.4	7.95	747	5	130	567	559	8.0	3.0	0.01	0.00012	1.90	0.70	2.60	0.69	1.91	0.261	0.247	9.96
MCT-14	04/15/01	3.04	12.48	7.85	533	380	109	675	405	270.0	20.0	0.04	0.00030	1.40	0.76	2.16	0.72	1.44	0.651	0.245	3.32
MCT-14	04/25/01	1.43	11.88	7.92	404	1500	94	1043	383	660.0	60.0	0.11	0.00085	1.30	1.15	2.45	1.04	1.41	1.290	0.308	1.90
MCT-14	05/13/01	22.53	9.6	8.56	896	30	165	688	666	22.0	3.0	0.01	0.00148	0.10	1.14	1.24	1.13	0.11	0.134	0.074	9.25
MCT-15	04/10/01	5.99	12.99	8.43	583	5	118	442	417	25.0	9.0	0.01	0.00009	0.90	0.18	0.17	0.91	1.08	0.187	0.106	0.91
MCT-15	04/26/01	9.41	10.23	8.22	398	1600	88	392	306	86.0	8.0	0.13	0.00373	1.50	1.24	2.74	1.11	1.63	0.463	0.226	5.92
MCT-15	05/13/01	16.14	11.32	8.60	444	5	105	373	334	39.0	7.0	0.01	0.00106	1.00	0.95	1.95	0.94	1.01	0.249	0.157	7.83
MCT-15	05/15/01	16.66	9.96	8.80	447	5	115	355	332	23.0	4.0	0.08	0.01310	0.90	1.33	2.23	1.25	0.98	0.217	0.129	10.28

APPENDIX D

Byre Lake Surface and Bottom Chemical Data Tables for 2000 through 2001

Table D-1. In-lake surface chemical samples for Byre Lake, Lyman County, South Dakota from 2000 through 2001.

Site	Depth	Date	Temperature (°C)	Dissolved Oxygen (mg/L)	pH (su)	Conductivity µS/cm3	Fecal Coliform (Colonies/100 ml)	E COLI Bacteria (Colonies/100 ml)	Alkalinity (mg/L)	Total Solids (mg/L)	Total Dissolved Solids (mg/L)	Total Suspended Solids (mg/L)	Volatile Total Suspended Solids (mg/L)	Ammonia (mg/L)	Un-ionized Ammonia (mg/L)	Nitrate - Nitrite (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Organic Nitrogen (mg/L)	Inorganic Nitrogen (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	Total Dissolved Phosphorus (mg/L)	Total Nitrogen : Total Phosphorus (mg/L) Ratio	Chlorophyll-*a* (mg/L)
BL-1	Surface	05/01/00	16.0	9.1	8.38	-	5	-	160	435	418	17.0	2.0	0.01	0.000616	0.10	1.07	1.06	0.11	1.17	0.071	0.010	16.48	7.00
BL-1	Surface	06/07/00	19.5	9.1	8.60	600	5	-	167	459	444	15.0	3.0	0.01	0.000662	0.20	0.93	0.92	0.21	1.13	0.083	0.034	13.61	18.77
BL-1	Surface	07/11/00	25.9	6.3	8.42	615	5	-	162	453	441	12.0	6.0	0.01	0.001380	0.05	0.63	0.62	0.06	0.68	0.049	0.018	13.88	15.80
BL-1	Surface	08/03/00	24.6	7.8	8.46	623	5	-	164	474	462	12.0	1.0	0.11	0.015102	0.05	1.31	1.20	0.16	1.36	0.058	0.029	23.45	22.44
BL-1	Surface	09/14/00	18.2	18.2	8.74	649	5	-	159	498	461	37.0	9.0	0.01	0.001082	0.05	0.77	0.76	0.06	0.82	0.102	0.018	8.04	24.50
BL-1	Surface	10/03/00	15.2	10.0	8.40	561	5	-	161	480	462	18.0	3.0	0.01	0.001330	0.05	0.86	0.85	0.06	0.91	0.052	0.040	17.50	16.95
BL-1	Surface	12/14/00	3.5	11.7	8.33	765	5	-	185	542	534	8.0	1.0	0.01	0.000608	0.10	0.93	0.92	0.11	1.03	0.035	0.009	29.43	11.43
BL-1	Surface	02/05/01	3.2	11.5	7.84	849	5	-	194	586	572	14.0	4.0	0.04	0.000836	0.10	1.01	0.97	0.14	1.11	0.044	0.024	25.23	1.24
BL-1	Surface	03/05/01	3.2	11.8	7.51	873	5	-	210	624	619	5.0	2.0	0.08	0.000032	0.10	0.85	0.77	0.18	0.95	0.022	0.008	43.18	7.34
BL-1	Surface	04/10/01	6.0	13.0	8.43	583	5	0.5	118	442	417	25.0	9.0	0.01	0.000042	0.90	0.18	0.17	0.91	1.08	0.187	0.106	5.78	34.73
BL-1	Surface	05/15/01	21.3	15.5	9.08	443	5	0.5	115	355	332	23.0	4.0	0.08	0.003443	0.90	1.33	1.25	0.98	2.23	0.217	0.129	10.28	81.18
BL-2	Surface	05/01/00	15.0	10.2	8.38	-	5	-	162	447	427	20.0	3.0	0.01	0.002108	0.10	1.07	1.06	0.11	1.17	0.074	0.007	15.81	-
BL-2	Surface	06/07/00	19.9	8.6	8.58	603	5	-	166	469	454	15.0	0.5	0.01	0.001323	0.10	0.89	0.88	0.11	0.99	0.086	0.030	11.51	13.13
BL-2	Surface	07/11/00	25.6	6.4	8.43	616	10	-	161	456	441	15.0	8.0	0.01	0.001304	0.10	0.30	0.29	0.11	0.40	0.044	0.025	9.09	-
BL-2	Surface	08/03/00	25.0	6.4	8.33	623	5	-	164	495	449	46.0	7.0	0.01	0.001375	0.05	0.94	0.93	0.06	0.99	0.123	0.022	8.05	22.44
BL-2	Surface	09/14/00	18.7	18.7	8.63	652	5	-	161	490	464	26.0	7.0	0.01	0.001601	0.05	0.78	0.77	0.06	0.83	0.084	0.020	9.88	-
BL-2	Surface	10/03/00	14.2	9.6	8.40	548	10	-	162	487	460	27.0	5.0	0.03	0.001964	0.05	0.89	0.86	0.08	0.94	0.066	0.041	14.24	-
BL-2	Surface	12/14/00	3.4	13.4	8.29	780	5	-	187	550	546	4.0	0.5	0.01	0.000230	0.10	0.99	0.98	0.11	1.09	0.040	0.006	27.25	9.69
BL-2	Surface	02/05/01	3.0	11.0	7.60	849	5	-	204	616	591	25.0	7.0	0.01	0.000074	0.10	1.05	1.04	0.11	1.15	0.064	0.019	17.97	-
BL-2	Surface	04/10/01	6.6	12.9	8.28	591	10	6.3	117	446	426	20.0	4.0	0.01	0.000352	1.10	0.47	0.46	1.11	1.57	0.229	0.129	6.86	-
BL-2	Surface	05/15/01	20.7	14.9	9.23	447	5	0.5	115	359	335	24.0	9.0	0.01	0.000000	0.40	2.80	2.79	0.41	3.20	0.148	0.062	21.62	-

Table D-2. In-lake bottom chemical samples for Byre Lake, Lyman County, South Dakota from 2000 through 2001.

Site	Depth	Date	Fecal Coliform (Colonies/100 ml)	E COLI Bacteria (Colonies/100 ml)	Alkalinity (mg/L)	Total Solids (mg/L)	Total Dissolved Solids (mg/L)	Total Suspended Solids (mg/L)	Volatile Total Suspended Solids (mg/L)	Ammoni (mg/L)	Nitrate - Nitrite (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Organic Nitrogen (mg/L)	Inorganic Nitrogen (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	Total Dissolved Phosphorus (mg/L)
BL-1	Bottom	05/01/00	5		160	441	417	24.0	4.0	0.01	0.20	0.92	0.91	0.21	1.12	0.075	0.007
BL-1	Bottom	06/07/00	10		167	457	444	13.0	0.5	0.03	0.20	0.81	0.78	0.23	1.01	0.070	0.031
BL-1	Bottom	07/11/00	5		170	458	448	10.0	4.0	0.69	0.05	0.99	0.30	0.74	1.04	0.079	0.058
BL-1	Bottom	08/03/00	5		174	454	438	16.0	4.0	0.53	0.05	1.72	1.19	0.58	1.77	0.126	0.074
BL-1	Bottom	10/03/00	5		165	181	162	19.0	4.0	0.01	0.05	0.62	0.61	0.06	0.67	0.059	0.035
BL-1	Bottom	04/10/01	5	1	118	440	414	26.0	7.0	0.01	0.90	0.67	0.66	0.91	1.57	0.195	0.106
BL-2	Bottom	09/14/00	5		162	494	464	30.0	7.0	0.01	0.05	0.58	0.57	0.06	0.63	0.112	0.030

APPENDIX E

Byre Lake Algae Data for 2000 through 2001

Table E-1. Byre Lake algal density (cells/ml) statistics for 2000 through 2001 by species.

Taxa	Density Mean	Species Occurrence	Density Sum	Density Stan Dev	Density Min	Density Max	Density %
Achnanthes minutissima	7	1	7	0	7	7	0.00%
Actinastrum hantzschii	65	1	65	0	65	65	0.03%
Amphiprora ornata	3	2	6	1	2	4	0.00%
Anabaena flos-aquae	342	1	342	0	342	342	0.15%
Anacystis marina	1,549	1	1,549	0	1,549	1,549	0.67%
Ankistrodesmus falcatus	178	7	1,248	321	3	901	0.54%
Ankistrodesmus sp.	9	2	17	11	1	16	0.01%
Aphanizomenon flos-aquae	23,563	5	117,815	10,456	10,114	37,173	50.74%
Aphanocapsa sp.	1,934	2	3,867	2,716	13	3,854	1.67%
Asterionella formosa	536	2	1,072	735	16	1,056	0.46%
Carteria sp.	60	1	60	0	60	60	0.03%
Characium limneticum	2	1	2	0	2	2	0.00%
Chlamydomonas sp.	480	11	5,279	1,009	7	3,310	2.27%
Chromulina sp.	119	6	711	83	16	240	0.31%
Chroomonas sp.	1,062	4	4,246	806	26	1,800	1.83%
Chrysochromulina parva	45	4	180	26	20	80	0.08%
Closteriopsis longissima	227	2	454	103	154	300	0.20%
Closterium sp.	11	1	11	0	11	11	0.00%
Cocconeis pediculus	18	1	18	0	18	18	0.01%
Cocconeis placentula	2	1	2	0	2	2	0.00%
Coelastrum microporum	20	1	20	0	20	20	0.01%
Cryptomonas erosa	122	6	729	98	5	246	0.31%
Cryptomonas sp.	519	4	2,075	579	4	1,280	0.89%
Cyclotella meneghiniana	888	2	1,775	1,230	18	1,757	0.76%
Cyclotella pseudostelligera	23	1	23	0	23	23	0.01%
Cyclotella stelligera	211	3	634	266	8	513	0.27%
Cymatopleura elliptica	1	1	1	0	1	1	0.00%
Cymatopleura solea	2	1	2	0	2	2	0.00%
Diatoma tenue v. *elongatum*	44	1	44	0	44	44	0.02%
Dictyosphaerium pulchellum	191	1	191	0	191	191	0.08%
Dinobryon sertularia	1,287	3	3,861	2,194	16	3,820	1.66%
Diploneis smithi	18	1	18	0	18	18	0.01%
Diplostauron sp.	1	1	1	0	1	1	0.00%
Euglena sp.	52	6	309	55	7	158	0.13%
Glenodinium sp.	3	3	10	3	1	6	0.00%
Gymnodinium sp.	7	1	7	0	7	7	0.00%
Gyrosigma sp.	3	2	6	3	1	5	0.00%
Kirchneriella sp.	410	2	820	552	20	800	0.35%
Mallomonas pseudocoronata	2	1	2	0	2	2	0.00%
Mallomonas sp.	221	6	1,324	401	8	1,034	0.57%
Melosira granulata	1,052	3	3,157	1,608	1	2,903	1.36%
Melosira granulata v. *angustissima*	47	3	140	37	17	88	0.06%
Micractinium pusillum	181	1	181	0	181	181	0.08%
Micractinium quadrisetum	60	1	60	0	60	60	0.03%
Micractinium sp.	70	1	70	0	70	70	0.03%
Microcystis aeruginosa	137	1	137	0	137	137	0.06%
Navicula capitata	7	1	7	0	7	7	0.00%
Navicula minima	48	2	95	21	33	62	0.04%
Navicula sp.	2	1	2	0	2	2	0.00%
Nitzschia acicularis	58	4	233	62	2	141	0.10%

Table E-1 (continued). Byre Lake algal density (cells/ml) statistics for 2000 through 2001 by species.

Taxa	Density Mean	Species Occurrence	Density Sum	Density Stan Dev	Density Min	Density Max	Density %
Nitzschia capitellata	18	1	18	0	18	18	0.01%
Nitzschia palea	42	1	42	0	42	42	0.02%
Nitzschia paleacea	48	4	191	20	36	77	0.08%
Nitzschia sp.	11	2	21	9	4	17	0.01%
Nitzschia vermicularis	10	3	29	7	4	17	0.01%
Ochromonas sp.	115	2	230	120	30	200	0.10%
Oocystis lacustris	124	1	124	0	124	124	0.05%
Oocystis pusilla	368	5	1,840	395	62	1,041	0.79%
Oocystis sp.	26	1	26	0	26	26	0.01%
Oscillatoria agardhii	311	1	311	0	311	311	0.13%
Pandorina morum	47	1	47	0	47	47	0.02%
Pascheriella tetras	29	1	29	0	29	29	0.01%
Pediastrum duplex	137	2	274	171	16	258	0.12%
Peronia sp.	1	1	1	0	1	1	0.00%
Phacus pseudonordstedtii	9	1	9	0	9	9	0.00%
Phacus sp.	41	1	41	0	41	41	0.02%
Rhodomonas minuta	659	6	3,954	683	5	1,904	1.70%
Scenedesmus acuminatus	70	1	70	0	70	70	0.03%
Scenedesmus quadricauda	94	2	188	42	64	124	0.08%
Selenastrum gracile	15	1	15	0	15	15	0.01%
Selenastrum minutum	21	6	123	20	2	57	0.05%
Sphaerocystis schroeteri	501	3	1,502	380	62	729	0.65%
Staurastrum sp.	1	1	1	0	1	1	0.00%
Stephanodiscus astraea minutula	538	5	2,690	980	3	2,274	1.16%
Stephanodiscus hantzschii	4,295	5	21,477	9,487	8	21,267	9.25%
Stephanodiscus minutus	15,408	2	30,816	21,620	120	30,696	13.27%
Surirella ovalis	3	2	5	1	2	3	0.00%
Syncrypta volvox	12	1	12	0	12	12	0.01%
Synedra acus	114	1	114	0	114	114	0.05%
Synedra sp.	10	1	10	0	10	10	0.00%
Synedra ulna	9	1	9	0	9	9	0.00%
Synura uvella	90	1	90	0	90	90	0.04%
Trachelomonas hispida	20	2	39	6	15	24	0.02%
Trachelomonas sp.	4	3	11	3	2	7	0.00%
Trachelomonas volvocina	18	2	36	18	5	31	0.02%
Unidentified algae	1,433	5	7,163	2,301	23	5,480	3.09%
Unidentified flagellates	1,428	5	7,138	1,738	23	3,920	3.07%
Unidentified pennate diatoms	1	1	1	0	1	1	0.00%
Uroglena sp.	597	1	597	0	597	597	0.26%

Table E-2. Byre Lake algal biovolume (μm^3/ml) statistics for 2000 through 2001 by species.

Taxa	Biovolume Mean	Biovolume	Biovolume Sum	Biovolume Stan Dev	Biovolume Min	Biovolume Max	Biovolume %
Achnanthes minutissima	350	1	350	0	350	350	0.00%
Actinastrum hantzschii	15,600	1	15,600	0	15,600	15,600	0.04%
Amphiprora ornata	12,000	2	24,000	5,657	8,000	16,000	0.06%
Anabaena flos-aquae	27,360	1	27,360	0	27,360	27,360	0.07%
Anacystis marina	6,196	1	6,196	0	6,196	6,196	0.01%
Ankistrodesmus falcatus	4,457	7	31,200	8,021	75	22,525	0.08%
Ankistrodesmus sp.	213	2	425	265	25	400	0.00%
Aphanizomenon flos-aquae	2,756,871	5	13,784,355	1,223,336	1,183,338	4,349,241	33.31%
Aphanocapsa sp.	7,734	2	15,468	10,864	52	15,416	0.04%
Asterionella formosa	117,920	2	235,840	161,786	3,520	232,320	0.57%
Carteria sp.	160,800	1	160,800	0	160,800	160,800	0.39%
Characium limneticum	4,618	1	4,618	0	4,618	4,618	0.01%
Chlamydomonas sp.	71,986	11	791,850	151,316	1,050	496,500	1.91%
Chromulina sp.	7,703	6	46,215	5,417	1,040	15,600	0.11%
Chroomonas sp.	68,998	4	275,990	52,412	1,690	117,000	0.67%
Chrysochromulina parva	3,780	4	15,120	2,222	1,680	6,720	0.04%
Closteriopsis longissima	80,812	2	161,624	36,753	54,824	106,800	0.39%
Closterium sp.	8,250	1	8,250	0	8,250	8,250	0.02%
Cocconeis pediculus	9,360	1	9,360	0	9,360	9,360	0.02%
Cocconeis placentula	920	1	920	0	920	920	0.00%
Coelastrum microporum	16,320	1	16,320	0	16,320	16,320	0.04%
Cryptomonas erosa	60,993	6	365,958	49,424	2,510	123,492	0.88%
Cryptomonas sp.	207,500	4	830,000	231,447	1,600	512,000	2.01%
Cyclotella meneghiniana	221,875	2	443,750	307,415	4,500	439,250	1.07%
Cyclotella pseudostelligera	3,795	1	3,795	0	3,795	3,795	0.01%
Cyclotella stelligera	32,757	3	98,270	41,303	1,240	79,515	0.24%
Cymatopleura elliptica	20,000	1	20,000	0	20,000	20,000	0.05%
Cymatopleura solea	32,400	1	32,400	0	32,400	32,400	0.08%
Diatoma tenue v. *elongatum*	31,680	1	31,680	0	31,680	31,680	0.08%
Dictyosphaerium pulchellum	2,865	1	2,865	0	2,865	2,865	0.01%
Dinobryon sertularia	1,029,600	3	3,088,800	1,754,918	12,800	3,056,000	7.46%
Diploneis smithi	7,560	1	7,560	0	7,560	7,560	0.02%
Diplostauron sp.	300	1	300	0	300	300	0.00%
Euglena sp.	29,870	6	179,220	31,829	4,060	91,640	0.43%
Glenodinium sp.	2,333	3	7,000	1,762	700	4,200	0.02%
Gymnodinium sp.	18,900	1	18,900	0	18,900	18,900	0.05%
Gyrosigma sp.	1,500	2	3,000	1,414	500	2,500	0.01%
Kirchneriella sp.	7,380	2	14,760	9,928	360	14,400	0.04%
Mallomonas pseudocoronata	3,500	1	3,500	0	3,500	3,500	0.01%
Mallomonas sp.	110,333	6	662,000	200,610	4,000	517,000	1.60%
Melosira granulata	578,783	3	1,736,350	884,218	550	1,596,650	4.20%
Melosira □ranulate v. *angustissima*	11,667	3	35,000	9,227	4,250	22,000	0.08%
Micractinium pusillum	6,154	1	6,154	0	6,154	6,154	0.01%
Micractinium quadrisetum	240	1	240	0	240	240	0.00%
Micractinium sp.	2,380	1	2,380	0	2,380	2,380	0.01%
Microcystis aeruginosa	4,521	1	4,521	0	4,521	4,521	0.01%
Navicula capitata	1,400	1	1,400	0	1,400	1,400	0.00%
Navicula minima	2,090	2	4,180	902	1,452	2,728	0.01%
Navicula sp.	500	1	500	0	500	500	0.00%
Nitzschia acicularis	16,310	4	65,240	17,421	560	39,480	0.16%
Nitzschia capitellata	6,480	1	6,480	0	6,480	6,480	0.02%

Table E-2 (continued). Byre Lake algal biovolume (µm^3/ml) statistics for 2000 through 2001 by species.

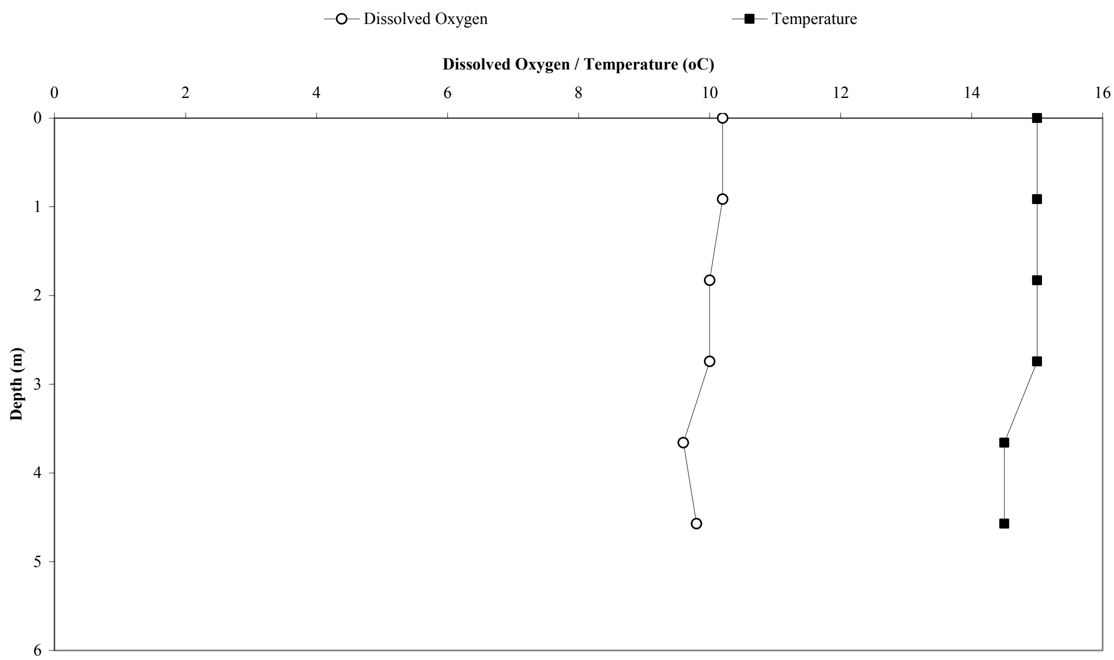
Taxa	Biovolume Mean	Biovolume	Biovolume Sum	Biovolume Stan Dev	Biovolume Min	Biovolume Max	Biovolume %
Nitzschia palea	22,050	1	22,050	0	22,050	22,050	0.05%
Nitzschia paleacea	4,680	4	18,718	1,931	3,528	7,546	0.05%
Nitzschia sp.	1,260	2	2,520	1,103	480	2,040	0.01%
Nitzschia vermicularis	1,160	3	3,480	799	480	2,040	0.01%
Ochromonas sp.	9,775	2	19,550	10,218	2,550	17,000	0.05%
Oocystis lacustris	38,192	1	38,192	0	38,192	38,192	0.09%
Oocystis pusilla	19,872	5	99,360	21,331	3,348	56,214	0.24%
Oocystis sp.	3,900	1	3,900	0	3,900	3,900	0.01%
Oscillatoria agardhii	14,928	1	14,928	0	14,928	14,928	0.04%
Pandorina morum	8,225	1	8,225	0	8,225	8,225	0.02%
Pascheriella tetras	2,900	1	2,900	0	2,900	2,900	0.01%
Pediastrum duplex	68,500	2	137,000	85,560	8,000	129,000	0.33%
Peronia sp.	225	1	225	0	225	225	0.00%
Phacus pseudonordstedtii	16,281	1	16,281	0	16,281	16,281	0.04%
Phacus sp.	41,000	1	41,000	0	41,000	41,000	0.10%
Rhodomonas minuta	13,180	6	79,080	13,667	100	38,080	0.19%
Scenedesmus acuminatus	4,200	1	4,200	0	4,200	4,200	0.01%
Scenedesmus quadricauda	14,758	2	29,516	6,661	10,048	19,468	0.07%
Selenastrum gracile	900	1	900	0	900	900	0.00%
Selenastrum minutum	410	6	2,460	401	40	1,140	0.01%
Sphaerocystis schroeteri	134,179	3	402,536	101,841	16,616	195,372	0.97%
Staurastrum sp.	240	1	240	0	240	240	0.00%
Stephanodiscus astraea minutula	188,300	5	941,500	342,907	1,050	795,900	2.28%
Stephanodiscus hantzschii	859,080	5	4,295,400	1,897,494	1,600	4,253,400	10.38%
Stephanodiscus minutus	5,392,800	2	10,785,600	7,567,174	42,000	10,743,600	26.07%
Surirella ovalis	3,000	2	6,000	849	2,400	3,600	0.01%
Syncrypta volvox	66,864	1	66,864	0	66,864	66,864	0.16%
Synedra acus	216,600	1	216,600	0	216,600	216,600	0.52%
Synedra sp.	2,800	1	2,800	0	2,800	2,800	0.01%
Synedra ulna	17,910	1	17,910	0	17,910	17,910	0.04%
Synura uvella	117,720	1	117,720	0	117,720	117,720	0.28%
Trachelomonas hispida	40,950	2	81,900	13,364	31,500	50,400	0.20%
Trachelomonas sp.	7,333	3	22,000	5,774	4,000	14,000	0.05%
Trachelomonas volvocina	33,930	2	67,860	34,655	9,425	58,435	0.16%
Unidentified algae	42,978	5	214,890	69,015	690	164,400	0.52%
Unidentified flagellates	42,828	5	214,140	52,134	690	117,600	0.52%
Unidentified pennate diatoms	100	1	100	0	100	100	0.00%
Uroglena sp.	71,640	1	71,640	0	71,640	71,640	0.17%

APPENDIX F

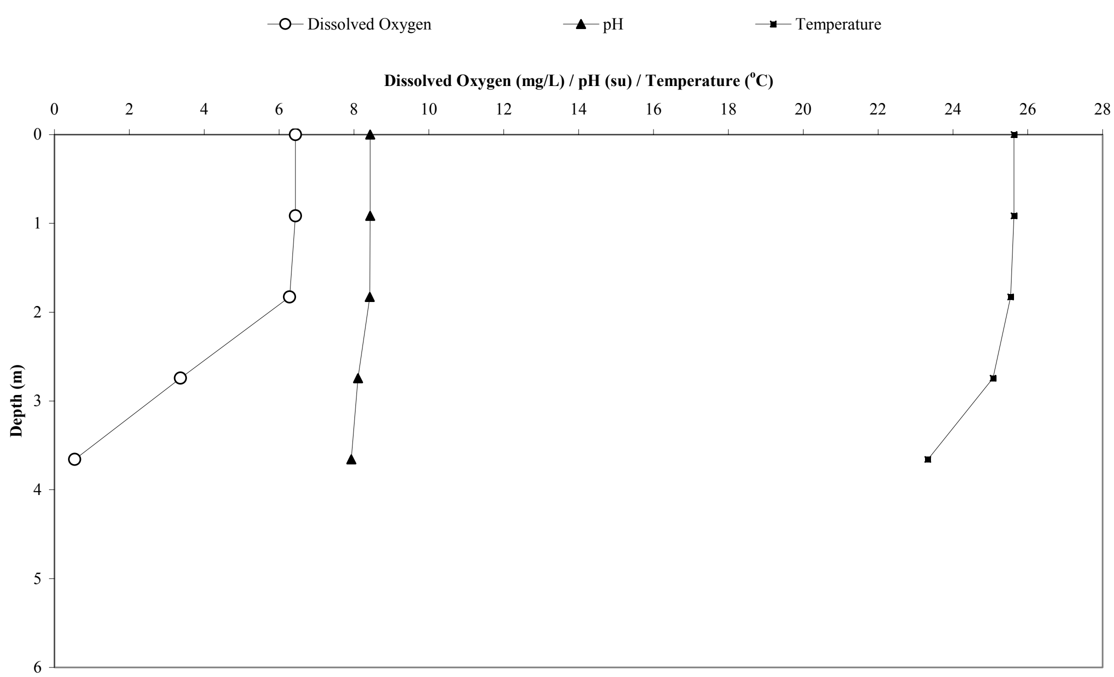
Byre Lake In-lake Temperature, Dissolved Oxygen and pH Profiles from 2000 through 2001

Byre Lake Profiles 2000 (BL-1)

Monthly Temperature (oC) and Dissolved Oxygen (mg/L) Profiles at LB-1 for Byre Lake, Lyman County, South Dakota for May 2000.

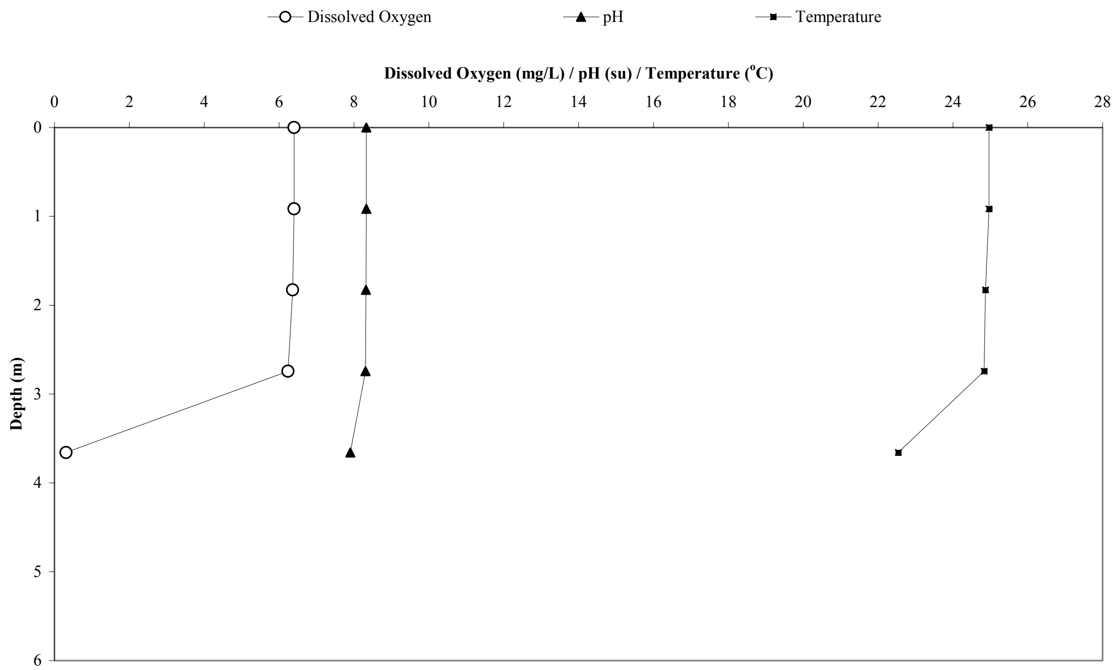


Monthly Dissolved Oxygen (mg/L), pH (su) and Temperature (^oC) at LB-1 for Byre Lake, Lyman County, South Dakota in July 2000

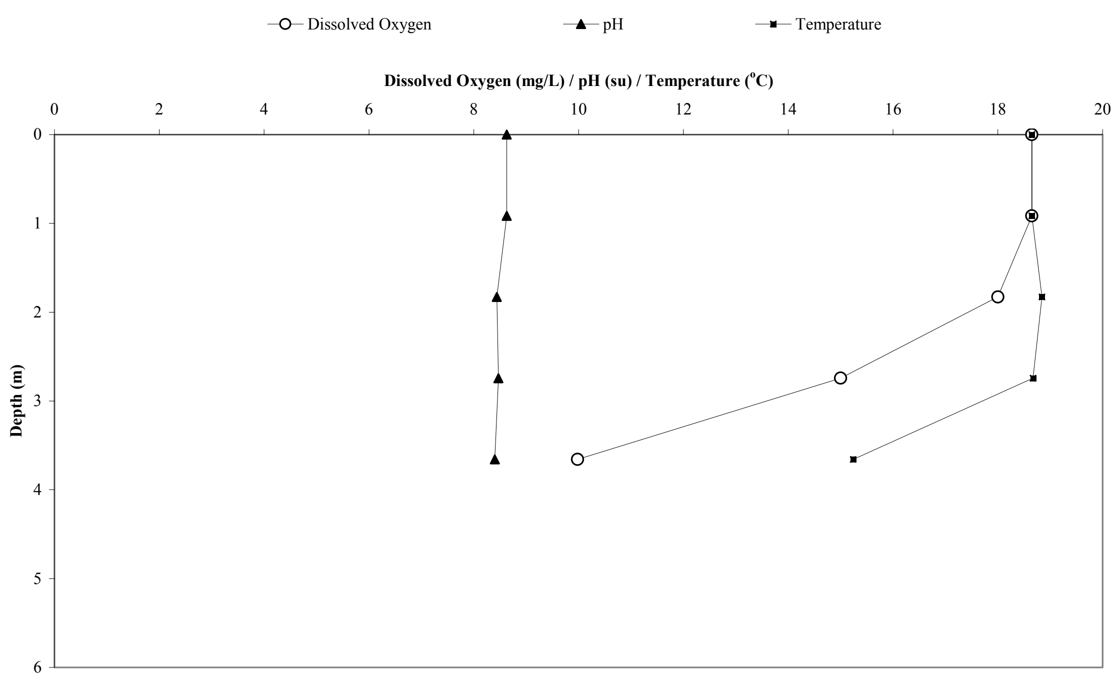


Byre Lake Profiles 2000 (BL-1)

Monthly Dissolved Oxygen (mg/L), pH (su) and Temperature (^oC) at LB-1 for Byre Lake, Lyman County, South Dakota in August 2000

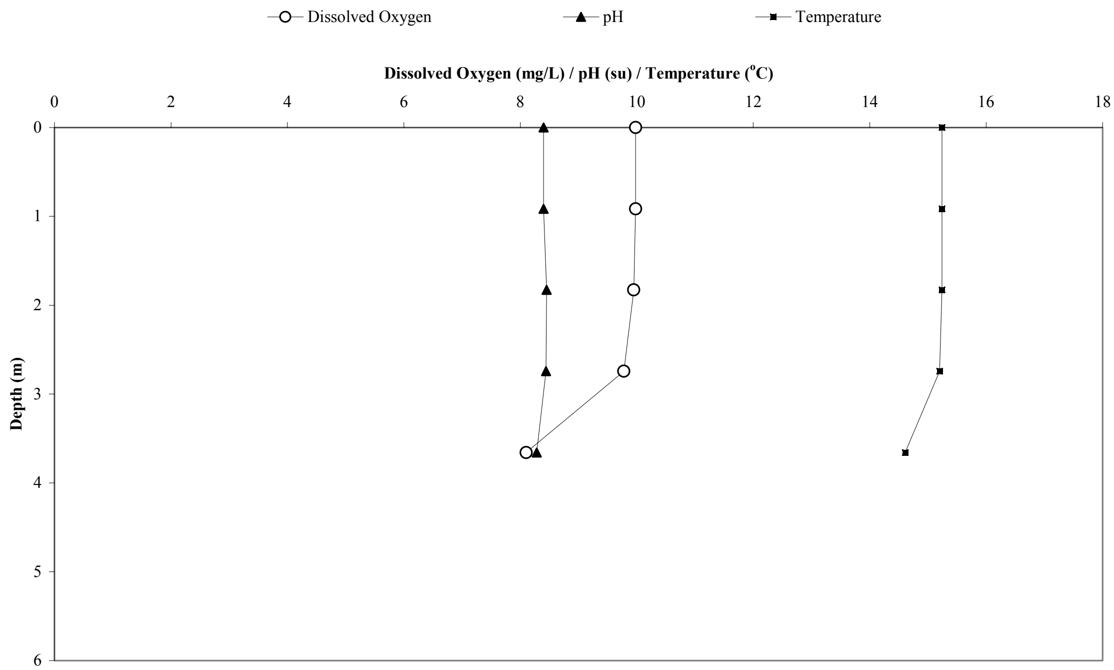


Monthly Dissolved Oxygen (mg/L), pH (su) and Temperature (^oC) at LB-1 for Byre Lake, Lyman County, South Dakota in September 2000

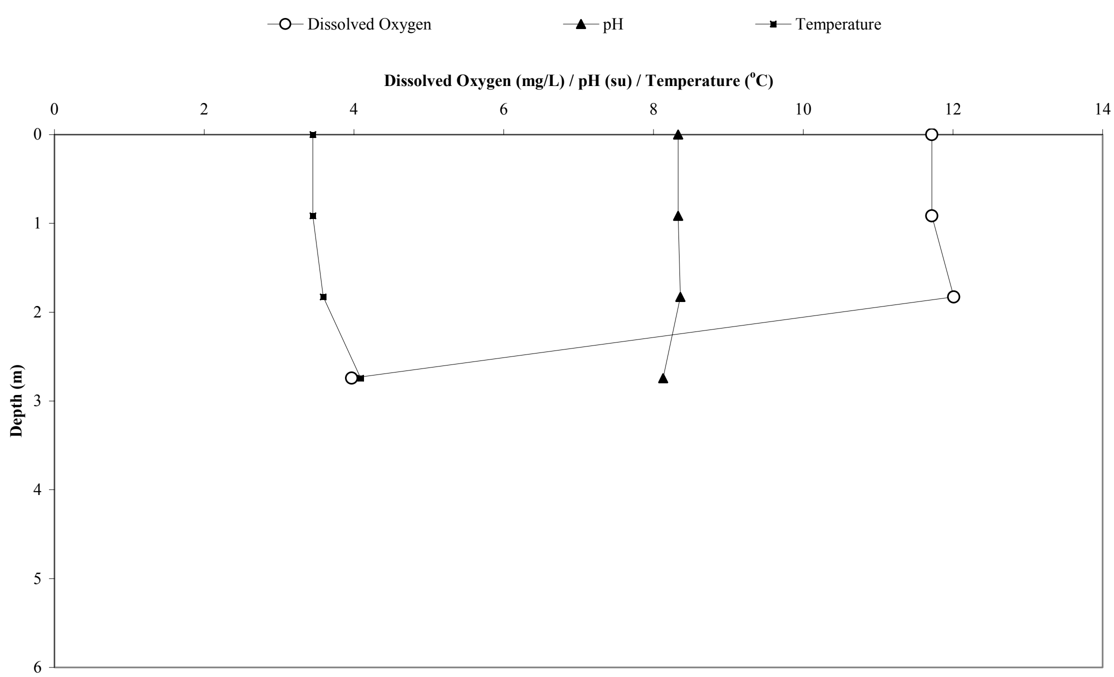


Byre Lake Profiles 2000 (BL-1)

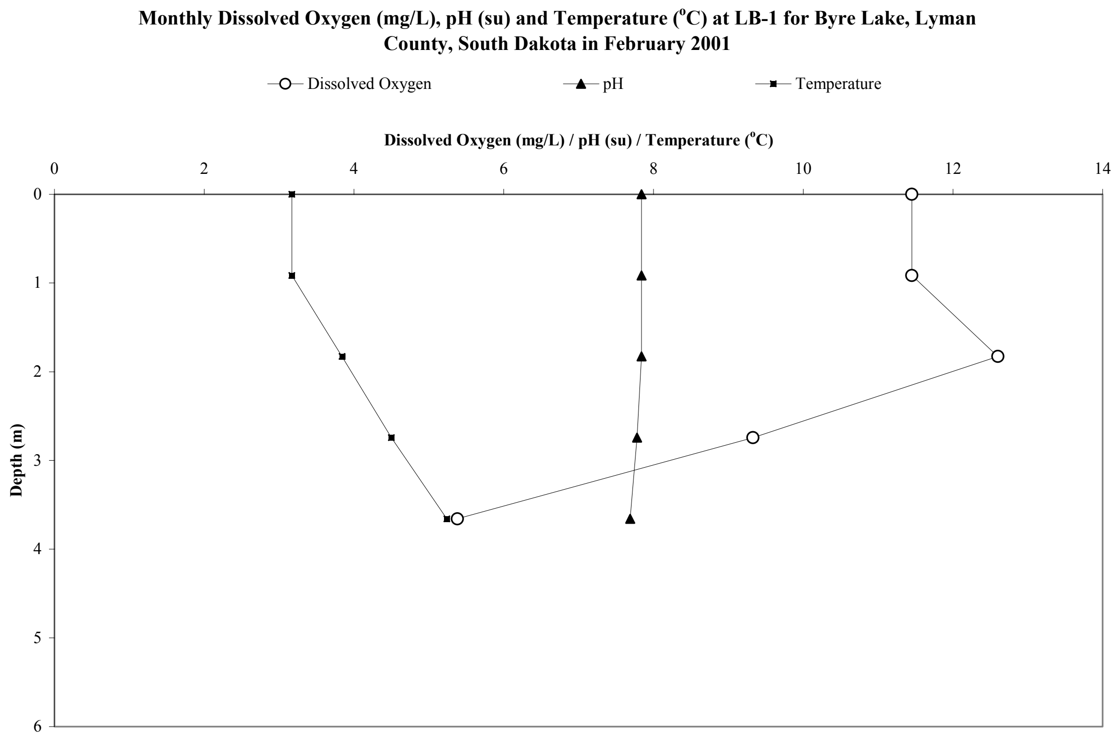
Monthly Dissolved Oxygen (mg/L), pH (su) and Temperature (^{o}C) at LB-1 for Byre Lake, Lyman County, South Dakota in October 2000

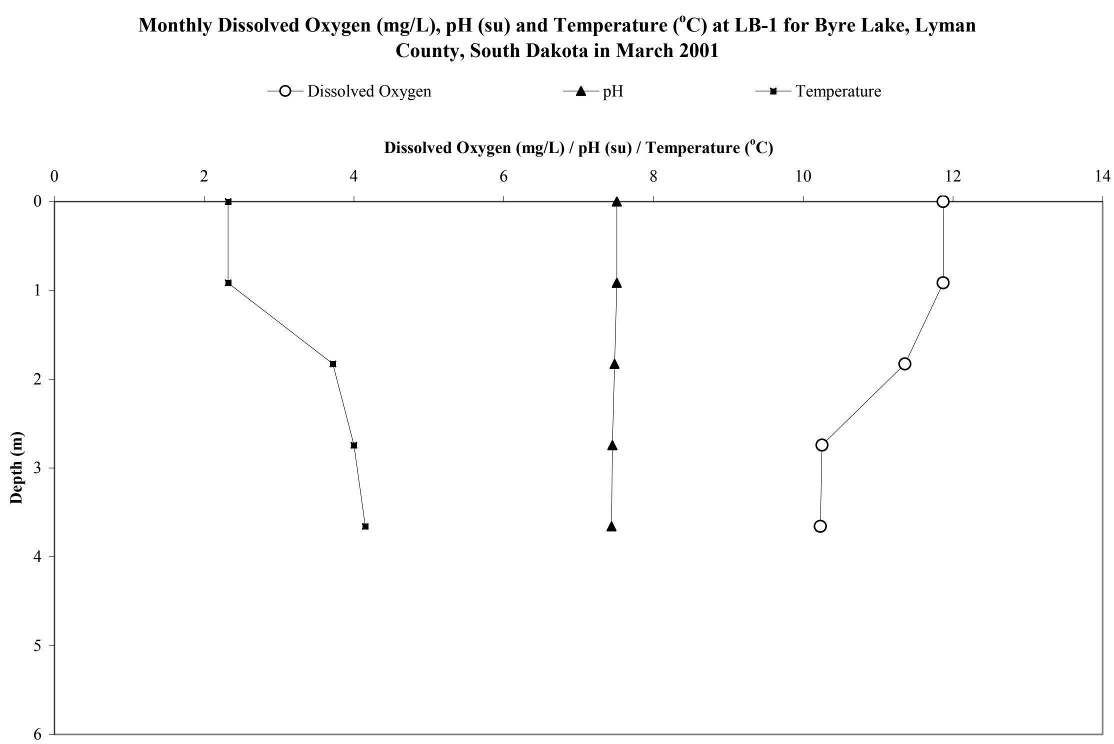


Monthly Dissolved Oxygen (mg/L), pH (su) and Temperature (^{o}C) at LB-1 for Byre Lake, Lyman County, South Dakota in December 2000



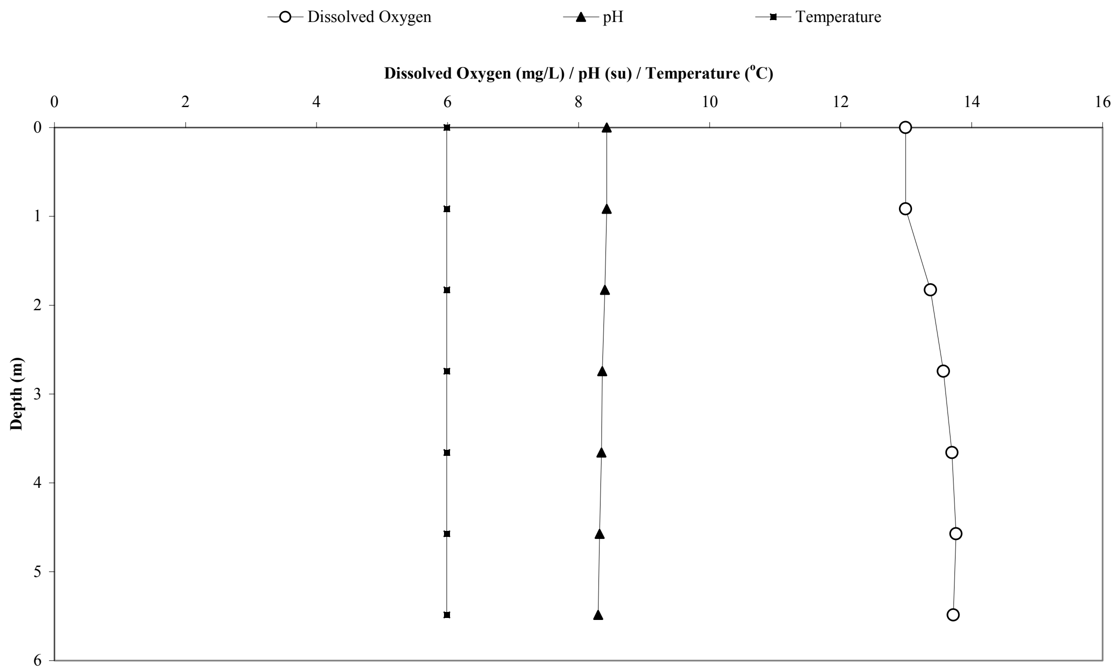
Byre Lake Profiles 2001 (BL-1)



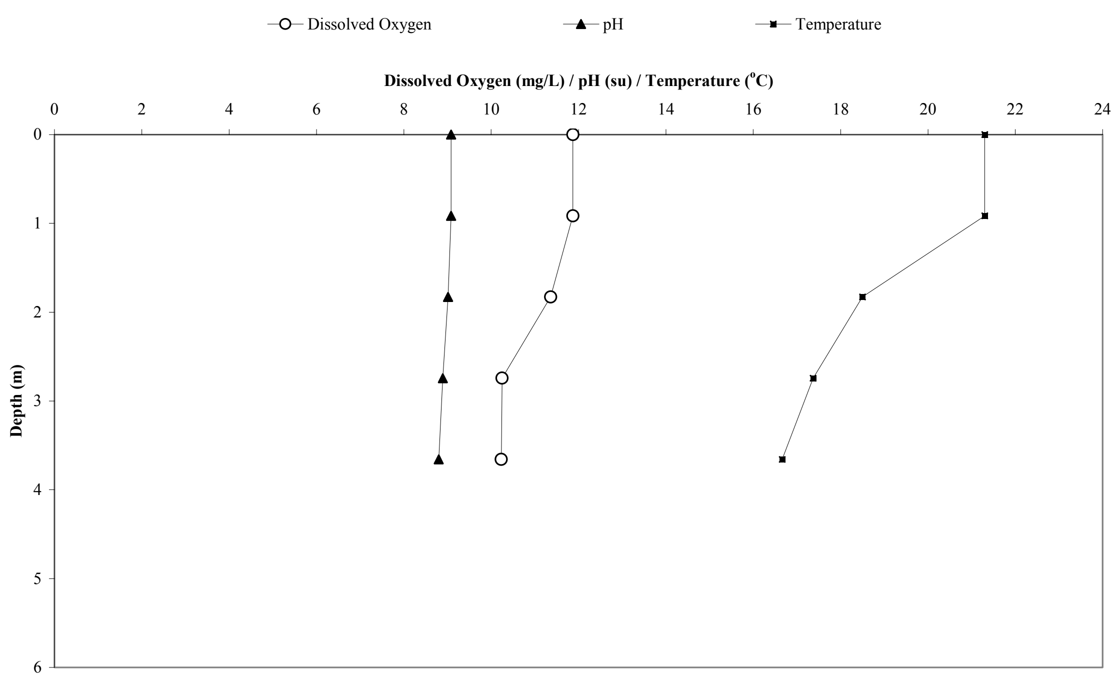


Byre Lake Profiles 2001 (BL-1)

Monthly Dissolved Oxygen (mg/L), pH (su) and Temperature (^{o}C) at LB-1 for Byre Lake, Lyman County, South Dakota in April 2001

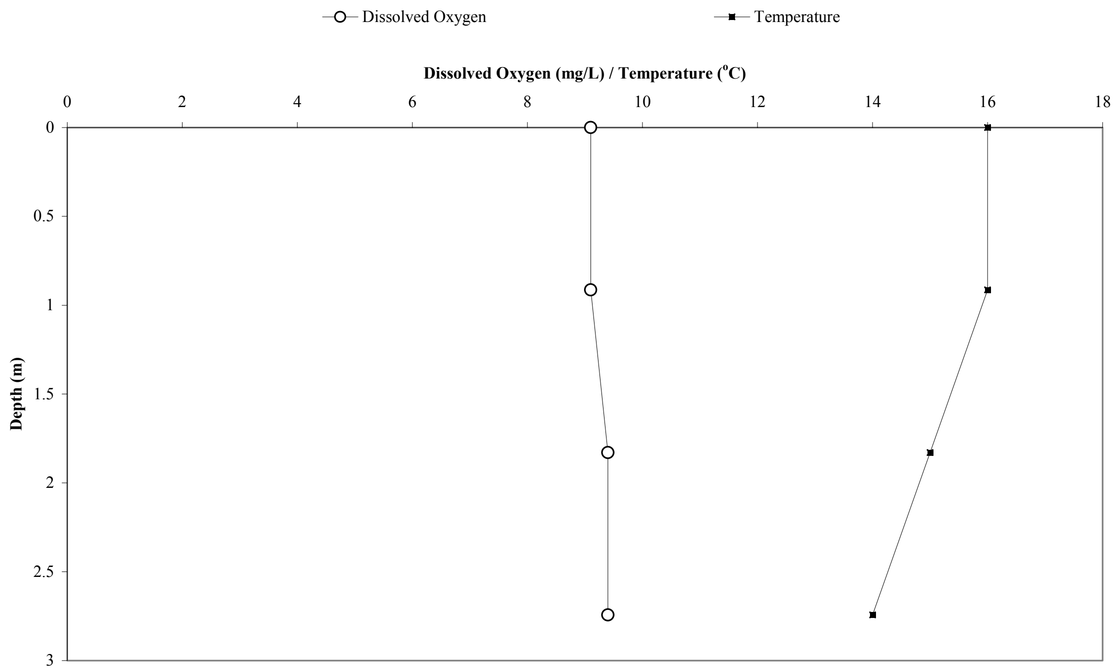


Monthly Dissolved Oxygen (mg/L), pH (su) and Temperature (^{o}C) at LB-1 for Byre Lake, Lyman County, South Dakota in May 2001

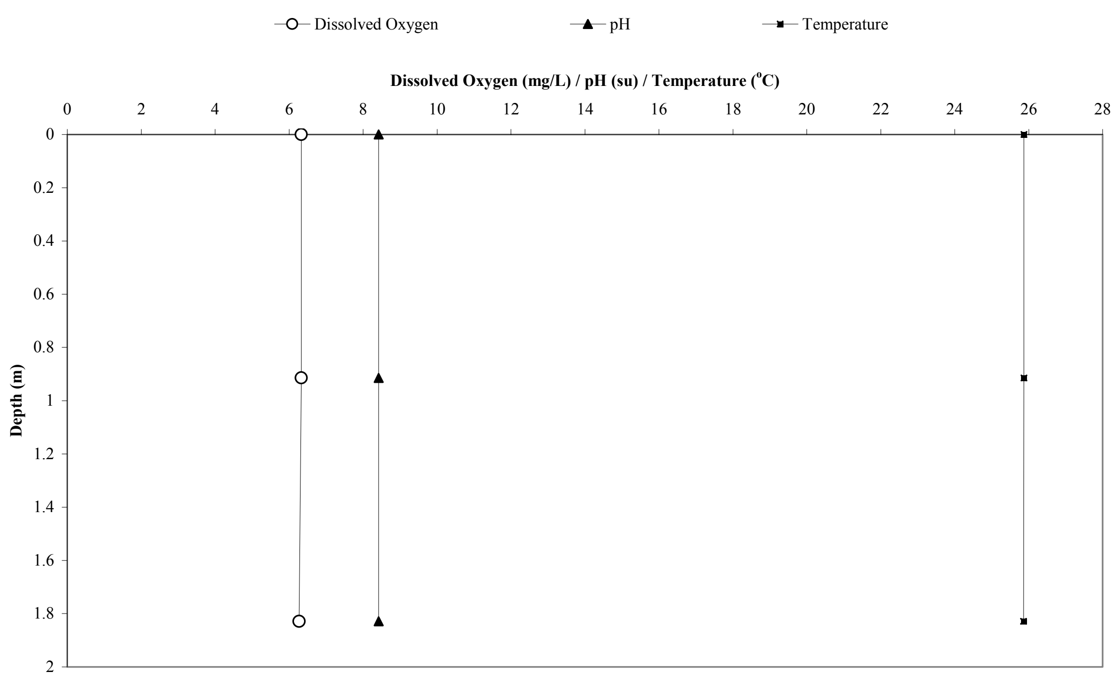


Byre Lake Profiles 2000 (BL-2)

Monthly Dissolved Oxygen (mg/L) and Temperature (°C) at LB-2 for Byre Lake, Lyman County, South Dakota in May 2000



Monthly Dissolved Oxygen (mg/L), pH (su) and Temperature (°C) at LB-2 for Byre Lake, Lyman County, South Dakota in July 2000



APPENDIX G

South Dakota Game, Fish and Parks Fisheries Report for Byre Lake

SOUTH

DAKOTA

FISHERIES

STATEWIDE FISHERIES SURVEYS, 2000
SURVEY OF PUBLIC WATERS
Part 1
Lakes – Region II

South Dakota
Department of
Game, Fish and Parks
Wildlife Division
Joe Foss Building
Pierre, South Dakota 57501-3182

Annual Report
No. 01-16

SOUTH DAKOTA STATEWIDE FISHERIES SURVEY

2102 - F-21-R-33

Name: Byre Lake **County:** Lyman
Legal Description: Sections 4 & 5, Township 75, Range 105.
Location From Nearest Town: 2½ miles N, 1½ miles E of Kennebec.

Date of Present Survey: July 24-26, 2000
Date Last Surveyed: July 8-10, 1997
Most Recent Lake Management Plan: F-21-R-29 **Date:** 1996
Management Classification: Warm Water Permanent
Contour Mapped: yes **Date:** July 23, 1969

Primary Species: (game and forage)
1. Walleye
2. Largemouth Bass
3. Yellow Perch
4. Bluegill

Secondary and Other Species:
1. Black Bullhead
2. Green Sunfish
3. Northern Pike

PHYSICAL CHARACTERISTICS

Surface Area: 125 acres **Watershed:** 12,800 acres
Maximum Depth: 17 feet **Mean Depth:** 7.1 feet
Lake Elevation at Survey (from known benchmark): -2 feet

1. Describe ownership of lake and adjacent lakeshore property:

Byre Lake is privately owned with easements to the State of South Dakota. Access is a gravel road to the north shore of the lake.

2. Describe watershed condition and percentages of land use:

Approximately 60% of the watershed is cropland with the remaining 40% being pasture or CRP.

3. Describe aquatic vegetative condition:

Submergent vegetation surrounds the entire shoreline and is present in nearly the entire west quarter of the lake.

4. **Describe pollution problems:**

The primary concern is siltation. This problem has been reduced somewhat since establishment of several CRP plots on the watershed.

5. **Describe condition of all structures, i.e. spillway, level regulators, boat ramps, etc.:**

Dam grade and spillway areas are in good condition. A concrete plank boat ramp, located on the north shore and gravel access road are also in good condition.

CHEMICAL DATA

1. **Describe general water quality characteristics:**

Water chemistry was sampled on Byre Lake, on July 24, 2000 using a Hach Water Quality Kit. The results are on Table 1.

2. **Thermocline:** no

3. **Secchi disc reading:** 3.5 ft.

4. **Stations for water chemistry located on attached map:** yes

Table 1. Water chemistry results from Byre Lake, Lyman County July 24, 2000.

Station number	Depth feet	Temp F	DO PPM	CO2 PPM	ALK MG\L	Hardness MG\L	pH
1	surface	74	7.6	52	154	227	8.5
1	16	73	4.4	56	143	210	8.0

BIOLOGICAL DATA

Methods:

1. **Describe fish collection methods and show sampling locations by gear type on the lake map.**

Byre Lake was sampled using eight, 3/4 inch frame nets sets and two, baby frame nets from July 24-26, 2000. Pulsed AC electrofishing was completed on Oct.18. Conductivity was 600 ohms. Coefelt settings were 260 volts and 7 amps with a 50-pulse width and a frequency of 100 pulses per second. Fish indices were calculated and analyzed using the Winfin computer program.

Results and Discussion:

1. Tables listing species, number, size, etc. of fish.

Table 2. Total catch of six, 10-minute electrofishing transects at Byre Lake, Lyman County, 10/18/00.

Spec	No	Low 80% CI	Mean CPUE	Up 80% CI	Low 90% CI	PSD	Up 90% CI	Low 90% CI	Stock Mean Wr	Up 90% CI
LMB	29	4.9	29.0	53.1	90	96	100	109.2	112.3	115.3
WAE	19	10.3	19.0	27.7	66	82	99	96.8	99.3	101.8

Table 3. Total catch of eight, 24 hour, 3/4 inch frame nets at Byre Lake, Lyman County, July 24-26, 2000.

Spec	No.	Low 80% CI	Mean CPUE	Up 80% CI	Low 90% CI	PSD	Up 90% CI	Low 90% CI	Stock Mean Wr	Up 90% CI
BLB		91.8	127.5	163.2	100	100	100	89.4	90.4	91.4
BLG	83	7.8	10.4	16.0	100	100	100	100.9	101.8	102.7
LMB	4	0.2	0.5	0.8	na	na	na	88.1	99.2	110.4
NOP	13	0.9	1.6	2.4	1	23	45	69.0	70.6	72.2
WAE	9	0.6	1.1	1.6	36	67	98	75.9	80.9	86.0
YEP	1	0.0	0.1	0.3	na	na	na	na	na	na

2. Brief narrative describing status of fish sampled, make reference to the tables.

Black Bullheads remain the dominant species since the lake survey in 1997. The current survey had a CPUE of 127.5, a PSD of 100 and a RSD-P of 2. Last survey had a CPUE of 145.8 with a PSD of 43. With the average length of bullheads increasing, and the absence of young bullheads, it appears that the predator base has stopped recruitment. As long as Byre Lake predator density remains high, this population should continue to decrease in density and increase in quality.

Bluegills were sampled in the frame nets after being absent in the 1997 survey. Our survey had a CPUE of 10.4. The population had excellent quality with a PSD of 100 and a RSD-P of 92. It appears recruitment has stopped with no fish under 150 mm sampled. The bluegills were healthy with a Wr of 102.

Largemouth bass are one of the three predatory fish in Byre Lake. Fall electrofishing had a CPUE of 29 fish per hour. PSD was 96 with a RSD-P of 67. Condition was excellent with a Wr of 112. Anglers should be enjoying one of the best size structures of bass ever seen in Region 2 small dams. Growth was excellent with the average bass reaching preferred length in less than five years.

Table 4. Average Back-calculated Length for Each Age Class of Largemouth Bass at Byre Lake, Lyman County, 2000.

			Age							
Year Class	**Age**	**N**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1999	1	1	90							
1997	3	2	76	155	236					
1996	4	8	83	159	247	301				
1995	5	12	85	194	286	336	376			
1994	6	1	94	240	355	411	429	447		
1992	8	1	117	189	297	351	393	424	457	484
Sample Size		25								
Population Mean (mm)			91	187	284	350	399	435	457	484
Population Standard Error			6	15	21	23	16	12	0	0
Population Length Increment			97	97	66	50	36	21	28	

Walleye numbers have dropped since last survey. In 1997, frame nets had a CPUE of 14.5 and a PSD of 11. Our 2000 survey showed a frame net CPUE of 1.1. Electrofishing yielded 19 fish per hour. PSD was 82. Summer Wr was 80.9. Fall Wr was 99.3, indicating an increase in forage from the young of the year. The large decrease in abundance is probably due to fishing pressure. Growth was good for walleye in a small dam. Obviously, natural reproduction is occurring since several year classes are present since the last stocking in 1995.

Table 5. Average Back-calculated Length for Each Age Class of Walleye in Byre Lake, Lyman County, 2000.

Year Class	Age	N	1	2	3	4
1999	1	5	241			
1998	2	7	201	299		
1997	3	4	170	329	397	
1996	4	1	180	302	418	504
Sample Size		17				
Population Mean (mm)			198	310	407	504
Population Standard Error			16	9	10	0
Population Length Increment			112	98	96	

Northern pike numbers have increased slightly since 1997 when a CPUE of 0.2 was recorded. This survey had a frame net CPUE of 1.6. Wr was 70.6. The poor condition shows the lack of forage during the summer period as was evident with the walleye population. The thirteen fish sampled had a PSD of 23.

RECOMMENDATIONS

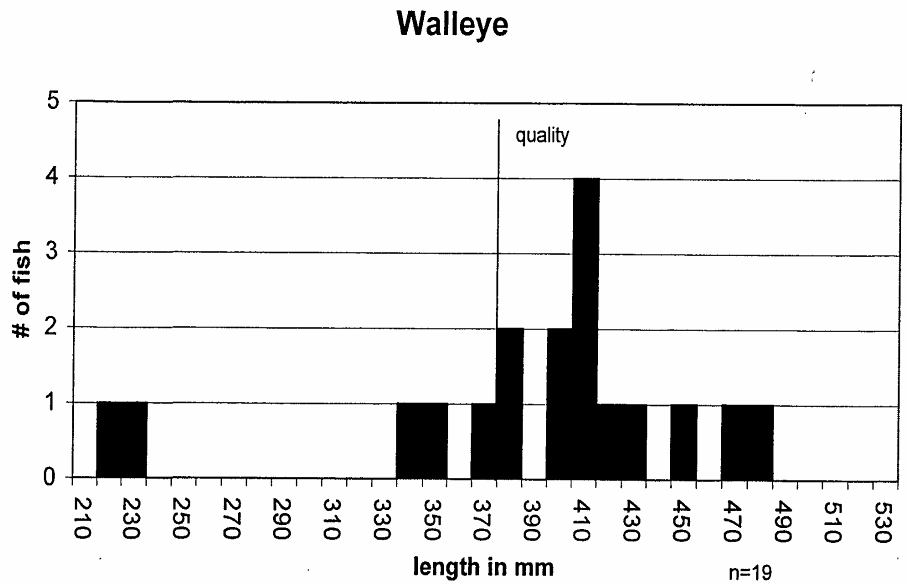
Describe management approach.

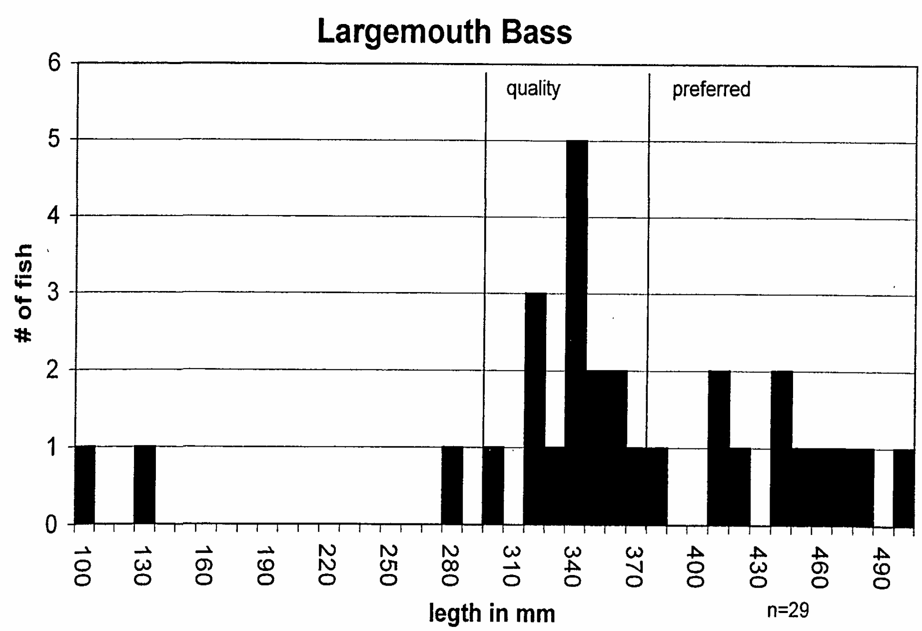
The lake looks great and should resurveyed in 2001 to sample all fish populations.

Stocking record for Byre Lake, Lyman County, 2000.

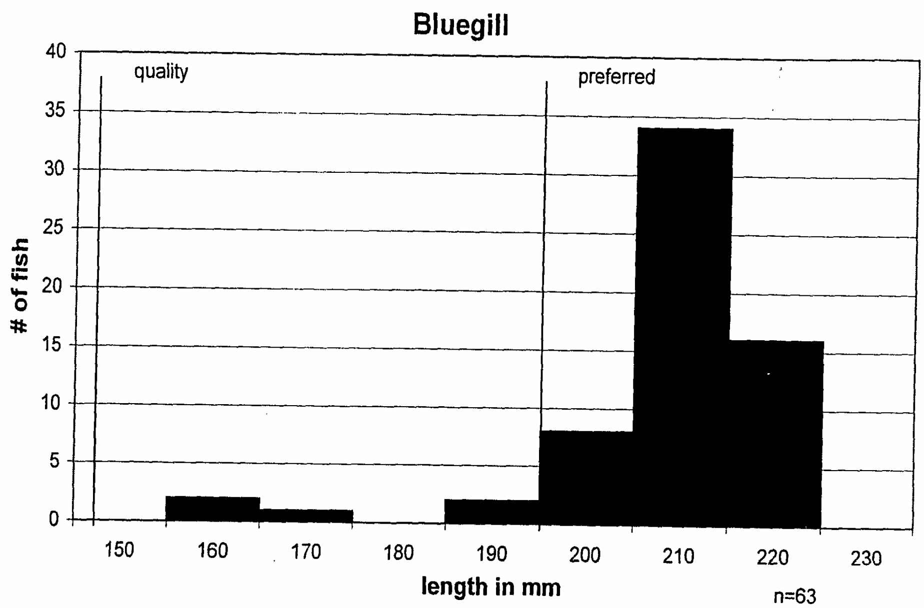
YEAR	NUMBER	SPECIES	SIZE
1991	7,000	FHM	ADT
1991	10,000	LMB	FGL
1991	14,000	LMB	FGL
1991	10,375	RBT	FGL
1991	13,800	WAE	FGL
1992	75,000	RBT	FGL
1992	4,660	WAE	FGL
1993	1,400	WAE	FGL
1994	3,125	WAE	FGL
1995	370	YEP	ADT

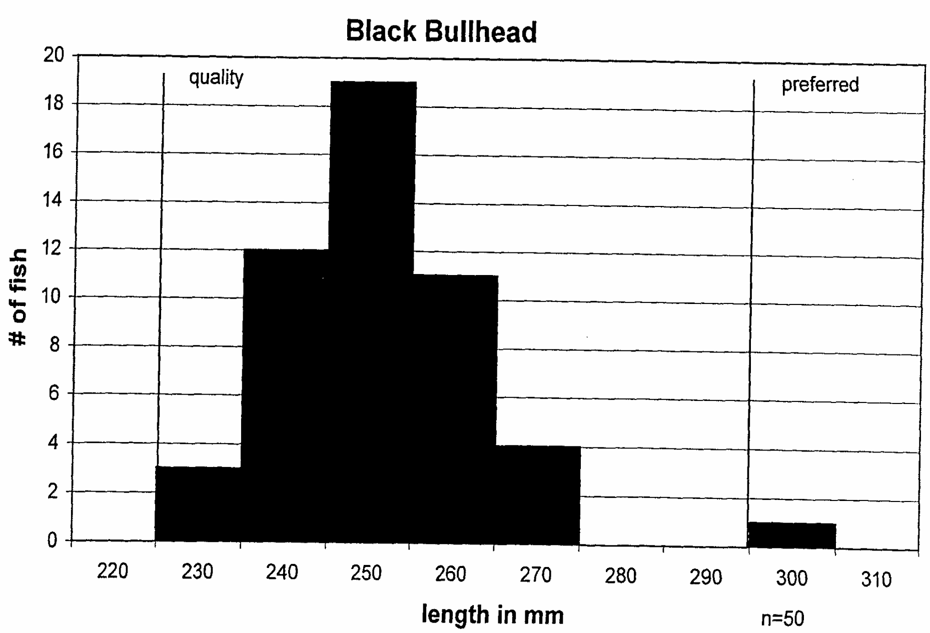
Byre Lake

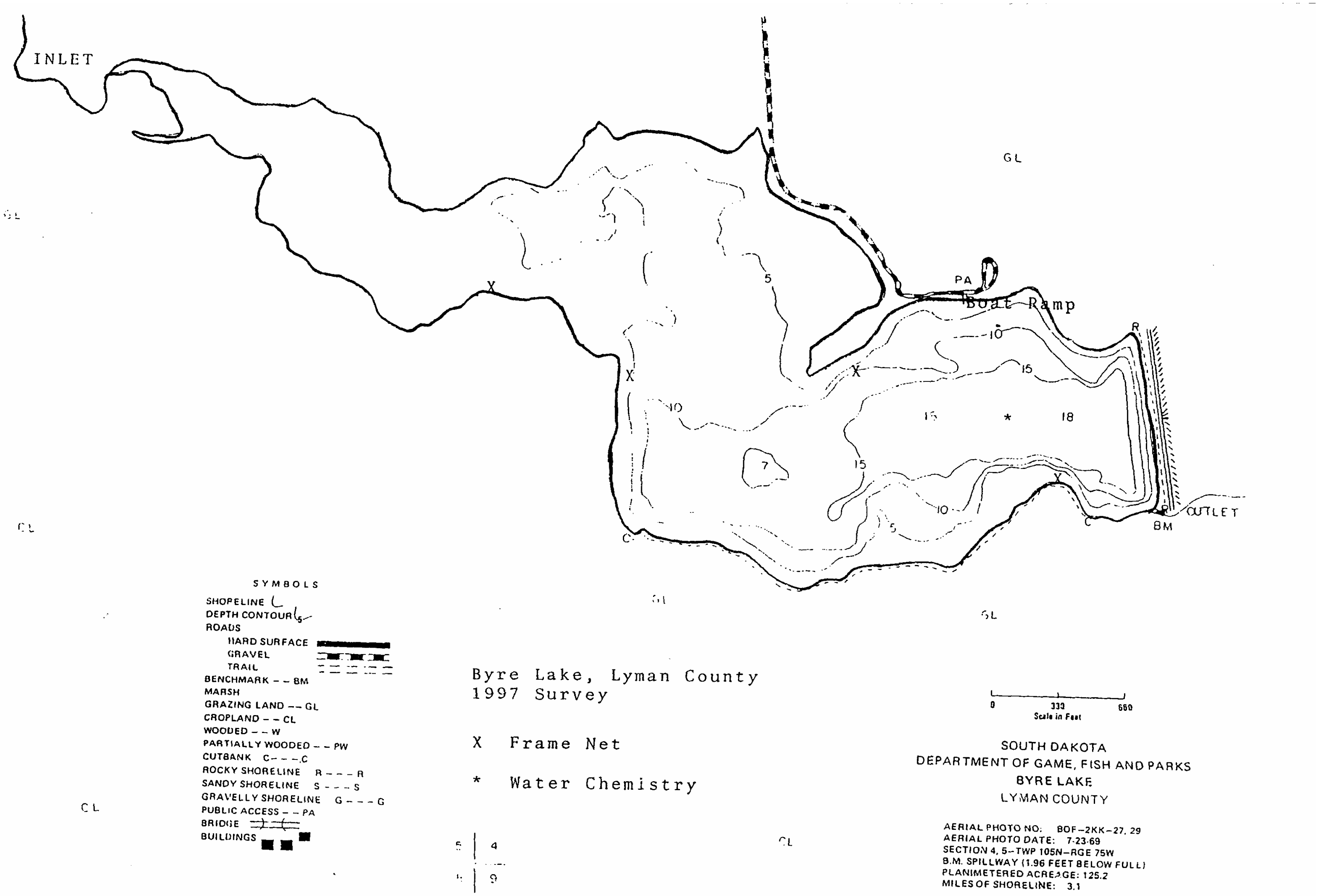

Walleye
quality
# of fish
5
4
3
2
1
0
210
230
250
270
290
310
330
350
370
390
410
430
450
470
490
510
530
length in mm
n=19


Largemouth Bass
quality
preferred
# of fish
6
5
4
3
2
1
0
100
130
160
190
220
250
280
310
340
370
400
430
460
490
legth in mm
n=29

Byre Lake


Bluegill
quality
preferred
40
35
30
25
20
15
10
5
0
# of fish
150
160
170
180
190
200
210
220
230
length in mm
n=63


Black Bullhead
quality
preferred
20
18
16
14
12
10
8
6
4
2
0
# of fish
220
230
240
250
260
270
280
290
300
310
length in mm
n=50


INLET
OUTLET
BM
Boat Ramp
PA
R
C
X
GL
CL
5
10
15
18
7
*
SYMBOLS
SHORELINE
DEPTH CONTOURS
ROADS
HARD SURFACE
GRAVEL
TRAIL
BENCHMARK - - BM
MARSH
GRAZING LAND - - GL
CROPLAND - - CL
WOODED - - W
PARTIALLY WOODED - - PW
CUTBANK C - - - C
ROCKY SHORELINE R - - - R
SANDY SHORELINE S - - - S
GRAVELLY SHORELINE G - - - G
PUBLIC ACCESS - - PA
BRIDGE
BUILDINGS
Byre Lake, Lyman County
1997 Survey
X Frame Net
* Water Chemistry
5 4
8 9
0 330 660
Scale in Feet
SOUTH DAKOTA
DEPARTMENT OF GAME, FISH AND PARKS
BYRE LAKE
LYMAN COUNTY
AERIAL PHOTO NO: BOF-2KK-27, 29
AERIAL PHOTO DATE: 7-23-69
SECTION 4, 5-TWP 105N-RGE 75W
B.M. SPILLWAY (1.96 FEET BELOW FULL)
PLANIMETERED ACREAGE: 125.2
MILES OF SHORELINE: 3.1

000082

APPENDIX H

Rare, Threatened and Endangered Species Documented in the Byre Lake Watershed and Medicine Creek, Lyman ands Jones Counties, South Dakota as of December 2002

Key to Codes Used in Natural Heritage Database Reports

FEDERAL STATUS	LE = Listed endangered
	LT = Listed threatened
	LELT = Listed endangered in part of range, threatened in part of range
	PE = Proposed endangered
	PT = Proposed threatened
	C = Candidate for federal listing, information indicates that listing is justified.
STATE STATUS	SE = State Endangered
	ST = State Threatened

An endangered species is a species in danger of extinction throughout all or a significant portion of its range. (applied range wide for federal status and statewide for state status)

A threatened species is a species likely to become endangered in the foreseeable future.

Global Rank	State Rank	Definition (applied rangewide for global rank and statewide for state rank)
G1	S1	Critically imperiled because of extreme rarity (5 or fewer occurrences or very few remaining individuals or acres) or because of some factor(s) making it especially vulnerable to extinction.
G2	S2	Imperiled because of rarity (6 to 20 occurrences or few remaining individuals or acres) or because of some factor(s) making it very vulnerable to extinction throughout its range.
G3	S3	Either very rare and local throughout its range, or found locally (even abundantly at some of its locations) in a restricted range, or vulnerable to extinction throughout its range because of other factors; in the range of 21 of 100 occurrences.
G4	S4	Apparently secure, though it may be quite rare in parts of its range, especially at the periphery. Cause for long term concern.
G5	S5	Demonstrably secure, though it may be quite rare in parts of its range, especially at the periphery.
GU	SU	Possibly in peril, but status uncertain, more information needed.
GH	SH	Historically known, may be rediscovered.
GX	SX	Believed extinct, historical records only.
G?	S?	Not yet ranked
_?	_?	Inexact rank
_T		Rank of subspecies or variety
_Q		Taxonomic status is questionable, rank may change with taxonomy
	SZ	No definable occurrences for conservation purposes, usually assigned to migrants
	SP	Potential exists for occurrence in the state, but no occurrences
	SR	Element reported for the state but no persuasive documentation
	SA	Accidental or casual

Bird species may have two state ranks, one for breeding (S#B) and one for nonbreeding seasons (S#N). Example: Ferruginous Hawk (S3B, SZN) indicates an S3 rank in breeding season and SZ in nonbreeding season.

Rare, Threatened or Endangered Species Documented in Grouse Creek and Byre Lake in the Medicine Creek Watershed
HUC 10140104
South Dakota Natural Heritage Database
12//9/2002

NAME	TOWNSHIP RANGE & SECTION	COUNTY	LAST OBSERVED	FEDERAL STATUS	STATE STATUS	STATE RANK	GLOBAL RANK	EODATA
WHOOPING CRANE *Grus americana*	107N079W 11	Lyman	1997-10-29	LE	SE	SZN	G1	3 CRANES FLYING
BURROWING OWL *Athene cunicularia*	107N079W 34	Lyman	1998-07		S3S4B	SZN	G4	ONE NESTING PAIR, ONE JUVENILE OWL IN JULY.
SWAINSON'S HAWK *Buteo swainsoni*	108N079W 33	Lyman	1994		S4B	SZN	G5	ACTIVE NET IN 1994
FERRUGINOUS HAWK *Buteo regalis* S	107N079W 11	Lyman	1999-04-09		S4B	SZN	G4	ADULT SITTING ON NEST IN 1994. 1998-ON NEST, SAME LOCATION, ON APRIL 16 AND 30. ON NEST ON APRIL 9, 1999.
SWAINSON'S HAWK *Buteo swainson*	107N078W 27	Lyman	1999-04-28		S4B	SZN	G5	SWAINSON'S HAWK AT NEST
BURROWING OWL *Athene cunicularia*	107N078W 21	Lyman	1999-07-15		S3S4B	SZN	G4	FOUR ACTIVE OWL NESTS, ONE JUVENILE OWL IN JULY. 1999-2 BURROWING OWLS REPORTED IN THIS DOG TOWN.
BURROWING OWL *Athene cunicularia*	001N031E 33	Jones	1998-07		S3S4B	SZN	G4	THREE ACTIVE NESTS, 4+ JUVENILES IN JULY.
PLAINS SPOTTED SKUNK *Spilogale putorius interrup*	001S031E 32	Jones	1993-04-05		S3		G5T4	ROAD KILL
BAIRD'S SPARROW *Ammodramus bairdii*	001N031E 9	Jones	1997-08-29		S2B	SZN	G4	AT LEAST 2 SINGING IN THIS AREA, PRESENT ALL SUMMER
BURROWING OWL *Athene cunicularia*	107N079W 34	Lyman	1998-07		S3S4B	SZN	G4	ONE ACTIVE NEST, 2 JUVENILE OWLS IN JULY.
SPRAGUE'S PIPIT *Anthus spragueii*	107N078W 7	Lyman	1997-07-29		S2B	SZN	G4	AT LEAST TWO SINGING IN SECTION 7, OTHERS HEARD IN SECTIONS 16 AND 17. HEARD IN AREA ALL SUMMER.
BAIRD'S SPARROW *Ammodramus bairdi*	107N078W 9	Lyman	1997-07-29		S2B	SZN	G4	AT LEAST FIVE SEEN OR HEARD, OTHERS IN SECTION 8 TO THE WEST AND IN SEC. 26 T108N R78W. PRESENT IN THESE AREAS ALL SUMMER.
WHOOPING CRANE *Grus Americana*	105N076W 31	Lyman	1998-05-07	LE	SE	SZN	G1	ONE CRANE ON GROUND FOR 5 DAYS

APPENDIX I

Byre Lake Total Maximum Daily Load Summary Document

TOTAL MAXIMUM DAILY LOAD EVALUATION

For

TOTAL PHOSPHORUS (TSI)

In

BYRE LAKE

GROUSE CREEK WATERSHED

(HUC 10160008)

LYMAN COUNTY, SOUTH DAKOTA

SOUTH DAKOTA DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES

APRIL, 2003

Byre Lake Total Maximum Daily Load April, 2003

Waterbody Type:	Lake (Impounded)
303(d) Listing Parameters:	Total phosphorus (TSI)
Designated Uses:	Domestic Water Supply Warmwater permanent fish life propagation water; Immersion recreation water; Limited contact recreation waters; Fish and wildlife propagation, recreation and stock watering water. Irrigation water
Size of Waterbody:	51.4 hectare (127.3 acres)
Size of Watershed:	9,326 hectare (22,946 acres)
Water Quality Standards:	Narrative and numeric
Indicators:	Average TSI
Analytical Approach:	BATHTUB, FLUX and AnnAGNPS
Location:	HUC Code: 10140104
TMDL Goal	
Total Phosphorus:	19.6% reduction in total phosphorus (7,550 kg/yr.)
TMDL Target	
Total Phosphorus:	TSI 68.02, mean TSI 65.00 (7,550 kg/yr.)

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

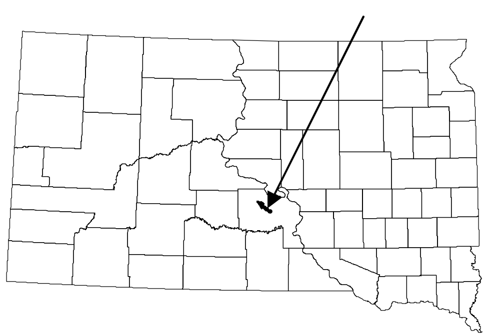


Figure 1. Byre Lake watershed location in South Dakota

Byre Lake is a 51.5 hectare (127.3-acre) man-made impoundment located in central Lyman County, South Dakota (Figure 1). Byre Lake is not listed in the 2002 South Dakota 303(d) Waterbody List; however the 2003 Byre Lake watershed assessment report identified Byre Lake as not meeting the ecoregional based TSI criteria. Watershed and in-lake modeling indicated that even under ideal conditions, Byre Lake could not attain current ecoregional TSI targets. Modeling data was used to develop watershed/site specific TSI target criteria. Byre Lake was identified for TMDL development for trophic state index (TSI), increased eutrophication.

The Byre Lake watershed encompasses approximately 9,286 ha (22,946 acres) and is drained by Grouse Creek (Figure 2). The damming of Grouse Creek near the town of Kennebec, South Dakota created the lake, which has an average depth of 2.15 meters (7.06 feet) and over 5.44 kilometers (3.38 miles) of shoreline. The lake has a maximum depth of 5.49 meters (18 feet) and holds 7,258.5 acre-feet of water. The outlet for the lake empties back into Grouse Creek, which empties into Medicine Creek and eventually reaches the Missouri River.

Problem Identification

Grouse Creek is the primary tributary to Byre Lake and drains predominantly agricultural land (approximately 56 percent). The stream carries nutrients (total nitrogen and total phosphorus) and sediment loads, which degrade the water quality of the lake, and cause increased eutrophication.

Mean TSI values were originally used to set current ecoregional beneficial use criteria for lakes in South Dakota (SD DENR, 2000a). Currently, the target for full support in ecoregion 43 is a mean TSI values ≤ 55.00. However, current ecoregional (ecoregion 43) target criteria appear not to fit Byre Lake based on AnnAGNPS watershed loading and BATHTUB in-lake eutrophication modeling. AnnAGNPS model was used to estimate watershed loading under ideal conditions (entire watershed converted to grassland with a minimum grass height of 10.2 cm (4 inches)) indicate the maximum phosphorus reduction in this watershed would be 28.1 percent (Appendix B). BATHTUB was then used to model AnnAGNPS phosphorus reduction to in-lake trophic response under ideal conditions. Data indicate under ideal conditions (mean TSI 64.16); Byre Lake could not meet ecoregional-based beneficial use criteria based on current targets.

Current watershed conditions (loading) result in a mean in-lake TSI value of 66.24 (Table 48). The Byre Lake/Grouse Creek watershed can not meet current ecoregional based beneficial use criteria which are unrealistic and unachievable in the Byre Lake watershed. Alternative site specific (watershed specific) evaluation criteria (fully supporting, mean TSI ≤ 65.00) is proposed based on AnnAGNPS modeling, BMPs and watershed specific phosphorus reduction attainability (Figure 63).

Currently, the total phosphorus load to Byre Lake is 9,391 kg/year (10.4 tons/year). Total phosphorus loads need to be reduced by 1,841 kilograms (19.6 %), resulting in a total phosphorus TMDL of 7,550 kilogram per year producing an average Trophic State Index (TSI) of 65.00.

Description of Applicable Water Quality Standards & Numeric Water Quality Targets

Byre 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) Domestic water supply water
(4) Warmwater permanent fish life propagation water;
(7) Immersion recreation water;
(8) Limited contact recreation water; and
(9) Fish and wildlife propagation, recreation and stock watering water and
(10) Irrigation water.

Individual parameters, including the lake's mean TSI value, determine the support of beneficial uses and compliance with standards. Byre Lake experiences nutrient enrichment and some nuisance algal blooms, which are typical signs of the eutrophication process. Byre Lake was identified in the 2003 Byre Lake / Grouse Creek Watershed Assessment as partially supporting based on mean TSI values and watershed/site specific beneficial use criteria developed using Annualized Agricultural Non-Point Source model (AnnAGNPS) modeling.

South Dakota has several applicable narrative standards that may be applied to the undesirable 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 assess the trophic status of a lake. SD DENR uses the mean (combined) Trophic State Index or TSI (Carlson, 1977) which incorporates a combination of Secchi depth, chlorophyll-*a* and total 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 Byre Lake.

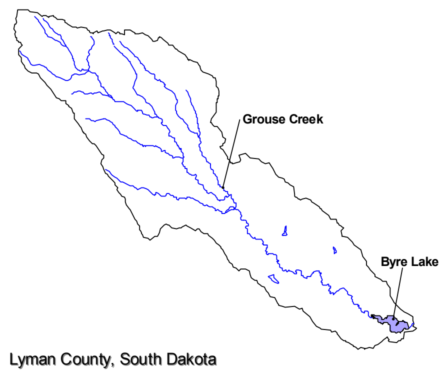


Figure 2. Byre Lake and Grouse Creek watershed.

Byre Lake currently has a modeled total phosphorus TSI of 69.76, a chlorophyll-*a* TSI of 60.61 and a Secchi TSI of 68.34 which translates to an average TSI of 66.24, which is indicative of increased levels of primary productivity (page 103). Assessment monitoring indicates that the primary cause of high productivity is increased total phosphorus loads from the watershed.

SD DENR recommended specific TSI parameters for Byre Lake are: 68.02 for total phosphorus, 59.96 for chlorophyll-*a* and 67.02 for Secchi visibility. The TMDL numeric target established to reduce total phosphorus loading to Byre Lake will lower the mean TSI to 65.00 (assessment final report, pages 131 through 134).

Pollutant Assessment

Point Sources
There are no point sources of pollutants of concern in this watershed.

Nonpoint Sources/ Background Sources
Nonpoint and background sources for the Byre Lake / Grouse Creek Watershed were estimated using FLUX and AnnAGNPS modeling.

Under current conditions, total nonpoint source loading of total phosphorus from the watershed to Lake Byre was estimated to be 9,391 kg and were attributed to agricultural sources. Nonpoint source load allocation of total phosphorus (1,841 kg) was subtracted from the total phosphorus TMDL (7,550 kg) to determine background source loading. The remaining total phosphorus loading (5,709 kg/yr) was attributed to background sources in the Byre Lake watershed.

Linkage Analysis
Water quality data was collected from 2 monitoring sites within the Byre Lake / Grouse Creek watershed. Samples collected at each site were taken according to South Dakota's 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 approximately 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 on pages 9 through 10, pages 18 through 21, 53 through 54 and 121 through 125 of the assessment final report.

In addition to water quality monitoring, data was collected to complete a watershed landuse model. The AnnAGNPS model was used to estimate potential nutrient load reductions from conservation tillage, fertilizer reduction, grazing management and buffer strips within the watershed through the implementation of various BMPs. See the AnnAGNPS section of the final report, Appendix B.

In-lake (aluminum sulfate treatment) BMPs were also used to estimate total phosphorus reductions. Five other BMPs were suggested (streambank stabilization, conversion of highly erodible cropland to rangeland, riparian management, shoreline stabilization and submerged aquatic macrophytes) however total phosphorus reduction percentages were not estimated because data was unavailable to calculate viable responses. Sediment and nutrient reductions for these BMPs are incorporated into the TMDL calculation by way of an implicit margin of safety. All estimates were based on conservative percent reductions applied to priority subwatersheds (assessment final report, pages 131 through 134).

Reducing the current total phosphorus load (9,391 kg/yr) a minimum of 19.6% (1,841 kg/yr) will reduce the average TSI value from 66.24 to 65.00. This can be accomplished by implementing tributary BMPs with an implicit margin of safety to support the TMDL target.

TMDL and Allocations

TMDL

Total phosphorus (kg) = 19.6% reduction

	0 kg/yr	(WLA)
+	1,841 kg/yr	(LA)
+	5,709 kg/yr	(Background)
+	Implicit	(MOS)
	7,550 kg/yr	(TMDL) [1]

[1] = TMDL Equation implies a 19.6% based on BMP attainability in total phosphorus reduction with all modeled tributary BMP implementations.

Wasteload Allocations (WLAs)

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

Load Allocations (LAs)

The result of the AnnAGNPS model indicates that conversion of select minimum tillage fields to no tillage could achieve a 3.1% (291 kg/yr) reduction and reduced fertilizer application could achieve a 4.3% (404 kg/yr) reduction in total phosphorus loading to Byre Lake.

Tributary total phosphorus reductions for grazing management 7.9% (742 kg/yr.) and buffer strips 4.3% (404 kg/yr.) were estimated AnnAGNPS.

In-lake total phosphorus reductions in TSI were also estimated for Byre Lake. They include and an aluminum sulfate treatment, 30% reduction in in-lake phosphorus concentrations resulting in a 4.1% reduction in in-lake total phosphorus TSI values.

A total phosphorus reduction of 19.6% (1,841) is needed to improve the mean TSI of Byre Lake to 65.00. AnnAGNPS modeling indicated that implementing only modeled BMPs in the Byre Lake / Grouse Creek watershed would meet watershed specific beneficial use target set for Byre Lake.

Seasonal Variation

Different seasons of the year can yield differences in water quality due to changes in temperature, precipitation and agricultural practices. To determine seasonal differences, Byre Lake samples were separated into winter (January-March, spring (April-June), summer (July-September) and fall (October-December).

Margin of Safety

All modeled total phosphorus reductions were calculated based on extremely conservative estimations built into the model and conservative total phosphorus reduction percentages using best professional judgment. Some BMPs (streambank stabilization, conversion of highly erodible cropland to rangeland, riparian management, shoreline stabilization and submerged aquatic macrophytes) were suggested however total phosphorus reduction percentages were not estimated due to inadequate models to calculate viable responses. Sediment and nutrient reductions for these BMPs are incorporated into the TMDL calculation by way of the implicit margin of safety (assessment final report, pages 131 and 134). Byre Lake needs a 19.6% total phosphorus reduction to improve average TSI values.

Critical Conditions

Based upon the 2000 through 2001 assessment data, nutrient loading to Byre Lake are most severe during the spring (runoff events) and impairments to Byre Lake are most severe during the late summer and early fall. This is the result of warm water temperatures and increased algal growth.

Follow-Up Monitoring

Byre Lake should be on the SD DENR round robin statewide lake assessment project and remain on the South Dakota Game, Fish and Parks normal lake survey to monitor and evaluate long-term trophic status, biological communities and ecological trends.

Periodically during the implementation project and once it is completed, monitoring will be necessary to assure that the TMDL has been reached and improvements in average TSI values occur.

Public Participation

During the Medicine Creek watershed Assessment Project, the Byre Lake watershed assessment project was initiated during the spring of 2000 with EPA Section 319 funds. Byre Lake was not on the priority list of Section 319 Nonpoint Source Pollution Control projects;

however, based on watershed assessment data Byre Lake partially supports watershed specific TSI criteria. American Creek Conservation District agreed to sponsor the project. Federal grant funds totaled $101,796 of which, Byre Lake was assessed. Funds were used for water quality analyses, equipment, supplies, travel, and wages for the local coordinator.

Efforts taken to gain public education, review, and comment during development of the TMDL involved:

1. American Creek Conservation District Board Meetings (20)
2. County Commission Meetings (2)
3. Individual contact with landowners in the watershed (continuous throughout the project).
4. Articles/pamphlets sent to landowners in the watershed (3)
5. Newspaper articles (2)
6. Final results presentation (1)

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

Implementation Plan

The South Dakota DENR is working with the American Creek Conservation District to initiate an implementation project beginning in 2004. It is expected that a local sponsor will request project assistance during the fall 2004 EPA Section 319 funding round.

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

June 3, 2004

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
Lake Alice
Byre Lake
Lake Hanson

Dear Mr. Pirner:

We have completed our review, and have received Endangered Species Act Section 7 concurrence from the U.S. 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.

In the course of developing TMDLs for impaired waters, EPA has recognized that not all impairments are linked to water chemistry alone. Rather, EPA recognizes that *"Section 303(d) requires the States to identify all impaired waters regardless of whether the impairment is due to toxic pollutants, other chemical, heat, habitat, or other problems."* (see 57 Fed. Reg. 33040 for July 24, 1992). Further, EPA states that "*...in some situations water quality standards – particulary designated uses and biocriteria – can only be attained if nonchemical factors such as hydrology, channel morphology, and habitat are also addressed. EPA recognizes that it is appropriate to use the TMDL process to establish control measures for quantifiable non-*

chemical parameters that are preventing the attainment of water quality standards." (see Guidance for Water Quality-based Decisions: The TMDL Process; USEPA; EPA 440/4-91-001, April 1991; pg. 4). We feel the State has developed TMDLs that are consistent with this guidance, taking a comprehensive view of the sources and causes of water quality impairment within each of the watersheds. For example, in several of the TMDLs, the State considered nonchemical factors such as trophic state index (TSI) and its relationship to the impaired uses. Further, we feel it is reasonable to use factors such as TSI as surrogates to express the final endpoint of the TMDL.

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)
Lake Alice*	phosphorus	TSI mean < 65	216 kg/yr total phosphorous load to the lake	Section 303(d)(1)	■ Phase I Watershed Assessment and TMDL Final Report, Lake Alice, Deuel County, South Dakota (SD DENR, July 2002)
Byre Lake	phosphorus	TSI mean ≤ 65	7,550 kg/yr total phosphorous load to the lake (19.6% reduction in average annual total phosphorus load)	Section 303(d)(1)	■ Phase I Watershed Assessment Final Report and TMDL, Byre Lake / Grouse Creek, Lyman County, South Dakota (SD DENR, April 2003)
Lake Hanson*	phosphorus	TSI mean < 65 Increase boatable acres in the lake (add 8 acres)	2,612 kg/yr total phosphorous load to the lake (5% reduction of in average annual total phosphorus load)	Section 303(d)(1)	■ Phase I Watershed Assessment and TMDL Final Report, Lake Hanson / Pierre Creek, Hanson County, South Dakota (SD DENR, December 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: Lake Alice, Deuel County
Point Source-control TMDL: Nonpoint Source-control TMDL: X (check one or both)
Date Received: May 17, 2004 Date Review completed: May 25, 2004 VEB

Review Criteria (All criteria must be met for approval)	**Approved** (check if yes)	**Comments**
■ **TMDLs result in maintaining and attaining water quality standards**	X	The waterbody classification uses which are addressed by this TMDL are warmwater semipermanent fish life propagation, immersion recreation, limited contact recreation, and criteria for fish and wildlife propagation, recreation and stock watering.
■ **Water Quality Standards Target**	X	Water quality target was established based on the targets in the document "Ecoregion Targeting for Impaired Lakes in South Dakota." These targets meet the fully support beneficial uses of identified lakes. This is a reasonable approach because the trophic status of the waterbody relates to the uses of concern.
■ **TMDL**	X	The TMDL is expressed in terms of annual phosphorus load to the lake. This is a reasonable way to express the TMDL for this lake because it provides an effective surrogate that reflects both aquatic life and recreational needs, and reflects the long response time of lakes of this type to pollutant controls within the watershed.
■ **Significant Sources Identified**	X	Significant sources were adequately identified in a categorical and/or individual source-by-source basis. All sources that need to be addressed through controls were identified.
■ **Technical Analysis**	X	Monitoring, empirical relationships, BATHTUB and FLUX modeling, and best professional judgement were used in identifying pollutant sources, and in identifying acceptable levels of pollutant control. This level of technical analysis is reasonable and appropriate because of the character of the pollutants, the type of land use practices, and the waterbody type.
■ **Margin of Safety and Seasonality**	X	An appropriate margin of safety is included through conservative assumptions in the derivation of the target and in the modeling. Additionally, 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 BMPs that can be tailored to seasonal needs.
■ **Allocation**	X	The allocation for the TMDL was a "load allocation" attributed to nonpoint sources. Allocation was attributed to range and cropland management practices, and internal loading.
■ **Public Review**	X	Public review and participation was conducted through meetings, electronic media, and mailings. The extent of public review is acceptable. Further, the review process sponsored by the State was adequate for purposes of developing a TMDL that will be implemented because of public acceptance.
■ **EPA approved Water Quality Standards**	X	Standards upon which this TMDL was based have been formally approved by the EPA. No tribal waters were involved in this TMDL.

■ TMDL Checklist ■

EPA Region VIII

State/Tribe: South Dakota Waterbody Name: Byre Lake, Lyman County Point Source-control TMDL: Nonpoint Source-control TMDL: X (check one or both) Date Received: May 17, 2004 Date Review completed: May 25, 2004 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 Byre Lake. The South Dakota Department of Environment and Natural Resources (SD DENR) has identified Byre Lake as a water that is intended to support a range of designated uses including: domestic water supply, warmwater permanent fish life propagation, immersion recreation, limited contact recreation, fish and wildlife propagation, recreation, stock watering, and irrigation. 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 Byre Lake during the period of the assessment (April 2000 through May 2001) was 66.2. Nutrient reduction response modeling was conducted with BATHTUB, an Army Corps of Engineers eutrophication response model. The results of the modeling show that 80% or more reduction in the total phosphorous loading from the watershed would be necessary to meet the ecoregion-based beneficial use TSI target of 55 or less. However, Byre 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, an alternative watershed specific TSI target has been established, which will fully support the beneficial uses for Byre Lake. The target used in this TMDL is: ■ TSI mean $\leq$ 65 (growing season average)

State/Tribe: South Dakota Waterbody Name: Byre Lake, Lyman County Point Source-control TMDL: Nonpoint Source-control TMDL: X (check one or both) Date Received: May 17, 2004 Date Review completed: May 25, 2004 VEB	
C. Significant Sources - **Approved**	The TMDL identifies the major sources of phosphorous as coming from nonpoint source agricultural landuses within the watershed and internal loading from bottom sediments within the lake. In particular, a loading analysis was done for nutrients and sediment considering various agricultural land use and land management factors.
D. Technical Analysis - **Approved**	The technical analysis addresses the needed phosphorous reduction to achieve the desired water quality. The TMDL recommends a 19.6% reduction in average annual total phosphorous loads to Byre Lake. Based on the loads measured during the period of the assessment the total phosphorous load should be 7,550 kg/yr to achieve the desired TSI target. This reduction is based in large part on the BATHTUB mathematical modeling of the Lake and its predicted response to nutrient load reductions. The Annualized Agricultural Non-Point Source Model (AnnAGNPS) model was used to simulate alterations in land use practices and the resulting nutrient reduction response. The nutrient loading source analysis, that was used to identify necessary controls in the watershed, was based on the identification of targeted or "critical" cells. Cell priority was assigned based on average nutrient and sediment loads produced that ultimately reach the outlet of the watershed. Cells that produce nitrogen, sediment *and* phosphorous loads greater than one standard deviation over the mean for the watershed were given a priority ranking of 1. Cells that produce loads for 2 out of the 3 pollutants greater than one standard deviation over the mean were given a priority ranking of 2. Cells that produce loads for 1 out of the 3 pollutants greater than one standard deviation over the mean were given a priority ranking of 3. The initial load reductions under this TMDL will be achieved through controls on the priority 1 and 2 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. Additionally, BMPs were specified that go beyond what is necessary to achieve the target, and 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 BMPs that can be tailored to seasonal needs.
F. TMDL - **Approved**	The TMDL established for Byre Lake is a 7,550 kg/yr total phosphorus load to the lake (19.6% reduction in annual total phosphorus load). Since the annual loading varies from year-to-year, this TMDL is considered a long term average percent reduction in phosphorous loading.
G. Allocation - **Approved**	This TMDL addresses the need to achieve further reductions in nutrients to attain water quality goals in Byre Lake. The allocation for the TMDL was a "load allocation" attributed to nonpoint sources. The allocation for phosphorous was attributed to such sources as runoff from cropland, rangeland and pastureland. There is a desire to move forward with controls in the areas of the basin where there is confidence that phosphorous reductions can be achieved through modifications to priority cells within the watershed combined with modification of grazing practices. Additional phosphorous load reductions are possible from streambank stabilization, conversion highly erodible cropland to rangeland, riparian management, and shoreline stabilization. Reduction percentages were not calculated for these additional BMPs.

<table>
<tr><td colspan="2">State/Tribe: South Dakota
Waterbody Name: Byre Lake, Lyman County
Point Source-control TMDL: Nonpoint Source-control TMDL: X (check one or both)
Date Received: May 17, 2004 Date Review completed: May 25, 2004 VEB</td></tr>
<tr><td>H. Public Participation - Approved</td><td>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, individual contact with the residents in the watershed, and widespread solicitation of comments on the draft TMDL. The State also employed the Internet to post the draft TMDL and to solicit comments. The level of public participation is found to be adequate.</td></tr>
</table>

■ TMDL Checklist ■

EPA Region VIII

State/Tribe: South Dakota
Waterbody Name: Lake Hanson, Hanson County
Point Source-control TMDL: Nonpoint Source-control TMDL: X (check one or both)
Date Received: May 17, 2004 Date Review completed: May 25, 2004 VEB

Review Criteria (All criteria must be met for approval)	**Approved** (check if yes)	**Comments**
■ **TMDLs result in maintaining and attaining water quality standards**	X	The waterbody classification uses which are addressed by this TMDL are warmwater semipermanent fish life propagation, immersion recreation, limited contact recreation and fish and wildlife propagation, recreation and stock watering.
■ **Water Quality Standards Target**	X	Water quality target was established based on the targets in the document "Ecoregion Targeting for Impaired Lakes in South Dakota." These targets meet the fully support beneficial uses of identified lakes. This is a reasonable approach because the trophic status of the waterbody relates to the uses of concern.
■ **TMDL**	X	The TMDL is expressed in terms of total phosphorus load to the lake, and the corresponding average annual percent reduction in phosphorous load. This is a reasonable way to express the TMDL for this lake because it provides an effective surrogate that reflects both aquatic life and recreational needs.
■ **Significant Sources Identified**	X	Significant sources were adequately identified in a categorical and/or individual source-by-source basis. All sources that need to be addressed through controls were identified as grazing lands, animal feeding operations and septic systems near the lake.
■ **Technical Analysis**	X	Monitoring, empirical relationships, AnnAGNPS, FLUX and BATHTUB modeling , and best professional judgement were used in identifying pollutant sources, and in identifying acceptable levels of pollutant control. This level of technical analysis is reasonable and appropriate because of the character of the pollutants, the type of land use practices, and the waterbody type.
■ **Margin of Safety and Seasonality**	X	An appropriate margin of safety is included through conservative assumptions in the derivation of the target and in the modeling. Additionally, BMPs were specified that go beyond what is necessary to achieve the target, and 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 BMPs that can be tailored to seasonal needs.
■ **Allocation**	X	The allocation for the TMDL was a "load allocation" attributed to nonpoint sources. Allocation was attributed to range and cropland management practices, and internal loading.
■ **Public Review**	X	Public review and participation was conducted through meetings, electronic media, and mailings. The extent of public review is acceptable. Further, the review process sponsored by the State was adequate for purposes of developing a TMDL that will be implemented because of public acceptance.
■ **EPA approved Water Quality Standards**	X	Standards upon which this TMDL was based have been formally approved by the EPA. No tribal waters were involved in this TMDL.

STATE OF SOUTH DAKOTA.

UNDER GOD THE PEOPLE RULE

GREAT SEAL.

1889

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