PHASE I
WATERSHED ASSESSMENT
FINAL REPORT

LAKE ALVIN
LINCOLN COUNTY, SOUTH DAKOTA

South Dakota Water Resource Assistance Program
Division of Financial and Technical Assistance
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State of South Dakota
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January, 2001

EXECUTIVE SUMMARY

Lake Alvin is a 43.3 hectare (107 acre) reservoir in northeastern Lincoln County, South Dakota. Lake Alvin is owned and managed by South Dakota Game, Fish and Parks (SD GF&P). Lake Alvin has a watershed of 11,336.5 hectares (28,013 acres) which is drained by Nine Mile Creek and includes the City of Harrisburg and the eastern portion of the City of Tea, South Dakota. Land use within the watershed is primarily agricultural.

Lake Alvin is listed on the 303(d) waterbody list as a priority 1 (high priority) watershed. Priority ranking follows the 1998 South Dakota 303(d) waterbody list criteria and was based upon water quality impairments, need and local interest (SD DENR 1998). Lake Alvin is listed for fecal coliform bacteria, water quality standard violations and increasing Trophic State Index (TSI trend).

The long term goal of the Lake Alvin watershed assessment project is to locate and document sources of non-point 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 water quality. This study was funded by 604(b), 104 (b)(3) funds, and local match with a total project cost of $63,251.00. South Dakota Department of Game, Fish and Parks personnel assisted in the collection of tributary flows and water quality samples. South Dakota Department of Environment and Natural Resources (SD DENR) staff collected all inlake samples and Lincoln County NRCS (Natural Resource Conservation Service), Lincoln Conservation District staff collected AGNPS modeling data.

During this study, there were no water quality standards exceedances for Nine Mile Creek east (downstream) or west (upstream) of Lake Alvin. However, three upstream tributary sites had fecal coliform counts in excess of 1,000 colonies/ 100 ml. No monthly inlake samples exceeded water quality standards for fecal coliform bacteria; however, three separate beach samples in June 1999 exceeded water quality standards for public beaches. Lake Alvin has had problems with high fecal coliform counts and beach closures in the past. South Dakota Game Fish and Parks reports most beach closures at Lake Alvin occur after heavy rains, suggesting runoff from the watershed is a major factor in increased fecal coliform counts. Implementing select tributary Best Management Practices (BMPs) will reduce fecal coliform counts from livestock and reduce the number of beach closures.

The increasing TSI trend observed in Lake Alvin from 1989 through 1999 is the result of increased nutrients by inlake (internal loading) and delivered loads. Decreasing sediment (erosion) and nutrients (nitrogen and phosphorus) inputs from Nine Mile Creek and the ungauged portion of the watershed will improve (lower) TSI values. This can be accomplished by implementing tributary and inlake BMPs on critical cells and priority areas identified by watershed assessment and Agricultural Non-Point Source pollution model (AGNPS) within the watershed.

Tributary hydrologic loading to Lake Alvin was monitored from March through November 1999 (232 days). Approximately 4,537 acre-feet of water flowed into Lake Alvin from the gauged portion of the watershed and an estimated 910 acre-feet of water was delivered to Lake Alvin from the ungauged portion in 1999. Peak hydrologic load from all subwatersheds occurred in the spring, with approximately two-thirds of the total hydrologic load delivered to each site by June 1999.

Nine Mile Creek was monitored for sixteen water quality parameters, most of which (68.8 percent) had the highest average concentrations and values in the summer. Three parameters (18.8 percent), dissolved oxygen, field pH and fecal coliform, had the highest concentrations and values in the spring. Two parameters (12.5 percent), total solids and total dissolved solids, had the highest values in the fall. There were two exceedances in water quality standards recorded during the project period (un-ionized ammonia and dissolved oxygen).

Sediment and nutrient loadings, total suspended sediment, total nitrogen and total phosphorus from Nine Mile Creek were by far the greatest at 94.1, 86.1 and 87.2 percent of the annual total load, respectively. The ungauged portion of the watershed contributed 5.9 percent of the total suspended solids load, 13.9 percent of the total nitrogen load and 12.8 percent of the total phosphorus loading to Lake Alvin based on modified coefficients.

Elutriate samples (sediment and receiving water) were collected from Lake Alvin in February and April 2000. Both elutriate and receiving water samples collected in February at LA-2a had detectable levels of Alachlor, Chlordane, Heptachlor Epoxide and Methoxychlor. Elutriate samples from site LA-2a taken in February also detected increased concentrations of compounds found in the receiving water along with two others not previously detected (Endrin and Heptachlor). Four of the six contaminates (Chlordane, Endrin, Heptachlor and Heptachlor Epoxide) found at LA-2a in February exceeded surface water quality standards for toxic pollutants based on human health value (ARSD § 74:51:01). The other two contaminates; Alachlor and Methoxychlor were not listed in the standards. When using these particular chemicals within the watershed, manufacturer recommendations and precautions should be followed when mixing, applying and disposing of these products. All water quality standards for toxic pollutants for human health and aquatic life values are based on beneficial use categories. Since Lake Alvin is not a domestic water supply, human health values are based fish beneficial use categories and are based upon lifetime exposure.

The elutriate sample from LA-2a that had detectable levels of chemicals in February and undetectable levels in April may have resulted from sampling (spatial) variability, suggesting highly localized contamination. Another alternative is that the sample was an anomaly based upon four of the six chemicals that have half lives longer than the period between sampling (63 days). At a minimum, Chlordane and Endrin (half-life of 4 years and 14 years, respectively) should have been detected in the April sample from LA-2a. Based on these observations, there does not appear to be a contaminate problem in Lake Alvin.

The amount of total suspended sediment, total nitrogen and total phosphorus retained in Lake Alvin during this study was approximately 284,529 kg (313.6 tons) or 71.8 percent of the total suspended solids load, 2,100 kg (2.3 tons) or 9.8 percent of the total nitrogen load and 604 kg (0.67 tons), or 45.9 percent of the total phosphorus load to the lake. Reducing the influx of total suspended sediment, total nitrogen and total phosphorus will be beneficial for improving the ecoregion based beneficial use category at Lake Alvin from non-supporting to partially supporting.

The reduction response model used to predict inlake response to reductions in tributary input was BATHTUB. BATHTUB is a predictive model that assesses the impacts of changes in water and/or nutrient loadings, and estimates nutrient loadings consistent with given water quality management objectives. Best management practice reductions were modeled to estimate TSI reduction for determining target recommendations.

Recommended targets for specific TSI parameters for Lake Alvin are: 64.55 for phosphorus, 65.93 for chlorophyll-*a* and 64.38 for Secchi visibility. To reach these goals, the phosphorus load will have to be reduced by 67 percent. This reduction should improve phosphorus TSI by 19.8 percent, chlorophyll-*a* TSI by 19.3 percent and Secchi TSI by 15.8 percent, which will improve inlake water quality. The recommended target for an average TSI value in Lake Alvin is 64.95. An overall average reduction in current loadings of approximately 67 percent is expected after implementing both tributary and inlake BMPs (Figure 73). The implicit margin of safety for phosphorus is inherently conservative in both tributary and inlake BMP reductions and explicit by an additional 14 percent phosphorus reduction over and above the 67 percent should ensure TSI target and Total Maximum Daily Load (TMDL) attainment in the Lake Alvin watershed (Table 47). Select inlake BMPs (mechanical circulator or aerator) should be implemented during tributary mitigation and others after (alum treatment and planting of submerged aquatic macrophytes) to achieve maximum benefit.

Based on current calculated fecal coliform watershed loading data ($4.50 * 10^{10}$ fecal coliform/day), fecal coliform reductions from Nine Mile Creek, the ungauged portion of the watershed and the swimming beach should be reduced 25 percent or the delivered fecal coliform load from 140 animals and not exceed $2.04 * 10^{10}$ fecal coliform/day, with an additional $1.32 * 10^{10}$ fecal coliform/day background. The TMDL for Lake Alvin is at $3.35 * 10^{10}$ fecal coliform/day based on current (1999) concentrations and loading.

A load reduction of 25 percent should be attainable by implementing select tributary BMPs, specifically, animal waste management systems to eliminate waste from a minimum of 140 animals (Figure 75). Additional reductions in fecal coliform concentrations may be achieved by riparian management, buffer strips and controlling localized contamination by humans and dogs through an information and education (I&E) program to educate the public on fecal coliform and ways to prevent beach contamination utilizing signs and brochures. Public compliance/participation should reduce localized fecal coliform counts from the swimming beach at Lake Alvin.

Reductions outlined above will improve both the esthetics and ecoregion based beneficial use category from non-supporting to fully supporting. Specific and narrative beneficial use criteria are assigned to all surface waters of the state. Lakes within each ecoregion were ranked by mean TSI values and categorized (rated) using natural breaks in the data and best professional judgement as either fully supporting, partially supporting or non-supporting (SD DENR 2000).

Some watershed improvements have been made recently, such as the construction of total retention wastewater treatment ponds for the City of the Harrisburg in 1999, and improvements to the City of Tea wastewater treatment ponds (1998). Initiating recommended inlake and tributary mitigation projects will improve the water quality of Nine Mile Creek and Lake Alvin. Long-term monitoring is recommended after implementation to evaluate BMP impacts, beneficial use and TSI trend.

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Introduction

Lake Alvin is a 43.3 hectares (107 acre) reservoir in northeastern Lincoln County, South Dakota and is located at 43.44° Latitude and 96.6083° Longitude (SE NE SEC. 43-T100N-R49W). The lake was named for Alvin Dempewolf, the only World War I soldier to die overseas from Harrisburg, South Dakota (WWP 1941). Lake Alvin is owned and managed by the South Dakota Department of Game, Fish and Parks (SD GF&P). The dam is 182.9 meters wide (600 feet), 11.0 meters high (36 feet) and has a 24.4 meter wide spillway (80 feet). The dam was designed by Benson and Schmitz and final construction was completed in 1954. By the early 1990s, portions of the primary spillway wall (right wall) had deteriorated and collapsed causing significant erosion. The primary spillway was repaired and renovated by the fall of 1994.

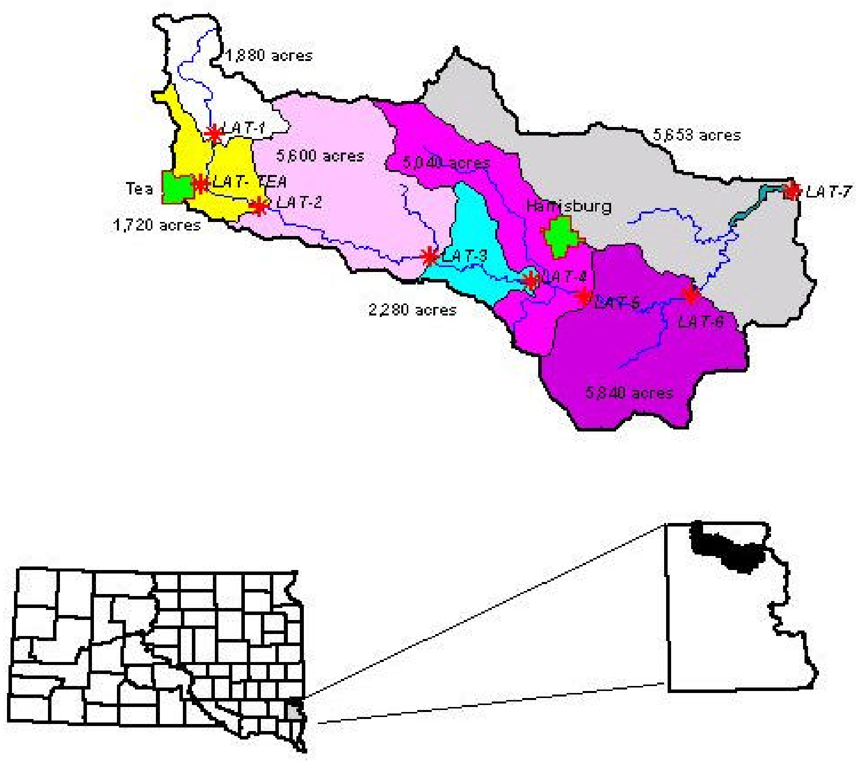


Figure 1. Nine Mile Creek sampling sites and subwatersheds.

Lake Alvin has a watershed of 11,336.5 hectares (28,013 acres) which is drained by Nine Mile Creek, Lincoln County. The watershed includes the City of Harrisburg and the eastern portion of the City of Tea, South Dakota (Figure 1). Land use within the watershed is primarily agricultural. The watershed is comprised of approximately 85 percent cropland and 15 percent pasture. The majority of the watershed is privately owned with only the land immediately adjacent to the lake owned by SD GF&P.

The climate for Lake Alvin and the surrounding area is classified as continental. Temperatures are extremely variable ranging from 37.8°C (100°F) in summer to -30°C (-22°F) in winter. Relative humidity ranges from 50 percent in the afternoon to 82 percent in the morning in summer and from 65 percent in the afternoon to 80 percent in the winter.

Average precipitation for the area is approximately 62.5 cm (24.62 inches), of which 47.3 cm (18.62 inches) falls during the growing season. Rainfall during the growing season typically comes from thunderstorms. Average snowfall is approximately 85.9 cm (33.8 inches). During this study (March through November) approximately 50.7 cm (20 inches) of precipitation fell.

The average annual evaporation (pan evaporation), which represents maximum or potential evaporation for small lakes in this area, is approximately 91.4 cm (36 inches). The calculated annual evaporation during the 1999 study was 84.1 cm (33.1 inches).

Wind in the Lake Alvin area averages approximately 11 miles per hour. Generally, prevailing winds in the summer are from the south and from the northwest in winter. High winds of 80.5 kilometers per hour (50 miles per hour) or more may occur any time of the year but are most likely in the summer during strong thunderstorms. Strong winds may also be associated with cold fronts and areas of deep low pressure in the spring, fall and winter months (USDA 1976).

Shoreline erosion occurs in scattered portions of the lake. Generally, erosion on the southern side of the lake is caused by cattle and livestock trampling, grazing and accessing the lake. Erosion on the northern side and select areas of the southern lake (areas inaccessible to cattle) appears to be from wave action and lake level changes undercutting steep banks which cause bank sloughing and collapse.

South Dakota Department of Environment and Natural Resources (SD DENR) has monitored Lake Alvin periodically since 1989, as part of the statewide lakes assessment. Monitoring data indicated a long-term increase in the trophic state index. The lake was placed on the 1998 South Dakota Waterbody List (303(d)) (SD DENR 1998). The total project cost was $63,251. The study was funded by $36,200 in 604(b) funds (Water Quality Management and Planning), $8,475 in 104 (b)(3) funds (Water Quality and Special Studies) (federal funds), and $18,576 local match ($2,000 city of Tea, $500 city of Harrisburg and $6,000 Lincoln County). South Dakota Department of Game, Fish and Parks personnel assisted in the collection of tributary flows, and water quality samples. South Dakota Department of Environment and Natural Resources staff collected all inlake samples and Lincoln County NRCS (Natural Resource Conservation Service) and Lincoln Conservation District staff collected AGNPS modeling data.

The reason for this study is that Lake Alvin is listed on the South Dakota 303(d) List, waterbodies needing Total Maximum Daily Loads (TMDL). Lake Alvin is listed for fecal coliform and increasing TSI trend (Trophic State Index) (SD DENR 1998). The present study documents impairment and suggests priority areas for BMPs (Best Management Practices) that may be used to mitigate current trends and reach targeted goals.

Fisheries Data

The most recent fisheries survey data was collected by South Dakota Game, Fish and Parks from June 29 through July 1, 1998. The current report is summarized below and is presented in Appendix A. Lake Alvin is being managed using the latest management plan (F-21-R-28) 1994. The lake is classified as a warmwater permanent fishery with five game and forage species and seven secondary fish species.

Fish collection consisted of setting ten overnight frame nets for three nights. Frame nets were constructed with steel frames and 1.9 cm (0.75 inch) bar mesh netting. All nets were checked and emptied every morning. Fish captured in each net were measured (total length), weighed (grams) and identified to species. Certain fish, black and white crappie, had scale samples taken to back-calculate length by year class (age).

Twelve species of fish were listed as primary, secondary or other species found in Lake Alvin. Eleven species of fish were collected in 1998. Three species of fish listed as primary, secondary or other species, largemouth bass (*Micropterus salmoides*), walleye (*Stizostedion vitreum*) and northern pike (*Esox lucius*) were not collected in 1998 and two species, orange-spotted sunfish (*Lepomis humilis*) and golden shiner (*Notemigonus crysoleucas*) were collected but not listed as secondary or other species for Lake Alvin.

In 1999, South Dakota State University (SDSU) was continuing an analysis of the 22.9 cm (9 inch) minimum size limit on crappie species in Lake Alvin. SD GF&P continued their normal lake sampling schedule and shared the data with SDSU. The Agency is trying to determine whether natural or angling mortality explains the lack of large crappie in lake survey samples. It is hoped that this study will shed some light on the causes for the low productivity Lake Alvin seems to display.

Endangered Species

There are no threatened or endangered species documented in the Nine Mile Creek watershed; however, the South Dakota Natural Heritage Database identified three species as being rare. This database contains documented identifications of rare, threatened or endangered species across the state and is listed in Appendix B. Species identified as rare were two species of plants, downy gentian (*Gentiana puberulenta*) and bush clover (*Lespedeza capitata*), and one species of Mollusca (bivalve), lilliput (*Toxolasma parvus*) have been found in the Nine Mile Creek watershed since 1976. The US Fish and Wildlife service lists the Whooping crane, Bald eagle, and Western prairie fringed orchid as species that could potentially be found in the area. None of these species was encountered during this study; however, care should be taken when conducting mitigation projects in the Nine Mile Creek watershed.

TRIBUTARY DATA

Tributary Methods and Materials

Tributary Site Information

Seven tributary locations were chosen for collecting hydrologic and nutrient information from the Lake Alvin watershed (Figure 1). Tributary site locations were chosen that would best show watershed managers which subwatersheds were contributing the largest nutrient and sediment loads. Stevens Type F paper graph recorders were placed at two of the seven tributary sites (LAT-5 and LAT-7) to record the water height (stage). The recorders were checked weekly to change the graph paper and reset the chart. After the chart was changed, daily stage height averages were calculated to the nearest 1/100th of a foot. Sites LAT-1, LAT-2, LAT-3 and LAT-4 had the Intermountain Environmental stream gauger and R2 data logger (FP10C) systems installed. Daily averages were calculated from Stevens Recorder graph paper and after the loggers were downloaded to a laptop computer. Site LAT –6 had an ISCO GLS (Great Little Sampler) sampler installed with a ISCO model 4230 bubbler stage recorder. Site LAT-TEA (storm sewer East of the City of Tea) was monitored using an ISCO model 6700 auto sampler containing a model 730 flow module. A Marsh-McBirney flow meter was used to measure water discharge at different stage heights at all tributary sites. Flow data was only collected once at the LAT-TEA site, so discharge was calculated/estimated using Flowmaster™ (Circular Channel Analysis and Design solved with Manning's Equation). Calculated cfs (cubic feet per second) data for various stages using Manning's equation is provided in Appendix C. At the remaining sites, 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 a regression equation for each site (Appendix D). These equations were used to calculate average daily loading for each site. The daily loadings were then totaled for an annual load for each parameter.

As with every project, problems arise when trying to collect accurate discharge data. Site LAT-5, located south of the City of Harrisburg, was vandalized several times during the study. The sampler consisted of one 25.4 cm (10 inch) water pipe, Stevens type F recorder and a steel stage recorder box mounted on top. Vandals shot the steel box and pipe from close range, spun the sampler and housing and knocked down the sampler twice. Stage data at this site was interrupted during these instances. Missing stage data was filled in by interpolation using known stage levels. All stage and discharge data were collected from early spring (March) to mid-fall (November), 1999.

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

Equation 1. Lake Alvin 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

The discharge curves and equations for all of the sites including the outlet can be found in Appendix D.

Water Quality Sampling

Samples collected at each site were taken according to South Dakota's EPA approved *Standard Operating Procedures for Field Samplers* (SD DENR 2000). 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 1998a). These documents can be referenced by contacting the South Dakota Department of Environment and Natural Resources at (605) 773-4254.

Agricultural Non-Point Source Model (AGNPS)

In addition to water quality monitoring, information was collected to complete a comprehensive watershed land use model. The AGNPS model was developed by the United States Department of Agriculture (Young et al. 1986) to give comparative parameter values for every forty-acre cell in a given watershed. Twenty-one parameters were collected for every 40-acre cell in the Lake Alvin watershed.

The twenty-one main parameters included:

1) Cell Number	2) Receiving Cell	3) Aspect Ratio
4) NRCS Curve #	5) Land Slope	6) Slope Length
7) Slope Shape	8) Manning's Coeff.	9) Soil Erodibility
10) Cropping Factor	11) Practice Factor	12) Surface Constant
13) Soil Texture	14) Fertilizer Level	15) Available Fertilizer
16) Point Source	17) Gully Source	18) COD Factor
19) Impoundment	20) Channel Indicator	21) Channel Slope

The point source indicator (16) lets the data collector enter a value if an animal feeding area is present in the cell. If the cell does contain an animal feeding area, there are approximately eight more parameters to collect to describe the feeding area. These parameters are:

1) Cell Number	2) Feedlot Area	3) Curve Number
4) Roofed Area	5) Area of land contributing water through the feedlot	
6) Buffer Data	7) Area of land between the feedlot and channeled flow	
8) Animal Data		

Parameters 5, 6, and 7, in the feedlot section, may require multiple sets of subdata if the curve numbers change over the land areas. The animal data (#8) may also require multiple parameters depending on how many different types of animals are in a given feeding area.

If one cell contains two different values for the same parameter, such as soil curve number (4), the local coordinator takes the value that covers the majority of the cell. Each 40-acre cell is given a modeled export value for phosphorus, nitrogen, and suspended solids. After the report is completed, the cells with high export values are field-checked to make sure the model highlights the correct problem areas in the watershed. The export values of each subwatershed are compared to each other and to the water quality monitoring data on a relative basis only.

Findings from the AGNPS report can be found throughout the water quality discussion in this document. Conclusions and recommendations will rely on water quality and AGNPS data. The entire AGNPS report is presented in Appendix E.

Tributary Water Quality (Standards and Seasonal)

South Dakota Water Quality Standards

All waters of the state (both lakes (§ 74:51:02:01) and streams (§ 74:51:03:01 includes irrigation)) are assigned the beneficial uses of fish and wildlife propagation, recreation and stock watering. Nine Mile Creek, from Lake Alvin to the Big Sioux River has been also assigned the beneficial uses of warmwater marginal fish life propagation water, and limited contact recreation water. Site LAT-7 (samples collected in Nine Mile Creek below the spillway) was the only site assigned these beneficial uses (Figure 1). Table 1 lists the most stringent water quality parameters that apply.

Table 1. South Dakota Water Quality Standard Limits for Nine Mile Creek from Lake Alvin to the Big Sioux River, Site LAT-7.

Parameter	Standard Limit
Un-ionized ammonia [1]	≤ 0.05 mg/L
Dissolved Oxygen	≥ 5.0 mg/L
pH	≥ 6.0 and ≤ 9.0 su
Temperature	≤ 32.2 °C
Suspended Solids [2]	≤ 263 mg/L
Fecal Coliform [3]	≤ 2,000 counts/100 ml (grab)

[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 ≤ 0.05 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 ≤ 263 mg/L or ≤ 150 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 ≤ 2,000 counts/100 ml is for a single sample or ≤ 1,000 counts/100 ml over a 30-day average (an average of 5 samples (minimum) taken in separate 24-hour periods).

The remaining sites (LAT-1 through LAT-6) are assigned these beneficial uses (Figure 1). Table 2 lists all water quality standards that apply to Nine Mile Creek west of Lake Alvin.

Table 2. South Dakota Water Quality Standard Limits for All Other Sites (LAT-1 through LAT-6).

Parameter	Limits
Nitrates [1]	≤ 50 mg/L
Alkalinity [2]	≤ 750 mg/L
pH	≥ 6.5 and ≤ 9.0 su
Total Dissolved Solids [3]	≤ 2,500 mg/L

[1] The daily maximum for nitrates is ≤ 88 mg/L or ≤ 50 mg/L for a 30-day average.

[2] The daily maximum for alkalinity is ≤ 1313 mg/L or ≤ 750 mg/L for a 30-day average.

[3] The daily maximum for total dissolved solids is ≤ 4,375 mg/L or ≤ 2,500 mg/L for a 30-day average.

Nine Mile Creek Water Quality Exceedance

There were no exceedances of water quality standards detected for Nine Mile Creek from Lake Alvin to the Big Sioux River. As discussed previously, beneficial uses in this section of Nine Mile Creek consist of warmwater marginal fish life propagation water, limited contact recreation water, irrigation, fish and wildlife propagation, recreation and stock watering. The sampled parameters for these uses include un-ionized ammonia, dissolved oxygen, pH, water temperature, total suspended solids and fecal coliform. Four other parameters (total petroleum hydrocarbon oil and grease, un-disassociated hydrogen sulfide, conductivity and sodium adsorption ratio) are also listed for these beneficial uses but were not sampled. This section of Nine Mile Creek receives the bulk of the runoff from the watershed. However, any exceedances in water quality standards upstream of Lake Alvin will be mitigated by hydrologic residence time and dilution in Lake Alvin before being discharged back into Nine Mile Creek.

The remainder of the watershed (Nine Mile Creek, west of Lake Alvin) is assigned the beneficial uses of irrigation and fish and wildlife propagation, recreation and stock watering. Parameters for these uses are nitrates, alkalinity, pH and total dissolved solids (Table 2). Four other parameters (total petroleum hydrocarbon oil and grease, un-disassociated hydrogen sulfide, conductivity and sodium adsorption ratio) are also listed for these beneficial uses but were not sampled. No exceedances of water quality standards were observed during the project period.

Table 3. Nine Mile Creek fecal coliform counts

Site	Date	Event	Concentration Colonies/100 ml
LAT-6	4/6/99	Storm	9300
LAT-5	7/14/99	Storm	3400

There are no fecal coliform bacteria standards in effect for Nine Mile Creek west of Lake Alvin. However, two sites LAT-5 and LAT-6 had fecal coliform counts in excess of the 2,000 colonies per 100 ml, the standard below Lake Alvin (Table 3). Both high fecal coliform counts were collected during storm events one in the spring and one in the summer. Two other samples collected at LAT-4 and LAT-5 on 4/6/99 had coliform counts greater than or equal to 1000 colonies/100 ml (Appendix F).

Runoff from animal feeding areas, cattle pastured in the riparian area or poor manure management may be responsible for the high fecal concentrations. Animal wastes were most likely the source because the fecal concentrations were highest during storm events

Seasonal Tributary Water Quality

Typically, water quality parameters will vary depending upon season due to changes in temperature, precipitation and agricultural practices. Fifty-three tributary water quality samples were collected during the project. These data were separated seasonally: spring (March 24 – May 31), summer (June 1 – August 31), and fall (September 1 – November 9). During the project, 30 discrete samples were collected in the spring, 21 in the summer and 2 samples in the fall months. One additional sample was also collected from LAT-TEA (storm sewer just east of the City of Tea) (Figure 1). However, data from this site was not used to calculate seasonal averages or loadings. Site LAT-TEA flows into Nine Mile Creek well above site LAT-2 resulting in mixing and dilution of the original load, creating a homogeneous sample at LAT-2. Tributary summer and fall samples were collected after heavy rainfall that occurred in scattered areas of the watershed. Not all sites were sampled during every runoff event in the summer and fall due to the scattered rains and intermittent flow.

Tributary Concentrations

Table 4. Average Seasonal Tributary Concentrations from Nine Mile Creek, Lincoln County, South Dakota[1] for 1999.

Parameter	Spring Sample Count	Spring Average	Spring Median	Summer Sample Count	Summer Average	Summer Median	Fall Sample Count	Fall Average	Fall Median
Dissolved Oxygen (mg/L)	29	8.99	8.65	21	5.48	5.65	2	8.70	8.70
Field pH (su)	23	8.23	8.14	21	7.98	8.01	2	7.70	7.70
Water Temperature (°C)	30	10.1	9.5	21	20.1	19.5	2	16.4	16.4
Fecal Coliform (# Colonies/ 100 ml)	30	477	55	21	366	165	2	133	133
Alkalinity(mg/L)	30	192	195	21	237	233	2	195	195
Total Solids (mg/L)	30	1511	1560	21	1917	1888	2	2466	2466
Total Suspended Solids (mg/L)	30	25	20	21	77	55	2	17	17
Total Dissolved Solids (mg/L)	30	1485	1529	21	1841	1833	2	2449	2449
Volatile Total Suspended Solids (mg/L)	30	4.5	4.0	21	10.5	9.0	2	2.5	2.5
Total Nitrogen (mg/L)	30	2.28	2.21	21	3.43	2.83	2	1.60	1.60
Organic Nitrogen(mg/L)	30	1.15	1.18	21	1.46	1.22	2	1.19	1.19
Ammonia-N (mg/L)	30	0.01	0.01	21	0.12	0.02	2	0.01	0.01
Nitrate-Nitrite-N (mg/L)	30	1.1	0.9	21	1.8	1.0	2	0.4	0.4
Total Kjeldahl-N (mg/L)	30	1.15	1.18	21	1.58	1.34	2	1.20	1.20
Total Phosphorus (mg/L)	30	0.176	0.179	21	0.316	0.273	2	0.141	0.141
Total Dissolved Phosphorus (mg/L)	30	0.122	0.126	21	0.199	0.144	2	0.103	0.103

[1] = Highlighted areas are the seasons that recorded the highest average concentrations for a given parameter.

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. The average and median concentrations of different parameters changed seasonally as shown in Table 4.

Dissolved oxygen concentrations were highest in the spring. It is likely that cooler water (cooler water can hold more oxygen) and higher flows and water turbulence in the spring agitates and aerates the water as it moves along the stream. Lower oxygen concentrations in the summer were most likely due to warm water temperatures, decomposition of organic matter and lower (slower) flows.

Alkalinity seems to be related to surface and groundwater runoff. The highest concentrations were in the summer when, theoretically, groundwater influence was most likely the highest. Groundwater typically has higher alkalinity than rainwater because of the soluble minerals in the soil.

Like alkalinity, higher total solids concentrations in the fall are most likely due to ground water. The summer had lower concentrations most likely from rainwater, which, like alkalinity, typically has lower concentrations than groundwater springs. Summer samples had the highest concentrations of suspended solids. Intense rains on agricultural lands typically cause higher erosion and higher suspended solids in the water.

Average nitrogen concentrations were highest in the summer. The summer average concentration of ammonia was 0.12 mg/L. The highest ammonia concentration collected was also in the summer (0.48 mg/L). This sample, collected on June 2, 1999, was 4.4 times higher than the standard deviation, showing the sample was unusual for the sample set. Eighty-five percent of the ammonia samples were below 0.10 mg/L and most (77.4 percent) were below the State Health Laboratory detection limit. Sources for high ammonia concentrations could be animal feeding areas, decomposition of organic matter, or runoff from applied fertilizer.

Nitrate-nitrite showed much more variability than ammonia. The summer season had the highest mean and median. The range of the nitrate-nitrite in the summer was from a minimum of 0.01 mg/L to a maximum of 4.4 mg/L. The maximum sample was collected at Site LAT-4 on June 29, 1999 (4.4 mg/L). A likely source of these high nitrates may have been from excessive fertilization of row crops, lawns and yards upstream of LAT-4.

Total Kjeldahl Nitrogen (TKN) is composed of mostly organic nitrogen. TKN had the highest concentrations in the summer. The highest concentration (2.86 mg/L at Site LAT-1) collected during the project period occurred on June 2, 1999. Because the sample occurred in the summer, the higher organic concentrations appear to be mostly from decaying organic matter in the drainage area. Fecal coliform bacteria were also found in most summer tributary samples, indicating animal waste does contribute to TKN concentrations.

Total phosphorus and dissolved phosphorus concentrations were highest in the summer. The average summer concentrations were 0.316 mg/L and 0.199 mg/L for total phosphorus and total dissolved phosphorus, respectively (Table 4). Increased phosphorus concentrations often coincide with higher fecal coliform or suspended solids concentrations. Average total suspended solids, total phosphorus and total dissolved phosphorus concentrations were highest in the summer while average fecal coliform concentrations were higher in the spring. This suggests that suspended solids may be the major transporter of phosphorus.

Fecal coliforms are an indicator of waste material from warm-blooded animals and usually indicate the presence of animal or human wastes. Fecal coliform concentrations were highest in the spring. The mean and median of the spring samples were 477 and 55 colonies/100 ml respectively. Summer samples also had elevated mean and median values, 366 and 165 colonies/100ml. Season-long grazing, runoff from animal feeding areas and poor manure management were the most likely sources of these fecal coliform counts.

Quality Assurance and Quality Control

Twelve quality assurance and quality control (QA/QC) samples were collected throughout the spring and summer sampling periods (Appendix G). Standard chemical analysis was done on all blank and duplicate samples collected. Three blank sample parameters (total solids, total dissolved solids and total phosphorus) had standard deviations greater than the mean of all blank samples. Total dissolved solids concentrations are calculated from total solids and total suspended solids. The April 22, 1999, blank sample had the highest concentration of total solids and total dissolved solids increasing the standard deviation past the mean. This was likely due to different brands of distilled water purchased for chemical blanks and equipment rinses. Total phosphorus also had a standard deviation greater than the mean. The sample blank collected on April 6, 1999, detected total phosphorus above the detection limit, which may be due to field contamination during handling.

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

Equation 2. Industrial statistic equation.

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

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

Three duplicate sample parameters (fecal coliform bacteria, total suspended solids and volatile total suspended solids) had the industrial statistic (%I) greater than 10 percent (absolute percent). All duplicate samples (four dates) varied more than 10 percent from the original samples for fecal coliform bacteria counts (# colonies/ 100 ml). Fecal coliform counts can vary considerably because of sample collection, incubation temperature and media variability. Total suspended solids and volatile total suspended solids were also above 10 percent on three dates (April 6, April 22 and June 2, 1999). Variations in field sampling techniques and preparation may be some reasons for differences. Overall, 89.1 percent of industrial statistics values were less than 10 percent different.

Seasonalized Tributary Hydrologic Loadings

Seven tributary monitoring sites were set up on Nine Mile Creek. All sites were monitored from March through November 1999 (232 days). A total of 5,597,286,807 liters (4,537 acre-feet) of water flowed into Lake Alvin from Nine Mile Creek over the project period. The overall tributary export coefficient (amount of water delivered per acre) for the gauged portion of this watershed was 250,326 liters (0.20 acre-feet). Export coefficients and seasonal loading percentages for each subwatershed are provided in Table 5.

Table 5. 1999 cumulative hydrologic loading and export coefficients for Nine Mile Creek, Lincoln County South Dakota.

		Hydrologic Loading			Export Coefficient	
		Liters	Acre-feet	Percent	Liters	Acre-feet
LAT-1	**Spring**	583,291,858	473	74.8%	3,102,613	0.25
	Summer	196,594,254	159	25.2%	104,571	0.08
	Total	**779,886,112**	**632**	**100.0%**	**3,207,184**	**0.33**
LAT-TEA[1]	**Spring**	3,303,008	2.68	28.3%	27,525	0.02
	Summer	8,270,040	6.70	70.9%	68,917	0.06
	Fall	88,188	0.07	0.8%	735	0.00
	Total	**11,661,237**	**9.45**	**100.0%**	**97,177**	**0.08**
LAT-2	**Spring**	1,065,318,868	864	86.3%	619,371	0.50
	Summer	164,674,443	134	13.3%	95,741	0.08
	Fall	4,612,110	4	0.4%	2681	0.00
	Total	**1,234,605,421**	**1,002**	**100.0%**	**717,793**	**0.58**
LAT-3	Spring	1,603,840,266	1,300	63.5%	286,400	0.23
	Summer	921,812,658	747	36.5%	164,609	0.13
	Total	**2,525,652,924**	**2,047**	**100.0%**	**451,009**	**0.36**
LAT-4	**Spring**	2,180,054,109	1,767	67.3%	956,164	0.78
	Summer	1,059,988,166	859	32.7%	464,907	0.38
	Total	**3,240,042,275**	**2,626**	**100.0%**	**1,421,071**	**1.16**
LAT-5	**Spring**	2,941,226,732	2,385	66.7%	583,577	0.47
	Summer	1,465,786,280	1,188	33.3%	290,831	0.24
	Total	**4,407,013,012**	**3,573**	**100.0%**	**874,408**	**0.71**
LAT-6	**Spring**	4,109,110,622	3,331	73.4%	703,615	0.57
	Summer	1,231,365,160	998	22.0%	210,850	0.17
	Fall	256,811,025	208	4.6%	43,975	0.04
	Total	**5,597,286,807**	**4,537**	**100.0%**	**958,440**	**0.78**

[1] = Storm sewer monitored near the City of Tea.

The peak hydrologic load for all subwatersheds occurred during the spring (highlighted values in Table 5). However, the storm sewer LAT-TEA had peak hydrologic load in the summer. The peak hydrologic load at LAT-TEA in summer was from increased water usage in the City of Tea (car washes and lawn watering). Approximately two thirds of the total water load was delivered to each site by June 1, 1999. All cumulative hydrologic loads increased downstream. Subwatershed LAT-4 had the highest export coefficient, 1.16 acre-feet/acre per year (Table 5).

Table 6. Hydrologic export coefficients by subwatershed (site) for the Lake Alvin watershed.

Site	Hydrologic Load Percent	Export Coefficient (acre-feet)
LAT–1	13.9	0.34
LAT-2	8.1	0.22
LAT-3	23.1	0.19
LAT-4	12.8	0.25
LAT-5	20.8	0.19
LAT-6	21.3	0.17

All gauged subwatersheds totaled 22,360 acres or 79.8 percent of the watershed. The remaining 5,653 acres or 20.2 percent was ungauged. The ungauged portion of the watershed was that area near Lake Alvin without defined tributaries. An estimated 1,122,272,520 liters (910 acre-feet) of water was delivered from the ungauged watershed to Lake Alvin in 1999. This value was calculated using a conservative export coefficient of 0.17 (Table 6).

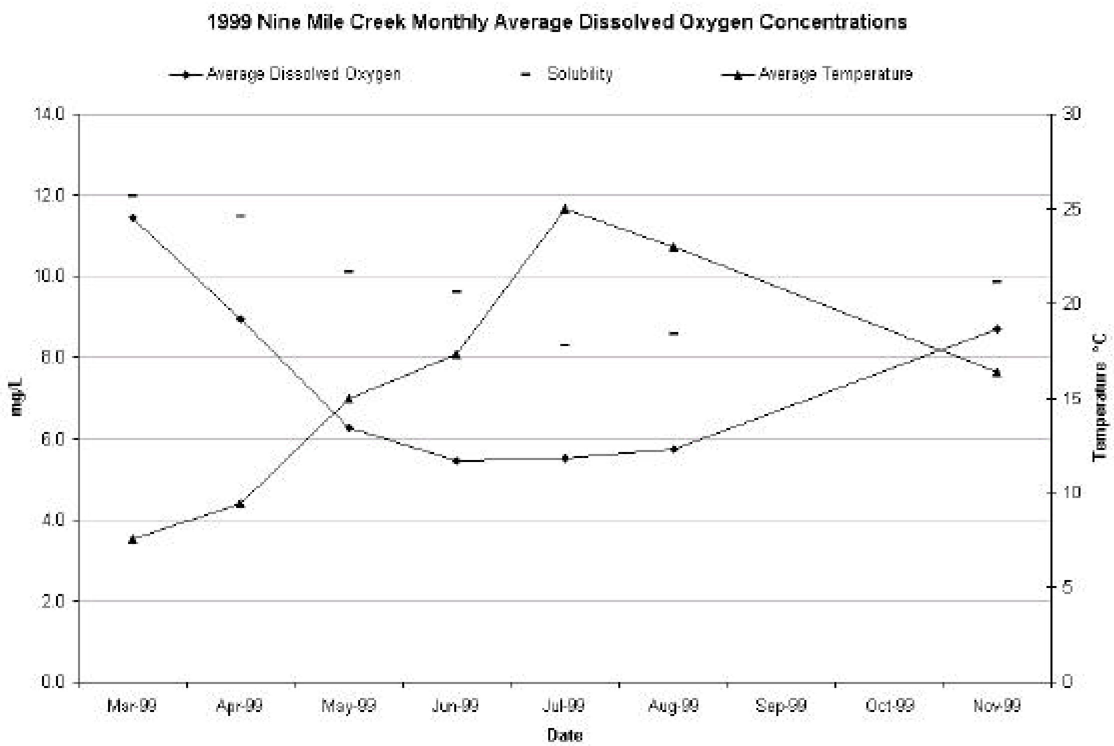
Tributary Water Quality and Loadings

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). Nine Mile Creek dissolved oxygen concentrations averaged 7.77 mg/L (median 7.50 mg/L) during this study.

The maximum dissolved oxygen concentration in Nine Mile Creek was 12.5 mg/L. That sample was collected at site LAT-6 on March 24, 1999 (Appendix F). March tributary samples had the highest average dissolved oxygen concentration, which was most likely a product of cooler water temperatures (Figure 2). The minimum dissolved oxygen concentration was 1.0 mg/L at LAT-2 on July 14, 1999. LAT-1 on July 14, 1999 also had a low dissolved oxygen reading of 2.0 mg/L. These same sites also had low concentrations during the June 29, 1999 sampling (Appendix F).

The relationship of oxygen solubility and temperature was observed during this study. Monthly average dissolved oxygen concentrations were highest during the cooler months of the sampling year (March, April and November) and were within 80 percent (average 88.4 percent) saturation (maximum solubility of oxygen in water). Oxygen solubility decreased with increasing water temperatures during warmer months (May, June, July



and August) and averaged 61.7 percent (Figure 2).

Figure 2. 1999 monthly average dissolved oxygen concentrations, solubility concentrations and temperature for Nine Mile Creek, Lincoln County, South Dakota.

Table 4 shows seasonal tributary average dissolved oxygen concentrations for Nine Mile Creek during the project. The highest seasonal concentration occurred in the spring at 8.99 mg/L. Oxygen level dropped off in the summer (5.48 mg/L) and started to increase again in the fall (8.70 mg/L). Seasonal and daily concentrations of chemicals (biotic and abiotic) in water can also affect dissolved oxygen concentrations. Table 4 indicates that during the summer there were increased average concentrations in ten of the thirteen chemical parameters monitored in Nine Mile Creek. Increased average chemical concentrations and increased temperatures in warmer months appear to contribute to reduced oxygen levels and solubility.

pH

pH is the measure of hydrogen ion concentration, the more free hydrogen ions, (i.e. more acidic) the lower the pH in water. The pH concentrations in Nine Mile Creek were not extreme in any samples. The relatively high alkalinity concentrations in Nine Mile Creek work to buffer dramatic pH changes. Since increases in decomposition decreases pH, increases in pH can be an indication of increased organic matter (non-decomposed) over time.

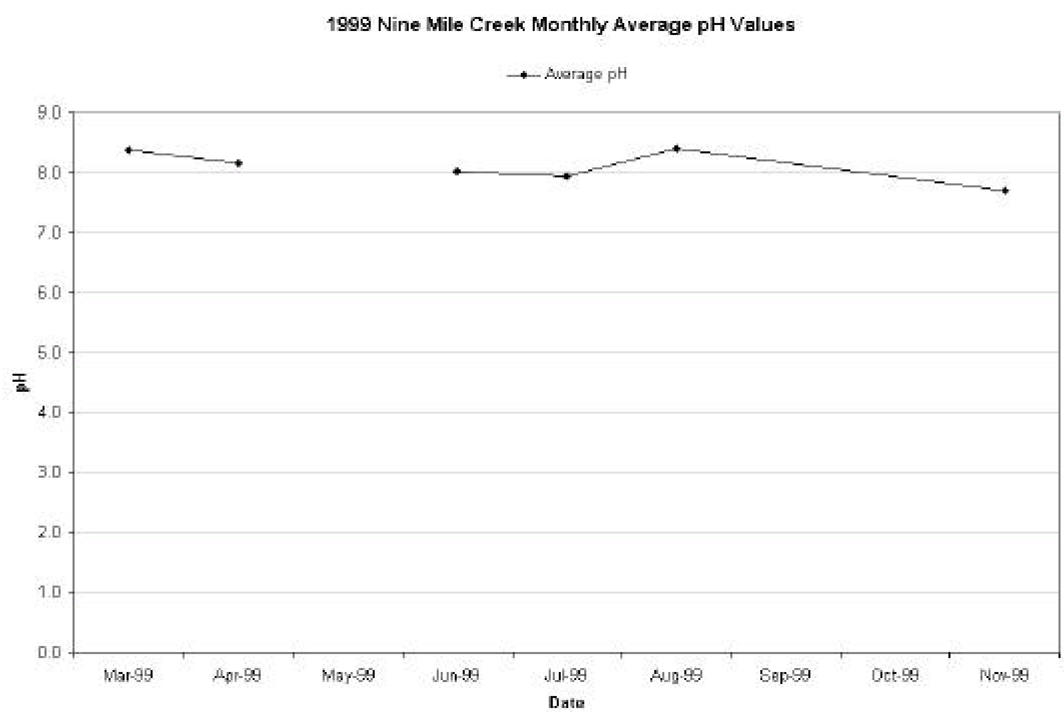


Figure 3. 1999 monthly average pH values for Nine Mile Creek, Lincoln County, South Dakota.

The pH concentrations in Nine Mile Creek averaged 8.11 su with a maximum of 8.85 su and a minimum of 7.46 su. Generally, pH concentrations were higher in the spring and peaked in late summer (Figure 3). Seasonal averages for pH concentrations were highest in the spring at 8.23 su (Table 4).

Total Alkalinity

Alkalinity refers to the quantity of different compounds that shift the pH to the alkaline side of neutral (>7). 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 7. Nine Mile Creek, 1999, total alkalinity loading per year by site.

Site	Watershed Percent (gauged)	Hydrologic Percent (gauged)	Kilograms Per year	Kilograms/year by site	Percent Total Load (gauged)	Export Coefficient (Kg/Acre)
LAT-1	8.4	13.9	180,178	180,178	17.9	95.8
LAT-2	7.7	8.1	227,177	46,999	4.7	27.3
LAT-3	25.0	23.1	538,877	311,700	31.0	55.7
LAT-4	10.2	12.8	633,668	94,791	9.4	41.6
LAT-5	22.5	20.8	830913	197,245	19.6	39.1
LAT-6	26.1	21.3	1,005,726	174,813	17.4	29.9

Generally, average monthly concentrations of alkalinity increased during this survey (Figure 4). The average alkalinity in Nine Mile Creek was 208.2 mg/L with a median of 151.5 mg/L. The minimum alkalinity concentration was 90 mg/L and was collected at site LAT-2 on November 9, 1999 (Appendix F). Only two sites (LAT-2 and LAT-6) were sampled (flowing) on November 9, 1999. Because sites LAT-1 and LAT-3 were dry, the water at site LAT-2 was a release (discharge) from the City of Tea wastewater lagoons, located southeast of the City of Tea. This situation was determined not to be representative because the retention ponds may have altered the acidity/alkalinity balance, and upon release, no mixing occurred with normal runoff because site LAT-2 had been dry since mid July, 1999. The November sample at LAT-2 was also 56.4 percent lower (116.4 mg/L) than the average alkalinity concentration during runoff events. For the reasons outlined above, the sample was excluded from this analysis. The adjusted minimum alkalinity concentration was 149 mg/L and was collected at sites LAT-5 and LAT-6 on April 12, 1999. The maximum alkalinity sample was 373 mg/L collected at site LAT-1 on July 14, 1999.

Seasonally, Nine Mile Creek average alkalinity concentrations increase in the summer months (Table 4). The increase in alkalinity is most likely due to total dissolved solids concentrating due to reduced runoff (22.0 percent of the total hydrologic load) and evaporation.

Total alkalinity loading by site was highest at site LAT-3 with 311,700 kg/year or 31.0 percent of the total alkalinity load (Table 7). Subwatershed export coefficients (kilograms/acre) were highest in the LAT-1 subwatershed (95.8 kg/acre), which is approximately 1.7 times more alkalinity runoff per acre than the next highest sub-watershed (LAT-3).

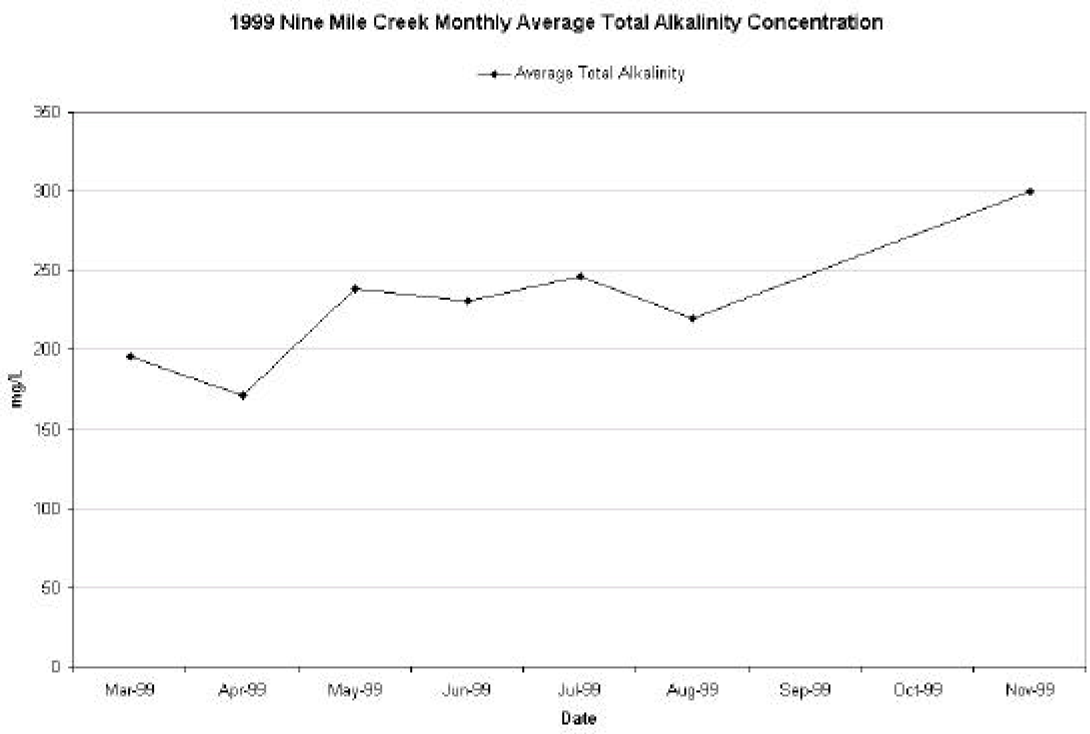


Figure 4. 1999 monthly average total alkalinity concentrations for Nine Mile Creek, Lincoln County, South Dakota.

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. Suspended volatile 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 Nine Mile Creek averaged 1,707.7 mg/L with a maximum of 2,695.0 mg/L and a minimum of 1,134.0 mg/L. Total dissolved solids concentrations averaged 1,660.4 mg/L with a maximum of 2589.0 mg/L and a minimum concentration of 1,101.0 mg/L. Generally, total and dissolved solids concentrations were lower in the spring and peaked in the fall (Figure 5). Seasonal averages for total and dissolved solids concentrations were highest in the fall (Table 4). Lower solids concentrations in the spring were from snow melt and spring runoff.

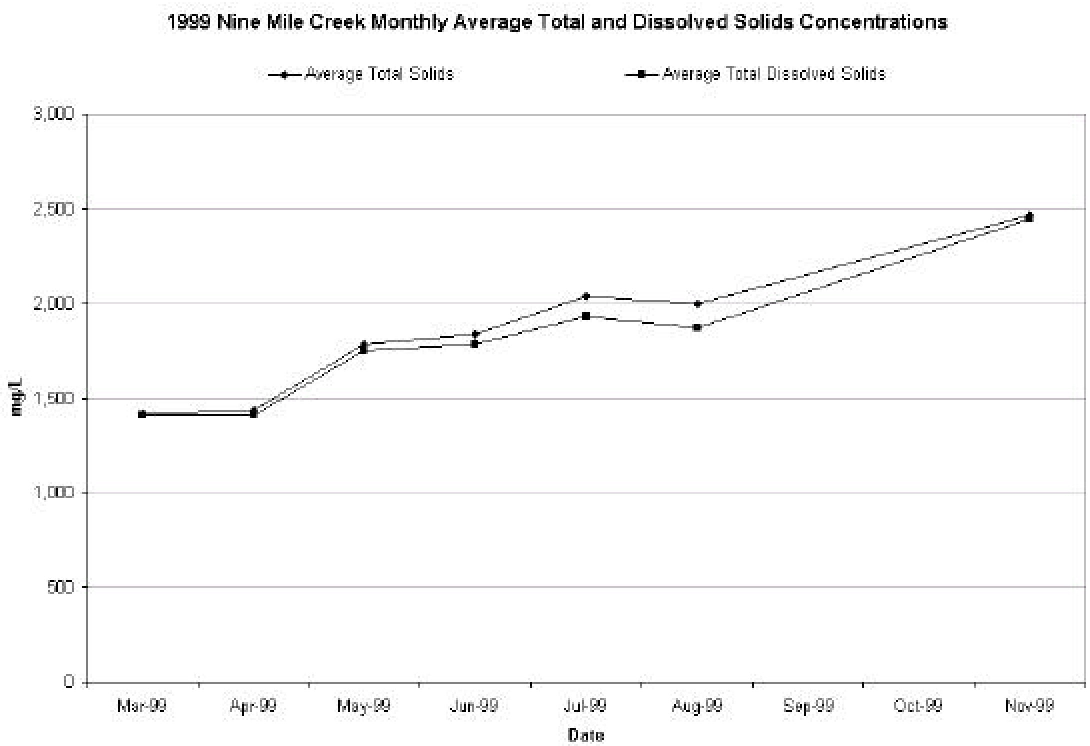


Figure 5. 1999 monthly average total and dissolved solids concentration for Nine Mile Creek, Lincoln County, South Dakota.

Table 8. Nine Mile Creek, 1999, total solids loading per year by site.

Site	Watershed Percent (gauged)	Hydrologic Percent (gauged)	Kilograms Per year	Kilograms/year by site	Percent Total Load (gauged)	Export Coefficient (Kg/Acre)
LAT-1	8.4	13.9	1,302,637	1,302,637	15.7	692.9
LAT-2	7.7	8.1	1,894,033	591,396	7.1	343.8
LAT-3	25.0	23.1	4,208,258	2,314,225	27.8	413.3
LAT-4	10.2	12.8	5,441,345	1,233,087	14.8	540.8
LAT-5	22.5	20.8	6,933,289	1,491,944	17.9	296.0
LAT-6	26.1	21.3	8,315,670	1,382,381	16.6	236.7

Total solids loading by site was highest at site LAT-3 with 2,314,225 kg/year or 27.8 percent of the total solids load (Table 8). Total dissolved solids loadings were also the highest at site LAT-3 with 2,208,053 kg/year or 27.4 percent of the total dissolved solids load (Table 9). Subwatershed export coefficients (kilograms/acre) were highest in the LAT-1 subwatershed (692.9 kg/acre), which is 1.68 times more solids per acre than the LAT-3 subwatershed, which had the highest percent load. Similarly, total dissolved solids also had the highest export coefficient in the LAT-1 sub-watershed (687.8 kg/acre), 1.74 times higher than subwatershed LAT-3, which also had the highest percent load.

Table 9. Nine Mile Creek, 1999, total dissolved solids loading per year by site.

Site	Kilograms per year	Kilograms/year by site	Percent Total Load (gauged)	Export Coefficient (kg/Acre)
LAT-1	1,292,996	1,292,996	16.0	687.8
LAT-2	1,880,080	587,084	7.3	341.3
LAT-3	4,088,133	2,208,053	27.4	394.3
LAT-4	5,209,452	1,121,319	13.9	491.8
LAT-5	6,653,450	1,443,998	17.9	286.5
LAT-6	8,067,858	1,414,408	17.5	242.2

The total suspended solids concentrations in Nine Mile Creek averaged 47.3 mg/L with a maximum of 222.0 mg/L and a minimum of 1.0 mg/L. Volatile total suspended solids concentrations averaged 7.0 mg/L with a maximum of 44.0 mg/L and a minimum concentration of 0.5 mg/L. Generally, average total suspended and volatile total suspended solids concentrations were lower in the spring and peaked in late summer (Figure 6). Seasonal averages for total suspended and volatile total suspended solids concentrations were highest in the summer (Table 4). This is in contrast to average seasonal total solids and total dissolved solids concentrations which were highest in the fall.

Table 10. Nine Mile Creek, 1999, total suspended solids loading per year by site.

Site	Kilograms per year	Kilograms/year by site	Percent Total Load (gauged)	Export Coefficient (Kg/Acre)
LAT-1	9,641	9,641	3.5	5.1
LAT-2	13,953	4,312	1.5	2.5
LAT-3	120,125	106,172	37.9	19.0
LAT-4	231,893	111,768	39.9	49.0
LAT-5	279,839	47,946	17.1	9.5
LAT-6	247,811	-0[1]	0	<0.1[2]

[1] = Total kilograms/year was reduced at LAT-6 by 32,028 kg.
[2] = Load per acre was not calculated due to a reduction in load within subwatershed.

Total suspended solids loading by site was highest at site LAT-4 with 111,768 kg/year or 45.1 percent of the total suspended solids load (Table 10). Volatile total suspended solids loadings were highest at site LAT-5 with 19,218 kg/year or 44.5 percent of the volatile total suspended solids load (Table 11). Subwatershed export coefficients (kilograms/acre) for total suspended solids were highest in the LAT-4 sub-watershed (49.0 kg/acre). Volatile total suspended solids export coefficients were also highest in subwatershed LAT-4 (4.2 kg/acre), 1.11 times higher than subwatershed LAT-5 which had the highest percent load (44.5 percent).

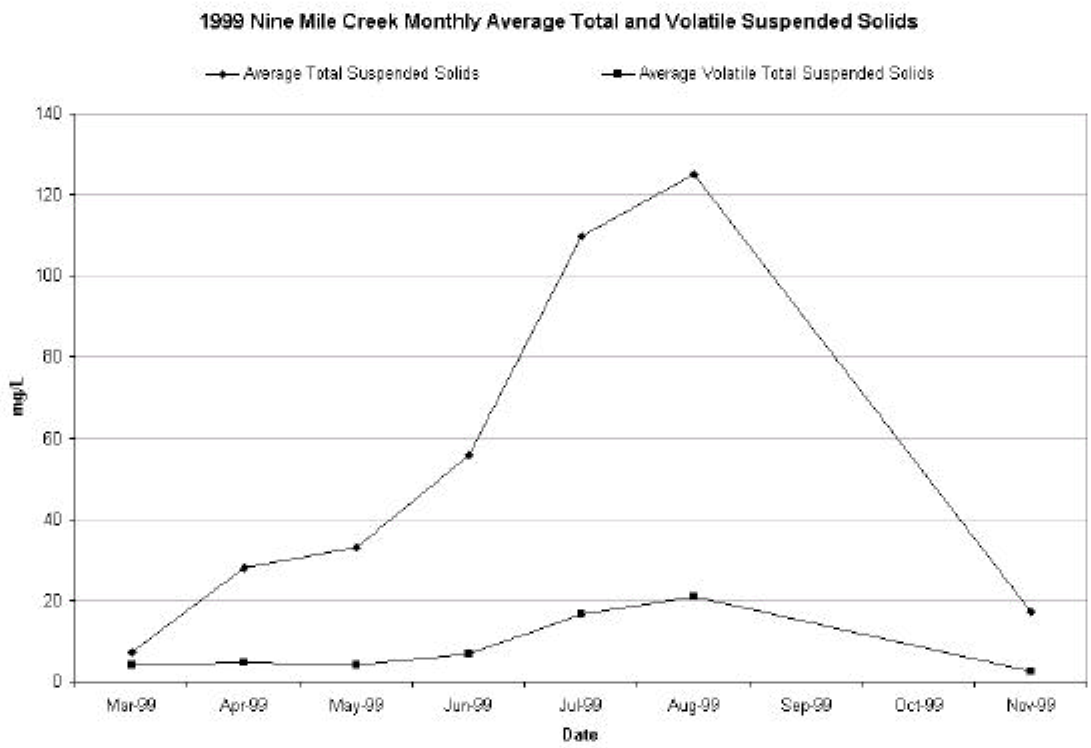


Figure 6. 1999 monthly average total and volatile suspended solid concentrations for Nine Mile Creek, Lincoln County, South Dakota.

Table 11. Nine Mile Creek, 1999, total volatile suspended solids loading per year by site.

Site	Kilograms per year	Kilograms/year by site	Percent Total Load (gauged)	Export Coefficient (kg/Acre)
LAT-1	2,470	2,470	5.7	1.3
LAT-2	3,634	1,164	2.7	0.7
LAT-3	14,417	10,783	24.9	1.9
LAT-4	24,022	9,605	22.2	4.2
LAT-5	43,239	19,217	44.5	3.8
LAT-6	35,894	0[1]	0.0	<0.1[2]

[1] = Total kilograms/year was reduced at LAT-6 by 7,345 kg.
[2] = Load per acre was not calculated due to a reduction in load within subwatershed.

Lake Alvin is on the 303(d) list (impaired waterbodies list) because of increasing TSI trend (Trophic State Index) (SD DENR 1998). Decreasing sediment (erosion) inputs from the Nine Mile Creek and the ungauged watershed will improve (lower) TSI values. Reducing sediment will improve non-algal turbidity, which will increase Secchi transparency, decreasing Secchi TSI values. Increasing transparency should also increase the growth of submerged macrophytes or algae, which would increase the uptake of nitrogen and phosphorus, reducing available nutrients that could cause algal blooms. Reducing sediment should also reduce sediment-related phosphorus, which may lower inlake 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. Decreasing sediment related phosphorus could lessen algae densities and blooms in Lake Alvin 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 TSI trend.

Subwatersheds that should be targeted for sediment (erosion) mitigation, based upon watershed assessment and AGNPS modeling export coefficients, are presented in priority ranking in Table 12:

Table 12. Nine Mile Creek and ungauged watershed mitigation priority sub-watersheds for sediment based on watershed assessment and AGNPS modeling.

Priority Ranking	Subwatershed	Export Coefficient (kg/Acre)	Kilograms Delivered	Sources
1	LAT-4	49.0	111,720.0	WA
2	Ungauged	26.3	148,673.9	AGNPS
3	LAT-3	19.0	106,400.0	WA/AGNPS
4	LAT-5	9.5	47,880.0	WA/AGNPS

WA = Watershed Assessment
AGNPS = Agricultural Non-Point Source Model

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.

Table 13. Nine Mile Creek, 1999, ammonia loading per year by site.

Site	Watershed Percent (gauged)	Hydrologic Percent (gauged)	Kilograms Per year	Kilograms/year by site	Percent Total Load (gauged)	Export Coefficient (Kg/Acre)
LAT-1	8.4	13.9	29	29	7.2	0.02
LAT-2	7.7	8.1	13	0[1]	0	<0.01[2]
LAT-3	25.0	23.1	70	57	13.9	0.01
LAT-4	10.2	12.8	308	238	58.4	0.10
LAT-5	22.5	20.8	392	84	20.6	0.02
LAT-6	26.1	21.3	408	16	3.8	0.01

[1] = Total kilograms/year was reduced at LAT-2 by 16 kg.
[2] = Load per acre was not calculated due to a reduction in load within subwatershed.

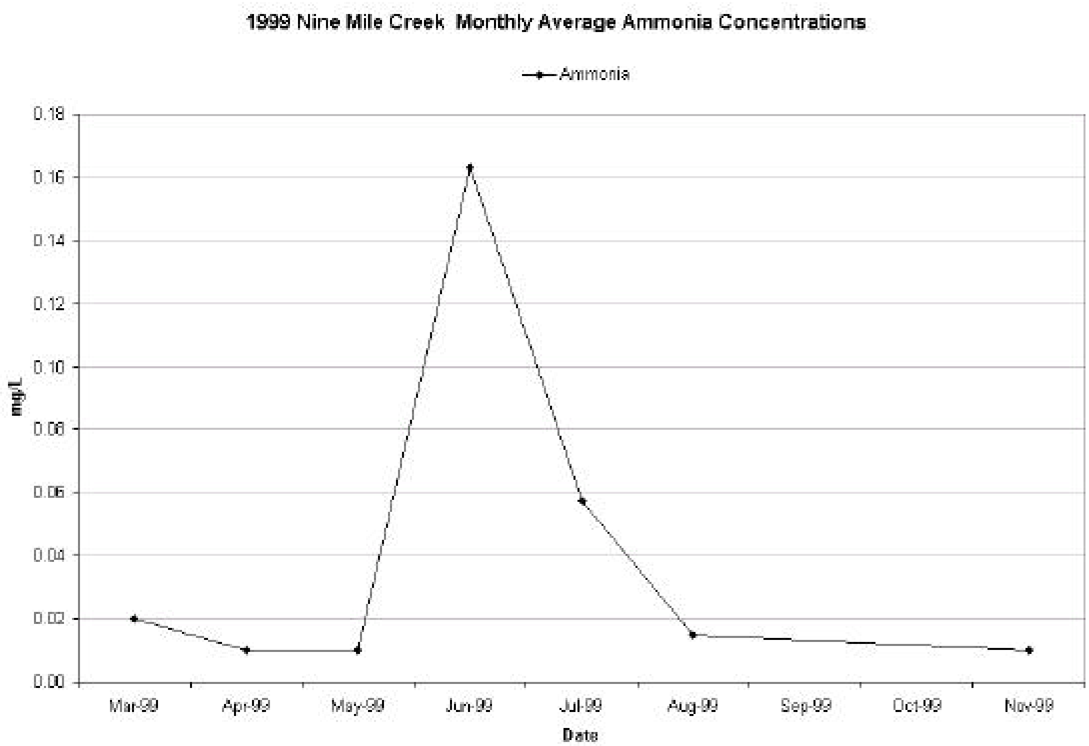


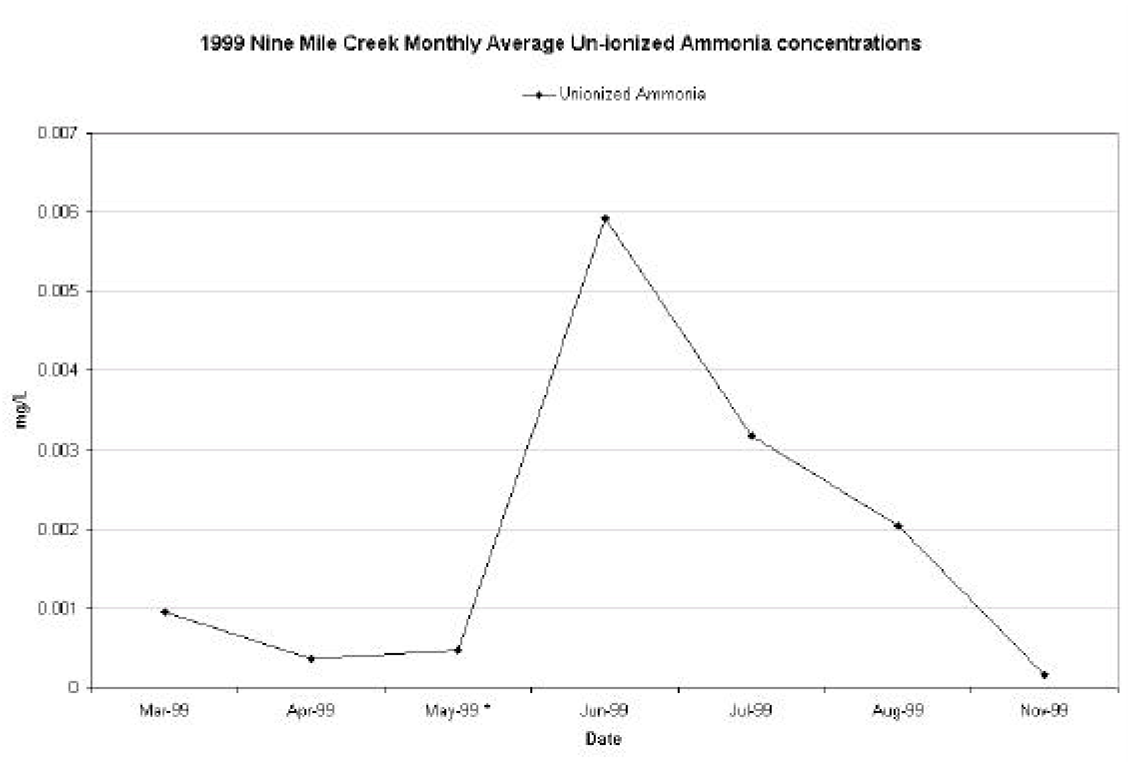
Figure 7. 1999 monthly average ammonia concentrations for Nine Mile Creek, Lincoln County, South Dakota.

The mean concentration in Nine Mile Creek was 0.05 mg/L with a median of 0.01 mg/L. The standard deviation was 0.11 mg/L which indicates a large variation in sample concentrations. Ammonia concentrations rose dramatically after May and returned below the laboratory detection limit (0.02 mg/L) by the end of August (Figure 7). The majority of ammonia samples (75.5 percent) collected in Nine Mile Creek were below the laboratory detection limit. Seasonally the highest concentrations of ammonia occurred in summer (0.12 mg/L) with average spring and fall concentrations below detection limits (Table 4).

Ammonia loading by site was highest at site LAT-4 with 238 kg/year or 58.4 percent of the total ammonia load (Table 13). Subwatershed export coefficients (kilograms/acre) were also highest in the LAT-4 subwatershed (0.10 kg/acre).

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.



*** = pH was estimated to calculate average un-ionized ammonia.**

Figure 8. 1999 monthly average un-ionized ammonia concentrations for Nine Mile Creek, Lincoln County, South Dakota.

The mean un-ionized ammonia concentration for Nine Mile Creek was 0.002 mg/L. The maximum concentration was 0.027 mg/L and the minimum concentration was 0.0001 mg/L. Tributary samples collected in May did not have pH measurements recorded due to equipment malfunction, so pH concentrations were interpolated from previous and subsequent pH data in order to calculate/estimate the un-ionized ammonia fraction for May. Un-ionized ammonia concentrations peaked in June at 0.027 mg/L and gradually declined to 0.0001 mg/L by November (Figure 8). The peak value was the result of increased temperature and total ammonia concentrations increasing the un-ionized ammonia fraction. Since un-ionized ammonia is a calculated fraction of ammonia (NH_4) the graphs in Figure 7 and Figure 8 are similar.

Nitrate-Nitrite

Nitrate and nitrite (NO_3^- and NO_2^-) are inorganic forms of nitrogen easily assimilated by algae and other 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 denitrification by bacteria. The process increases with increasing temperature and decreasing pH.

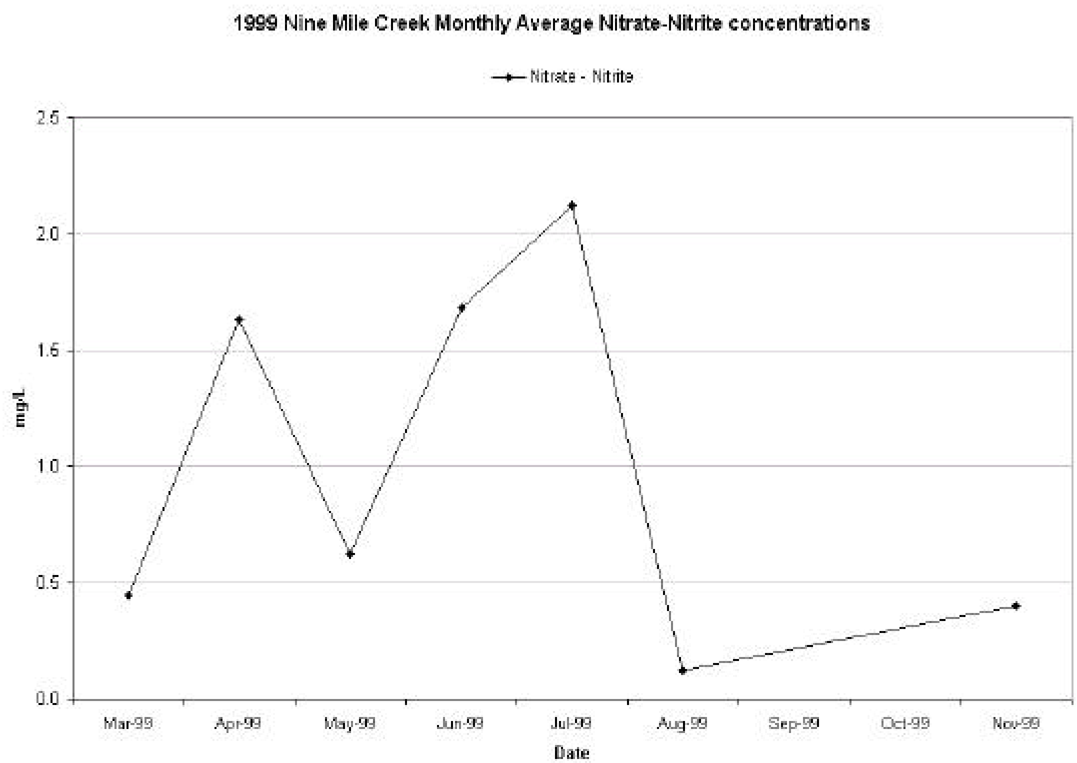


Figure 9. 1999 monthly average nitrate-nitrite concentrations for Nine Mile Creek, Lincoln County, South Dakota.

The average nitrate-nitrite concentration for Nine Mile Creek was 1.3 mg/L (median 0.8 mg/L) for the entire project. The maximum concentration of nitrate-nitrite was 8.3 mg/L on July 14, 1999 at LAT-3 and a minimum of 0.1 mg/L in nine separate samples (generally from LAT-1 and LAT-2). Two peaks were observed in the data, one in April and one in July (Figure 9). Seasonally, average nitrate-nitrite concentrations were elevated in the spring (1.2 mg/L) and peaked in the summer at 1.8 mg/L (Table 4). Nitrate-nitrite loading by site was highest at site LAT-3 with 5,158 kg/year or 46.8

percent of the total nitrate-nitrite load (Table 14). Subwatershed export coefficients (kilograms/acre) were also highest in the LAT-3 subwatershed at 0.92 kg/acre.

Table 14. Nine Mile Creek, 1999, nitrate–nitrite loading per year by site.

Site	Watershed Percent (gauged)	Hydrologic Percent (gauged)	Kilograms Per year	Kilograms/year by site	Percent Total Load (gauged)	Export Coefficient (Kg/Acre)
LAT-1	8.4	13.9	396	396	3.6	0.21
LAT-2	7.7	8.1	679	283	2.6	0.16
LAT-3	25.0	23.1	5,837	5,158	46.8	0.92
LAT-4	10.2	12.8	7,180	1,343	12.2	059
LAT-5	22.5	20.8	9,381	2,201	20.0	0.44
LAT-6	26.1	21.3	11,030	1,649	14.9	0.28

Total Kjeldahl Nitrogen / Organic Nitrogen

Total Kjeldahl Nitrogen (TKN) is used to calculate organic nitrogen. TKN minus ammonia derives organic nitrogen. Sources of organic nitrogen can include release from dead or decaying organic matter, septic systems or agricultural waste. Organic nitrogen is broken down to more usable ammonia and other forms of inorganic nitrogen by bacteria.

Table 15. Nine Mile Creek, 1999, Total Kjeldahl Nitrogen loading per year by site.

Site	Watershed Percent (gauged)	Hydrologic Percent (gauged)	Kilograms Per year	Kilograms/year by site	Percent Total Load (gauged)	Export Coefficient (Kg/Acre)
LAT-1	8.4	13.9	1,438	1,438	19.3	0.76
LAT-2	7.7	8.1	1,516	78	1.1	0.05
LAT-3	25.0	23.1	3,185	1,669	22.4	0.30
LAT-4	10.2	12.8	4,290	1,105	14.8	0.48
LAT-5	22.5	20.8	6,009	1,719	23.1	0.34
LAT-6	26.1	21.3	7,446	1,437	19.3	0.25

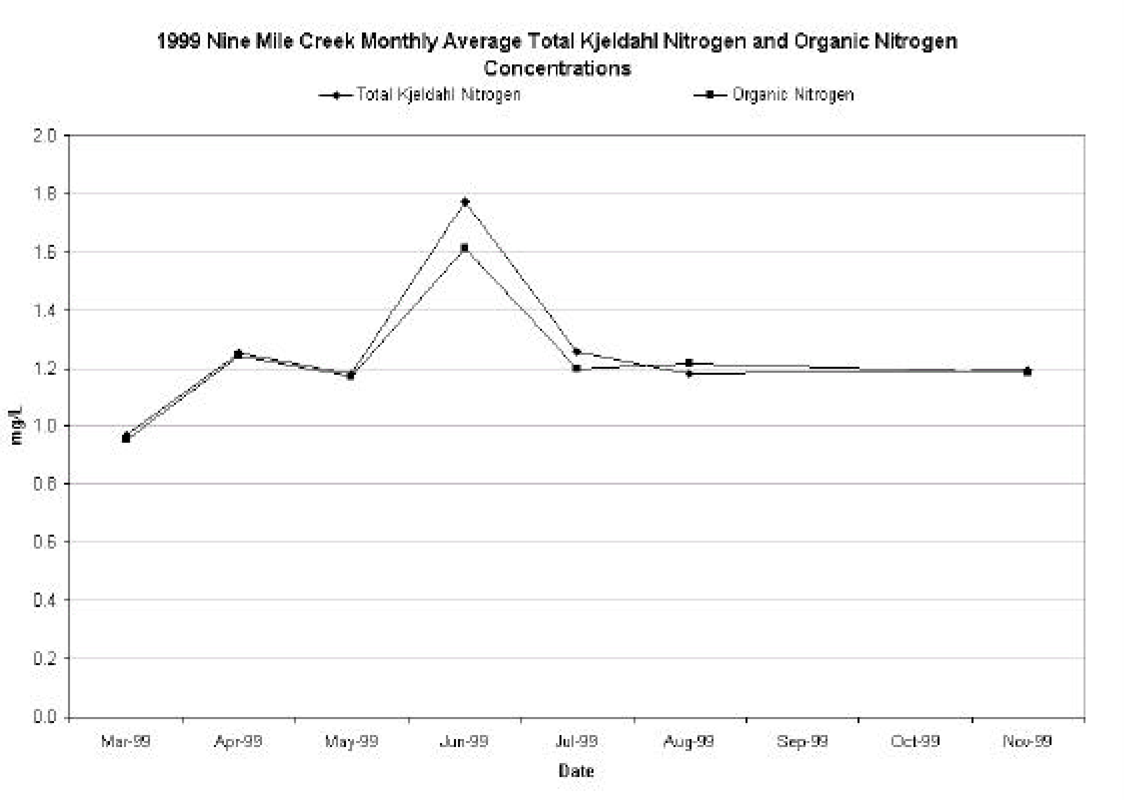


Figure 10. 1999 monthly average Total Kjeldahl Nitrogen and organic nitrogen concentrations for Nine Mile Creek, Lincoln County, South Dakota.

TKN concentrations in Nine Mile Creek averaged 1.32 mg/L with a maximum concentration of 2.86 mg/L and a minimum of 0.73 mg/L. Organic nitrogen concentrations averaged 1.26 mg/L with a maximum of 2.67 mg/L and a minimum concentration of 0.72 mg/L. There was an increase in both TKN and organic nitrogen concentration in the early summer (June) (Figure 10). Since organic nitrogen is calculated from TKN, the divergence in averages in June and July coincides with increased ammonia concentrations over that same period (Figure 7). Seasonal averages for TKN and organic nitrogen concentrations were highest in the summer (Table 4).

Table 16. Nine Mile Creek, 1999, organic nitrogen loading per year by site.

Site	Watershed Percent (gauged)	Hydrologic Percent (gauged)	Kilograms Per year	Kilograms/year by site	Percent Total Load (gauged)	Export Coefficient (Kg/Acre)
LAT-1	8.4	13.9	1,409	1,409	20.0	0.75
LAT-2	7.7	8.1	1,503	94	1.3	0.05
LAT-3	25.0	23.1	3,115	1,612	22.9	0.29
LAT-4	10.2	12.8	3,982	867	12.3	0.38
LAT-5	22.5	20.8	5,616	1,634	23.2	0.32
LAT-6	26.1	21.3	7,038	1,422	20.2	0.24

TKN loading by site was highest at site LAT-5 with 1,719 kg/year or 23.1 percent of the total load (Table 15). Organic nitrogen loadings were also highest at site LAT-5 with 1,634 kg/year or 23.2 percent of the organic nitrogen load (Table 16). Subwatersheds export coefficients (kilograms/acre) for both TKN and organic nitrogen were highest in the LAT-1 subwatershed (TKN 0.76 kg/acre and organic nitrogen 0.75 kg/acre) (Table 15 and Table 16). LAT-1 subwatershed export coefficients (kg/acre) for TKN and organic nitrogen were 2.24 and 2.34 times greater, respectively, than the LAT-5 sub-watershed which had the highest percent total load.

Total Nitrogen

Total nitrogen is the sum of nitrate-nitrite and TKN concentrations. Total nitrogen is used mostly in determining the limiting nutrient (nitrogen or phosphorus) and will be discussed later in this section and in the lake section of this report. The maximum total nitrogen concentration found in Nine Mile Creek was 9.38 mg/L at LAT-3 on July 14, 1999 (Appendix F). Average monthly total nitrogen concentrations peaked in the summer (Figure 11). The mean concentration for the entire sampling season was 2.74 mg/L and the standard deviation for total nitrogen was 1.67 mg/L. The organic nitrogen fraction (percent) of total nitrogen concentration ranged from 11.4 to 96.0 percent and averaged 57.5 percent.

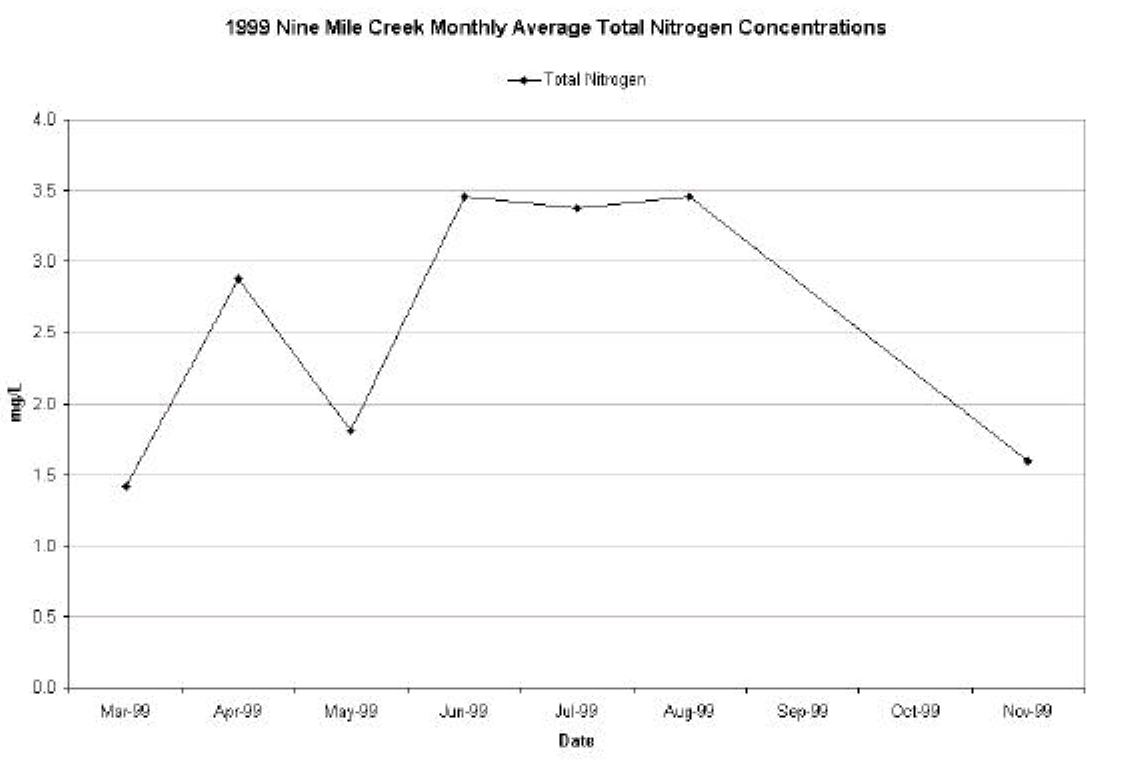


Figure 11. 1999 monthly average total nitrogen concentrations for Nine Mile Creek, Lincoln County, South Dakota.

Seasonally, average total nitrogen concentrations were high in the spring (2.28 mg/L, median 2.21 mg/L) and peaked during the summer (3.43 mg/L, median 2.83 mg/L) (Table 4).

Total nitrogen loading by site was highest at site LAT-3 with 6,827 kg/year or 36.9 percent of the total nitrogen load (Table 17). Subwatershed export coefficients (kilograms/acre) were also highest in the LAT-3 subwatershed (1.22 kg/acre).

Table 17. Nine Mile Creek, 1999, total nitrogen loading per year by site.

Site	Watershed Percent (gauged)	Hydrologic Percent (gauged)	Kilograms Per year	Kilograms/year by site	Percent Total Load (gauged)	Export Coefficient (Kg/Acre)
LAT-1	8.4	13.9	1,834	1,834	9.9	0.98
LAT-2	7.7	8.1	2,195	361	2.0	0.21
LAT-3	25.0	23.1	9,022	6,827	36.9	1.22
LAT-4	10.2	12.8	11,471	2,449	13.3	1.07
LAT-5	22.5	20.8	15,390	3,919	21.2	0.78
LAT-6	26.1	21.3	18,476	3,086	16.7	0.53

Decreasing nitrogen inputs from the Nine Mile Creek and the ungauged watershed may improve (lower) TSI values. Reducing nitrogen (especially organic nitrogen) could improve non-algal turbidity, which may increase Secchi transparency, which would decrease Secchi TSI values. Increasing transparency should increase the growth of submerged macrophytes, which would increase the uptake of nitrogen and phosphorus, reducing available nutrients that could cause algal blooms in Lake Alvin. Reduced densities of algae should improve algal turbidity and decrease chlorophyll-*a* concentrations. Reducing available inlake nitrogen, phosphorus and algae densities should decrease all TSI values. These reductions over time should reverse the TSI trend. Increasing the densities of submerged macrophytes in Lake Alvin will also create littoral zone cover for macroinvertebrates, forage fish and ambush points for predator species.

Subwatersheds that should be targeted for total nitrogen mitigation based upon watershed assessment and AGNPS modeling export coefficients are presented by priority ranking in Table 18.

Table 18. Nine Mile Creek and ungauged watershed mitigation priority sub-watersheds for nitrogen based on watershed assessment and AGNPS modeling.

Priority Ranking	Subwatershed	Export Coefficient	Kilograms Delivered	Sources
1	LAT-3	1.22	6832.0	WA
2	LAT-4	1.07	2439.6	WA
3	LAT-1	0.98	1842.4	WA/AGNPS
4	Ungauged	0.84	4748.5	AGNPS

WA = Watershed Assessment
AGNPS = Agricultural Non-Point Source Model

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 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 sediments unless released by increased stage (water level), discharge or current. Resuspending phosphorus and other nutrients associated with sediment into the water column should show increased concentrations during summer rain events (increased stage and flow). Nutrient accumulation may have been seen in average total phosphorus and to some extent, average total nitrogen concentrations, during the summer months when samples were collected only during heavy rain events (Figure 12 and Figure 11). In the summer, reduced flows and discharge deposit phosphorus and other nutrients associated with sediment on the stream banks and floodplain of Nine Mile Creek. Summertime rain events increase flows and resuspend 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 Nine Mile Creek.

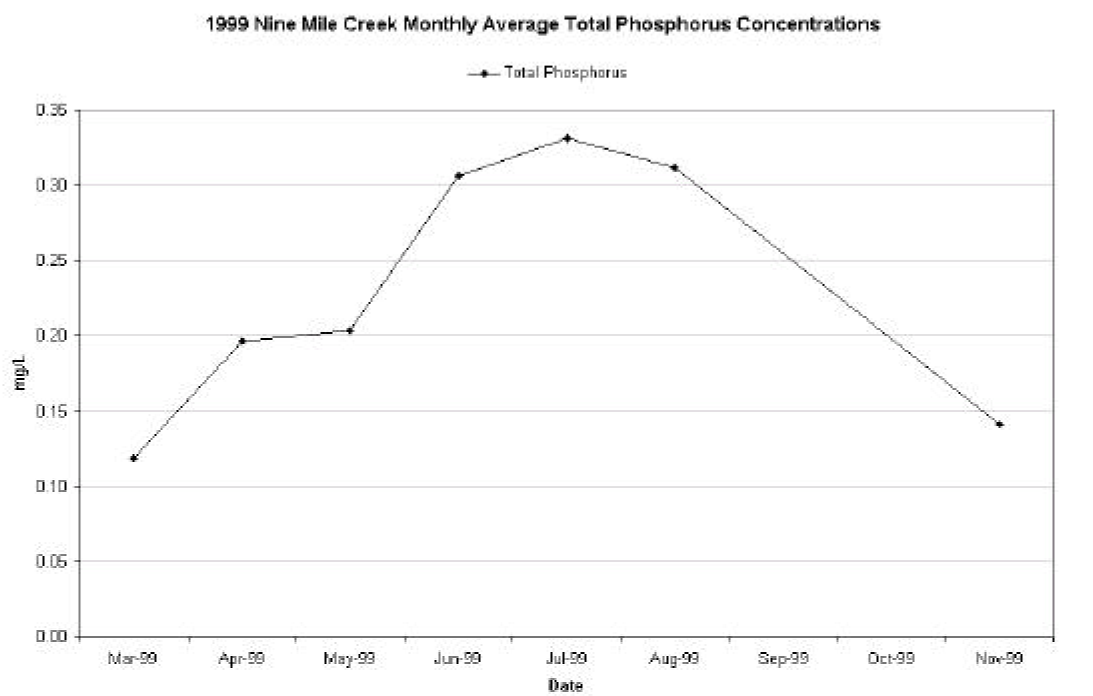


Figure 12. 1999 monthly average total phosphorus concentrations for Nine Mile Creek, Lincoln County, South Dakota.

The average total phosphorus concentration for Nine Mile Creek was 0.232 mg/L (median 0.210 mg/L) during the project. The maximum concentration of total phosphorus was 0.995 mg/L on July 14, 1999 at LAT-2 and a minimum of 0.082 mg/L at LAT-6 on November 9, 1999 (Appendix F). Since algae/periphyton only need 0.02 mg/L of phosphorus to produce algal blooms in lakes (Wetzel, 1983), Nine Mile Creek average delivery concentration was 11.6 times the phosphorus needed to produce algal blooms in Lake Alvin.

Table 19. Nine Mile Creek, 1999, total phosphorus loading per year by site.

Site	Watershed Percent (gauged)	Hydrologic Percent (gauged)	Kilograms Per year	Kilograms/year by site	Percent Total Load (gauged)	Export Coefficient (Kg/Acre)
LAT-1	8.4	13.9	171	171	14.9	0.09
LAT-2	7.7	8.1	314	143	12.5	0.08
LAT-3	25.0	23.1	586	272	23.7	0.05
LAT-4	10.2	12.8	727	141	12.3	0.06
LAT-5	22.5	20.8	981	255	22.2	0.05
LAT-6	26.1	21.3	1,147	165	14.4	0.03

As can be seen from the graph in Figure 12, there were seasonal increases in phosphorus from May to July with a slight dip in August 1999. Seasonally, total phosphorus concentrations were elevated in the spring (0.176 mg/L) and peaked in the summer (0.316 mg/L) (Table 4).

Total phosphorus loading by site was highest at site LAT-3 with 272 kg/year or 23.7 percent of the total phosphorus load (Table 19). However, subwatershed export coefficients (kilograms/acre) were highest in the LAT-1 subwatershed (0.09 kg/acre). This is 1.80 times more total phosphorus per acre than subwatershed LAT-3 (0.05 kg/acre) which had the highest percent total load.

Decreasing total phosphorus inputs from the Nine Mile Creek and the ungauged watershed will improve (lower) TSI values. Reducing phosphorus will decrease algal turbidity, which should increase Secchi transparency and decrease Secchi TSI values. Reducing phosphorus input should lower inlake 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 the TSI trend observed in Lake Alvin.

Subwatersheds that should be targeted for phosphorus mitigation based upon watershed assessment and AGNPS modeling export coefficients and are presented in priority ranking in Table 20.

Table 20. Nine Mile Creek and ungauged watershed mitigation priority sub-watersheds for phosphorus based on watershed assessment and AGNPS modeling.

Priority Ranking	Subwatershed	Export Coefficient	Kilograms per Acre	Sources
1	LAT-1	0.09	169.2	WA/AGNPS
2	LAT-2	0.08	137.6	WA
3	Ungauged	0.06	339.2	AGNPS
4	LAT-4	0.06	136.8	WA

WA = Watershed Assessment
AGNPS = Agricultural Non-Point Source Model

Total Dissolved Phosphorus

Total dissolved phosphorus is the fraction of total phosphorus that is readily available for use by algae. Dissolved phosphorus will sorb on suspended materials if they are present in the water column and if they are not already saturated with phosphorus. Dissolved phosphorus is readily available to algae for uptake and growth.

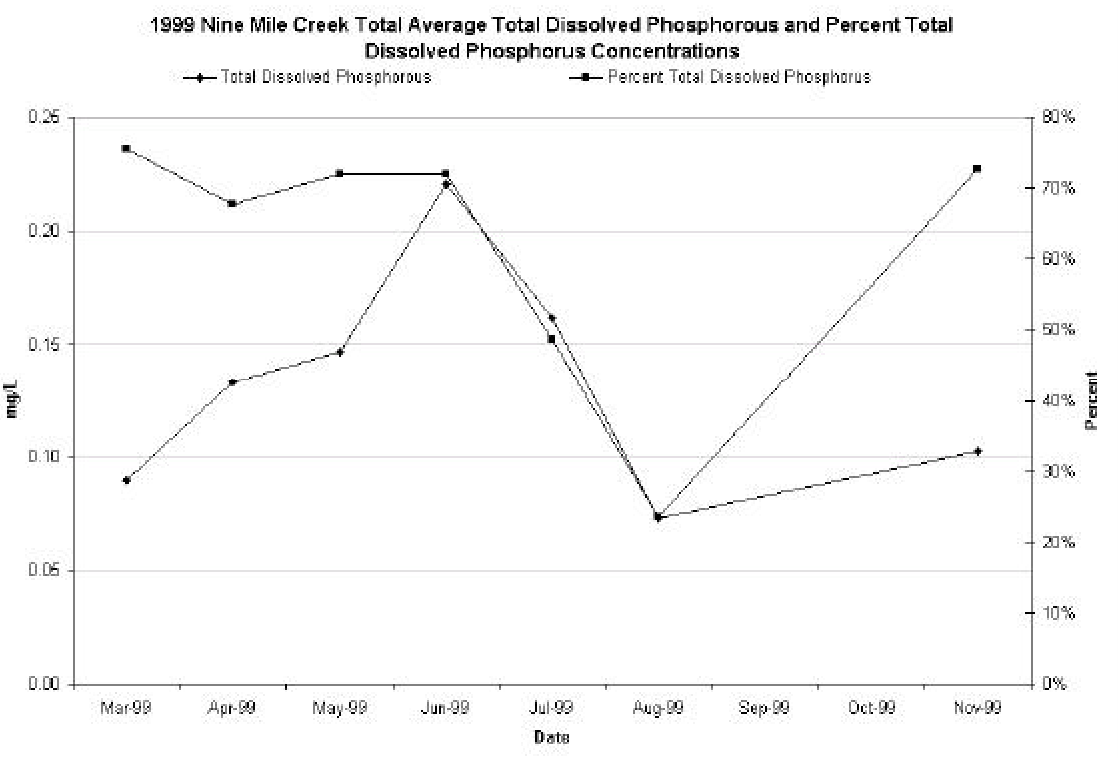


Figure 13. 1999 monthly average total dissolved phosphorus concentrations for Nine Mile Creek, Lincoln County, South Dakota.

The average total dissolved phosphorus concentration for Nine Mile Creek was 0.147 mg/L (median 0.120 mg/L) (Table 4). The maximum concentration of total phosphorus was 0.744 mg/L on July 14, 1999 at LAT-2 and a minimum of 0.016 mg/L at LAT-7 (outlet) on July 14, 1999 (Appendix F). During this study, the percentage of total dissolved phosphorus to total phosphorus ranged from 11.5 percent in the summer to 94.7 percent in spring and averaged 62.4 percent over the project (Figure 13).

Table 21. Nine Mile Creek, 1999, total dissolved phosphorus loading per year by site.

Site	Watershed Percent (gauged)	Hydrologic Percent (gauged)	Kilograms Per year	Kilograms/year By site	Percent Total Load (gauged)	Export Coefficient (Kg/Acre)
LAT-1	8.4	13.9	139	139	23.9	0.07
LAT-2	7.7	8.1	269	130	22.5	0.08
LAT-3	25.0	23.1	379	110	18.8	0.02
LAT-4	10.2	12.8	387	8	1.4	<0.01
LAT-5	22.5	20.8	570	183	31.5	0.04
LAT-6	26.1	21.3	582	12	2.1	<0.01

As can be seen from the graph in Figure 13, there were seasonal increases in total dissolved phosphorus from March to June with a sharp dip in July and August 1999 (Figure 13). Seasonally, total dissolved phosphorus concentrations were elevated in the spring (0.121 mg/L) and peaked in the summer (0.199 mg/L) (Table 4).

Total dissolved phosphorus loading by site was highest at site LAT-5 with 183 kg/year or 31.5 percent of the total dissolved phosphorus load (Table 21). However, subwatershed export coefficients (kilograms/acre) were highest in the LAT-2 subwatershed (0.08 kg/acre). This is 2.0 times more total dissolved phosphorus delivered per acre than subwatershed LAT-5 (0.04 kg/acre).

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 1983). 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. 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).

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, total nitrogen to total phosphorus ratio of 16:1 was used to determine phosphorus limitation.

Nitrogen and phosphorus ratios were calculated for all tributary samples (53 samples) and monthly averages are shown in Figure 14; however, only data from LAT-6 (Figure 15) was evaluated because those concentrations (ratios) influence Lake Alvin directly.

Table 22. Seasonal average total nitrogen-to-total phosphorus ratios based on sample concentrations for Nine Mile Creek and LAT-6.

	Nine Mile Creek (all sites)	LAT-6 (inlet)
Spring	13.3	17.0
Summer	14.0	17.3
Fall	13.1	17.4[1]
Overall Average	**13.6**	**17.2**

1 = not an average, only one sample taken

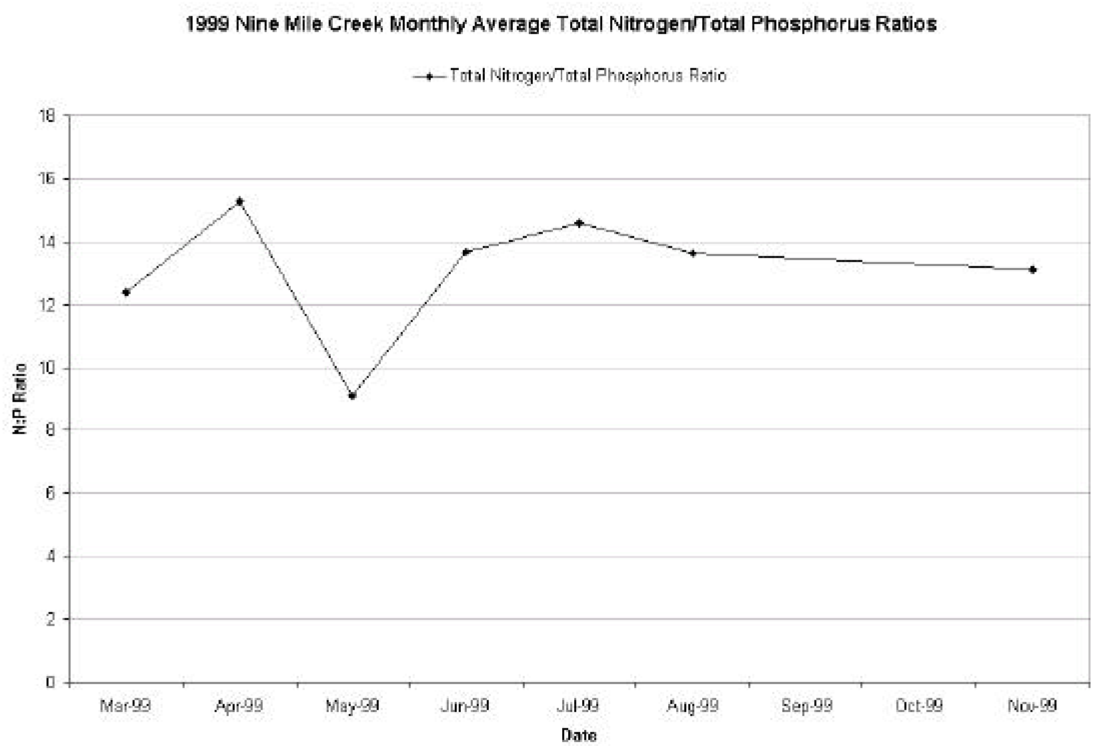


Figure 14. 1999 average monthly total nitrogen/total phosphorus ratios based on concentrations for Nine Mile Creek, Lincoln County, South Dakota.

Seasonally, overall average monthly tributary total nitrogen / total phosphorus ratios for all sites were more erratic in the spring during increased flows and averaged 13:1 (Figure 14 and Table 22). The average ratio increased slightly in the summer to 14:1 and declined slightly in the fall. All average seasonal ratios were elevated at LAT-6 and slightly increased from spring to the fall (Table 22). Individual ratios for LAT-6 are shown in Figure 15 and seasonally, little change in average nitrogen-to-phosphorus ratios were observed.

Table 23. Nine Mile Creek annual total nitrogen-to-total phosphorus loading and concentration ratios by site for 1999.

Site	Hydrologic Load Percent	Load Ratio	Concentration Ratio
LAT–1	13.9	11:1	8:1
LAT-2	8.1	7:1	6:1
LAT-3	23.1	15:1	10:1
LAT-4	12.8	16:1	14:1
LAT-5	20.8	16:1	17:1
LAT-6	21.3	16:1	17:1

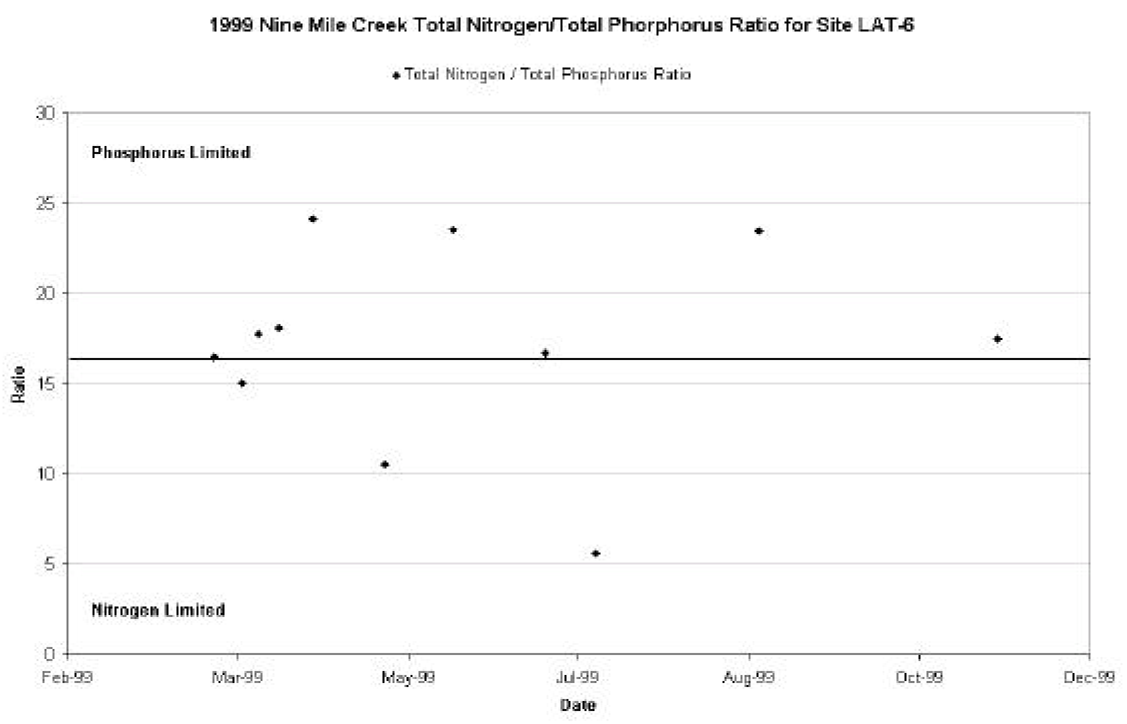


Figure 15. 1999 average monthly total nitrogen-to-total phosphorus ratios based on concentrations at LAT-6 for Nine Mile Creek, Lincoln County, South Dakota.

LAT-6 contributes 80.3 percent of the total hydrologic load to Lake Alvin. Total nitrogen-to-total phosphorus ratios based on loading and concentrations by site were higher in the lower portion of the watershed (Table 23). Annual loading ratios at LAT-4, LAT-5 and LAT-6 were 16:1. Based on the criteria previously proposed, metabolic activity and community structure based on nutrient limitations was not a factor in the lower portions of Nine Mile Creek. Ratios based on loadings represent total nitrogen-to-total phosphorus concentrations that initially influence Lake Alvin.

Ungauged Portion of Watershed

The ungauged portion of the project is comprised of the area immediately around the lake and portions of the watershed to the northwest and the south. It was estimated from the AGNPS model that 20.2% of the watershed was not gauged. To determine hydrologic loading of the ungauged portion of the watershed a conservative export coefficient was used (0.161 acre-feet) based upon the export coefficient for the LAT-6 subwatershed (0.165 acre-feet). After the total from the ungauged sites was added to the loadings total, it was found that the ungauged area contributed an additional 16.1 percent of the hydrologic load to the lake. AGNPS data was used to estimate the additional percent of phosphorus, sediment and nitrogen loadings to the lake. AGNPS calculated export coefficients were adjusted using export coefficients derived from water quality loading data. A simple ratio was used to modify AGNPS export coefficients. This ratio was the average AGNPS gauged export coefficient over the AGNPS ungauged export coefficient compared to the average gauged water quality export coefficient over the unknown ungauged export coefficient. Modified export coefficients are listed in Table 24. The ungauged portion of the watershed contributed an additional 22.8 percent of the phosphorus, 34.7 percent of the sediment and 20.4 percent of the total nitrogen using adjusted export coefficients.

In the ungauged portion of the watershed, AGNPS identified 18 critical cells for erosion (sediment), 11 critical cells for nitrogen and 11 critical cells for phosphorus. Critical cells for erosion were targeted/selected as delivering greater than four tons of sediment per acre. Nitrogen critical cells were targeted as delivering greater than 3.18 kg (7.0 pounds) per acre of total nitrogen and critical cells for phosphorus delivering more than 1.25 kg (2.75 pounds) of total phosphorus per acre. The percentage of critical cells in the ungauged portion of the watershed was 32.1 percent for sediment, 22.9 percent for nitrogen and 22.9 percent for phosphorus of the critical cells targeted in the entire watershed.

There were four animal feeding areas within the ungauged portion of the watershed. AGNPS ranked the feedlots within the ungauged watershed from 13 to 51. The feeding areas, along with improper manure management, and overgrazed pastures in the ungauged portion of the watershed were the most likely sources of nutrients and sediment to Lake Alvin. The estimated loads for the ungauged section of the watershed are significant and will be considered in tributary loading (Table 24) and watershed mitigation.

Table 24. 1999 ungauged percent loading and adjusted export coefficients for Nine Mile Creek, Lincoln County, South Dakota.

Ungauged Parameter	Percent Total Load [1]	Export Coefficient
Percent Watershed	20.2	NA
Hydrologic (Acre-feet)	16.7	0.16
Total Suspended Solids (kg)	34.7	26.3
Total Nitrogen (kg)	20.4	0.84
Total Phosphorus (kg)	22.8	0.06

[1] = Ungauged load was calculated and added to gauged load to determine percent load

Summary of Tributary Sites

Nine Mile Creek was monitored for tributary loading to Lake Alvin from March through November, 1999 (232 days). Approximately 4,537 acre-feet of water flowed into Lake Alvin from the gauged portion of the watershed (22,360 acres) in 1999. The export coefficient (water delivered per acre) for this area of the watershed was 0.20 acre-feet. The remaining 5,653 acres or 20.2 percent of the watershed was ungauged. During this study an estimated 910 acre-feet of water was delivered to Lake Alvin from the ungauged watershed. Peak hydrologic load for all subwatersheds occurred in the spring, with approximately two thirds of the total hydrologic load delivered to each site by June 1999.

Nine Mile Creek was monitored using sixteen water quality parameters, most of which (68.8 percent) had the highest average concentrations and values in the summer. Three parameters (18.8 percent), dissolved oxygen, field pH and fecal coliform, had the highest concentrations and values in the spring. Two parameters (12.5 percent), total solids and total dissolved solids had the highest values in the fall. There were no exceedances of water quality standards observed during the project period.

One of the two parameters for which Lake Alvin was listed on the South Dakota 303(d) list was fecal coliform; however, there are no fecal coliform bacteria standards for Nine Mile Creek west of Lake Alvin. Three sites at the lower end of the watershed, LAT-4, LAT-5 and LAT-6 had elevated fecal coliform counts. Samples collected at LAT-5 (3,400 colonies/100 ml) and LAT-6 (9,300 colonies/100 ml) had coliform counts in excess of the standard in Lake Alvin (2,000 colonies/100 ml (grab)). Two other samples collected at LAT-4 and LAT-5 had coliform counts greater than or equal to 1000 colonies per 100 ml. Seasonally, fecal coliform counts were highest in the spring, high in the summer and lower in the fall. Grazing within and along Nine Mile Creek, runoff from animal feeding areas and poor manure management were the most likely sources of these high fecal coliform counts.

The other parameter Lake Alvin was listed for on the impaired waterbodies list was an increasing TSI trend. This watershed assessment and AGNPS modeling identified critical cells and priority areas within the watershed for mitigation (treatment). Those cells and areas were selected/chosen based on export coefficients for nutrients (nitrogen and phosphorus) and sediment (erosion/total suspended solids) and were listed throughout this report and in Appendix E. All of these watershed parameters eventually effect inlake concentrations and TSI values in Lake Alvin. Reductions in any or all of these parameters should lower inlake TSI values.

Decreasing sediment (erosion) inputs from Nine Mile Creek and the ungauged watershed will improve (lower) TSI values. Reducing sediment will improve non-algal turbidity, which will increase Secchi transparency, decreasing Secchi TSI values. Reducing sediment reduces available phosphorus for algae growth and uptake, which will have a two-fold affect on TSI values. Decreasing available phosphorus could lessen algae densities and blooms in Lake Alvin which should reduce algal turbidity, improving Secchi TSI values. Lower algal densities will decrease chlorophyll-*a* concentrations, reducing chlorophyll-*a* TSI values. 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.

Reducing nitrogen (especially organic nitrogen) and phosphorus concentrations in the Lake Alvin watershed could reduce non-algal turbidity, which in turn may increase Secchi transparency, which would decrease Secchi TSI values. Increasing transparency should, as discussed above, increase the growth of submerged macrophytes, increasing the uptake of nitrogen and phosphorus thereby making it unavailable to the algal community. Reduced densities of algae should reduce algal turbidity and decrease chlorophyll-*a* concentrations. Reducing available inlake nitrogen, phosphorus and algae densities should decrease all TSI values. These reductions over time should reverse present TSI trends. Increasing densities of submerged macrophytes will also create littoral zone cover for macroinvertebrates and forage fish, and ambush points for predator species.

Subwatersheds that should be targeted for sediment, nitrogen and total phosphorus mitigation, based on watershed assessment and AGNPS modeling export coefficients, are presented in priority ranking in Table 25.

Table 25. Nine Mile Creek and ungauged watershed mitigation priority sub-watersheds for sediment, nitrogen and phosphorus, based on watershed assessment and AGNPS modeling.

Priority Ranking	Sediment Subwatershed	Sediment Export Coefficient	Nitrogen Subwatershed	Nitrogen Export Coefficient	Phosphorus Subwatershed	Phosphorus Export Coefficient
1	LAT-4	49.0	LAT-3	1.22	LAT-1	0.09
2	Ungauged	26.3	LAT-4	1.07	LAT-2	0.08
3	LAT-3	19.0	LAT-1	0.98	Ungauged	0.06
4	LAT-5	9.5	Ungauged	0.84	LAT-4	0.06
5	LAT-1	5.1	LAT-5	0.78	LAT-3	0.05
6	LAT-2	2.5	LAT-6	0.53	LAT-5	0.05
7	LAT-6	0.0	LAT-2	0.21	LAT-6	0.03

Tributary Recommendations

Tributary recommendations are based on best management practices and best professional judgement. All reductions were modeled or calculated using water quality and/or AGNPS data collected during this study. AGNPS critical cells for sediment, nitrogen, phosphorus and animal feeding areas within the watershed are shown in Figure 78, Figure 79, Figure 80 and Figure 81. Stream habitat and watershed condition data was collected by SD GF&P personnel (Newton Hills State Park) and NRCS personnel based in Canton, South Dakota. Reduction percentages given in Table 26 are the expected percent reduction in sediment and nutrients delivered to Lake Alvin based on 1999 loading data.

Minimum Tillage

Minimum tillage reductions were predicted using the AGNPS model. Reductions in sediment, nitrogen and phosphorus were based upon mitigating fifty, 40-acre critical cells throughout the watershed. Critical cell numbers and locations can be found in the AGNPS report in Appendix E. Reduction estimates for each parameter in percent are presented in Table 26.

Riparian Management

Restricting cattle and other livestock access to Nine Mile Creek, establishing riparian and buffer zones, along with areas immediately adjacent to the lake, should reduce nutrient loadings to Lake Alvin by 11.5 percent. Nutrient loading values were calculated using the number animals in and around Nine Mile Creek times the daily waste produced per animal type. Annual nutrient loading reductions were adjusted based upon the number of days animals were in and around Nine Mile Creek throughout the year. Livestock numbers were determined by NRCS personnel based on data from the AGNPS feedlot model. Daily waste values per animal unit were based on the livestock waste facilities handbook (MPS 1976). Treatments should include constructing fences or other barriers to restrict livestock access to the riparian area, livestock cross over structures and alternative watering with nose pumps along Nine Mile Creek, especially vulnerable areas frequented by livestock. Other alternatives could include seasonal access or rotational grazing but reductions would tend to be lower because livestock would still impact the riparian area seasonally.

Streambank Stabilization

South Dakota Department of Game, Fish and Parks personnel surveyed and identified areas of Nine Mile Creek impacted by livestock. Field variables such as total linear distance of impacted areas (left and right streambanks) and bank height were estimated and predicted reductions in sediment, nitrogen and phosphorus were calculated. Sediment will be reduced by 5.8 percent and nutrients by 1.0 percent (Table 26). Reduction estimates were calculated using the Michigan Department of Natural Resources, Pollutants Controlled Calculation and Documentation manual (MI DEQ

1999). 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.

Fertilizer Application

Reducing fertilizer application rates and/or altering temporal applications (time of application) could reduce nutrient loading to Lake Alvin 11.1 percent (Table 26). Nutrient reductions were estimated using the AGNPS model with critical cell numbers and locations provided in Appendix E. 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 Lake Alvin.

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 NRCS office in Canton estimated public participation in constructing buffer strips on Nine Mile Creek. It was estimated that three of the six subwatersheds would construct buffer strips. Calculated reduction percentages were based upon this scenario. Conservative reduction percentages were used to predict sediment and nutrient reductions (35 percent for sediment and 25 percent for nitrogen and phosphorus) in the Lake Alvin watershed. Reductions were calculated for the top three priority subwatersheds for each parameter, and reductions in the overall annual loading to Lake Alvin were estimated. Of all the watershed restoration techniques evaluated, buffer strips offered the greatest percent reduction in sediment and nutrients delivered to Lake Alvin (Table 26).

Animal Feeding Areas

Ten animal feeding areas were identified by AGNPS as being potential sources of sediment and nutrient enrichment in the Lake Alvin watershed. The AGNPS model ranked the animal feeding areas based upon field observation and owner/operator data. Out of the ten feeding areas AGNPS identified (ranked) five feeding areas in the 40 to 51 category based on a 0 (low impact) to 100 (high impact) scale.

Analysis consisted of running the model with five feeding areas greater than 40 removed and comparing that data with the original data which included feeding areas. Removing five animal feeding areas will reduce nitrogen and phosphorus loading to the lake by 1.3 percent and 2.0 percent, respectively. Percent reductions are considered conservative because AGNPS underestimates the impact of animal feeding areas near Lake Alvin. During this study, cattle were observed in and around Nine Mile Creek below LAT-6. Since cattle in were not in a specific feeding area, AGNPS is not equipped to model reductions thus underestimating the overall load to the lake.

Five feeding areas with AGNPS ratings of 40 or greater should have animal waste management systems constructed to lower nutrient loading to Lake Alvin.

Implementing any or all best management practices will have an overall positive impact on Lake Alvin over time.

Table 26. Estimated delivered reduction percentages for select best management practices for Nine Mile Creek, Lincoln County, South Dakota.

	Parameter (Percent Reduction)		
Best Management Practice (BMP)	**Sediment**	**Nitrogen**	**Phosphorus**
Minimum till (50 critical cells)	14.8	4.4	4.3
Riparian Management (creek, riparian area and buffer strip)	-	3.0	8.5
Streambank stabilization (eroded areas)	5.8	0.1	0.9
Fertilizer (reduced application rates and temporal application)	-	7.7	3.4
Buffer strips (Three subwatersheds)	29.9	32.4	28.1
Animal Feeding Areas (AGNPS rating ≥ 40)	-	1.3	2.0
Estimated Total Reduction to Lake Alvin	**50.5**	**48.9**	**47.2**

INLAKE DATA

Inlake Methods and Materials

Two inlake sample locations were chosen for collecting nutrient, biological and sediment data from Lake Alvin during the study. The locations of the inlake sampling sites are shown in Figure 16. A sample set consisted of a surface and a bottom sample collected from each site each month. Additional inlake data were collected in 1989, 1991, 1992 and 1998 for the state-sponsored annual Statewide Lake Assessment. These samples were used to analyze water quality trends over time.

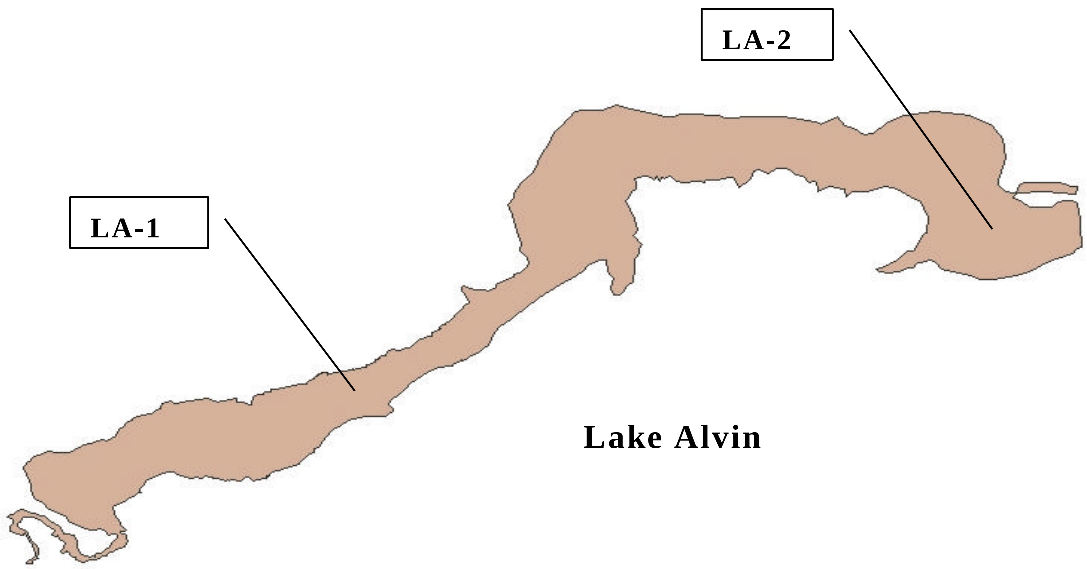


Figure 16. Lake Alvin inlake sampling sites for 1999.

Statewide Lake Assessment samples were collected by compositing three widely separated sub-sample sites for both surface and bottom samples in each lake (Stueven and Stewart, 1996). All samples were collected and analyzed according to the *South Dakota Standard Operating Procedures for Field Samplers* (SD DENR 2000)

The water quality sample set analyzed by the State Health Laboratory consisted of the following parameters:

Total Alkalinity	Total Solids	Total Suspended Solids
Ammonia	Nitrate-Nitrite	Total Kjeldahl Nitrogen
Fecal Coliform	Total Phosphorus	Total Dissolved Phosphorus

Water quality parameters that were calculated from the parameters analyzed above were:

Un-ionized Ammonia	Organic Nitrogen	Total Nitrogen

In addition to the chemical water quality data above, inlake field parameters and biological data were also collected. The following are a list of field parameters collected:

Water Temperature	Air Temperature	Dissolved Oxygen Profiles
Field pH	Secchi Depth	Chlorophyll-*a*
Algae surface samples		Elutriate samples
Macroinvertebrate benthic samples		

Chlorophyll-*a* samples were used with phosphorus and Secchi disk data to evaluate the trophic status and trends in Lake Alvin (Carlson 1977). TSI (Trophic State Index) reductions were predicted using BATHTUB modeling (US ACOE 1999).

All algae samples were analyzed by Aquatic Analysts and enumeration results were entered into a database to be analyzed. Aquatic Analysts provided identification, enumeration and biovolume data: however, biovolume was re-calculated using local biovolume values and all analysis was based on these values. Original data provided by Aquatic Analysts is provided in Appendix J.

All samples collected at the inlake sites were taken according to South Dakota's EPA-approved *Standard Operating Procedures for Field Samplers* (SD DENR 2000). Water samples were sent to the State Health Laboratory in Pierre, SD for analysis. One Quality Assurance/Quality Control sample was collected in Lake Alvin in accordance with South Dakota's EPA-approved *Nonpoint Source Quality Assurance/Quality Control Plan* but the sample was lost (SD DENR 1998a). These documents can be obtained by contacting the Department of Environment and Natural Resources at (605) 773-4254.

Inlake Water Quality (Standards and Seasonal)

South Dakota Inlake Water Quality Standards

Lake Alvin has been assigned the beneficial uses of:

(4) Warmwater permanent fish life propagation
(7) Immersion recreation
(8) Limited contact recreation
(9) Fish and wildlife propagation, recreation and stock watering waters

When the above uses have two or more standard limits for the same parameter, the most stringent standard is applied. Table 27 shows the most stringent standards for the parameters sampled in Lake Alvin during the study.

Table 27. South Dakota Water Quality Standard Limits for Lake Alvin, Lincoln County, South Dakota.

Parameter	Standard Limit
Un-ionized ammonia [1]	≤ 0.04 mg/L
Dissolved Oxygen	≥ 5.0 mg/L
pH	≥ 6.5 and ≤ 9.0 su
Total Suspended Solids [2]	≤ 90 mg/L
Temperature	≤ 26.67 °C
Fecal Coliform [3]	≤ 400 counts/100 ml (grab)
Alkalinity	≤750 mg/L
Nitrates [4]	≤ 50 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.

[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) and may not exceed 200 counts/100 ml in more than 20 percent of the samples in the same 30-day period.

[4] The daily maximum for nitrates is ≤ 88 mg/L or ≤ 50 mg/L for a 30-day average.

The following discussion will be based on individual parameters. The discussion will include the importance of the parameter and its effect on the water quality of Lake Alvin. For the following discussion, the parameter concentrations for the two sites will be averaged if both sites were sampled on the same date.

Lake Alvin Water Quality Exceedance

There were two exceedances of inlake water quality standards for Lake Alvin during the sampling period. Lake Alvin water quality is influenced by the 28,013 acre watershed of Nine Mile Creek; however, both water quality exceedances were from surface water samples collected from LA-2 (Table 28).

Table 28. Water quality standards exceedances in surface water samples collected from Lake Alvin in 1999.

Date	Site	Parameter	Standard	Exceedance
8/12/99	LA-2	Un-ionized Ammonia [1]	2.08 mg/L	3.62 mg/L
8/12/99	LA-2	Dissolved Oxygen	≥ 5.0 mg/L	3.4 mg/L

[1] = Standard (1.75 times 1.19 mg/L) was calculated based on water temperature (25°C) and pH (7.8 su) at the time of sample collection.

Both water quality exceedances occurred at LA-2 on August 12, 1999. The un-ionized ammonia at LA-2 exceeded the water quality standard by a factor of 1.74. The sample collected from LA-1 on the same date was below detection limits (< 0.02 mg/L) (Appendix I). The ammonia concentration at LA-2 on that date was the highest sampled during the project (3.26 mg/L). However, the percentage of un-ionized ammonia was only 3.5 percent.

The dissolved oxygen standard was also exceeded at LA-2 in August 1999. The dissolved oxygen surface concentration at LA-2 was 1.6 mg/L below the water quality standard (Table 28). The surface sample collected from LA-1 on the same date was well above the water quality standard of 5.0 mg/L (8.3 mg/L) (Appendix I).

One of the impairments Lake Alvin is listed for in the 1998 South Dakota 303(d) Waterbody List is fecal coliform (SD DENR 1998). During this study, no monthly inlake samples exceeded the standards for fecal coliform bacteria. Beach samples collected by SD GF&P exceeded the water quality standard for public beaches (Chapter 74:04:08:07). During 1999, three separate beach samples (June 7, 14 and 16, 1999; >1,600, 500 and >16,000 colonies/100 ml, respectively) exceeded surface water quality standards and public beaches ($\leq$ 400 colonies per 100 ml for any one sample or three consecutive 24-hour samples $\leq$ 200 colonies per 100 ml). The beach reopened on June 23, 1999, and did not exceed the beach standards the rest of the season. One possible reason for the elevated fecal coliform counts in June may have been the sampling technique used to collect these samples. On the dates with elevated fecal counts, samples were collected directly from the shore of the beach rather than wading out from shore to collect the samples. Other possibilities are human or animal wastes in the swimming beach area.

Seasonal Inlake Water Quality

Typically, water quality parameters will vary depending upon season due to changes in temperature, precipitation and agricultural practices. Sixteen inlake water quality samples were collected during the project. These data were separated seasonally into spring (March 24 – May 31), summer (June 1 – August 31), fall (September 1 – November 9) and winter (December 1). During the project, four discrete samples were collected in the spring, four in the summer, six samples in the fall and two samples in the winter months. For comparison to tributary loadings, only spring, summer and fall data are presented in Table 29.

Seasonal Inlake Concentrations

Sediment and nutrient concentrations can change dramatically with changes in season. Hydrologic loads to the lake in the spring may have small nutrient and sediment concentrations; however, more water usually indicates increases in nonpoint source runoff and thus results in higher loadings of nutrients and sediment. The average and median concentrations of different parameters changed with the seasons as shown in Table 29.

Dissolved oxygen concentrations were highest in the spring due to cooler water temperatures (cooler water can hold more oxygen). The lower oxygen concentrations in the summer were most likely due to warm water temperatures and decomposition of organic matter.

Seasonal alkalinity concentrations were highest in the spring and dropped in the summer and fall, while tributary concentrations were lowest in the spring and highest in the fall. All average inlake seasonal alkalinity concentrations were lower than the average seasonal tributary concentrations (Table 29 and Table 4).

Table 29. Average Seasonal Surface Concentrations from Lake Alvin, Lincoln County, South Dakota for 1999 [1].

		Spring			Summer			Fall	
Parameter	**Count**	**Average**	**Median**	**Count**	**Average**	**Median**	**Count**	**Average**	**Median**
Dissolved Oxygen (mg/L)	4	10.3	10.8	4	7.4	7.9	6	9.5	9.3
Field pH (su)	4	8.1	8.1	4	8.0	7.9	6	8.6	8.6
Water Temperature (°C)	4	14.9	15.0	4	25.8	25.8	6	12.8	11.5
Fecal Coliform (# Colonies/ 100 ml)	4	10.0	10.0	4	12.5	10.0	6	10.0	10.0
Alkalinity(mg/L)	4	172.8	173.0	4	142.0	143.5	6	144.8	148.0
Total Solids (mg/L)	4	1452.5	1465.0	4	1637.3	1641.5	6	1694.2	1694.0
Total Suspended Solids (mg/L)	4	16.3	16.5	4	15.5	15.5	6	17.5	17.5
Total Dissolved Solids (mg/L)	4	1438.8	1455.5	4	1620.6	1623.3	6	1676.2	1675.5
Volatile Total Suspended Solids (mg/L)	4	4.3	4.0	4	8.5	8.0	6	10.2	9.0
Total Nitrogen (mg/L)	4	3.41	3.49	4	2.79	1.97	6	2.10	2.16
Organic Nitrogen(mg/L)	4	1.69	1.62	4	1.72	1.64	6	2.03	2.07
Ammonia-N (mg/L)	4	0.02	0.01	4	0.82	0.01	6	0.03	0.01
Nitrate-Nitrite-N (mg/L)	4	1.70	1.60	4	0.20	0.13	6	0.05	0.05
Total Kjeldahl-Nitrogen (mg/L)	4	1.71	1.65	4	2.59	1.62	6	2.05	2.11
Total Phosphorus (mg/L)	4	0.091	0.091	4	0.339	0.158	6	0.304	0.305
Total Dissolved Phosphorus (mg/L)	4	0.019	0.017	4	0.132	0.036	6	0.167	0.160
Secchi Depth (meters)	4	0.6	0.6	4	0.9	0.8	6	0.6	0.6
Chlorophyll-a (ug/m3)	4	56.7	51.0	4	103.6	108.6	6	90.8	89.9
TSI-S (Secchi)	4	67.8	67.2	4	62.2	63.1	6	68.4	68.7
TSI-P (Phosphorus)	4	69.0	69.2	4	80.2	67.5	6	86.6	86.7
TSI-C (Chlorophyll-a)	4	78.4	78.2	4	83.3	85.2	6	83.7	83.7
Mean TSI	12	71.8	71.5	12	75.2	75.5	18	79.6	80.2

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

All inlake solids concentrations (total solids, total dissolved solids, total suspended solids and volatile total suspended solids) were highest in the fall.

The summer average concentration of ammonia was 0.82 mg/L. The highest ammonia concentration was collected in the summer (3.26 mg/L). That sample, collected on August 12, 1999, was four times higher than the standard deviation in ammonia, showing the sample was unusual for the sample set. Eighty-one percent of the ammonia samples were below the State Health Laboratory detection limit (< 0.02 mg/L). Sources for high ammonia concentrations could be livestock wading in the lake, animal feeding areas, decomposition of organic matter, or runoff from applied fertilizer.

Similar to ammonia, nitrate-nitrite had the highest average concentration in summer. The summer season had the highest mean and median. The range of the nitrate-nitrite in the summer was from a minimum of 0.05 mg/L to a maximum of 2.3 mg/L. The maximum sample was collected at site LA-2 on April 27, 1999.

Total Kjeldahl Nitrogen (TKN) is composed of mostly organic nitrogen. TKN had the highest concentrations in the summer. The highest concentration collected during the project period (5.74 mg/L at site LA-2) was on August 12, 1999 (Appendix I). However, average organic nitrogen concentrations were highest in the fall (Table 29).

A parameter Lake Alvin was listed for in the 303(d) document was fecal coliform bacteria. During this study, fecal coliform counts (colonies/100 ml) were generally below 10 colonies per 100 ml. One sample collected on July 21, 1999 at site LA-1 contained 20 colonies per 100 ml, well below the surface water quality and public beach standards.

Average total phosphorus concentrations were highest in the summer, while total dissolved phosphorus had the highest average concentrations in the fall (Table 29). Chlorophyll-*a* is a pigment in plants that may be used to estimate the biomass of algae found in a water sample (Brower, 1984). Average chlorophyll-*a* concentrations were highest in the summer that coincided with increased blue-green algae numbers in July, 1999.

All average Trophic State Index (TSI) values (Secchi, phosphorus, chlorophyll-*a* and mean TSI) were highest in the fall.

Inlake Water Quality

Water Temperature

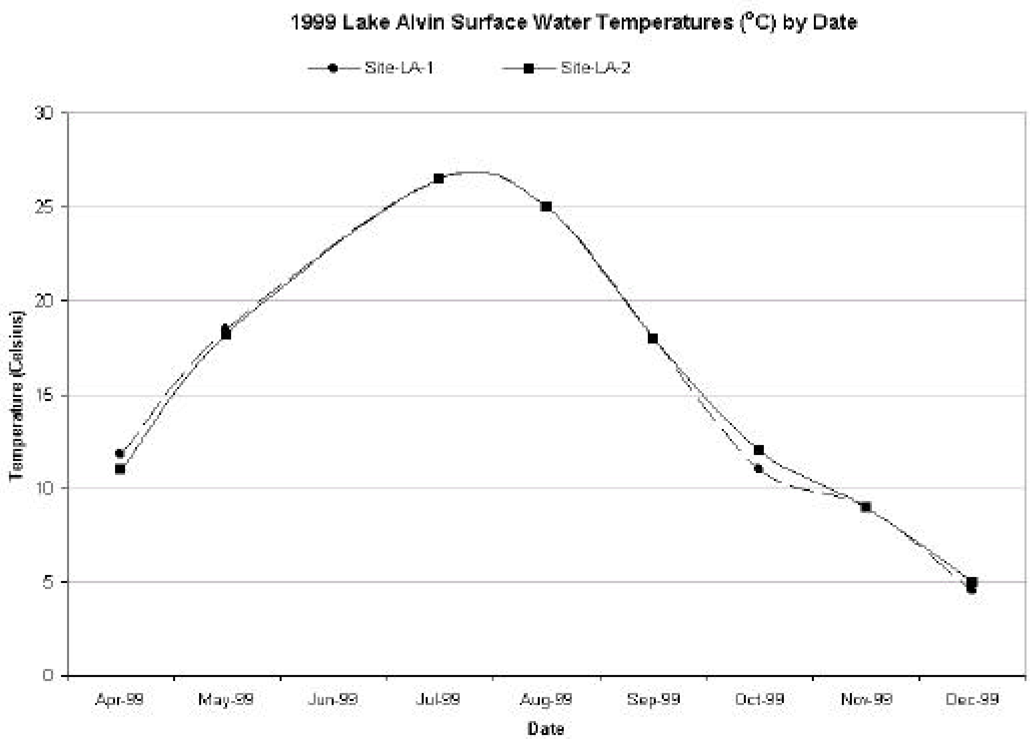


Figure 17. Surface water temperatures by date and sampling site for Lake Alvin Lincoln County, South Dakota in 1999.

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 algae 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. The mean surface water temperature in Lake Alvin over the sampling season was 15.6° C. Figure 17 shows surface water temperatures throughout the project period for both inlake sampling sites. No significant differences were detected within or between sampling sites ($p>0.05$). The maximum surface water temperature measured during the sampling season was 26.5 ^{o}C taken in mid-July, 1999. Temperature profiles (thermal stratification) were significantly different in the spring, summer and fall ($p<0.05$). Mean seasonal water temperature profiles for inlake sampling sites are shown in Figures 18 through 21, while all temperature (and dissolved oxygen) profiles are provided in Appendix H.

Dissolved Oxygen

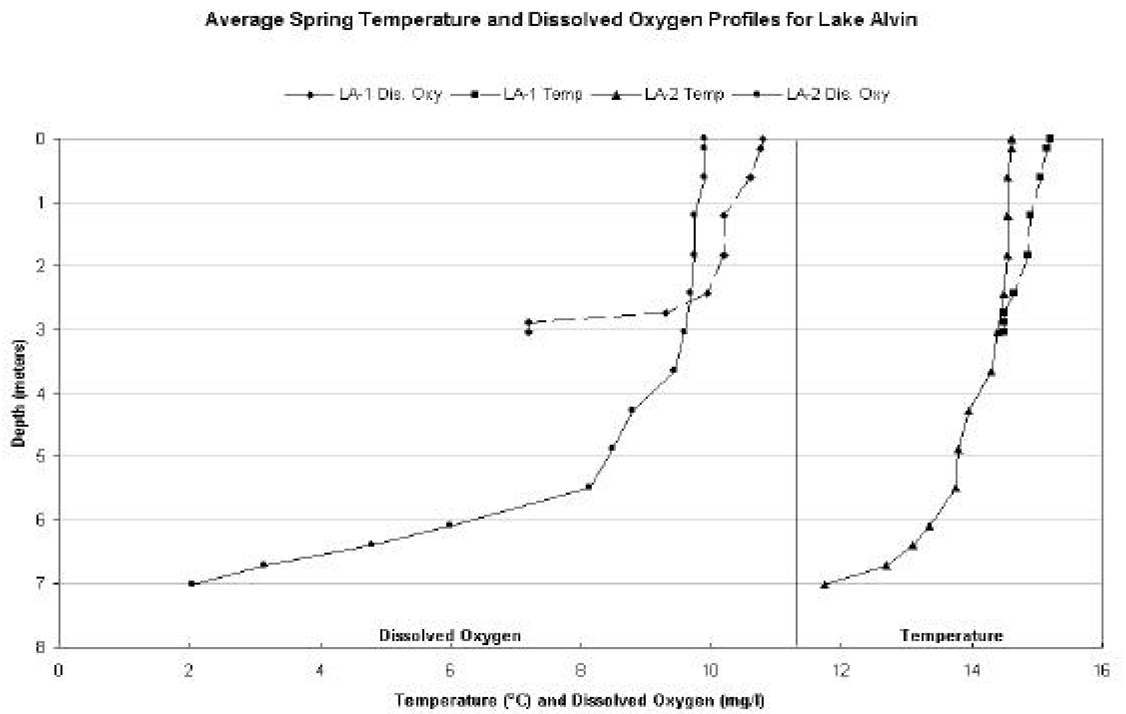


Figure 18. Average spring dissolved oxygen and temperature profiles by sampling site for Lake Alvin, Lincoln County, South Dakota in 1999.

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 increase surface oxygen levels of a lake. Surface water dissolved oxygen averaged 9.6 mg/L (median 9.7 mg/L) over the entire duration of the study. Figures 18 through 21 shows seasonal average dissolved oxygen profiles for the project.

The maximum surface-water oxygen concentration in Lake Alvin was 13.4 mg/L. That sample was collected at LA-2 on December 1, 1999. At site LA-2, high dissolved oxygen concentrations were most likely a product of water temperature. Cool water temperatures increase the solubility of oxygen (cool water can hold more oxygen). The minimum dissolved oxygen concentration was 3.4 mg/L at the surface of LA-2 on August 12, 1999. As the sample was collected in the morning (0915), the lake may have been recovering from low, nighttime oxygen levels because of respiration demand; however, dissolved oxygen at LA-1 was 8.3 mg/L at 0845 in the morning. 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).

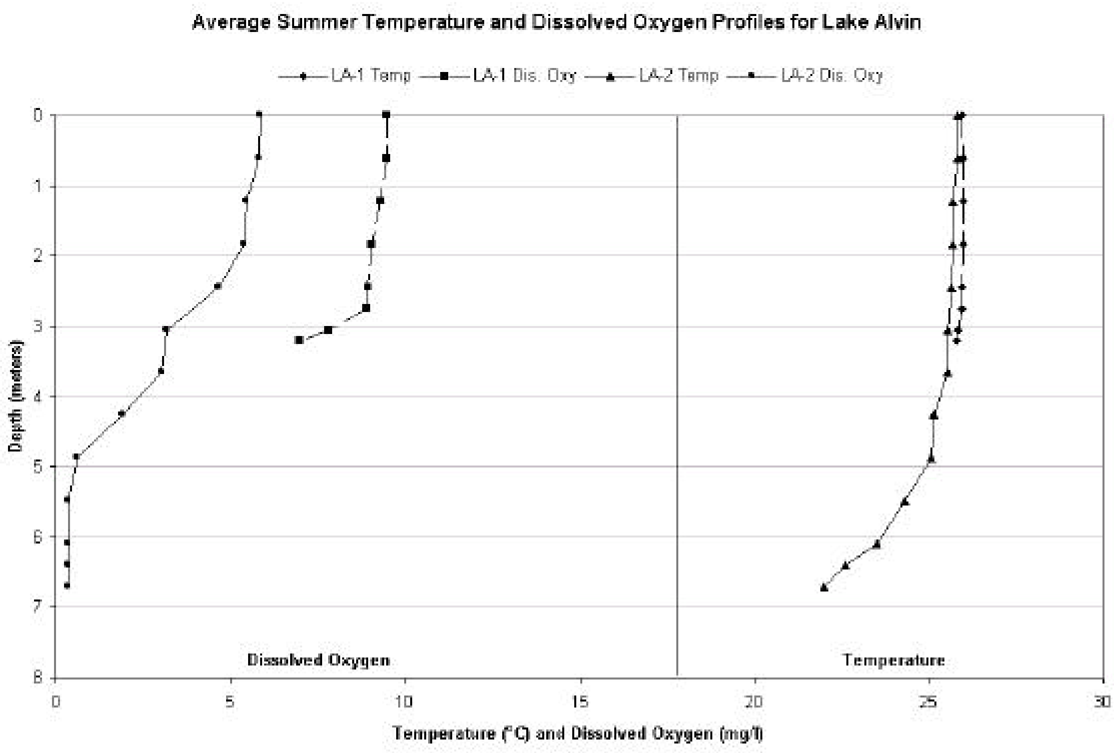


Figure 19. Average summer dissolved oxygen and temperature profiles by sampling site for Lake Alvin, Lincoln County, South Dakota in 1999.

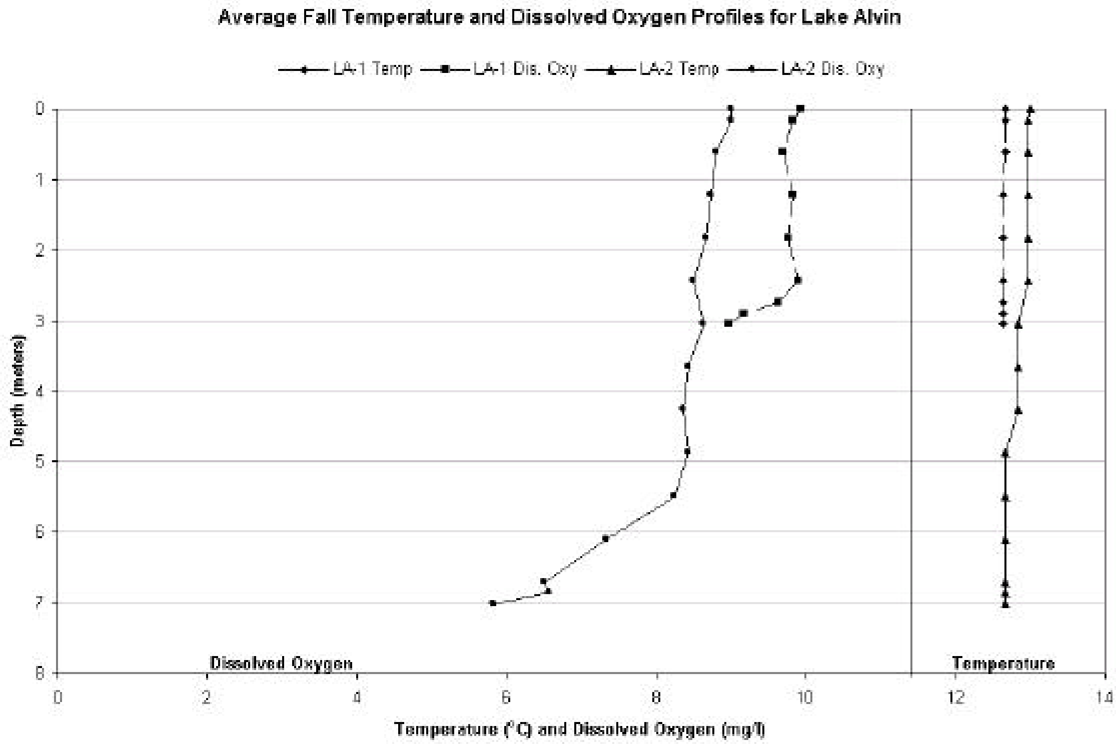


Figure 20. Average fall dissolved oxygen and temperature profiles by sampling site for Lake Alvin, Lincoln County, South Dakota in 1999.

Oxygen stratification was observed in the water column at site LA-2 near the dam. Surface water dissolved oxygen samples were statistically similar between sites while hypolimnion (bottom) dissolved oxygen concentrations were significantly different ($p<0.05$). Some common causes of oxygen depletion in the water column are: aerobic decomposition of organic matter, lack of photosynthesis from aquatic plants, drastic temperature changes in a water column, and no wind or wave action. Under ice and with heavy snow conditions, Lake Alvin may experience short periods of low oxygen due to decomposition of organic matter. In reservoirs, organic matter tends to collect downstream in deeper water near the dam (site LA-2) (Planas 1975). Seasonal differences were observed in dissolved oxygen profiles specifically in mean spring (10.3 mg/L) and summer (7.4 mg/L) profiles (Figure 18 and Figure 19). Although low oxygen levels may be present at deeper depths during the spring and summer months, fish migrate to areas of the lake with more moderate temperature and oxygen levels to reduce stress. Appendix H has all the dissolved oxygen profiles collected in Lake Alvin in 1999 and 2000.

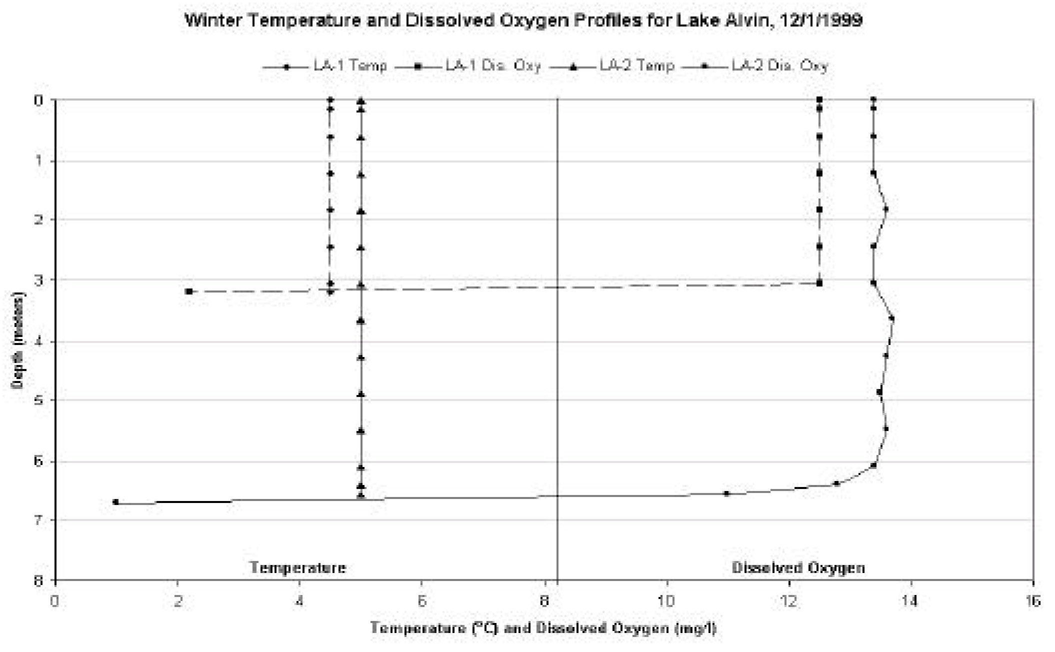


Figure 21. December dissolved oxygen and temperature profiles by sampling site for Lake Alvin, Lincoln County, South Dakota in 1999.

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. The 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 (bottom). Increases in the different species of carbon come at the expense of oxygen. Decomposers will use oxygen to break down the 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.

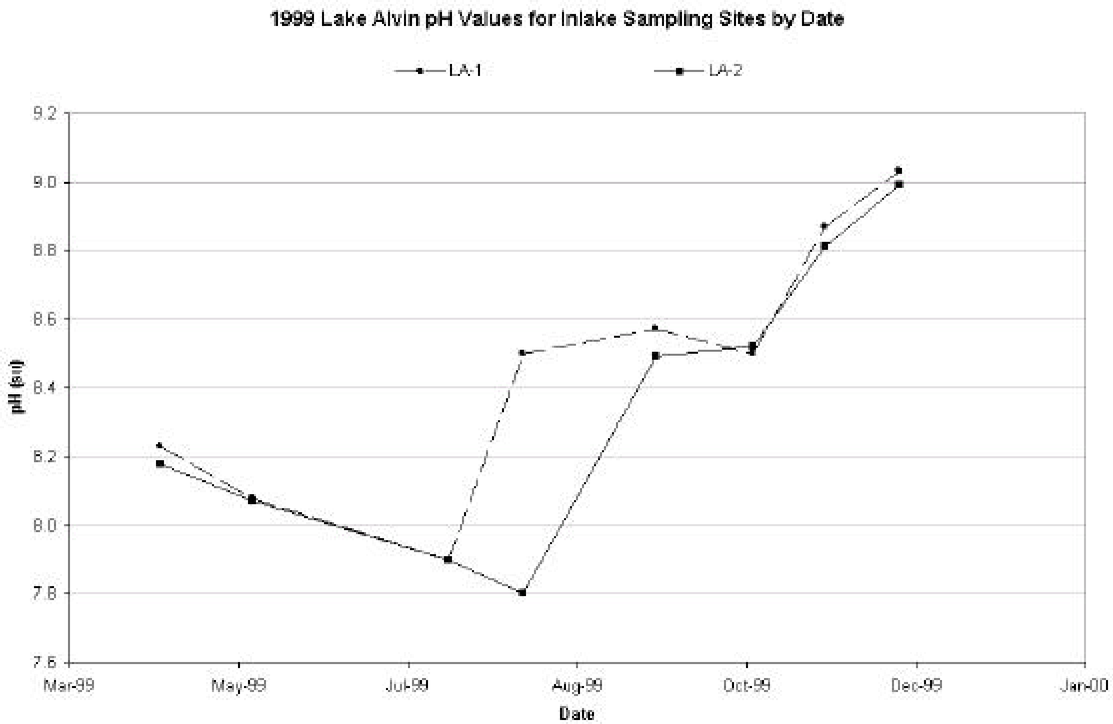


Figure 22. Monthly pH concentrations by date and sampling site for Lake Alvin Lincoln County, South Dakota in 1999.

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 from the spring to the summer and increased sharply in the fall (Figure 22). The higher algae production during the fall most likely increased the pH concentration. The increased separation from site LA-1 and LA-2 in pH during August may be due to increased decomposition and respiration rates at LA-2. Minimum pH and dissolved oxygen concentrations (7.8 su. and 3.4 mg/L, respectively) were collected at LA-2 in August of 1999 which supports the hypothesis of increased decomposition and respiration at this site. Both sites were statistically similar ($p>0.05$) with an average pH concentration of 8.4 su and a median of 8.5 su.

Seasonally, pH concentrations were highest in the fall with a mean and median of 8.6 su (Table 29 and Figure 22). Concentrations in pH during the winter nearly exceeded the inlake water quality standard for pH ($\geq$ 9.0 su.), which may indicate increased organic material during this time of year.

Secchi Depth

Secchi depth is a measure of inlake clarity and turbidity. The Secchi disk is 20 cm in diameter and usually painted with opposing black and white quarters (Lind, 1985) (Figure 23). The Secchi disk is used worldwide for comparison of the clarity of water. Secchi disk readings are also used in Carlson's Trophic State Index (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 transparency. Low Secchi depth readings may indicate hyper-eutrophy because of suspended sediments and/or high algal biomass.

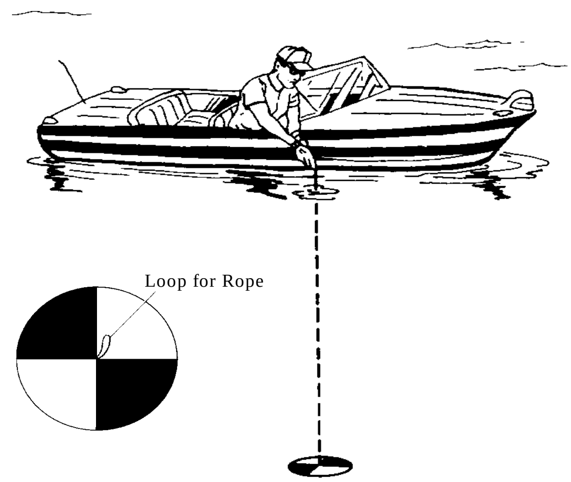


Figure 23. Secchi disk technique.

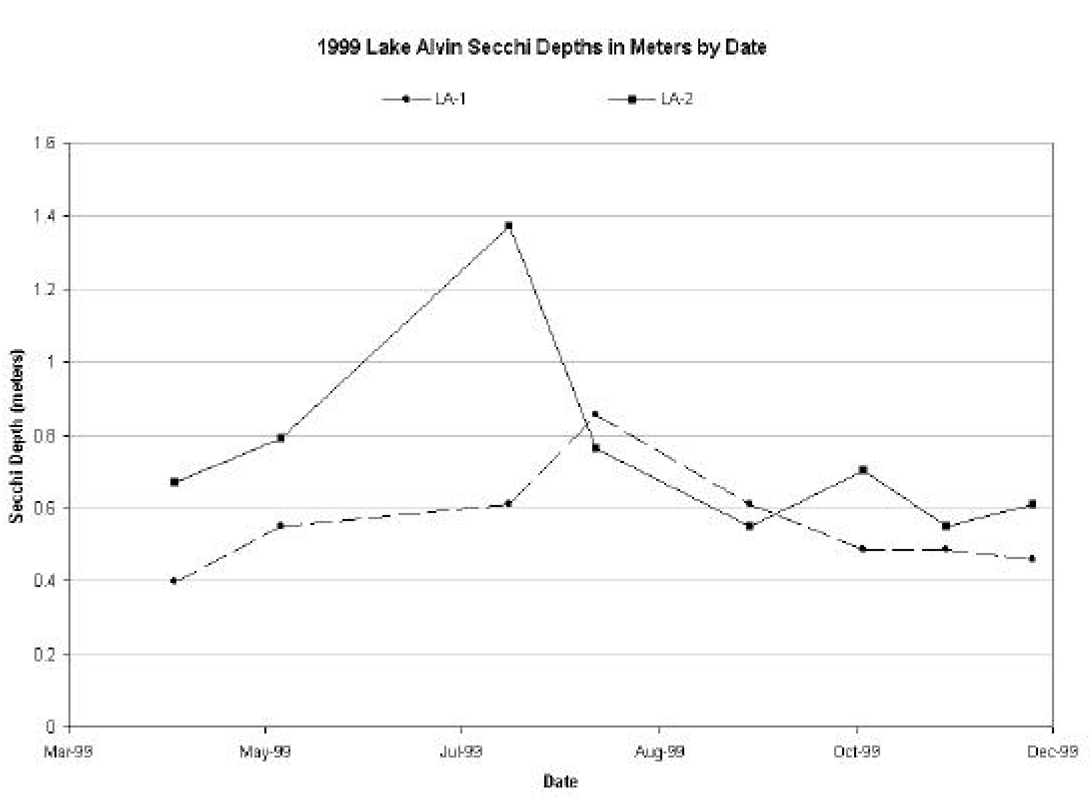


Figure 24. Monthly Secchi depth by date and sampling site for Lake Alvin, Lincoln County, South Dakota in 1999.

Figure 24 shows lower Secchi depth readings in late summer and fall, especially at site LA-2. The highest Secchi disk reading was 1.37 meters (4.5 feet) at LA-2 on July 21, 1999. This agrees with lower numbers of algae at site LA-2, increasing the Secchi depth in July. Total suspended solids and chlorophyll-*a* concentrations (9.0 mg/L and 30.85 mg/m^3, respectively) were low on this date, which increased transparency. As total suspended solids and chlorophyll-*a* concentrations increase, Secchi depths decrease. Average seasonal Secchi depths were highest in the summer months (Table 29). Secchi depth readings were significantly different between stations ($p<0.05$). Since Secchi depth is one parameter used in measuring trophic state, TSI values between inlake sites were also statistically different ($p<0.05$).

Alkalinity

As discussed previously, alkalinity refers to the quantity of different compounds that shift the pH to the alkaline side of neutral (>7). The average alkalinity in Lake Alvin was 151.8 mg/L with a median of 151.5 mg/L. The minimum alkalinity concentration (113 mg/L) was collected at LA-1 in August of 1999, while LA-2 had an alkalinity concentration of 168 mg/L on the same day. Other parameter concentrations were extremely high or low during the August, 1999, sampling date.

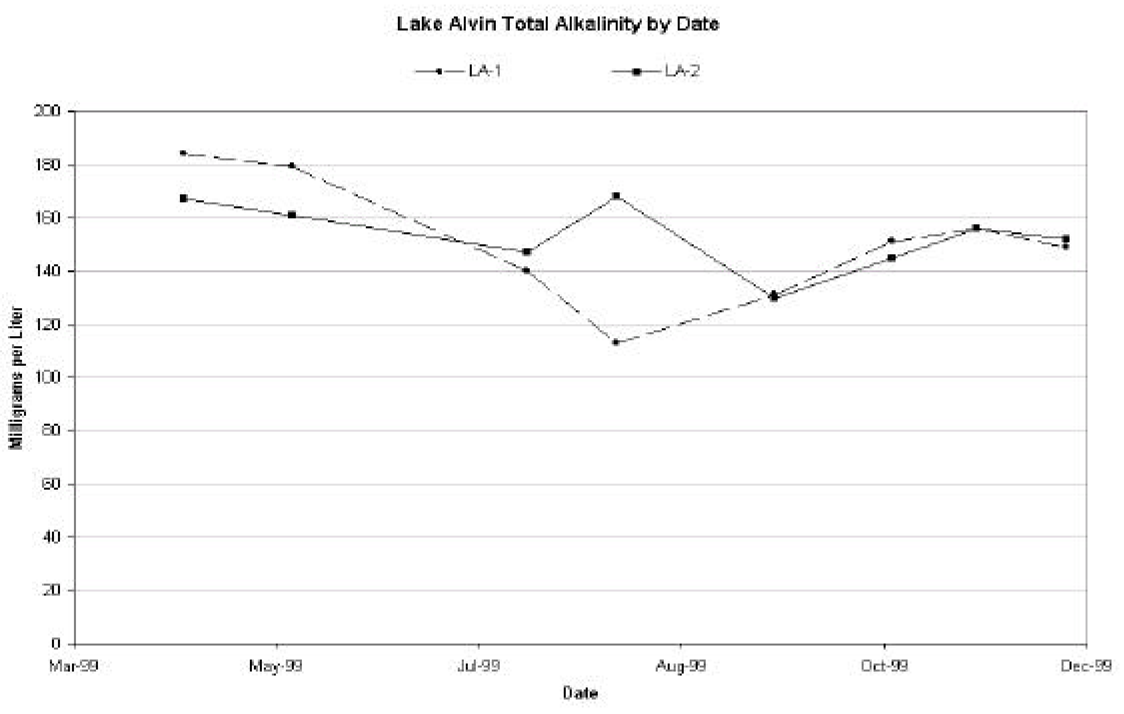


Figure 25. Monthly alkalinity concentrations by date and sampling site for Lake Alvin, Lincoln County, South Dakota in 1999.

The maximum alkalinity sample (184 mg/L) was collected on April 27, 1999 (Appendix I). Generally, alkalinity concentrations trended down and although not statistically significant, pH concentrations increased especially in the fall. Seasonally, the highest average concentration occurred in the spring and gradually decreased from summer to fall and winter (Figure 25).

Solids

Total solids are the 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. Suspended volatile solids are that portion of suspended solids that are organic (organic matter that burns in a 500^o C muffle furnace).

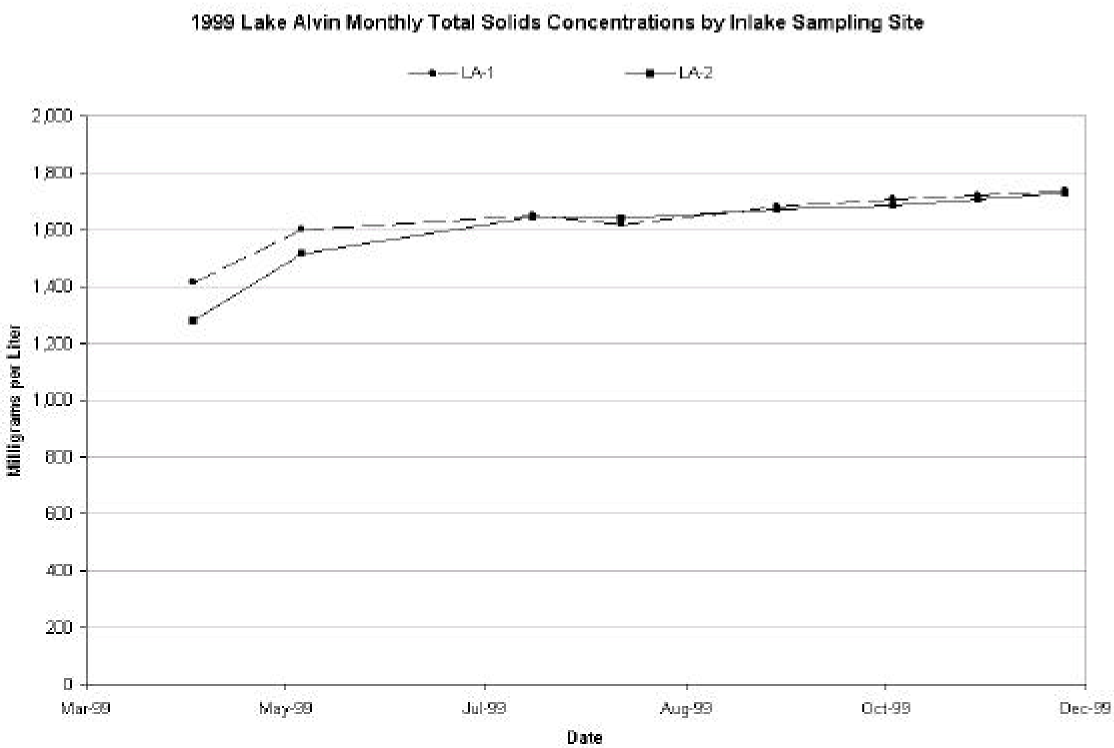


Figure 26. Monthly total solids concentration by date and sampling site for Lake Alvin, Lincoln County, South Dakota in 1999.

The total solids concentrations in Lake Alvin averaged 1624.5 mg/L with a maximum of 1739.0 mg/L and a minimum of 1280.0 mg/L. Generally, total solids concentrations were lower in the spring and peaked in the fall (Figure 26). Seasonal averages for total solids concentrations were highest in the fall (Table 29). The lower solids concentrations in the spring were from snow melt and spring runoff. Total solids concentrations were statistically similar between sites ($p>0.05$).

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

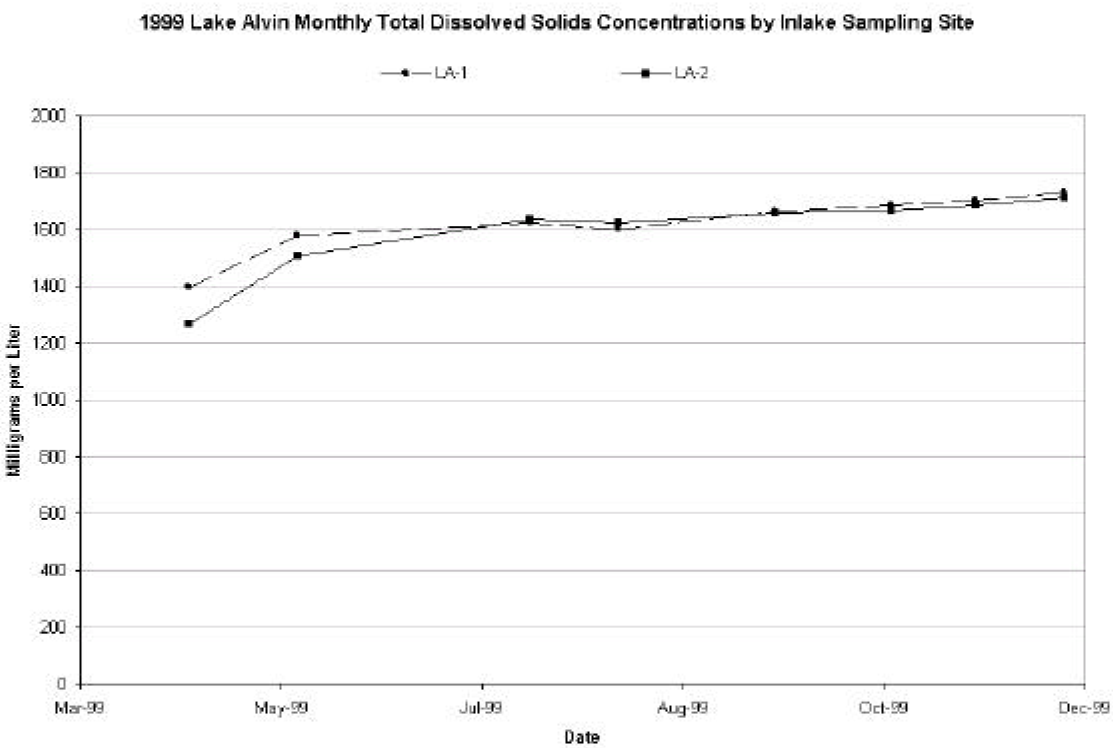


Figure 27. Monthly total dissolved solids concentration by date and sampling site for Lake Alvin, Lincoln County, South Dakota in 1999.

The total dissolved solids concentrations in Lake Alvin averaged 1607.9 mg/L with a maximum of 1730.0 mg/L and a minimum of 1266.0 mg/L. Similar to total solids, total dissolved solids concentrations were lower in the spring and peaked in the fall (Figure 27). Ninety-nine percent of the total solids concentrations were comprised of total dissolved solids. Seasonal averages for total dissolved solids concentrations were highest in the fall (Table 29). The lower dissolved solids concentrations in the spring were from snow melt and spring runoff. Total dissolved solids concentrations between LA-1 and LA-2 were statistically similar ($p>0.05$).

Suspended solids are organic and inorganic particles that do not pass through a filter and based upon tributary loading and the sediment budget contribute to inlake sedimentation rates.

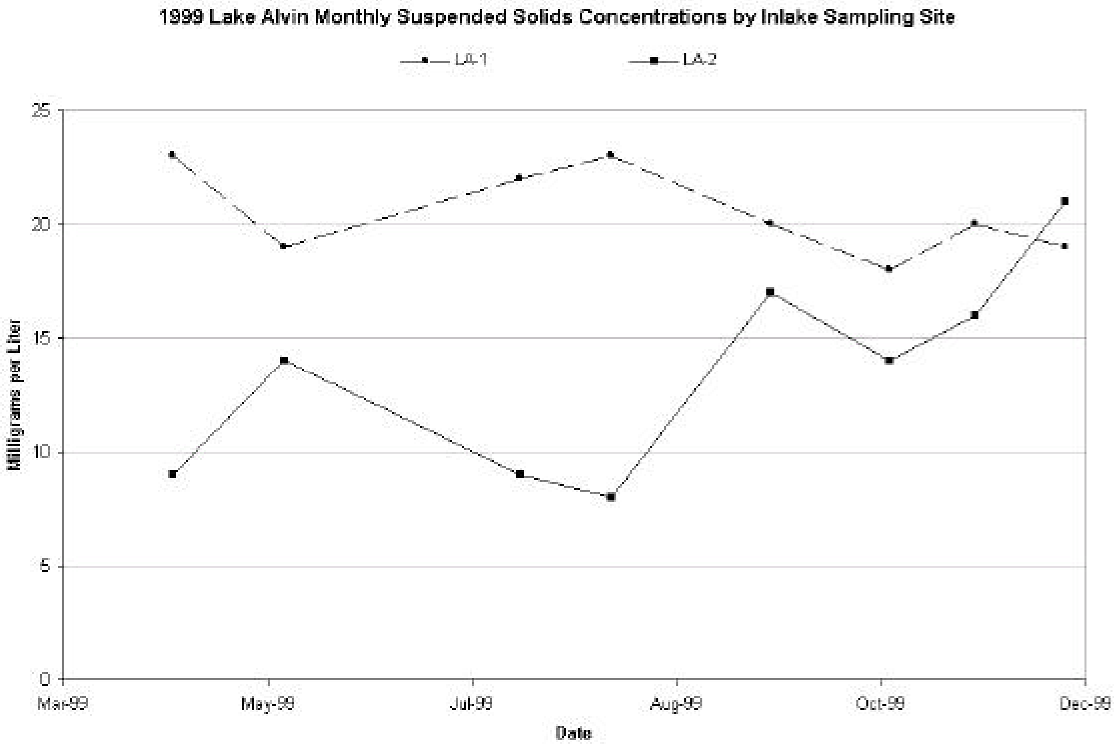


Figure 28. Monthly average total suspended solids concentrations by date and sampling site for Lake Alvin, Lincoln County, South Dakota in 1999.

The total suspended solids concentrations in Lake Alvin averaged 18.5 mg/L with a maximum of 23.0 mg/L and a minimum of 8.0 mg/L. Seasonal averages for total suspended solids concentrations were highest in the summer (Table 29). The maximum surface water concentrations of suspended solids were collected on April and August 1999 (23 mg/L) both at LA-1 (Appendix I). The main tributary (Nine Mile Creek) transports the majority of suspended solids load (62.5 percent) to Lake Alvin and flows into LA-1. LA-1 had significantly more total suspended solids than LA-2 in 1999 ($p<0.05$) (Figure 28).

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

Volatile total suspended solids concentrations averaged 7.9 mg/L with a maximum of 15.0 mg/L and a minimum concentration of 3.0 mg/L. Seasonal average volatile total suspended solids concentrations were lower in the spring and peaked in the early fall (Figure 29). The maximum surface water concentrations of volatile total suspended solids was collected in September 1999 (15 mg/L) at LA-2 (Figure 28). No significant differences were detected between inlake sampling sites ($p>0.05$).

The percentage of volatile total suspended solids in total suspended solids by site ranged widely. LA-1 percent volatile ranged from 13 percent to 78 percent and LA-2 ranged from 33 percent to 88 percent. The highest percentages of volatile solids occurred from August through October.

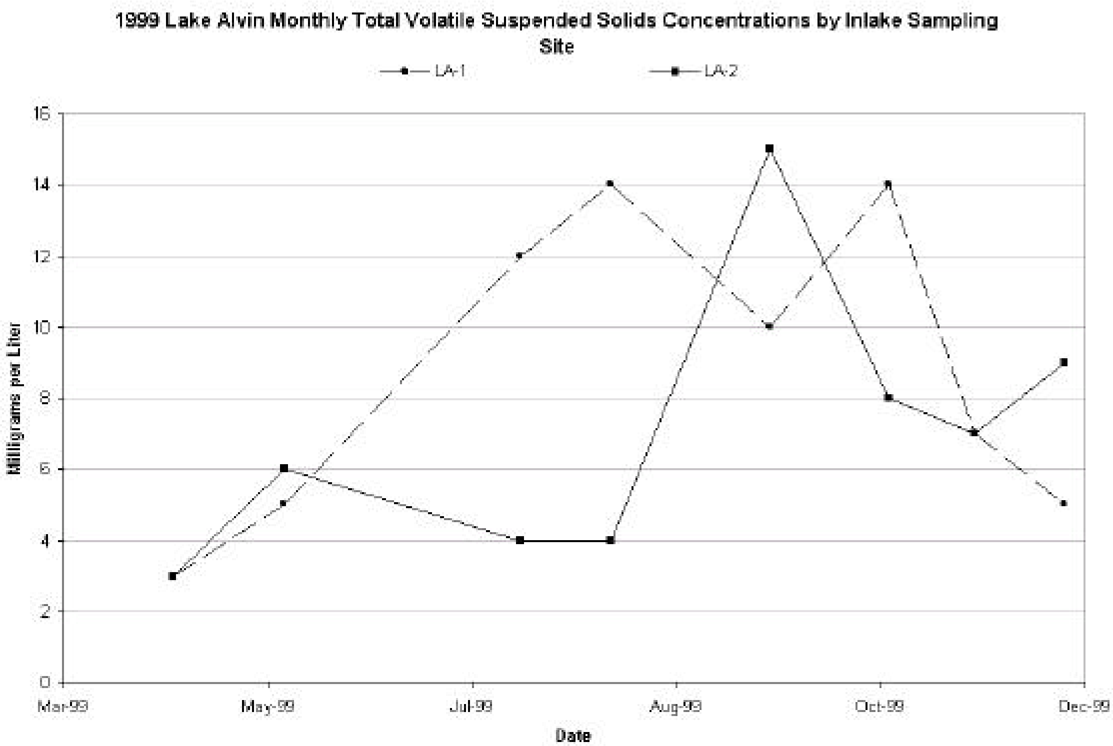
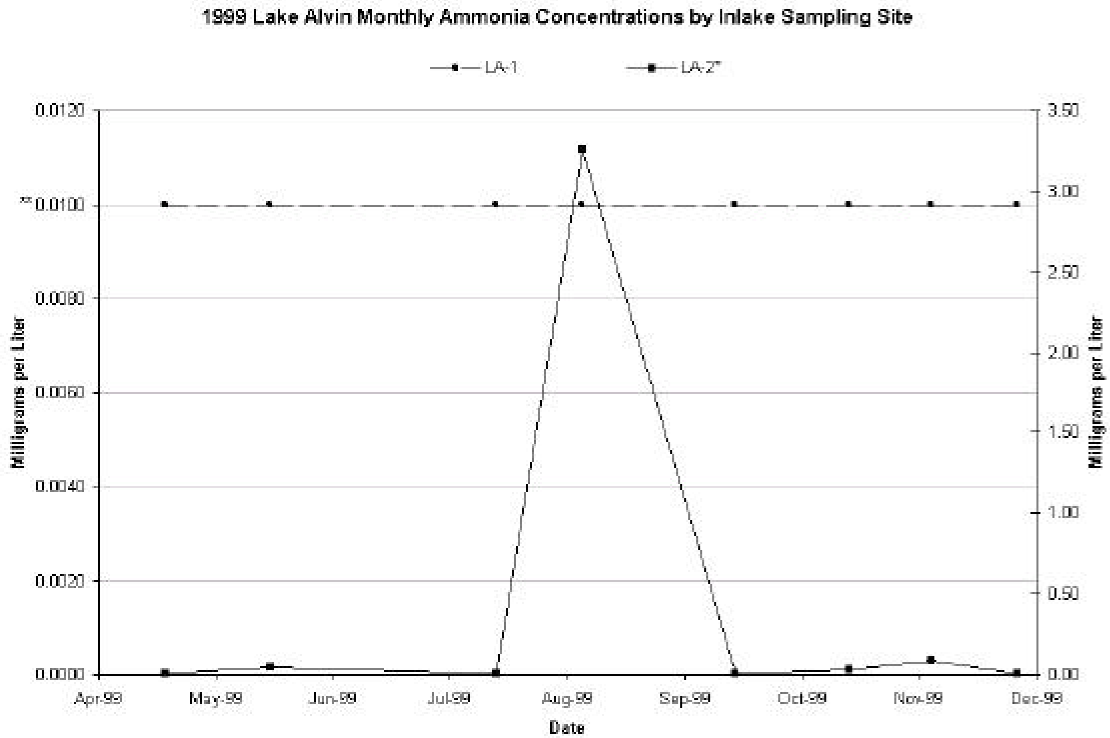


Figure 29. Monthly volatile total suspended solids concentrations by date and sampling site for Lake Alvin, Lincoln County, South Dakota in 1999.

Total suspended solids and volatile total suspended solids affect Secchi transparency and chlorophyll-*a* concentrations, respectively. One parameter Lake Alvin is listed for on the 303(d) list (impaired waterbodies list) is an increasing TSI trend (Trophic State Index) (SD DENR 1998). Decreasing inlake total suspended solids (organic and inorganic) should improve (lower) all TSI values, and over time, should improve inlake water quality.

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 Lake Alvin comes from Nine Mile 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.

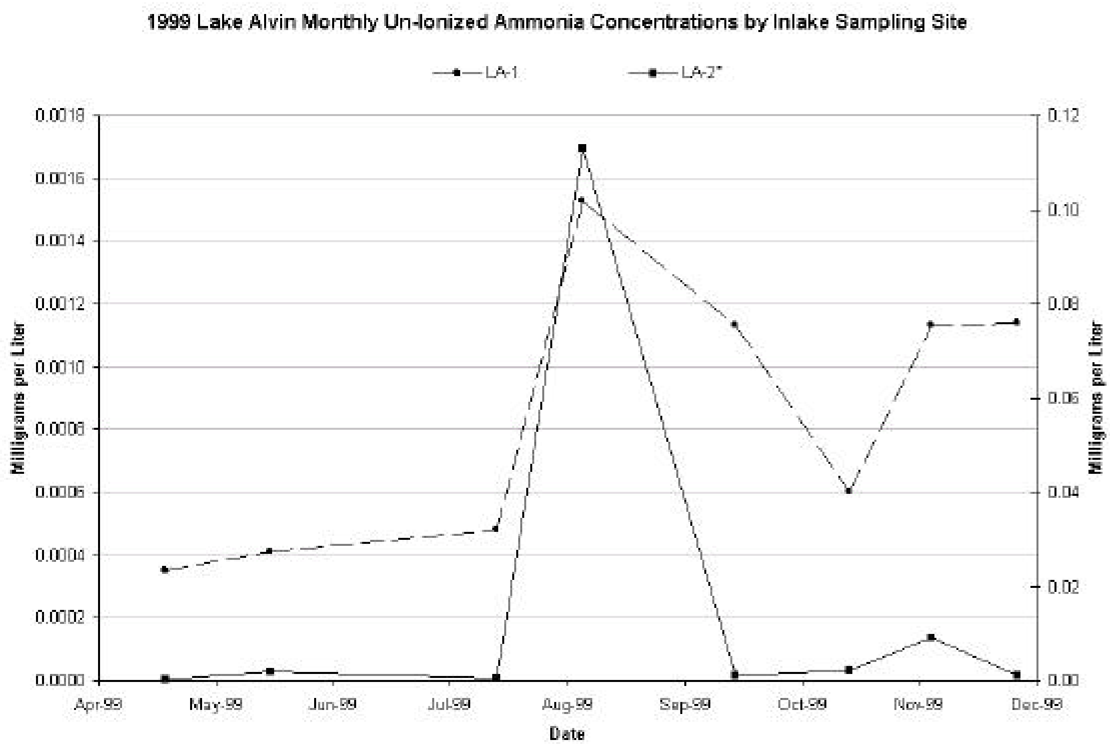


*** = LA-2 is graphed on second Y-axis.**
**** = Below laboratory detection limits (< 0.02 mg/L)**

Figure 30. Monthly ammonia concentrations by date and sampling site for Lake Alvin, Lincoln County, South Dakota in 1999.

The mean concentration of ammonia in Lake Alvin was 0.22 mg/L with a median of 0.01 mg/L. The standard deviation was 0.13 mg/L which indicates a large variation in the sample concentrations. On August 12, 1999, the ammonia concentration at LA-2 was 3.3 mg/L, 15 times higher than the average for the entire sampling season (0.22 mg/L) (Figure 30). Cattle were observed near LA-2, wading in and around the southern shoreline of Lake Alvin. Other parameters (nitrogen and phosphorus) at LA-2 on this date were elevated or depressed (dissolved oxygen 3.4 mg/L). Ammonia concentrations at LA-2 in September had dropped below laboratory detection limits with no cattle present along the shoreline. Cattle in and around the lake appear to be a contributing factor in increased ammonia concentrations in Lake Alvin especially at LA-2. Seventy-five percent of all surface samples collected at Lake Alvin were below laboratory detection limits. Seasonal average concentrations were highest in the summer months.

Decomposing 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).



*** = LA-2 is graphed on second Y-axis**

Figure 31. Monthly un-ionized ammonia concentrations by date and sampling site for Lake Alvin, Lincoln County, South Dakota in 1999.

Un-ionized Ammonia

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. The mean un-ionized ammonia concentration for Lake Alvin was 0.008 mg/L. The maximum concentration was 0.113 mg/L and the minimum concentration of 0.0003 mg/L. Un-ionized ammonia concentrations peaked in August at 0.113 mg/L and declined to 0.0001 mg/L by September. This peak was the result of increased ammonia concentrations at LA-2 in August increasing the un-ionized ammonia fraction. Since un-ionized ammonia is a calculated fraction of ammonia the graphs for LA-2 in Figure 30 and Figure 31 are similar.

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.

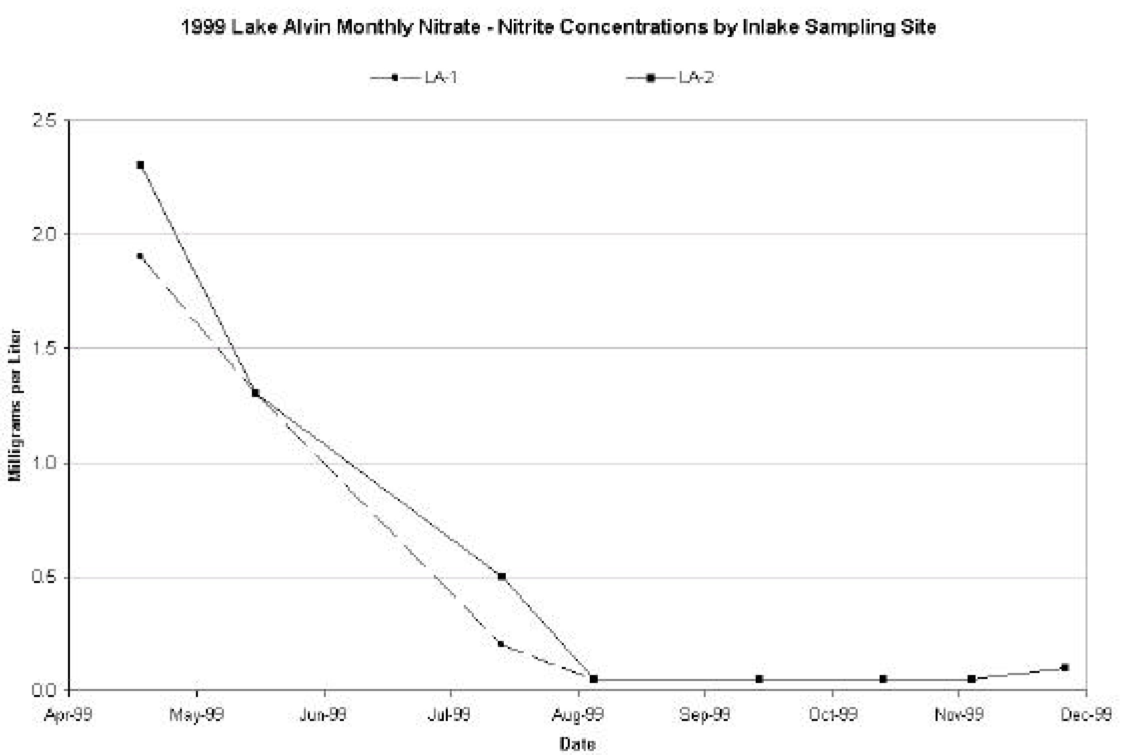


Figure 32. Monthly nitrate-nitrite concentrations by date and sampling site for Lake Alvin, Lincoln County, South Dakota in 1999.

The average nitrate-nitrite concentration for Lake Alvin was 0.51 mg/L (median 0.07 mg/L), with a maximum of 2.3 mg/L and a minimum concentration of 0.05 mg/L. Seasonal average nitrate–nitrite concentrations peaked in the spring, declined sharply by late summer and stayed low until winter when a slight increase was observed (Figure 32 and Table 29). Nitrogen and phosphorus concentrations in eutrophic lakes are frequently higher after ice out (spring) due to accumulation over the winter through decay and low algal numbers. Nitrate-nitrite is the inorganic portion of total nitrogen. No significant differences in nitrate–nitrite concentrations were detected between inlake sampling sites ($p>0.05$).

Figure 32 reflects a similar trend observed in the total nitrogen-to-total phosphorus ratio (Figure 52). This is partially explained by the percentage of nitrate-nitrite to total nitrogen concentrations was higher from April through July (35.3 percent) than from August through December (3.1 percent).

Total Kjeldahl Nitrogen

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

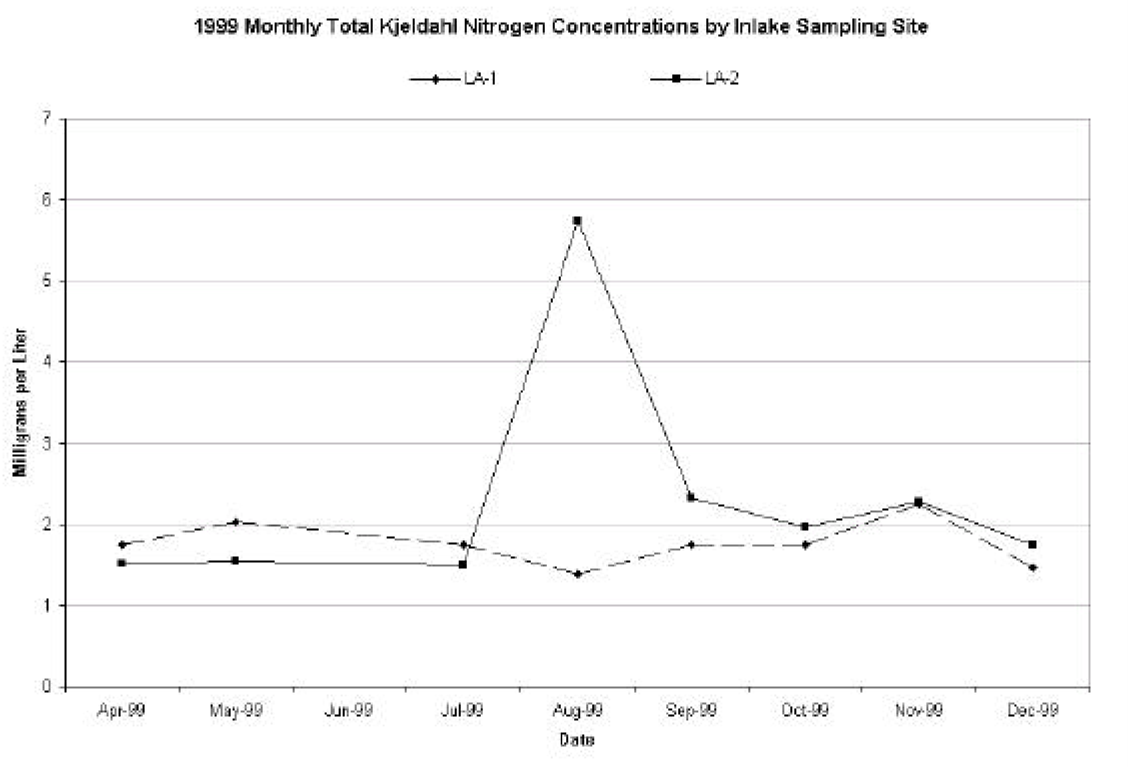


Figure 33. Monthly Total Kjeldahl Nitrogen (TKN) concentrations by date and sampling site for Lake Alvin, Lincoln County, South Dakota in 1999.

The average and median TKN concentrations were 2.04 mg/L and 1.75 mg/L respectively. There was a definite increase in the TKN concentrations at LA-2 in August 1999, similar to ammonia, organic and total nitrogen concentrations (Figure 30 and Figure 33 through Figure 35). The increase was most likely due to cattle in and around LA-2. Seasonally, average TKN concentrations were highest in the summer (2.59 mg/L). Monthly TKN concentrations were statistically similar between inlake sampling sites ($p>0.05$).

Organic Nitrogen

The organic portion of TKN (TKN minus ammonia) is graphed on Figure 34. Organic nitrogen percentages (percent organic nitrogen in TKN) ranged from 43.2 percent to 99.6

percent and averaged 95.5 percent. The lowest organic percentage was in August 1999 at LA-2 (43.2 percent).

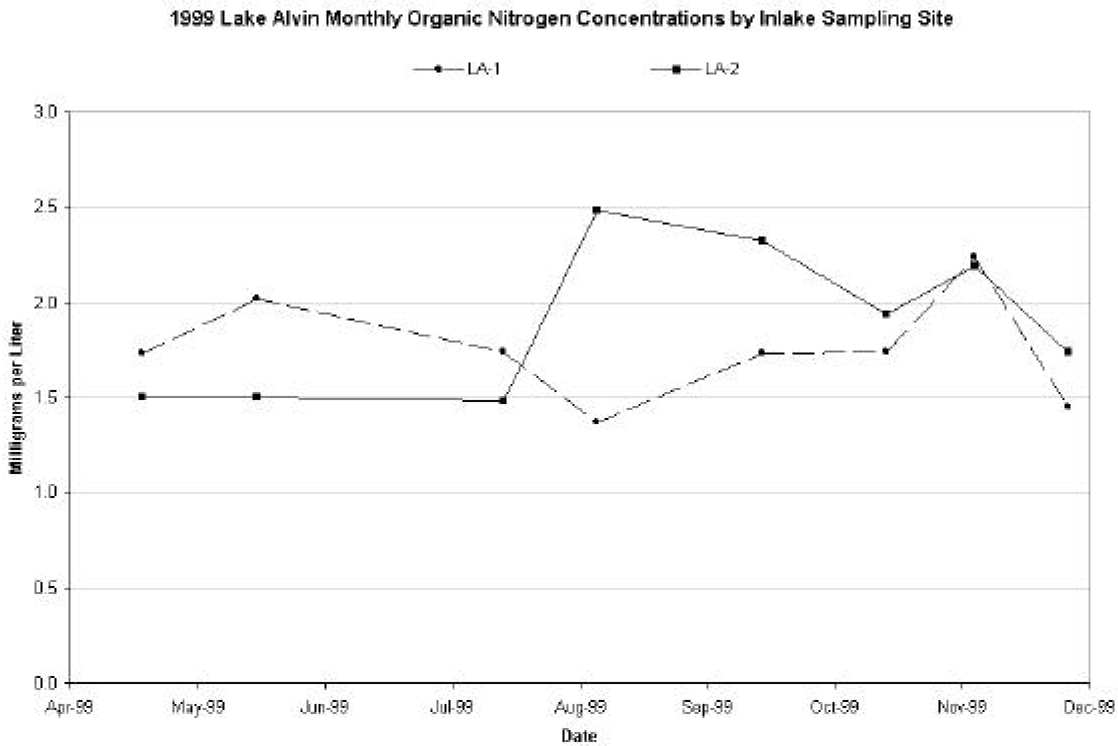


Figure 34. Monthly organic nitrogen concentrations by date and sampling site for Lake Alvin, Lincoln County, South Dakota in 1999.

The average organic nitrogen concentration for Lake Alvin was 1.8 mg/L (median 1.7 mg/L), with a maximum of 5.7 mg/L and a minimum concentration of 1.4 mg/L. Seasonal average organic nitrogen concentrations peaked in the fall (Table 29). No significant differences in organic nitrogen concentrations were detected between inlake sampling sites ($p>0.05$).

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 later in this report. The average total nitrogen concentration for Lake Alvin was 2.6 mg/L (median 2.2 mg/L), with a maximum of 5.8 mg/L and a minimum concentration of 1.4 mg/L. Seasonally, the average total nitrogen concentrations for Lake Alvin were highest in the spring despite the August peak at LA-2 (Table 29 and Figure 35).

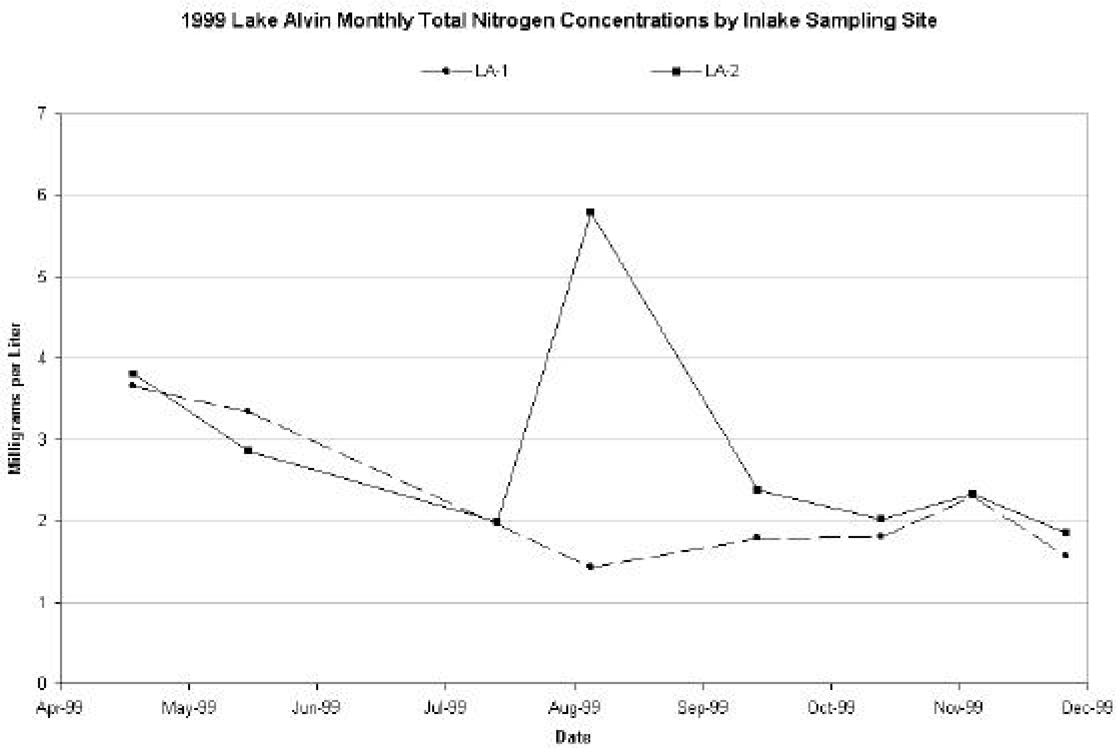


Figure 35. Monthly total nitrogen concentrations by date and sampling site for Lake Alvin, Lincoln County, South Dakota in 1999.

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, and waste from septic tanks 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 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 a lake from the sediments is called internal loading and can be a large contributor of phosphorus available to algae (Zicker 1956).

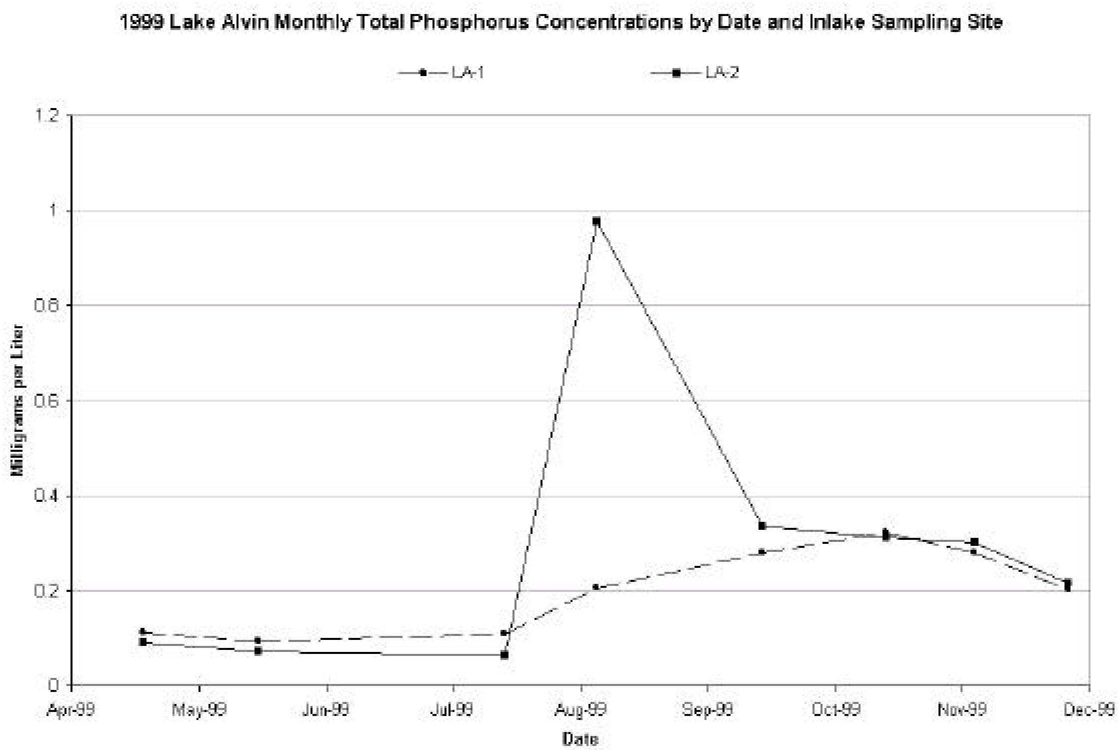


Figure 36. Monthly total phosphorus concentrations by date and sampling site for Lake Alvin, Lincoln County, South Dakota in 1999.

The average concentration of total phosphorus throughout the study period was 0.248 mg/L (median 0.211 mg/L). As observed with total nitrogen, the maximum sample concentration was collected at LA-2 on August 12, 1999 (0.977 mg/L) (Figure 36). Based upon 1999 dissolved oxygen profiles, dissolved oxygen concentrations may have reached zero, weakening the microzone and releasing phosphorus from the sediments from April through August 1999(Appendix H). The minimum concentration of total phosphorus occurred at LA-2 on July 21, 1999 (0.064 mg/L), one month prior to the maximum concentration at the same site (LA-2).

Seasonally, average total phosphorus concentrations were low in the spring, highest in the summer and slightly lower in the fall (Figure 36). On average, Lake Alvin had 12.4 times more total phosphorus than the amount needed to cause algal blooms (0.02 mg/L) (Wetzel 1983). During the 1999 sampling season, inlake total phosphorus was in excess from August through December with an average inlake concentration of 0.328 mg/L (Figure 44). For those months total phosphorus was 16.4 times the phosphorus needed to cause algal blooms. Although the highest densities of algae occurred in the fall, no major algae nuisance blooms were reported for Lake Alvin in 1999. Based on this information, excess phosphorus did not appear to increase productivity. Since phosphorus can cause algal blooms, reducing phosphorus loads (tributary and internal loads) over time should promote better water quality.

Total Dissolved Phosphorus

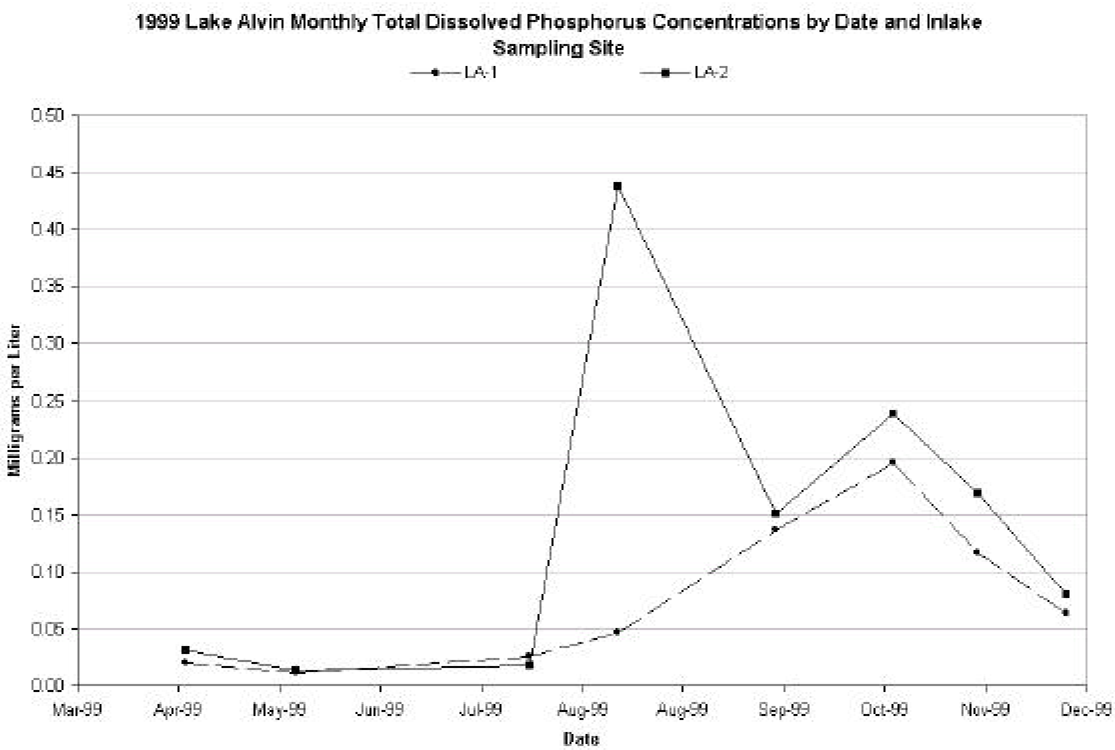


Figure 37. Monthly total dissolved phosphorus concentrations by date and sampling site for Lake Alvin, Lincoln County, South Dakota in 1999.

Total dissolved phosphorus is the fraction of total phosphorus that is readily available for use by algae. Dissolved phosphorus will sorb on to suspended materials (organic and inorganic) if present and not already saturated with phosphorus. Inlake total dissolved phosphorus and chlorophyll-*a* concentrations for each date were averaged because algae densities, which respond to available phosphorus concentrations, were also averaged for Lake Alvin. Figure 38 indicates a good relationship between average chlorophyll-*a* and total dissolved phosphorus concentrations (R^2=0.73). As the availability of total dissolved phosphorus increases, so do chlorophyll-*a* concentrations.

Generally, increased total suspended solids concentrations decrease concentrations of available total dissolved phosphorus; however, during this study total suspended solids showed a poor relationship to total dissolved phosphorus (R^2=0.01). The overall average percent phosphorus that was dissolved during the project was 44 percent. Percentages of total dissolved phosphorus ranged from 22.7 percent in the spring to 76.8 percent in the fall. The average dissolved phosphorus concentration in Lake Alvin was 0.109 mg/L (median 0.072 mg/L). Since algae only need 0.02 mg/L of phosphorus to produce an algal bloom (Wetzel 1983), Lake Alvin averages 5.4 times the available phosphorus needed for algal blooms.

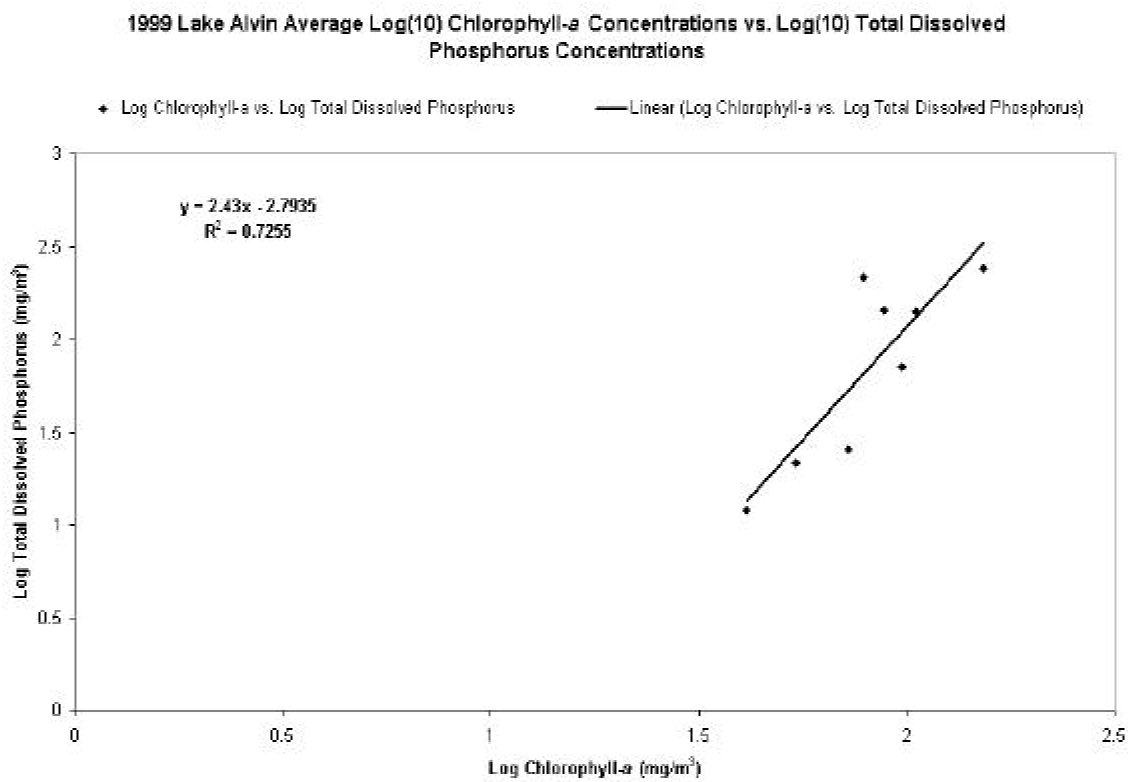


Figure 38. Average $\log_{(10)}$ chlorophyll-a concentrations vs. $\log_{(10)}$ total dissolved phosphorus concentrations by date and sampling site for Lake Alvin, Lincoln County, South Dakota in 1999.

Seasonal average total dissolved phosphorus concentrations were low in the spring, increased in summer and were highest in the fall (Table 29). As stated in the total phosphorus section, total phosphorus, part of which is total dissolved phosphorus (on average 44 percent), was in excess from August through December. During these months, total dissolved phosphorus concentrations averaged 46.5 percent of total phosphorus or 7 times the available phosphorus needed to cause algal blooms.

Average algae densities were highest in October and were still relatively high in December, theoretically, utilizing total dissolved phosphorus (available phosphorus) for growth. Total dissolved phosphorus concentrations did show a decline during this time (Figure 37). Data indicate that Lake Alvin has an abundance of phosphorus (total and dissolved) to cause algal blooms. Since no nuisance algal blooms were reported by DENR personnel during sampling, other conditions (other nutrients or light transparency) suppressed excessive productivity. Algal densities in Lake Alvin were relatively high in 1999, however, densities did not produce thick floating mats of objectionable masses along the shoreline. Reducing inlake phosphorus concentrations will, over time, reduce Carlson TSI values and increase water quality.

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 seem to lessen fecal 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.

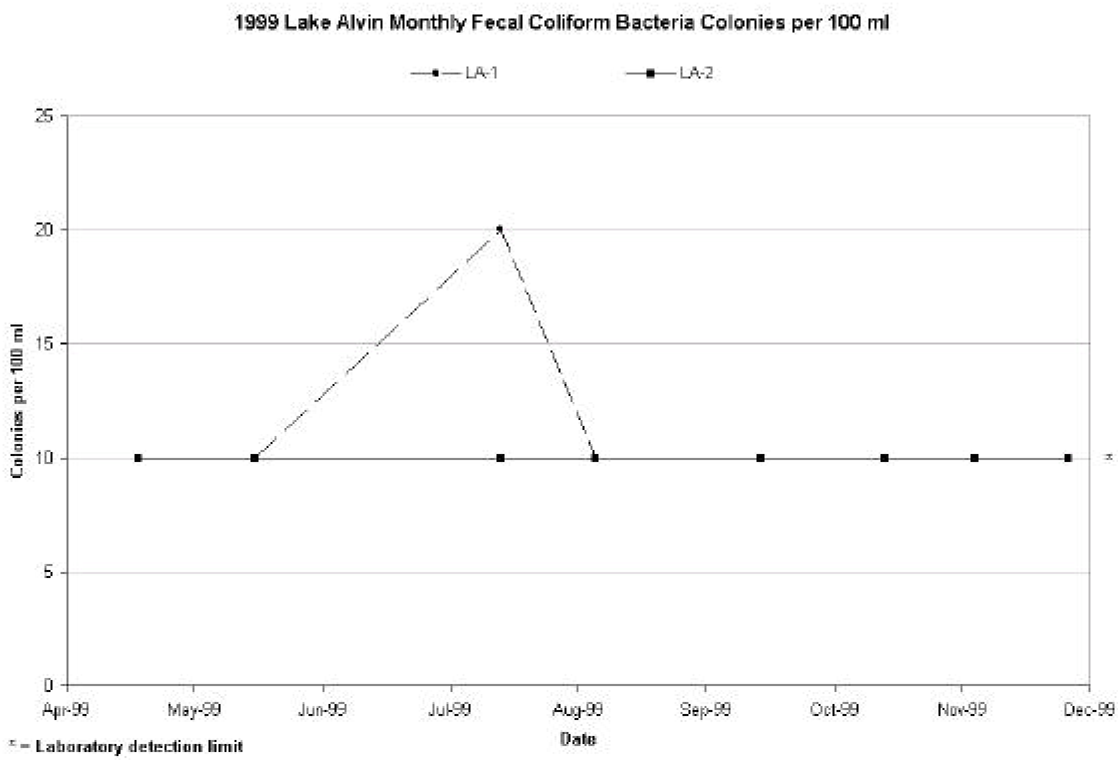


Figure 39. Fecal coliform bacteria colonies per 100 milliliters by date and sampling site for Lake Alvin, Lincoln County, South Dakota in 1999.

Inlake fecal coliform concentrations are typically low because of exposure to sunlight and dilution of bacteria in a larger body of water. Of the 16 individual samples collected, 93.7 percent of fecal coliform concentrations were below detection limits. The maximum concentration (20 colonies/100 ml) was collected on July 21, 1999 at LA-1. LA-2's fecal coliform counts were below the detection limit on the same date, which indicates inlake spatial variability. LA-1 was closer to the Nine Mile Creek inlet and an area where horses have access to the lake. The average fecal coliform bacteria count was 10.6 colonies/100 ml. These data indicate that inlake fecal coliform bacteria concentrations are not a problem at Lake Alvin. Figure 39 shows the inlake fecal coliform concentrations by date.

During this study, cattle were sited wading in and around Lake Alvin especially, across from the swimming beach. Since high nutrient concentrations usually accompany elevated fecal bacteria counts, controlling animal waste would decrease both fecal coliform and nutrient concentrations alike.

Water quality standards for fecal coliform are in effect from May 1 through September 30. During 1999, three separate beach samples (June 7, 14 and 16, 1999) exceeded water quality standards for public beaches ($\leq$ 1,000 colonies/ 100 ml for any one sample, $\leq$ 300 colonies/ 100 ml for two consecutive samples or $\leq$ 200 colonies/ 100 ml for three consecutive samples) at > 1,600, 500 and > 16,000 colonies per 100 ml, respectively (Chapter 74:04:08:07). After those events, beach samples did not exceed standards the rest of the season. Lake Alvin has had problems with high fecal coliform counts and beach closures in the past (SD DENR 1998b and SD DENR 2000b).

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 inlake sampling sites during the project. No samples were collected in June due to logistical problems. Overall, the chlorophyll-*a* concentrations in Lake Alvin were high (Figure 40).

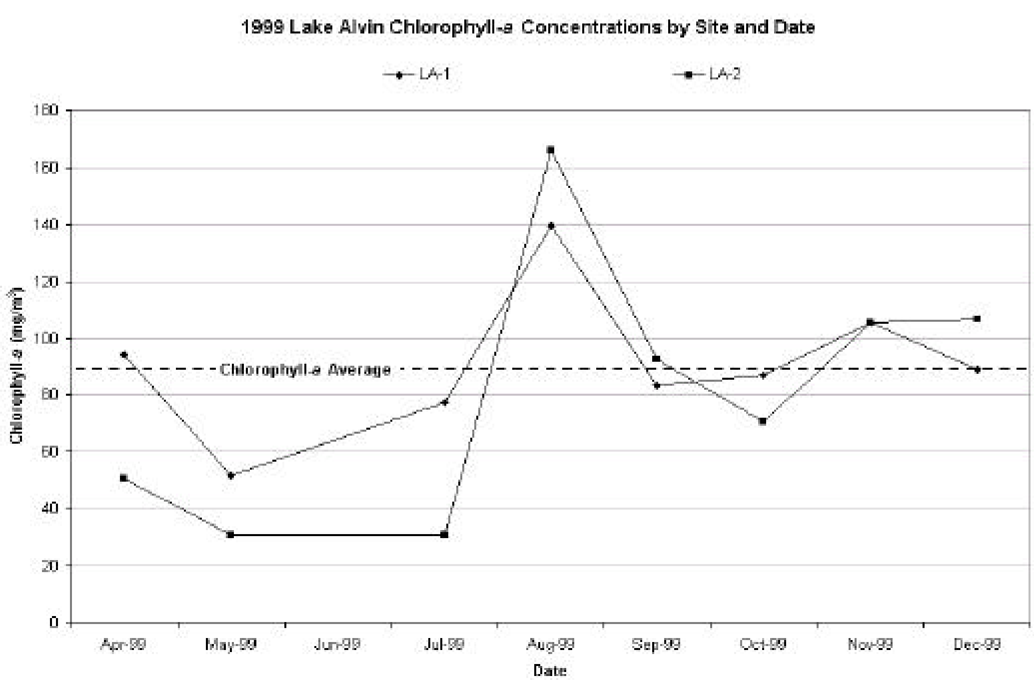


Figure 40. Monthly chlorophyll-*a* concentrations by date and sampling site for Lake Alvin, Lincoln County, South Dakota in 1999.

The maximum inlake chlorophyll-*a* concentration (166.2 mg/m^3) was collected on August 21, 1999 at LA-2. Both samples (LA-1 and LA-2) from August were much higher than the average. Figure 40 indicates that the high readings found in August 1999 were 1.9 times higher than the overall average (86.3 mg/m^3). The median chlorophyll-*a* concentration for the project was 87.1 mg/m^3. The site separation in chlorophyll-*a* concentrations in April and July correspond to large differences in algal biovolume at each site (Figure 40).

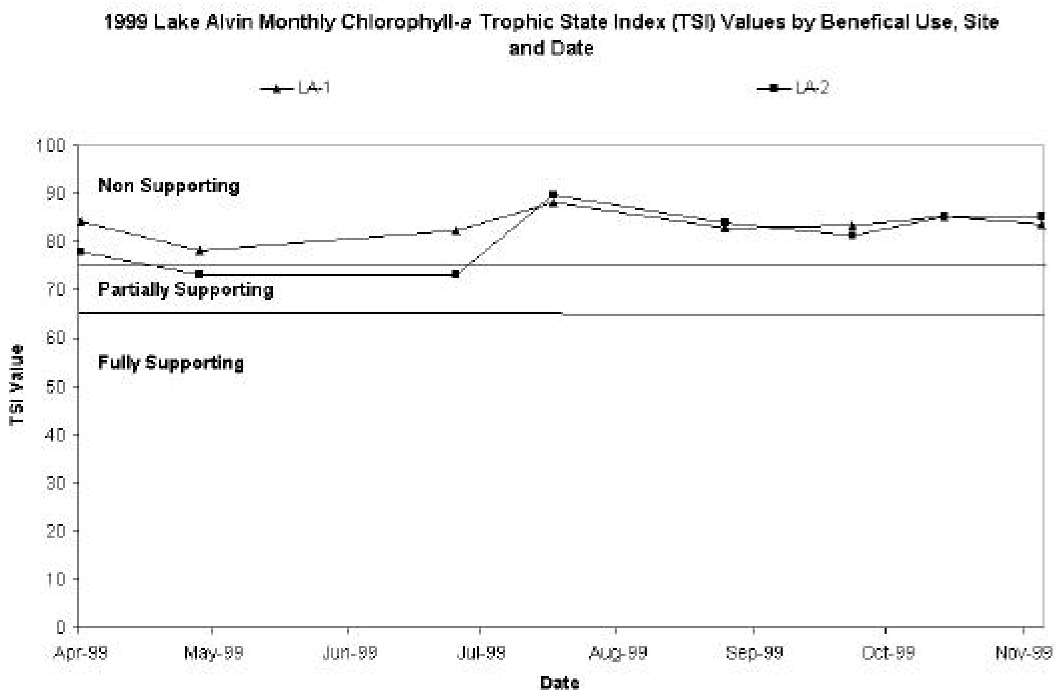


Figure 41. Monthly chlorophyll-*a* trophic state index (TSI) by beneficial use support categories, date and sampling site for Lake Alvin, Lincoln County, South Dakota in 1999.

If chlorophyll-*a* were the only parameter used to estimate the trophic status of a lake, Lake Alvin would be rated as non-supporting or hyper-eutrophic with an average TSI value of 82.41 (Figure 41 and Figure 42). Figure 41 indicates all but two sample dates during the project had TSI values were not supporting beneficial uses, and using Carlson trophic categories, all TSI values were in the hyper-eutrophic range (Figure 42).

Figure 42 indicates that Lake Alvin was hyper-eutrophic for the whole sampling season from April through November. Chlorophyll-*a* TSI values deviated slightly at LA-2 from April through July although not statistically ($p>0.05$).

Typically, chlorophyll-*a* and total phosphorus have a direct relationship. As total phosphorus concentrations increase so, do chlorophyll-*a* concentrations. Each lake usually shows a different relationship because of factors including, but not limited to: nutrient ratios, temperature, light, suspended sediment, and hydrologic residence time.

Chlorophyll-*a* samples for the two sites were averaged for each date so that they could be plotted against total phosphorus concentrations to determine their relationship in Lake Alvin. 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 $R^2 = 1.0$. There were too few data points (4) to determine seasonal relationships (growing season) between chlorophyll-*a* and total phosphorus.

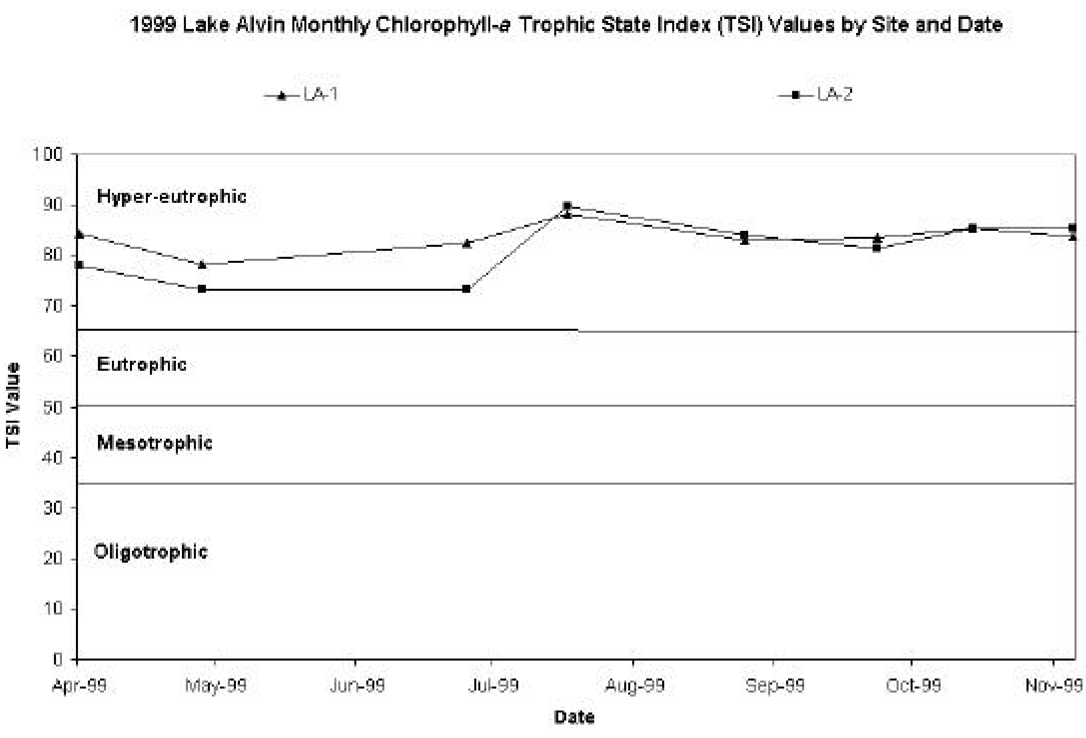


Figure 42. Monthly chlorophyll-*a* trophic state index (TSI) by Carlson trophic categories, date and sampling site for Lake Alvin, Lincoln County, South Dakota in 1999.

The chlorophyll-*a*-to-total phosphorus relationship in Lake Alvin using all data was excellent with an R^2 = 0.80 (Figure 43). The regression equation used to predict chlorophyll-*a* concentrations from total phosphorus concentrations for Lake Alvin is shown below.

Equation 3. Lake Alvin total phosphorus to chlorophyll-*a* regression equation.

$$y= 1.5998x + 0.7498$$

y = $Log_{(10)}$ of predicted chlorophyll-a concentration
x = $Log_{(10)}$ of total phosphorus concentration in µg/L

The relationship between phosphorus and chlorophyll *a* (regression equation) can be used to estimate a reduction in chlorophyll-*a* that can result by reducing inlake phosphorus concentrations.

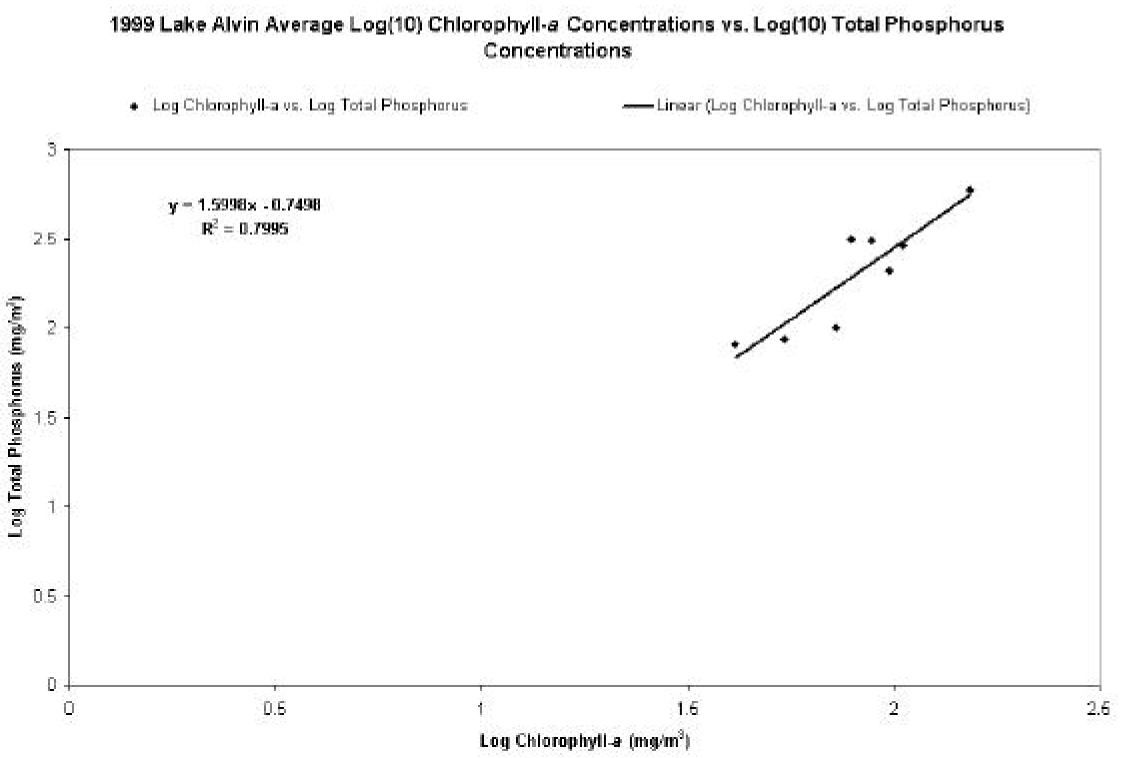


Figure 43. Chlorophyll-*a* concentrations vs. total phosphorus concentrations by date and sampling site for Lake Alvin, Lincoln County, South Dakota in 1999.

This data can be used to model inlake response based on Vollenweider and Kerekes 1980. The better the relationship the more confident lake managers can be in the expected results. For this study, reduction response modeling for chlorophyll-*a* concentrations was done using 'BATHTUB' (US ACOE 1999).

Inlake 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 a 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.

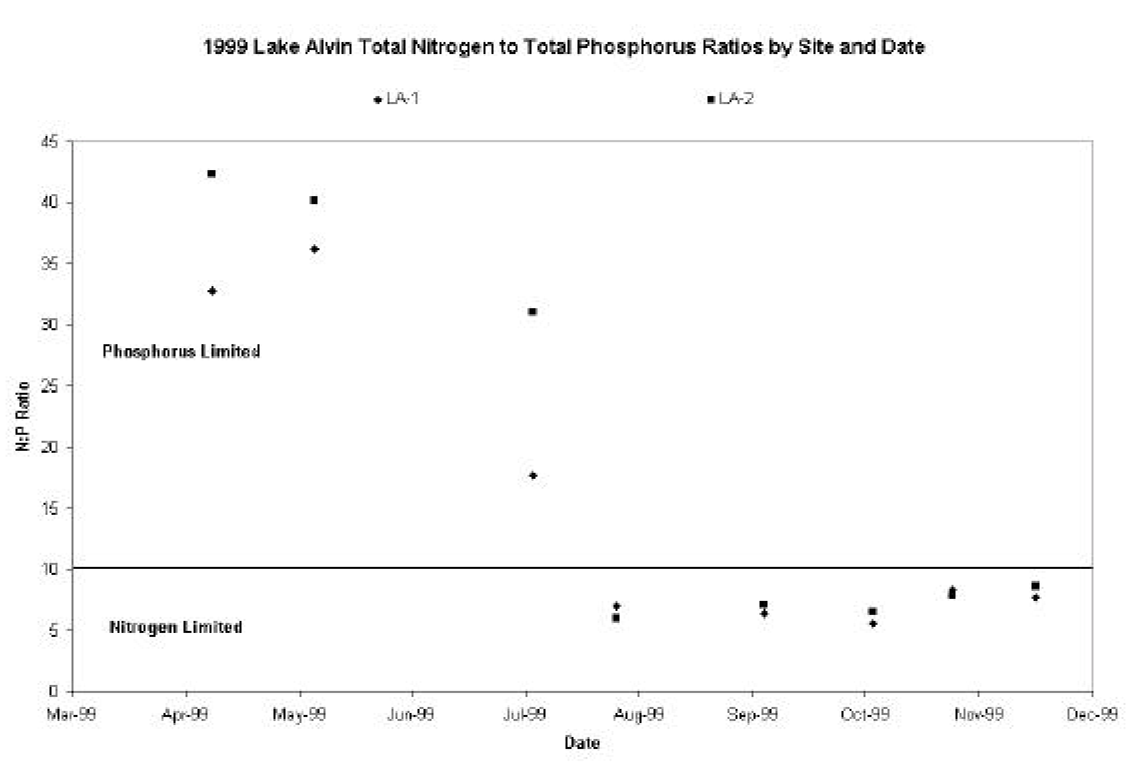


Figure 44. Total nitrogen to total phosphorus ratios by date and sampling site for Lake Alvin, Lincoln County, South Dakota for 1999.

During the spring, Lake Alvin was generally phosphorus-limited but became nitrogen-limited by mid-summer and throughout the fall. Nitrogen concentrations generally increase under the ice during winter and then gradually decline by early summer. The average total nitrogen-to-total phosphorus ratio in Figure 44 is 16.9:1 (phosphorus-limited above 10) with a standard deviation of 14.1. Lake Alvin was phosphorus-limited on three of the eight sampling dates during the spring and early summer.

As stated earlier, limiting factors can be anything physical or chemical that limits the growth or production of organisms. Although phosphorus limitation was detected in the spring, algal densities (cells/ml) increased in May and gradually decreased in August and September; however, biovolume (μm^3/ml) continued to increase through the shift in limiting factors (Figure 44 and Figure 47). At this same time *Aphanizomenon flos–aquae*, a nitrogen-fixing alga (able to fix dissolved atmospheric nitrogen N_2 via heterocysts when concentrations are reduced), declined in August (after the shift) and *Oscillatoria* sp., a non-nitrogen fixing alga (not able to fix atmospheric nitrogen), declined from 95,025 μm^3/ml in August to zero from September through November. This data tends to support the TN:TP ratio shift from phosphorus limited to nitrogen limited.

From August through December, theoretically, nitrogen was the limiting factor; however, beginning in September, algae densities (cells/ml) began to increase and by October algae density tripled, to the highest densities encountered in this study (compare Figure 45 with Figure 49; Figure 47 and page 75). Algae densities declined slightly by December but densities were still relatively high. This suggests that other factors were acting on the algal population such as total suspended solids (organic and inorganic), stratification (thermal), water temperature, Secchi depth (turbidity) and the unusually warm fall temperatures in 1999 (ice up not until late December). During this study, nutrients did not appear to be as limiting as other factors in determining algae population densities.

Phytoplankton

Planktonic algae were collected monthly at two sites in Lake Alvin from April to December, 1999, and consisted of 42 taxa which represented 27 genera within seven major algal divisions (phyla) (Appendix J, Table J-1). Diatoms (Bacillariophyta) were the most diverse group with 18 taxa, followed by green algae (Chlorophyta) with 9 taxa and blue-green algae (Cyanophyta) with 5 taxa. The remaining 10 taxa were evenly distributed among four phyla of motile (flagellated) algae which included cryptomonads (Cryptophyta), yellow-brown algae (Chrysophyta), euglenoids (Euglenophyta), and dinoflagellates (Pyrrhophyta).

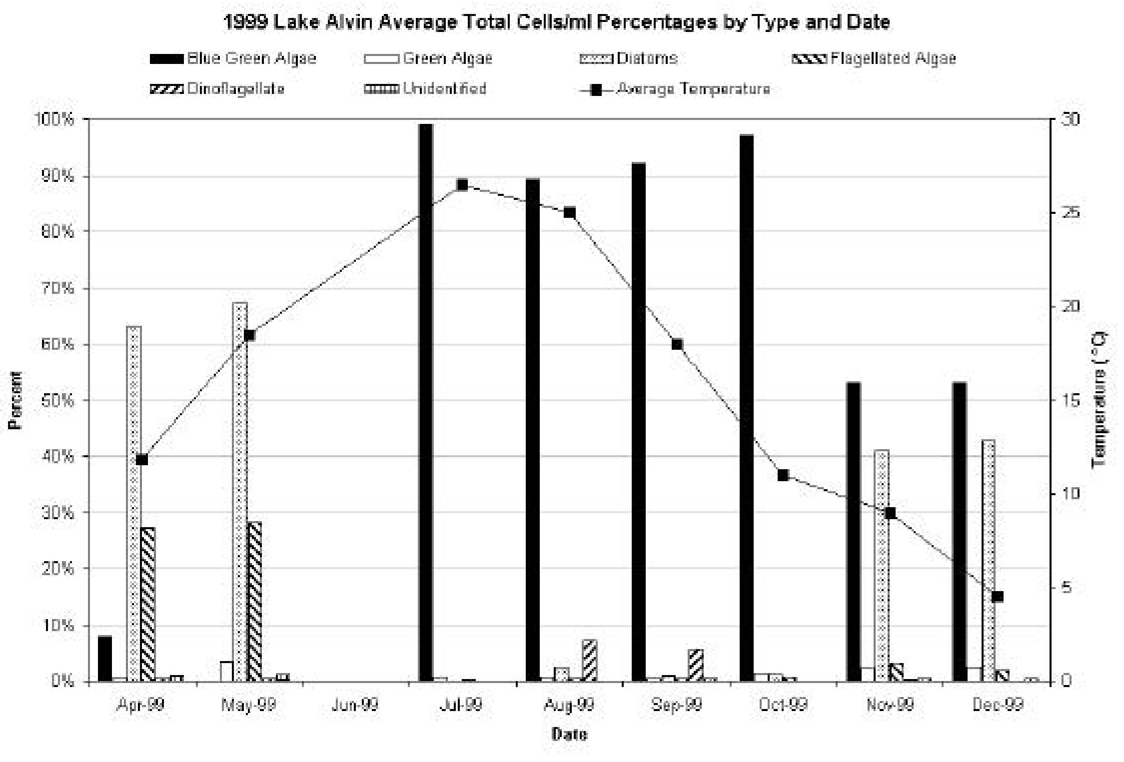


Figure 45. Monthly algal cells per milliliter percentages and temperature (° C) by algal type and date for Lake Alvin, Lincoln County, South Dakota in 1999.

Maximum populations of flagellated algae, green algae, and diatoms were encountered during the cooler seasons of the year, spring and fall (Figures 45, 51, and 52). Dinoflagellates exhibited late summer peaks in August and September (Figure 45 and 46), whereas blue-green algae were most common in July and October 1999 (Figure 49 and 50). Annual total algae densities in Lake Alvin displayed a bimodal distribution during 1999 with a peak in July and October (Figure 47). A single annual peak in total algae biovolume was recorded in November at the end of a steady monthly increase from May through October (Figure 47). The July and October maxima were due to large blooms of blue-green algae, mainly *Aphanizomenon* sp. (Figure 50) and the November biovolume maximum was produced mainly by a large autumn bloom of centric diatoms, *Cyclotella and Stephanodiscus* (Figure 45). Smaller numbers of blue-green algae and relatively moderate densities of a large-bodied dinoflagellate, *Peridinium* sp., were responsible for the large disparity in total algal density and biovolume evident in Figure 47 for August and September (Figures 46 and 49). The largest number of algae species were present in spring and fall with lower species richness recorded in late summer and early fall (Table 30). This pattern of seasonal diversity was due primarily to the distribution of diatom species, which were the most diverse algal group in Lake Alvin during 1999. Diatoms are frequently present in larger numbers during the cooler parts of the year in temperate latitudes (Hutchinson 1957).

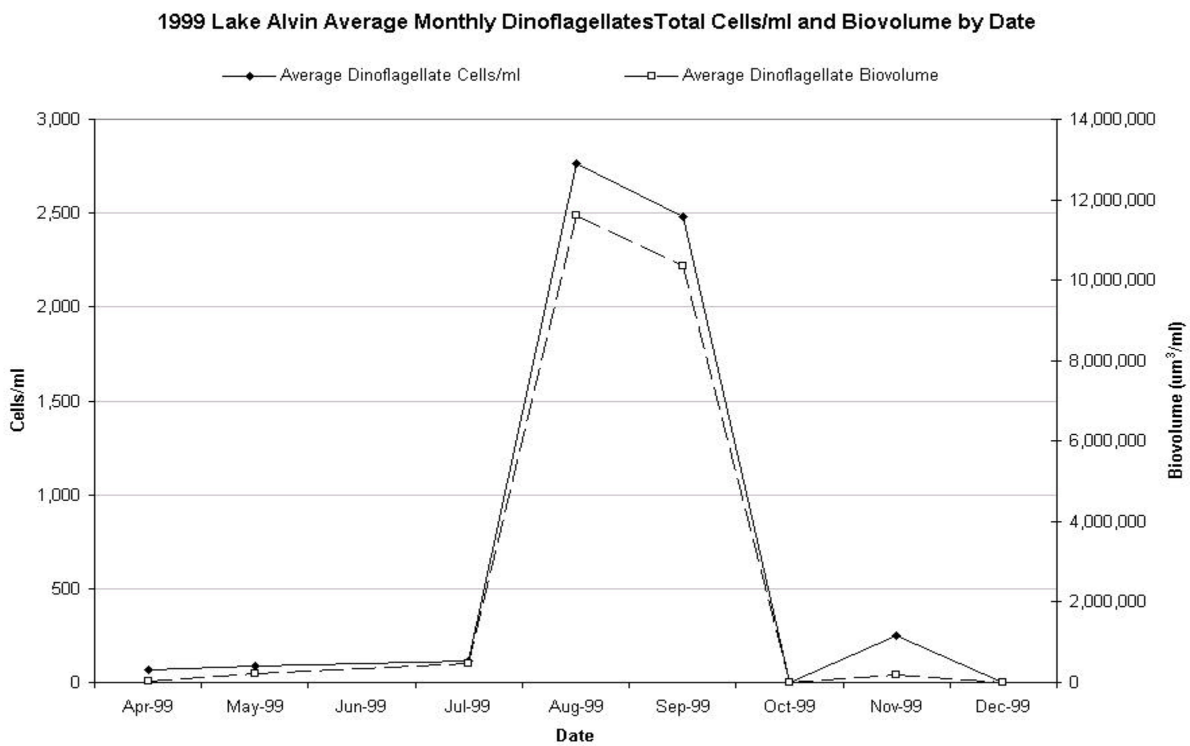


Figure 46. Monthly total dinoflagellate cells per milliliter and biovolume (µm^3/ml) by date for Lake Alvin, Lincoln County, South Dakota in 1999.

Phytoplankton monthly density ranged from 14,040 cells/ml in April to 131,724 cells/ml in October, 1999. Monthly biovolume ranged from 3.966 µl/L (= 3,966,000 µm^3/ ml x 10^{-6}) to 18.345 µl/L in November. Average monthly density and biovolume for this study period amounted to 71,725 cells/ml and 13.576 µl/L.

The algae communities of eutrophic hardwater lakes in the Midwest are frequently dominated by blue-green algae and diatoms with green algae comprising a small percentage of the total population (Prescott 1962). Lake Alvin algae populations conformed to the above model in most respects. However, in terms of biovolume, dinoflagellates were dominant in August and September. *Aphanizomenon flos-aquae* was the only abundant blue-green species during 1999, occurring as a minimum of 28,654 cells/ml in August and at a maximum density of 127,883 cells/ml in October (Appendix J, Table J-2). Biovolumes for those densities ranged from 3.352 µl/L to 14.962 µl/L.

The initial algae samples of this survey were collected in late April and May, 1999. Sample analysis for both in-lake sites indicated a mean population of 14,040 algal cells/ml in April. Sixty-three percent of this total (8,854 cells/ml) was comprised of a medium-sized spring bloom of small centric diatoms of the genera *Cyclotella* and *Stephanodiscus* (Appendix J, Tables J-2 and J-3). By late May, this bloom of mostly small centric diatoms had declined to an average of 3,074 cells/ml to be replaced by a larger bloom of a small pennate diatom, *Nitzschia acicularis* (12,812 cells/ml). *N. acicularis* made up 52 percent of the total algal population which had nearly doubled to 24,412 cells/ml in late May October (Appendix J, Table J-2). *Nitzschia* spp. are known to actively grow on sediments of rivers and littoral substrates of lakes and occur only incidentally in the plankton when they are suspended by wind and wave action. Blooms of these taxa are infrequently observed in the water column of lakes. Algal biovolume in late May was produced primarily by *Nitzschia acicularis*, *Cryptomonas erosa*, and *Stephanodiscus* species (Figure 49).

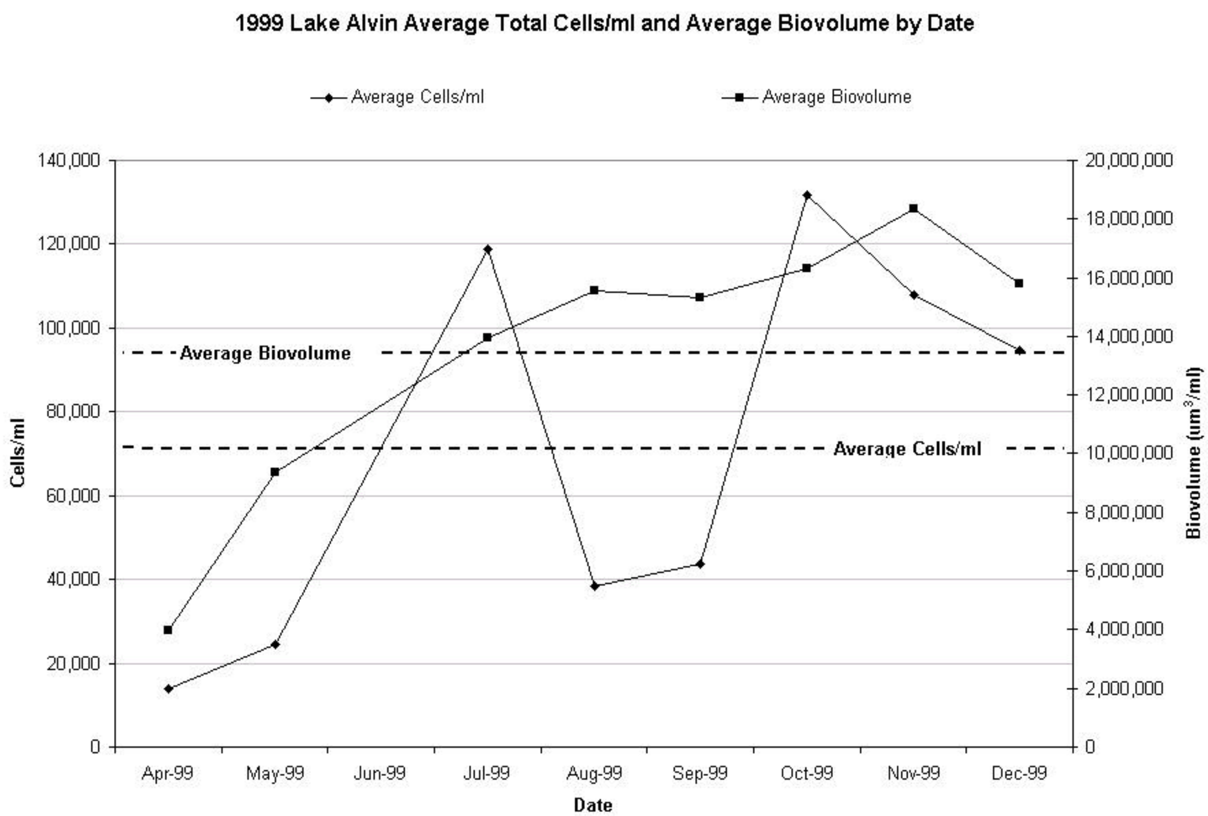


Figure 47. Monthly total algal cells per milliliter and biovolume (µm^3/ml) by date for Lake Alvin, Lincoln County, South Dakota in 1999.

Two common flagellated cryptophyte algae, *Rhodomonas minuta* (= *Chroomonas* sp. (Butcher)) and *Cryptomonas erosa* that made up nearly 12 percent of total algae in April increased to 24 percent (5,915 cells/ml) in late May (Figure 45 and Figure 51). Another common taxon in spring samples was *Chlamydomonas* sp., a green flagellate (Figure 51 and Appendix J, Tables J-2 through J-4).

The next samples collected on July 21,1999, indicated a nearly five-fold increase in algal density to 118,818 cells/ml. Warm surface water temperatures approaching 30 ^{o}C may have inhibited cooler water algae species, in particular, diatoms which decreased sharply to trace densities of 13 cells/ml. July marked the first record of the blue-green *Aphanizomenon flos–aquae*, a late appearance, which may have been due to the lack of sampling in June and early July.

Aphanizomenon was present as a bloom at both sites, at a mean density of 111,588 cells/ml. Another bloom-forming blue-green alga, *Microcystis aeruginosa*, was found in moderate abundance (7,903 cells/ml) only at site LA-2 on this date.

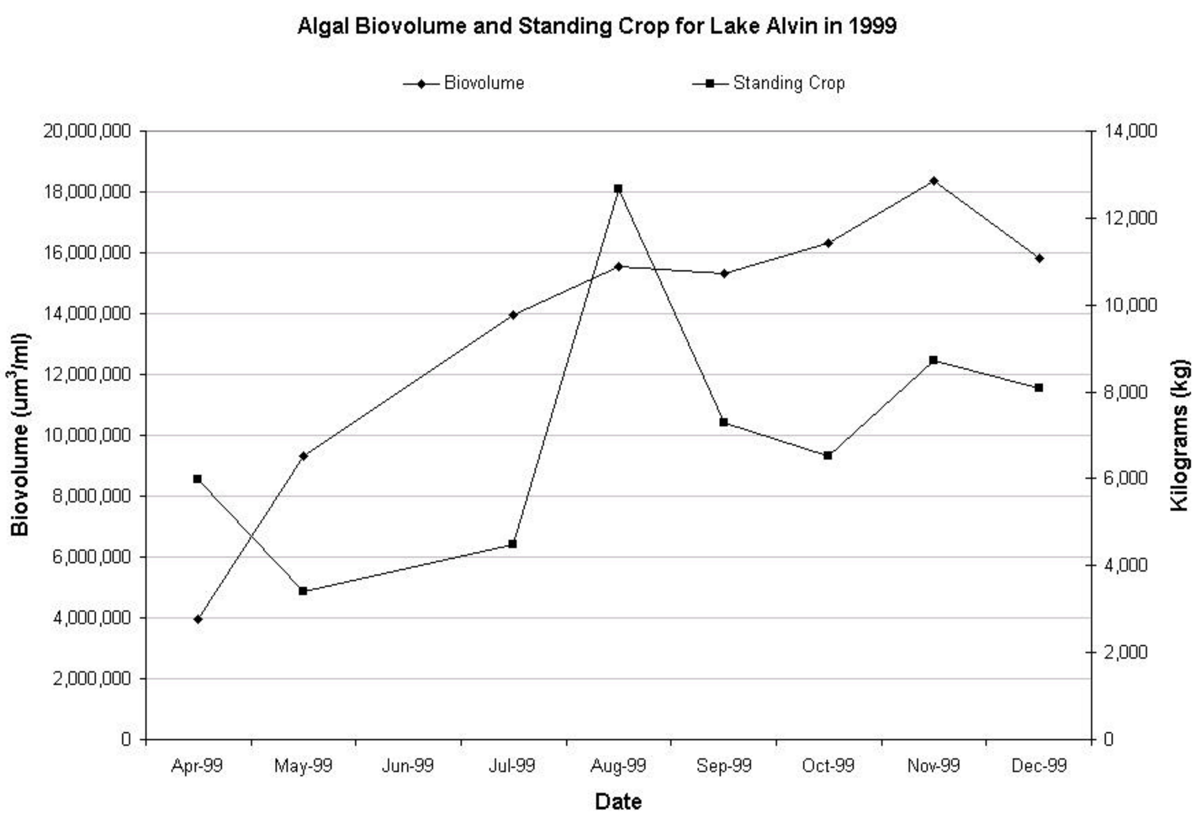


Figure 48. Algal biovolume (µm^3/ml) and standing crop (kg) for Lake Alvin, Lincoln County, South Dakota in 1999.

Figure 48 indicates there was a steady rise in standing crop and biovolume of algae in Lake Alvin during 1999. Biovolume is the volume of algae (µm^3/ml) and standing crop is the biomass present, usually expressed as the dry weight (kg) of a population in a given area (entire lake) at a given time (month). Standing crop was calculated using APHA (1995) method based on chlorophyll-*a* concentration (chlorophyll-*a* concentration (mg/m^3) x 67). Standing crop and biovolume were moderately correlated (r = 0.49) with the largest deviation occurring in August. The August peak in standing crop was due primarily to large bloom of dinoflagellates, a relatively large organism. During this time (from July to August), a shift in nutrient limitation occurred, from phosphorus-limited to nitrogen-limited. At this same time *Aphanizomenon flos–aquae*, a nitrogen-fixing alga (able to fix dissolved atmospheric nitrogen N_2 via heterocysts when inorganic concentrations are reduced), declined in August (after the shift) and *Oscillatoria* sp., a non-nitrogen fixing alga (not able to fix atmospheric nitrogen), declined from 95,025 μm^3/ml in August to zero from September through November.

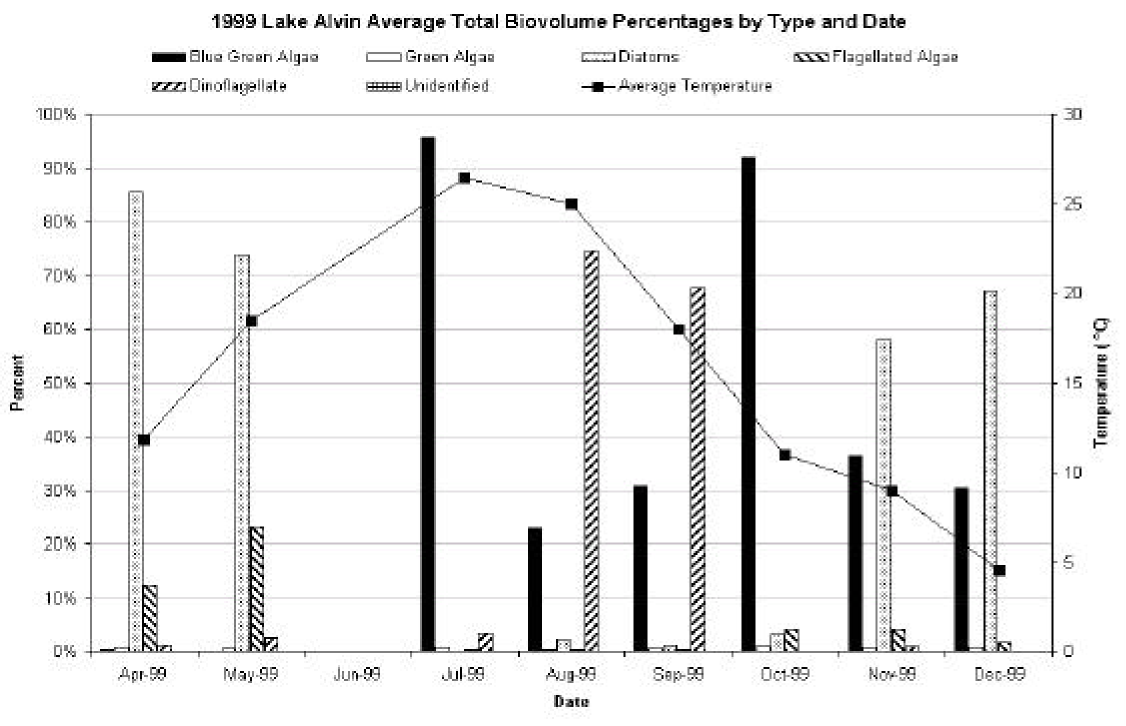


Figure 49. Monthly algal biovolume (μm^3/ml) percentages and temperature (° C) by algal type and date for Lake Alvin, Lincoln County, South Dakota in 1999.

August and September mean algae populations declined to low summer densities of 38,366 and 43,786 cells/ml, respectively, due to a corresponding decrease in *Aphanizomenon flos–aquae* densities to 28,654 and 40,341 cells/ml in August and September. At the same time, there was an exponential increase in densities of the dinoflagellate *Peridinium* sp. (probably *Glenodinium gymnodinium*) from 114 cells/ml in July to 2,764 cells/ml in August and 2,461 cells/ml in September. Since this is large-sized organism, the latter densities were responsible for most of the late summer algal biovolume for Lake Alvin (Figure 46, Figure 47, Figure 49 and Appendix J, Table J-4). The time period immediately preceding that bloom was marked by maximum lake water temperatures and phosphorus levels (Figure 49).

Table 30. Total Number of algae taxa by month in Lake Alvin, Lincoln County South Dakota in 1999.

Date	Total
April	20
May	17
July	16
August	12
September	11
October	12
November	16
December	13

In late October, the *Aphanizomenon flos–aquae* population increased to 127,883 cells/ml and comprised 97 percent of the total algae, which represented an annual maximum for this species as well as total algal densities for the study. A large autumn increase in *Aphanizomenon* is unusual because this taxon is considered a summer (warm-water) species. *Peridinium* sp., another apparent warm-water form in Lake Alvin, was not recorded in October or for the rest of this survey. Green algae increased in October to 1,768 cells/ml. Seventy-three percent of the green algae population was comprised of *Oocystis* sp.

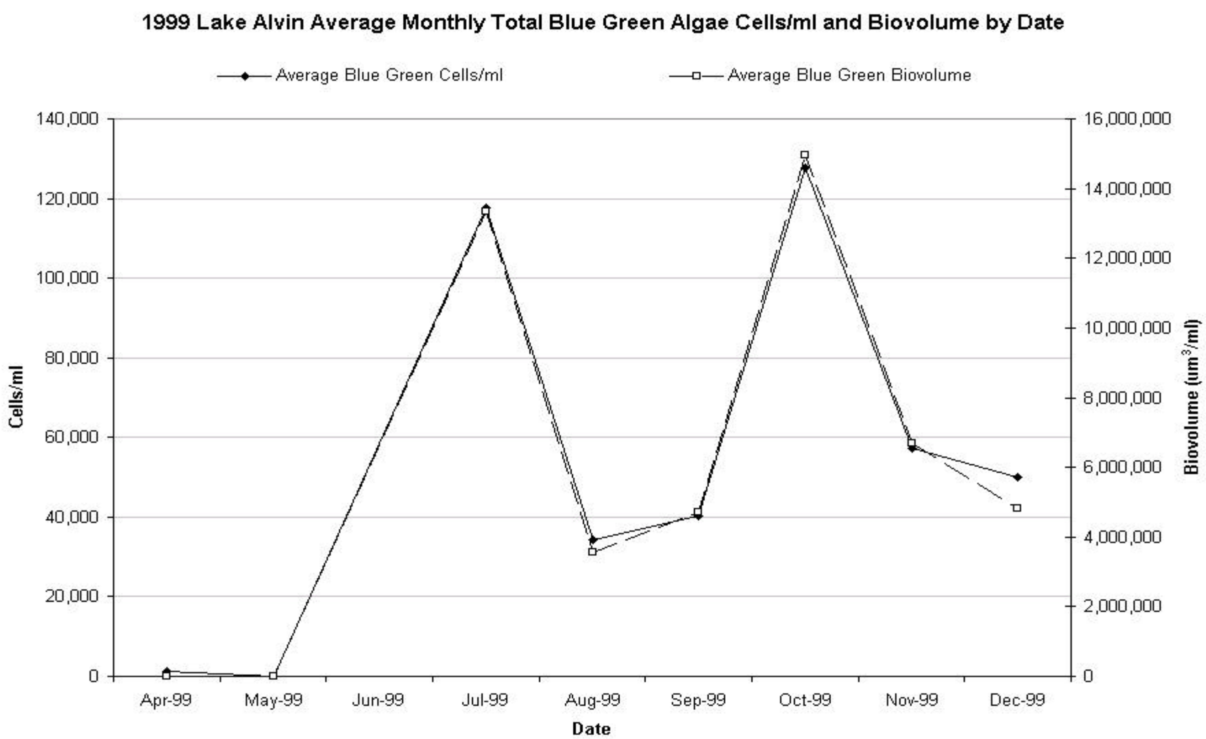


Figure 50. Monthly total blue green algae cells per milliliter and biovolume (μm^3/ml) by date for Lake Alvin, Lincoln County, South Dakota in 1999.

Contrary to expectations, the Lake Alvin algae population decreased only moderately (23 percent) in late fall from the peak October levels to 107,911 and 94,744 cells/ml in early November and December, respectively (Figure 47 and Appendix J, Table J-4). Diatoms, mainly *Cyclotella* spp. and *Stephanodiscus* spp., made up 41 percent and 43 percent of the total algae density for November and December and were primarily responsible for the annual biovolume maximum in November (Figure 47). One large-sized diatom, *Stephanodiscus astraea* (probably *S. niagarae*) at a mean density of only 899 cells/ml comprised 18 percent of the total algal biovolume for the two months. Green algae, mostly *Oocystis* sp., increased moderately to 2,745 cells/ml and 2,432 cells/ml during late fall (Appendix J, Table J-4). Surprisingly, *Aphanizomenon* was recorded as still being present in substantial numbers during November and December at 57,197 cells/ml and 39,092 cells/ml, respectively (Appendix J, J-2 and Figure 49).

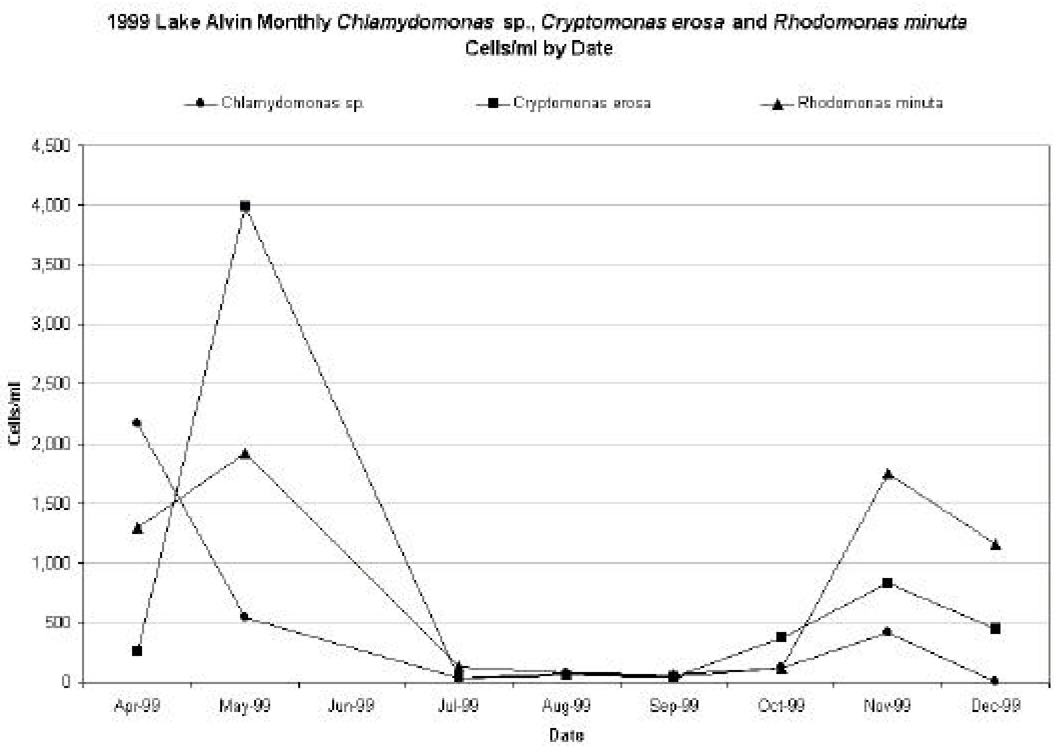


Figure 51. Monthly *Chlamydomonas* sp., *Cryptomonas erosa* and *Rhodomonas minuta* densities in cells per milliliter by date for Lake Alvin, Lincoln County, South Dakota in 1999.

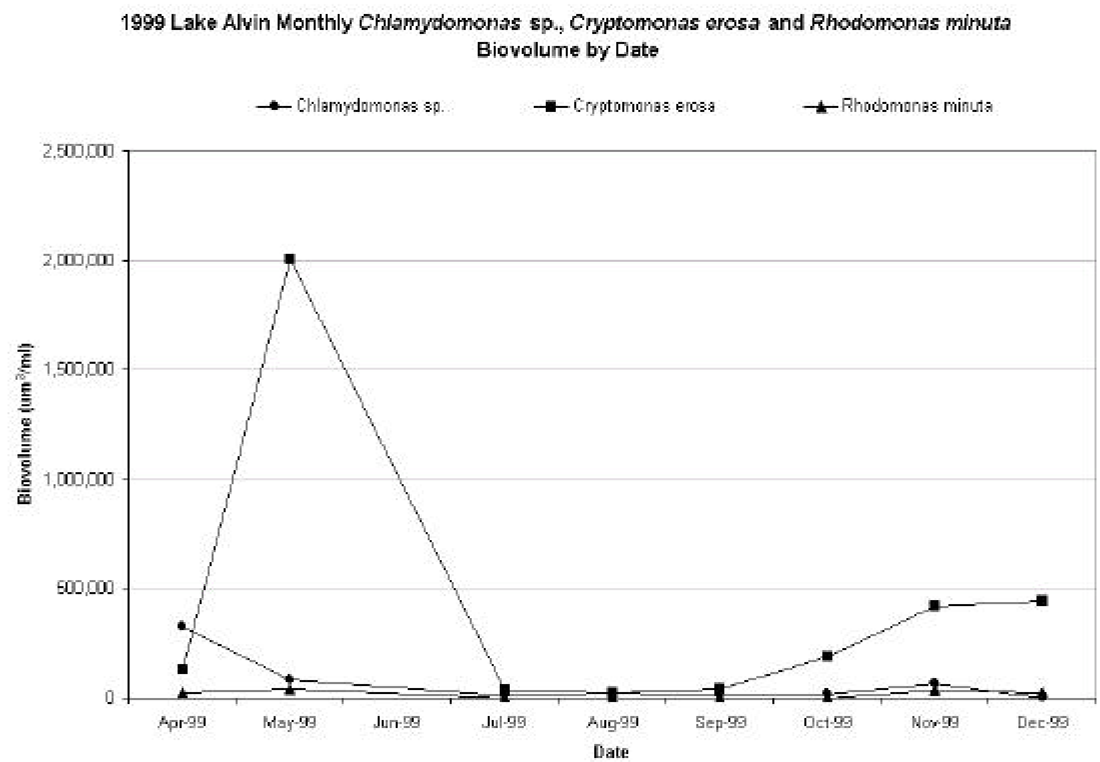


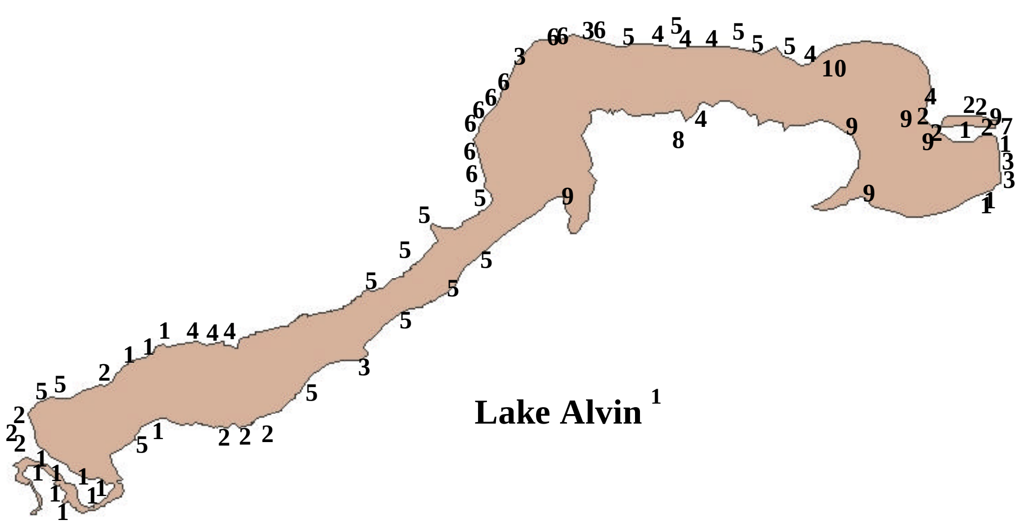
Figure 52. Monthly *Chlamydomonas* sp., *Cryptomonas erosa* and *Rhodomonas minuta* biovolume (μm^3/ml) by date for Lake Alvin, Lincoln County, South Dakota in 1999.

The Lake Alvin algae community exhibited some unusual trends during this survey that are not commonly observed in other eutrophic lakes in eastern South Dakota. For example, annual diatom peaks usually occur in spring rather than in late autumn, as during this survey. Correspondingly, highest annual algal densities are usually recorded in spring and/or summer rather than in the fall (Figure 47). In addition, spring blooms of *Nitzschia acicularis* and summer blooms of dinoflagellates of the *Peridinium/ Glenodinium* genera did not appear to be common in other monitored state lakes. However, they were recorded previously in a few other highly eutrophic state lakes, notably, spring blooms of *Nitzschia acicularis* in Clear Lake (Deuel Co.) and Lake St. John; and summer blooms of *Peridinium* (previously recorded as *Glenodinium gymnodinium*) in Lake Faulkton (Faulk Co.), Lake Campbell (Brookings Co.) and Rosehill Lake (Hand Co.) Moreover, even though nutrients and water temperatures were at high levels in Lake Alvin during August and September 1999, blue-green algae, primarily *Aphanizomenon flos-aquae*, actually decreased abruptly in those months. Obviously, additional study is required to help clarify some of the apparent inconsistencies that arose in the course of the present survey.

Aquatic Macrophyte Survey

An aquatic macrophyte survey of Lake Alvin was conducted on August 12 and 13, 1999. The survey consisted of surveying the entire shoreline and identifying emergent and terrestrial plant species followed by 16 inlake transects to quantify the submergent plant community (Figure 53 and Figure 54). Each transect had from one to four survey points to evaluate the macrophyte community. Sampling at each survey point consisted of casting a plant grapple approximately 6 meters in four separate directions (north, south, east and west), slowly retrieving the grapple and identifying the plant species retained on the grapple.

The shoreline survey identified a number of common riparian emergent and wetland (lakeshore) plant species similar to other lakes in this ecoregion (ecoregion 46R, SD DENR 2000a). Aquatic plant species were identified using Fassett (1957). Reed canary grass *Phalaris arundinacea* was the most abundant shoreline species encountered at Lake Alvin in 1999.



[1] = Numbers correspond to general locations of specific plant species and are found in Table 31.

Figure 53. General locations of plant species found in Lake Alvin, Lincoln County, South Dakota in 1999.

Sixteen transects and 49 survey points revealed no submergent plant species (Appendix K). However, seven small areas (several plants each) near transects 8A, 13A and D, 14A and D, 15A and the outlet to the Lake (LAT-7) did have submergent macrophytes. There are several possible explanations for this at Lake Alvin. Relatively steep inlake drop-off (reduced inlake littoral zone) and reduced Secchi depth indicating sharply reduced light penetration because of organic and inorganic turbidity.

Table 31. Emergent and submergent plant species list found in Lake Alvin, Lincoln County, South Dakota in 1999.

Number	**Common Name** Shoreline survey	**Scientific Name**
	<u>Emergent</u>	
1	Narrow-leaf Cat Tail	*Typha augustifolia*
2	Sand-bar Willow	*Salix longifolia*
3	River Bulrush	*Scirpus fluviatilis*
4	Soft-stem Bulrush	*Scirpus validus*
5	Reed Canary Grass	*Phalaris arundinacea*
6	Swamp Smartweed	*Polygonium coccineum*
7	Prairie Cordgrass	*Spartina pectinata*
8	Arrowhead	*Sagittaria latifolia var. obtusa*
	<u>Submergent</u>	
9	Floating-leaf Pondweed	*Potamogeton natans*
10	Sago Pondweed	*Potamogeton pectinatus*

Canfield (1985) proposed a model to determine maximum depth of colonization (MDC) for submerged macrophytes. The model is influenced by regional differences in plant response to changes in available light and seasonal characteristics. The model used was as follows.

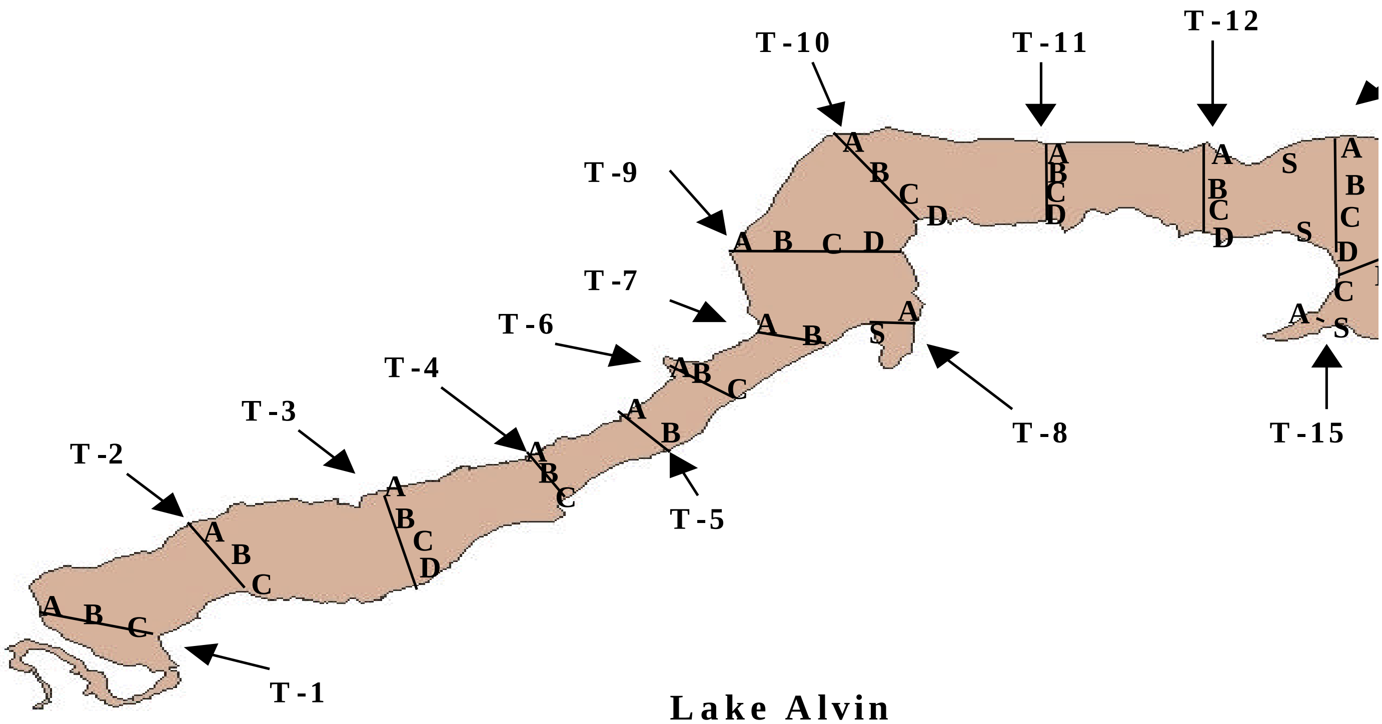
Equation 4. Maximum depth of colonization equation

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

MDC = Maximum depth of colonization
SD = Secchi depth

The calculated maximum depth of colonization in Lake Alvin is 1.45 meters (4.8 feet), using the 0.65 meter (2.1 feet) Secchi depth measured during August. Increasing Secchi depth to 1.2 meters (3.9 feet) will improve MDC depth to 2.03 meters (6.7 feet), allowing 28.6 percent more colonizational area for aquatic macrophytes.

The lack of submerged vegetation in Lake Alvin appears to be a result of decreased light penetration due to organic and inorganic turbidity, and areas of relatively steep littoral zones. Reductions in sediment and nutrient loads to the lake should improve Secchi depth and transparency. Improving Secchi depth will allow littoral colonization of submerged macrophytes in regions of Lake Alvin conducive to colonization, which will increase the uptake of nutrients and increase habitat for fish and macroinvertebrates.



S = Locations of submergent macrophytes

Figure 54. Submergent macrophyte transect locations at Lake Alvin, Lincoln County, South Dakota 19

Benthic Macroinvertebrates

Two sets of benthic macroinvertebrate samples were collected from Lake Alvin, one on March 29, 2000, and the second on April 27, 2000. Sampling was initiated by elutriate analysis results (elutriate section) to monitor the existing benthic macroinvertebrate community at each inlake sampling site. Three benthic sampling sites were selected along a transect at each inlake sampling site (Figure 55). Samples were collected using a Petite Ponar grab sampler (aperture: 232 cm^2). Bottom samples were sieved in the field using a U.S. Standard #30 mesh sieve; organisms and the remaining debris were preserved in 70% alcohol.

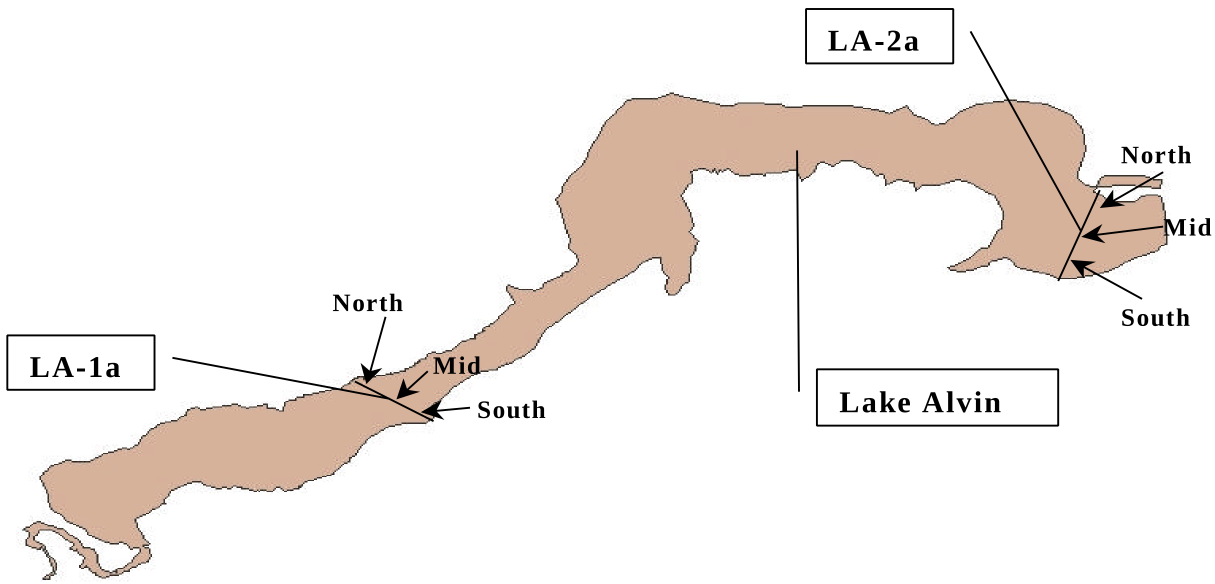


Figure 55. Benthic macroinvertebrate sampling sites at Lake Alvin, Lincoln County, South Dakota, 2000.

Benthic samples were returned to the laboratory and rinsed in a 78 µm mesh sieve. The retained material was stored in 70% alcohol for later analysis. Macroinvertebrates from most samples were picked from the debris using a stereo zoom microscope at a magnification of 20x. March samples from site LA-2a (North) contained an excessive amount of inorganic debris (mostly sand and gravel). This sample was sorted using a modified flotation technique (Anderson 1959). Macroinvertebrate identification to the lowest possible taxonomic level followed Merritt and Cummings (1996), Pennak (1978), Usinger (1956) and Epler (1995).

Aquatic worms (oligochaetes) and midge larvae (chironomids) comprised 50.4 percent and 24.7 percent of the benthic invertebrates collected by Petite Ponar dredge during the two sampling dates, March 29 and April 27, 2000 (Table 32). Midges exhibited the highest diversity with seven taxa collected but oligochaetes were generally more common. The great majority of oligochaetes consisted of small immature individuals.

Table 32. Total benthic macroinvertebrate species by date and percent collected at Lake Alvin, Lincoln County, South Dakota in 2000.

Taxon	March 29, 2000	April 27, 2000	Total Number counted	Percent
Chironomus plumosus gr.	91	14	105	24.7%
Cryptochironomus sp.	2	0	2	0.5%
Procladius sp.	16	14	30	7.1%
Ostracods	0	1	1	0.2%
Ceratopogonids	19	12	31	7.3%
Oligochaetes	109	105	214	50.4%
Cladotanytarsus sp.	0	1	1	0.2%
Cladopelma sp.	4	20	24	5.7%
Hexagenia sp.	2	1	3	0.7%
Chaoborus sp.	2	6	8	1.9%
Paratendipes sp.	1	0	1	0.2%
Nematodes	0	4	4	0.9%
Paratanytarsus sp.	1	0	1	0.2%
Total	247	178	425	

Density (organisms/ m^2) of chironomids, including pupae, was higher in March (275/ m^2) while numbers of oligochaetes decreased only slightly from 261/ m^2 in March to 251/ m^2 in late April (Appendix L, Table L-2). The major change in the benthic population between months was a sharp decline in the number of *Chironomus plumosus* larvae, probably partially the result of an early emergence of these midges during April. The decrease in *Chironomus* numbers resulted in the decline of the total benthic population from 591/m^2 in March to 462/m^2 in late April.

Relative abundance of the taxa collected during this study is summarized by location on Table 32. Generally, benthic densities and diversity were higher at site LA-1a on the upper reservoir (Appendix L, Tables L-1 and L-2). Site LA-1 (south) contained a small number of the burrowing mayfly *Hexagenia* sp. *Hexagenia* sp. are susceptible to low oxygen levels (< 1 mg/L (ppm)) and their survival can be indicative of at least fair water quality (Edmunds et al. 1976). The presence of moderate numbers of *Hexagenia* 'tusks' in most samples suggested that this mayfly was more common and widespread in Lake Alvin in past years. By contrast, ceratopogonids (biting midges), and many taxa of oligochaetes, chironomids, some snails and fingernail clams (*Sphaerium* spp.) are known to be very tolerant of pollution and low oxygen levels.

LA-2a (Mid and South) on the lower reservoir (Figure 55) contained extremely few or none of even the very tolerant taxa mentioned above. No macroinvertebrates were present in mud samples from Site 2 (Mid). Extremely severe environmental conditions probably existed at Site 2 that inhibited colonization and survival of benthic invertebrates (Appendix L, Tables L-1 and L-2). Anoxic sediments, with consequent buildup of toxic substances such as hydrogen sulfide and ammonia in winter under ice cover, may have inhibited those organisms. Extremely low dissolved oxygen concentrations at LA-2 contributed to the depauperate nematode community at Lake Alvin (Wetzel 2001). This study proposes the installation of an artificial oxygenation system (mixer or aerator) for the deeper waters of the lower reservoir which would produce more habitable substrate and result in recolonization of those areas by invertebrate taxa from the upper reservoir. Larvae and pupae of the larger chironomid species (e.g. *Chironomus* spp.) and *Hexagenia* sp., where available, are important food sources for both forage fish and game fish. An increase in the abundance of those organisms, in addition to enhancing the cycling and disposal of incoming nutrients (from their uptake by algae to invertebrates and fish), would help improve the fishery in Lake Alvin by enlarging the food base on which fish depend.

Table 33. Lake Alvin Shannon diversity and evenness values by site and date for inlake benthic macroinvertebrates [1]

		March 3, 2000		April 27, 2000	
Location	**Site**	**Shannon Base (2)**	**Evenness**	**Shannon Base (2)**	**Evenness**
North	LA-1a	1.90	0.74	1.66	0.64
North	LA-2a	2.21	0.74	1.88	0.94
South	LA-1a	1.64	0.55	1.65	0.49
South	LA-2a	-[2]	-[2]	0.81	0.81
Mid	LA-1a	1.64	0.64	2.01	0.78
Mid	LA-2a	0	0	0	0
Average [3]	**-**	**0.55**	**0.21**	**0.86**	**0.52**

[1] = Values calculated excluding fingernail clams, nematodes and ostracods.
[2] = Too few species to run analysis.
[3] = Combined subsites by date.

Diversity, evenness, community similarity and percent similarity were calculated within and between sampling sites in Lake Alvin (Bower et al. 1990). Shannon base (2) was used to calculate diversity values (the higher the value the more diverse the community). Evenness values range from 0.0 to 1.0 and express the nearness of the data to maximum diversity. Jaccard coefficient was used to determine community similarity, values range from 0.0 if no species common to both communities are found to 1.0 when all the same species are found in both communities. The Jaccard coefficient of community value is a measure of the presence or absence of species between communities. Percent similarity is the total average percent of species from both communities.

Table 34. Lake Alvin community analysis by site comparing communities by date (March 29, 2000 to April 27, 2000) using Jaccard coefficient and percent similarity values for inlake benthic macroinvertebrates [1].

Location	Site	Jaccard Coefficient	Percent Similarity
North	LA-1a	0.50	0.39
North	LA-2a	0.50	0.39
South	LA-1a	0.60	0.83
South	LA-2a	0.33	0.50
Mid	LA-1a	0.83	0.59
Mid	LA-2a	0	0
Average [2]	**-**	**0.39**	**0.21**

[1] = Values calculated excluding fingernail clams, nematodes and ostracods
[2] = combined subsites by date.

Subsites at LA-1a and LA-2a (north) had similar diversity and relatively high evenness values for both sampling dates. LA-2a Mid and LA-2a South had severely depressed diversity and evenness values (Table 33). Community comparisons between sampling dates and within subsites were similar at LA-1a with an average Jaccard coefficient of community of 0.64 and percent similarity of 0.60. Average benthic community coefficients and percent similarity values for LA-2a were much lower (average 0.27 and 0.29, respectively), with a significant portion of the value coming from LA-1a (north) (Table 34). Jaccard coefficient of community and percent similarity values were low (0.33 and 0.47, respectively) when comparing communities as a whole (LA-1a to LA-2a, combining subsites and dates), due in part to the depressed conditions at LA-2a (Table 35).

Table 35. Lake Alvin overall community analysis (combining subsites and dates) comparing LA-1a to LA-2a[1].

Comparison	Jaccard Coefficient	Percent Similarity
LA-1a to LA-2a	0.33	0.47

[1] = Values calculated excluding fingernail clams, nematodes and ostracods

Benthic macroinvertebrate samples were collected from Blue Dog Lake and Enemy Swim Lake in February, 1999 by SD DENR personnel, benthic diversity and evenness data will be used to compare with March, 2000 samples from Lake Alvin. Blue Dog Lake in Day County is a 1,502 acre natural lake that is partially supporting its beneficial uses and Enemy Swim Lake, also in Day County, is a 2,146 acre natural lake fully supporting its beneficial uses. Both lakes are in the same ecoregion (46) as Lake Alvin, however, Lake Alvin is a reservoir. March samples were chosen for comparison because they were collected through the ice, similar to February samples collected from Blue Dog and Enemy Swim Lakes.

The average diversity values for Lake Alvin (LA-1a and LA-2a) in March was 1.72 and 0.73, respectively (Table 33). Both sites at Blue Dog Lake (East and West) had similar diversity values (1.62 and 1.48, respectively) and were nearly those of Lake Alvin site LA-1a (Appendix L, Table L-3). Blue Dog Lake benthic sampling sites were similar to Lake Alvin in depth (approximately 2.4 m) and beneficial use status as diversity indices indicate. Species richness between Lake Alvin (10 species) and Blue Dog Lake (11 species) were also similar, however Blue Dog Lake species included amphipods, nematodes, Trichoptera, Ephemeroptera and water mites, groups common in eutrophic lakes (Appendix L, Table L-4 and Table L-5). LA-2a samples were extremely depressed in diversity (average 0.73), evenness (average 0.25) and species richness (8 species). LA-2a (north) was the only site with enough data to run metrics, so no valid comparison could be made with available data. Benthic samples from Enemy Swim Lake, a mesotrophic lake fully supporting beneficial uses, had diversity and evenness values well above those in Lake Alvin or Blue Dog Lake (partially supporting beneficial uses).

At present, severe conditions at LA-2a for benthic life in the sediments of Lake Alvin are also indicated by the absence or rarity of a number of invertebrate groups usually common in eutrophic lakes and reservoirs (Appendix L, Table L-4 and Table L-5. Conditions LA-2a could be improved by installing an inlake circulator or aerator during the spring and summer improving dissolved oxygen concentrations in Lake Alvin. Improving oxygen concentrations in the hypolimnion will allow benthic macroinvertebrates to re-colonize and process the organic material in this area.

Sediment Survey

A sediment survey was conducted in Lake Alvin on February 22 and 23, 2000. 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. All 311 survey sites were recorded by GPS (Global Positioning System) (Figure 56).

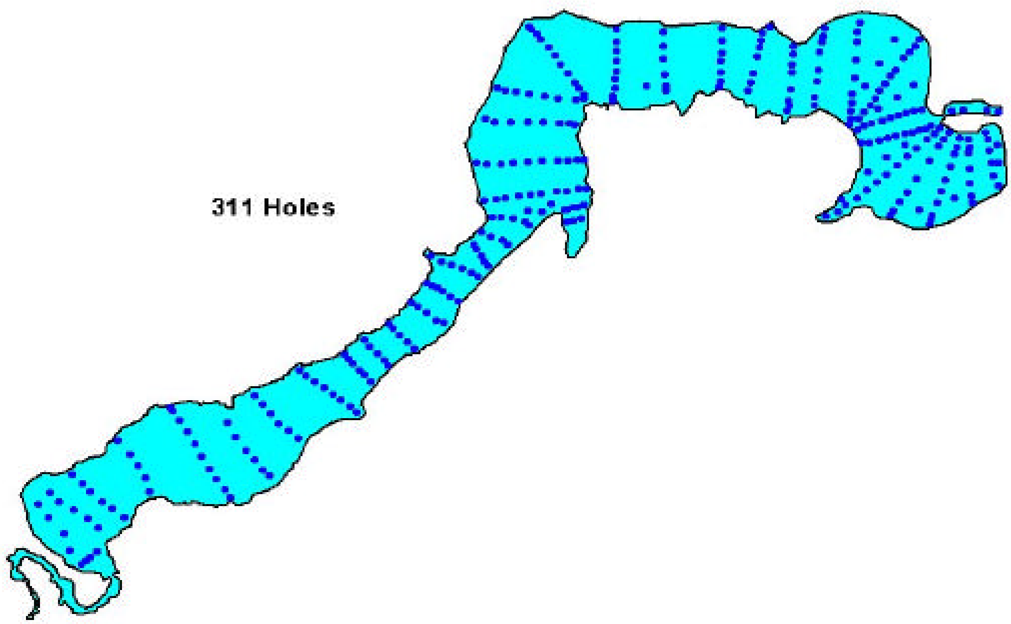
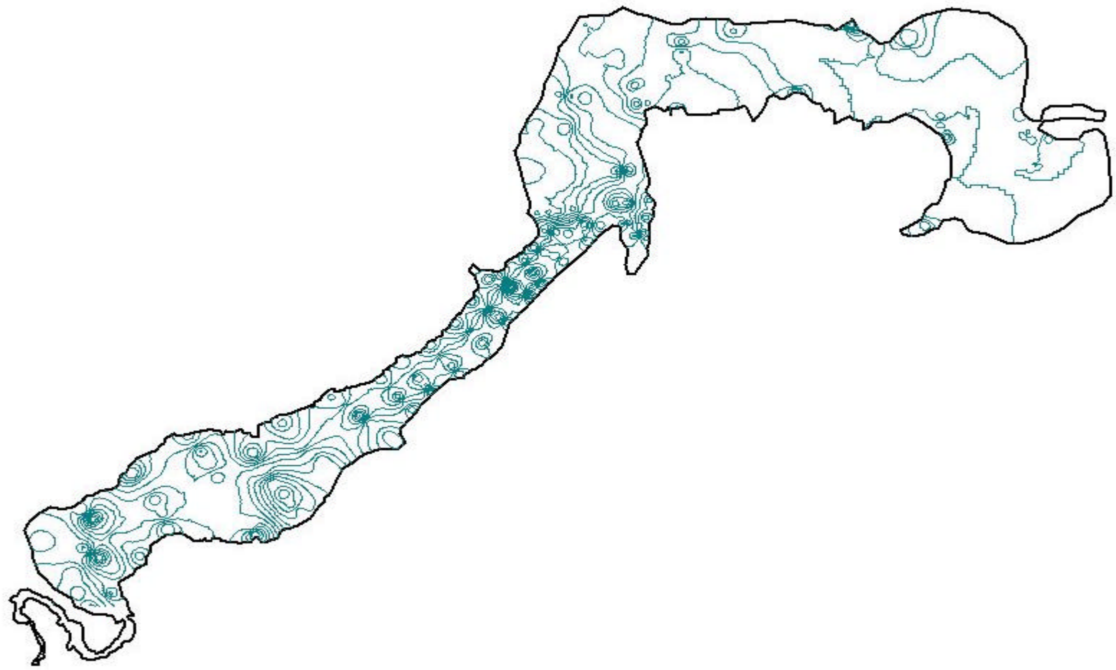


Figure 56. Lake Alvin sediment sampling points

Sediment depths ranged from 0.15 to 2.74 meters, with the majority of the sediment in the upper (western) portion of the lake (Figure 57). Total sediment volume within Lake Alvin is 133,309.3 m^3 (108 acre-feet). At the time of this survey, the average depth of sediment in Lake Alvin was 0.31 meters (1.01 feet). The estimated load (Nine Mile Creek and ungauged) to Lake Alvin for 1999 was 396,485 kg. Kilograms were converted to cubic meters by dividing total kilograms of sediment delivered by 2,162.5 kg/m^3 (Stueven and Bren 1999). An estimated 183.3 m^3 of sediment were delivered to Lake Alvin. Dividing cubic meters by the total acres of Lake Alvin (107) estimates cubic meters per acre (1.71 m^3/acre) and multiplying by 0.00081 derives acre-feet (0.0014 acre-feet/acre). Finally, multiplying feet by 3,048 yields an overall increase of 4.27 mm of sediment depth over the entire lake during this study.



Contour lines 0.15 meters (0.5 feet) apart

Figure 57. Lake Alvin Contour map of sediment depth

The dam that created Lake Alvin was finished in 1954. Based on a constant sedimentation rate of 4.27 mm (0.17 inches) per year obtained during this study, Lake Alvin would have approximately 0.19 meters (0.62 feet) of sediment built up over 45 years since its impoundment. This is 61.3 percent of the actual measured amount, suggesting that yearly sedimentation rates vary.

Elutriate Analysis (Sediment Analysis)

Elutriate samples are used to determine chemical substances (contaminates) in sediment samples. In general, contaminates are composed of various metals, pesticides and herbicides (Appendix M, Table M-1 and Table M-2). 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 contaminates.

Elutriate samples were collected from Lake Alvin on February 24, 2000 and April 27, 2000. February samples at both sites were collected through the ice. Sediment and receiving water were collected from both inlake sampling sites and analyzed separately. All sediment samples were collected using a stainless steel Petite Ponar dredge. All samples were preserved and transported at 4° C.

Receiving water samples collected in February at site LA-2a had detectable levels of Alachlor, Chlordane, Heptachlor Epoxide and Methoxychlor in µg/l (ppb – parts per billion) (Table 36). Alachlor is a herbicide that is highly toxic to aquatic plants and along with the insecticides Heptachlor Epoxide, Methoxychlor, and Chlordane are highly toxic to fish and freshwater invertebrates. February receiving water samples from LA-1a and samples collected in April at sites LA-1a and LA-2a did not detect elevated levels of these four compounds (Appendix M, Table M-2).

Table 36. Elutriate and receiving water concentrations of herbicide and insecticides detected at site LA-2a in February 24, 2000 Lake Alvin, Lincoln County, South Dakota.

Contaminate	Receiving Water (mg/l)	Elutriate(mg/l)	Percent Increase
Alachlor	1.55	1.98	21.7%
Chlordane	1.52	1.89	19.6%
Endrin	-	1.39	I
Heptachlor	-	0.939	I
Heptachlor Epoxide	1.48	1.60	7.5%
Methoxychlor	1.94	2.37	18.1%

I = Increased from non-detect

Elutriate samples from site LA-2a taken in February also detected increased concentrations of compounds found in the receiving water along with two others not previously detected (Table 36). The newly detected compounds were the insecticides Endrin and Heptachlor. Similar to the receiving water samples, elutriate samples from LA-1a and samples collected in April at sites LA-1a and LA-2a did not detect elevated levels of these six compounds (Appendix M, Table M-2).

Table 37. $LC_{(50)}$ (Lethal Concentration) values for fish species found in Lake Alvin

Contaminate	Largemouth Bass	Bluegill	Common Carp	Catfish	Northern Pike	Yellow Perch
Alachlor	-	4.3 mg/L	4.6 mg/L	6.5 mg/L	-	-
Chlordane	-	57 to 75 µg/l	-	-	-	-
Endrin	-	-	-	-	-	-
Heptachlor	10 µg/l	5.3 to 13 µg/l	-	-	6.2 µg/l	-
Heptachlor Epoxide[2]	10 µg/l	5.3 to 13 µg/l	-	-	6.2 µg/l	-
Methoxychlor	-	20 to 65µg/l	-	20 to 65µg/l[1]	20 µg/l	20 to 65 µg/l

1 = Channel catfish
2 = More toxic than Heptachlor

Lethal concentration ($LC_{(50)}$) values are specific concentrations at which 50 percent of the organisms die under controlled conditions. All detectable February 2000 herbicide and insecticide concentrations were below published $LC_{(50)}$ values (Table 36 and Table 37).

Although below $LC_{(50)}$ levels, the elutriate and receiving water concentrations could stress and bioaccumulate in biological communities (macrophyte, phytoplankton, invertebrate and fish) near LA-2a in Lake Alvin.

Several of these compounds break down in a relatively short time frame (8 to 46 days), while others persist much longer (250 days to 14 years) (Table 38). Endrin, Heptachlor and Heptachlor Epoxide half-life values shown in Table 38 are for soils and not for aquatic environments. Chemical magnification in biological tissues (bioaccumulation) ranged from non-significant to 37,000 times ambient concentrations, with the highest being those having the longest half-life.

Table 38. Solubility, half-life and bioaccumulation values for herbicides and insecticides found in Lake Alvin

Contaminate	Solubility in water	Half life	Bioaccumulation Factor
Alachlor	PIS[3]	8 days	5.8 NS
Chlordane	PIS	4 years	3,000
Endrin	LS[4]	14 years[1]	1,335 to 10,000
Heptachlor	AIS[5]	250 day[1]*	200 to 37,000
Heptachlor Epoxide	AIS	250 days[1]	200 to 37,000
Methoxychlor	PIS	37 to 46 days	NS[2]

1 = Rate in soil
2 = Not significant in fish, however bioaccumulation factor in invertebrates significant (snails 8,570)
3 = Practically insoluble in water
4 = Low solubility in water
5 = Almost insoluble in water

Four of the six contaminates (Chlordane, Endrin, Heptachlor and Heptachlor Epoxide) found at LA-2a in February exceeded surface water quality standards for toxic pollutants based on human health value (ARSD § 74:51:01). The other two contaminates; Alachlor and Methoxychlor were not listed in the standards. When using these particular chemicals within the watershed, manufacturer recommendations and precautions should be followed when mixing, applying and disposing of these products. All water quality standards for toxic pollutants for human health and aquatic life values are based on beneficial use categories. Since Lake Alvin is not a domestic water supply, human health values are based fish beneficial use categories and are based upon a lifetime of exposure (70 years).

The elutriate sample from LA-2a that had detectable levels of chemicals in February and undetectable levels in April may have resulted from sampling (spatial) variability, suggesting highly localized contamination. Another alternative is that the sample was an anomaly based upon four of the six chemicals that have half lives longer than the period between sampling (63 days). At a minimum, Chlordane and Endrin (half-life of 4 years and 14 years, respectively) should have been detected in the April sample from LA-2a. Based on these observations, there does not appear to be a contaminate problem in Lake Alvin.

Hydrologic, Sediment and Nutrient Budgets for Lake Alvin

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 the 1999 tributary sampling season (March to November). During 1999, rainfall was 91.8 percent of normal (1999-21.91, average 23.86 inches) and the average temperature was 104.4 percent of normal (1999-47.5 °F, average 45.5 °F). Sampling and gauging began when ice left the stream and continuous discharge measurements could be collected.

Hydrologic inputs to Lake Alvin included precipitation, tributary runoff both gauged and ungauged, and ground water (Figure 58). Hydrologic outputs from Lake Alvin included the water leaving the lake over the spillway from the end of March to the middle of November 1999 and evaporation. Precipitation data was acquired from the state climatologist in Brookings, South Dakota. Monthly precipitation data was taken from the Sioux Falls field station. Tributary sites were gauged when possible, and, as stated in the previous section, ungauged discharge was estimated using the AGNPS model and the data modified (adjusted) using gauged export coefficients.

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 82 days out of 232 days of monitoring (35.3 percent).

Table 39. Hydrologic budget for Lake Alvin in 1999.

Parameter	Input (acre-feet)	Parameter	Output (acre-feet)
Precipitation	195.19	**Evaporation**	295.05
Nine Mile Creek	4,537.89	**Outlet Discharge**	5,358.51
Ungauged Watershed	909.86		-
Sub Total	**5,642.94**		**5,653.56**
Groundwater	10.62		-
Total	**5,653.56**		**5,653.56**

One factor never directly measured in Lake Alvin was the total volume of ground water that passed through the lake. Table 39 indicates that more water left the lake than entered from surface water (than entered using tributary (gauged and ungauged) and precipitation data). After

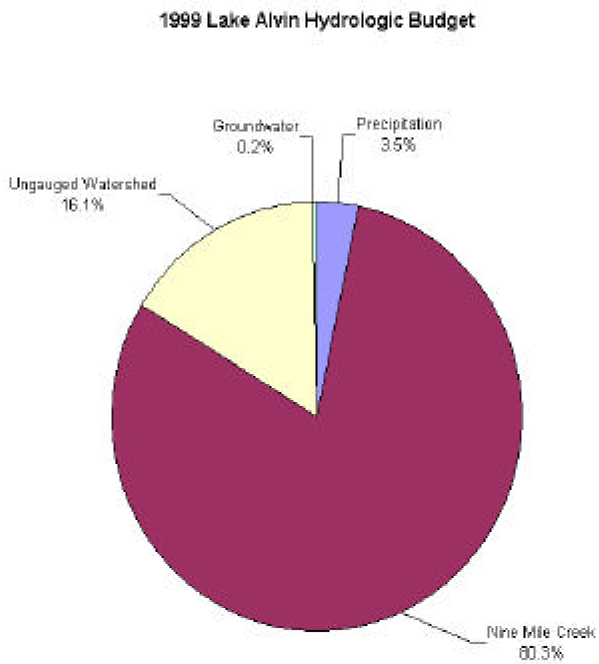


Figure 58. Hydrologic loading by parameter for Lake Alvin, Lincoln County, South Dakota by source in 1999.

all of the hydrologic inputs were subtracted from the outputs, only 13,100 m^3 (10.62 acre-feet) of water was unaccounted. The difference (10.62 acre-feet) was attributed (estimated) to be from ground water. Groundwater is usually of very good quality and has little effect on the overall water quality of the lake due to the reduced percentage.

Major sources of water input to Lake Alvin was Nine Mile Creek at 80.3 percent of the total hydrologic load, followed by the ungauged portion of the watershed contributing 16.1 percent. Other sources of input were precipitation and groundwater contributing 3.5 and 0.2 percent of the total load, respectively (Figure 58).

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 Nine Mile Creek and the estimated amount from the ungauged portion of the watershed, Lake Alvin received approximately 183.3 m^3 (0.15 acre-feet) of sediment in 1999. The volume of sediment was calculated by dividing the annual kilograms of sediment (396,485 kg) by 2,162.5 kg/m^3 (Stueven and Bren 1999).

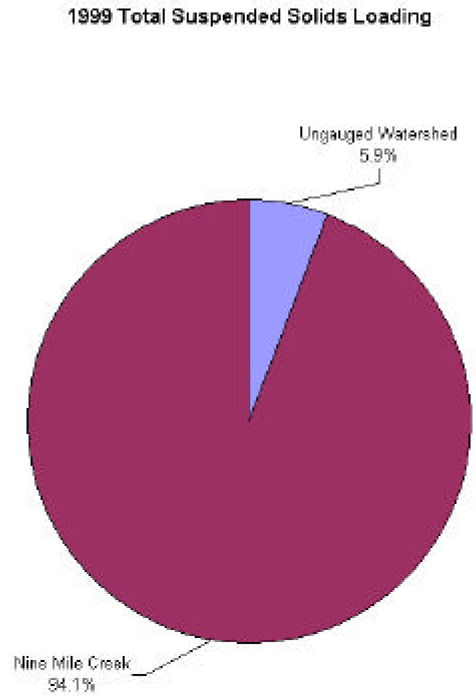


Figure 59. Percent total suspended solids loading to Lake Alvin, Lincoln County, South Dakota by source in 1999.

Figure 59 shows the estimated percentage of total suspended solids loading from Nine Mile Creek areas derived from water quality sampling. Measured loadings from Nine Mile Creek were by far the greatest at 94.1 percent. The ungauged portion of the watershed contributed 5.9 percent of the total suspended solids load to Lake Alvin based upon modified coefficients. A percentage of this load was from erosion from lack of vegetative cover, cutbank erosion and bank sloughing near the shoreline. The majority of these areas on the southern side of the lake are caused in part by allowing cattle access to these areas. Cattle tend to consume and trample down vegetative cover causing increased erosion and bank stabilization problems

The calculation of total suspended solids at the outlet (LAT-7) found approximately 111,956 kg or 51.8 m^3 (0.04 acre-feet) of sediment leaving Lake Alvin. The amount of sediment retained in Lake Alvin during this study was approximately 284,529 kg, which is 62.8 m^3 (0.05 acre-feet) or 71.8 percent of the total loading to the lake in 1999.

To estimate the average organic portion of total suspended solids leaving Lake Alvin, the total kilograms per year of volatile total suspended solids were divided by the total suspended solids to predict the percentage of organic suspended solids. The organic percentage of suspended solids measured at LAT-7 (outlet) was 36.9 percent. In comparison, the overall average inlake percentage of volatile total suspended solids at LA-1 (up stream site) was 49.4 percent while the percentage of volatile total suspended solids at LA-2 (inlake sampling site closest to the outlet) was 51.9 percent. The estimated volatile total suspended solids that was discharged from Lake Alvin was approximately 19.1 m^3 (0.02 acre-feet) using the outlet overall average and 26.9 m^3 (0.02 acre-feet) using the average inlake concentration percentage at LA-2. Reducing suspended solids concentrations to Lake Alvin should be beneficial in reducing trophic state indices and the non-supporting (hyper-eutrophic) condition of the lake.

Nitrogen Budget

Inputs for the nitrogen budget for Lake Alvin were from tributaries (gauged and ungauged) and ground water. 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 nitrate from the time it enters the lake until it leaves.

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 is impossible 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 data was collected, the inputs will be estimated as minimal and not considered in this report. The estimated ungauged tributary inputs for nitrogen parameters were calculated using the nearest sub-watershed export coefficient (LAT-6). The following charts show the percent of nitrogen loadings from different sources (Figure 60, Figure 61, Figure 62, and Figure 63).

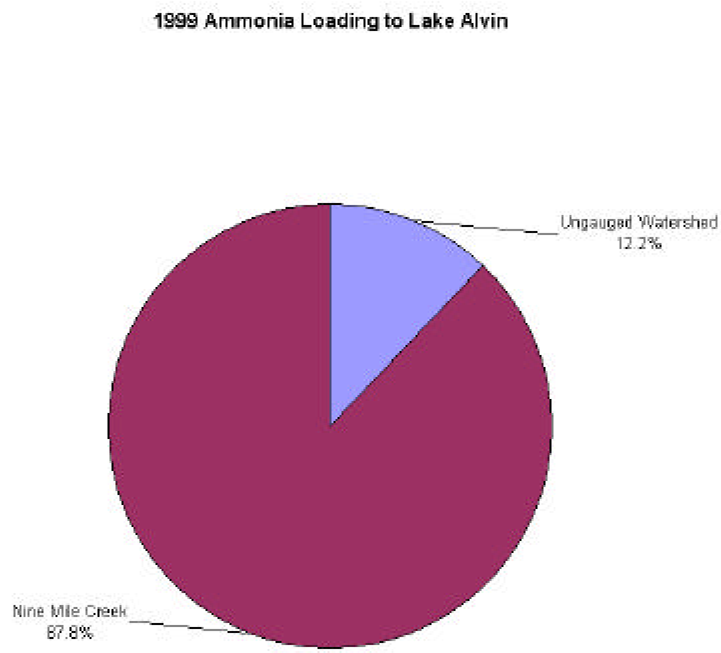


Figure 60. Percent ammonia loading to Lake Alvin, Lincoln County, South Dakota by source in 1999.

The ammonia (NH_3) budget for Lake Alvin showed an increase in inlake ammonia of 222.3 kg (490.1 pounds) or 47.8 percent of the total loading to the lake. As can be seen from Figure 60, the largest input was from Nine Mile Creek (88.7 percent). Approximately 52.2 percent of the total ammonia load to Lake Alvin was lost to algae or converted to other forms of nitrogen because ammonia is inorganic and is readily used by algae for uptake and growth.

Another inorganic parameter sampled was nitrate-nitrite (NO_3^- and NO_2^-). The nitrate-nitrite budget indicated Lake Alvin was retaining a small amount of nitrate. The estimated amount of nitrate-nitrite added (retained in) to Lake Alvin was 26.3 percent of the input or 3,317.7 kg (3.7 tons). Nine Mile Creek had the largest input of nitrate-nitrite (87.4 percent) partially because it comprises 79.8 percent of the watershed (Figure 61). Blue-green algae can take up nitrate-nitrite nitrogen if available and convert it to ammonia for use through a nitrate reduction process.

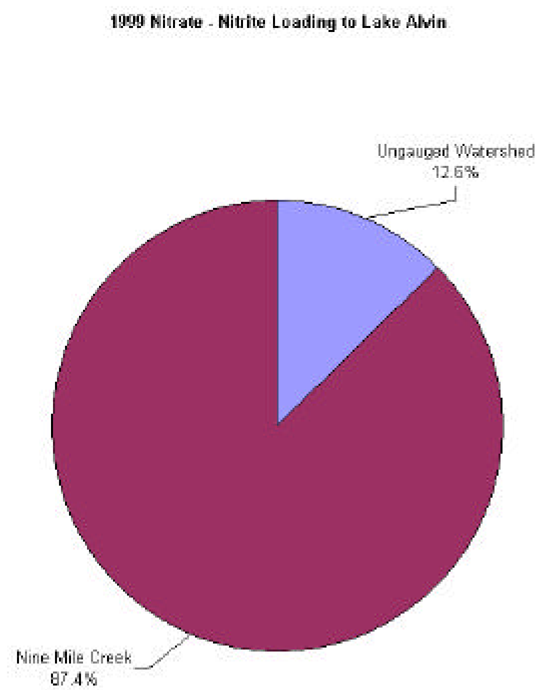


Figure 61. Percent nitrate-nitrite loading to Lake Alvin, Lincoln County, South Dakota by source in 1999.

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. Figure 62 shows Nine Mile Creek contributed the largest input 7,037.5 kg or 83.6 percent of the total organic nitrogen loading. Approximately 1,397.9 kg (1.5 tons) or 16.6 percent more organic nitrogen left Lake Alvin than entered from the tributaries, indicating a reduction in a portion of the available nitrogen during the project (6.5 percent).

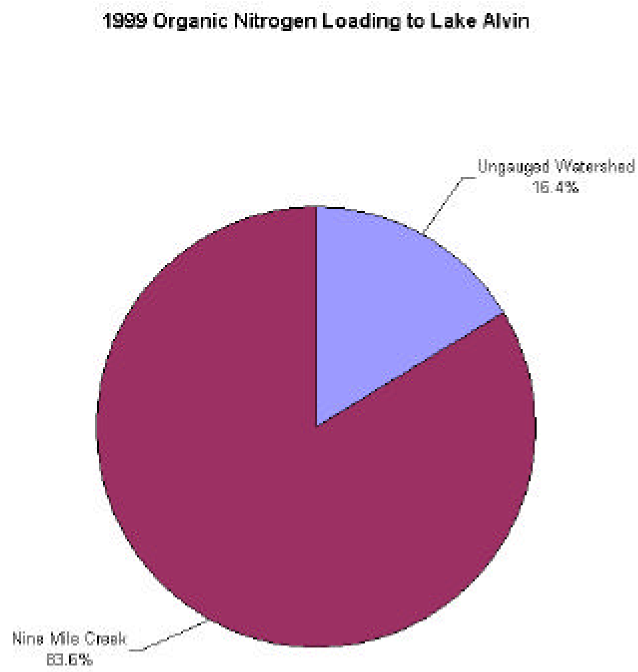


Figure 62. Percent organic nitrogen loading to Lake Alvin, Lincoln County, South Dakota by source in 1999.

Total nitrogen concentrations are derived from adding TKN concentrations to nitrate–nitrite concentrations. Approximately 2,100 kg (2.3 tons) or 9.8 percent of the total nitrogen load was retained in Lake Alvin during 1999. Figure 63 identifies Nine Mile Creek as contributing the largest input 18,476 kg or 86.1 percent of the total nitrogen loading. 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. Reductions in the organic nitrogen portion of total nitrogen may partially support the inlake total nitrogen-to-total phosphorus ratios switching from a phosphorus-limited in the spring to nitrogen-limited in the summer into early winter (Figure 44). 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 hypereutrophic (non-supporting) condition found in Lake Alvin.

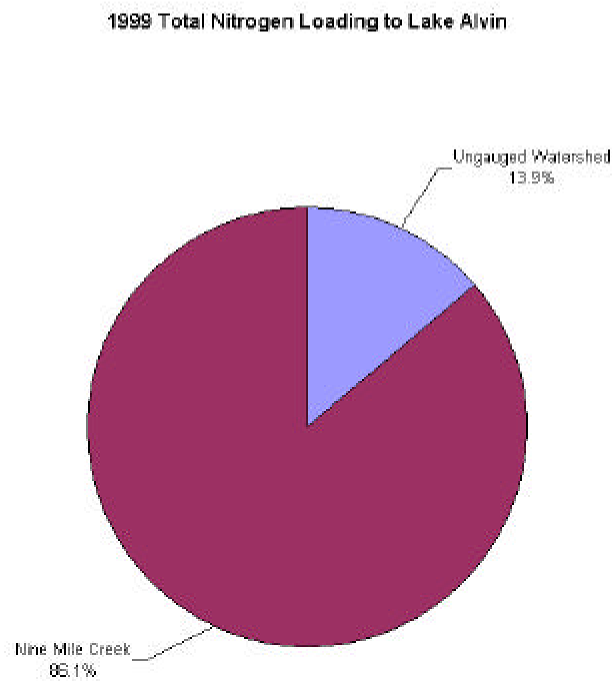


Figure 63. Percent total nitrogen loading to Lake Alvin, Lincoln County, South Dakota by source in 1999.

Phosphorus Budget

Total phosphorus inputs to Lake Alvin during the 1999 sampling season totaled approximately 1,314 kg (1.4 tons). Inputs to Lake Alvin included gauged tributaries, an estimate for ungauged tributaries, ground water, and precipitation (Figure 64). The ground water load of phosphorus in most lakes is insignificant compared to tributary inputs. In addition, as with nitrogen, there is no way to know how much ground water entered the lake and how much left the lake. Assuming the same concentration is leaving through ground water as entering, (0.02 mg/L) the load to Lake Alvin would only be 0.26 kg or 0.02 percent of the total phosphorus load to the lake (Wetzel 1983). The precipitation load was multiplied by 0.03 mg/L, an average often found in unpopulated areas (Wetzel, 1983), and was 7.2 kg (15.9 pounds) or 0.5 percent. The ungauged tributary load was estimated by using adjusted export coefficients derived from water quality loading data.

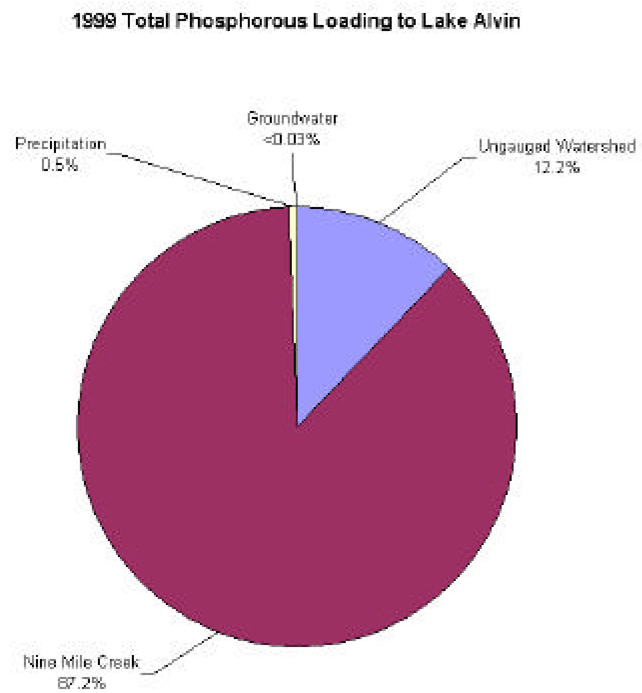


Figure 64. Percent total phosphorus loading to Lake Alvin, Lincoln County, South Dakota by source in 1999.

The total load out of Lake Alvin was approximately 710 kg (3.6 tons). In the 1999 sampling season, there was an estimated 604 kg (0.67 tons), or 45.9 percent more phosphorus entered the lake than left the lake. This does not include the phosphorus attached to the sediment that fell in or eroded from the shoreline. Because sediment is an excellent source of phosphorus, any erosional areas near the shoreline of the lake contributed (delivered) an unmeasured source of phosphorus to the lake. The phosphorus from shoreline erosion would most likely be found as total phosphorus instead of dissolved phosphorus. Again, Nine Mile Creek contributed the largest load (1,147 kg) or 87.2 percent of the total phosphorus load to Lake Alvin. Increased inlake concentrations of total phosphorus were observed from late summer through early winter. Related to the discussion from the total nitrogen budget, increasing total phosphorus concentrations in conjunction with steady or decreasing total nitrogen concentrations contributes to the shift in nutrient limitation observed in 1999.

Lake Alvin had no excessive nuisance algal blooms; however, Figure 47 shows that there were increases algal cells/m and biovolume from July through December indicating algae were assimilating total phosphorus and to some extent total nitrogen during this period. This suggests total phosphorus concentrations were not controlling algae production in Lake Alvin in 1999. Other factors or combination of factors such as total nitrogen, total suspended solids or light transparency may have controlled the algal population during this time.

Increases in inlake total phosphorus were not from the release of phosphorus from bottom sediments because surface water total phosphorus concentrations were not significantly different from bottom concentrations collected at the same time ($p>0.05$). However, the sediment release of phosphorus to the hypolimnion during the spring and summer may have augmented epilimnion concentrations during this time. Reducing the influx of total phosphorus will improve the overall trophic state of the lake and increase the beneficial use status of Lake Alvin.

Total Dissolved Phosphorus

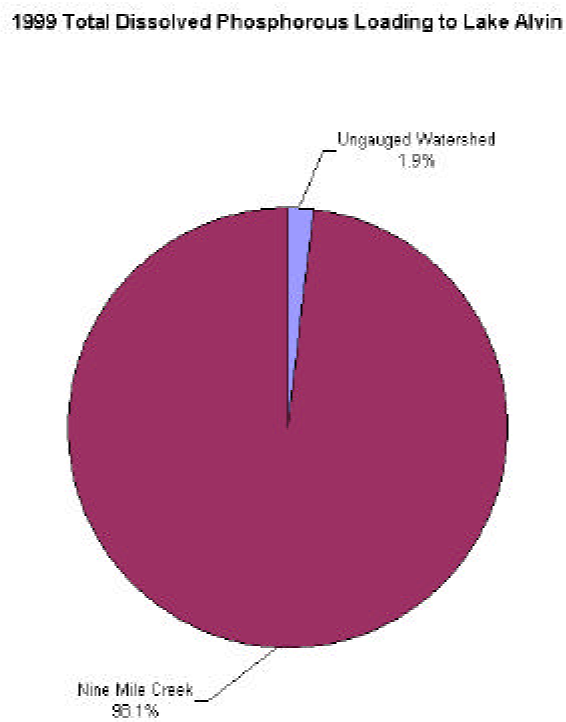


Figure 65. Percent total dissolved phosphorus loading to Lake Alvin, Lincoln County, South Dakota by source in 1999.

The inputs of total dissolved phosphorus (Figure 65) in Lake Alvin were estimated at 594 kg (0.65 tons). Lake Alvin retained approximately 68.6 percent (407 kg) of the total dissolved phosphorus load. Tributary loading percentage of dissolved phosphorus in total phosphorus was 45.2 percent while the outlet percentage of total dissolved phosphorus was only 26.2 percent. The 19 percent difference may imply internal utilization of total dissolved phosphorus by algae for metabolism, growth and reproduction. Decreases may also be from the tendency of dissolved phosphorus to sorb on to particles suspended in the water column both organic and inorganic. Reducing the influx of total dissolved phosphorus will improve the overall trophic state of Lake Alvin.

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 the lake. Trophic states range from oligotrophic (least productive) to hyper-eutrophic (excessive amounts of nutrients and production). Table 40 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 for Lake Alvin are shown in Table 41 and a graph showing all of the TSI readings for 1999 plotted on Carlson trophic levels is shown in Figure 66.

Table 40. Carlson trophic levels and numeric ranges by each 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. This document proposed ecoregion-specific targeted TSI values based on beneficial uses. 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 statewide. Lake Alvin is in ecoregion 46R and is categorized as partially supporting based on the SD DENR (2000a) document. There are three beneficial use categories: non-supporting, partially supporting and fully supporting. Numeric ranges for beneficial use categories are shown in Table 41.

Table 41. Ecoregion 46 R beneficial use category and Carlson TSI numeric ranges by category.

Ecoregion (46 R) Beneficial Use Category	TSI Numeric Range
Non-Supporting	76 – 100
Partially Supporting	66 – 75
Fully Supporting	0 – 65

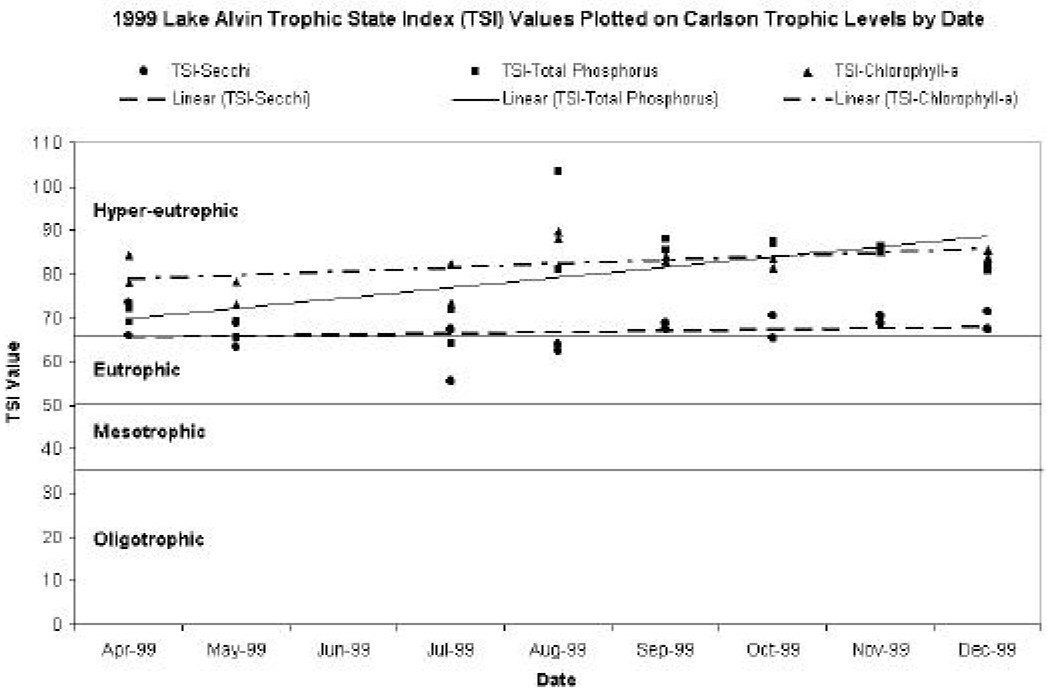


Figure 66. TSI values for phosphorus, chlorophyll-*a* and Secchi concentrations plotted by Carlson trophic level with trend lines from Lake Alvin, Lincoln County, South Dakota by date in 1999.

Trophic state index values are plotted using beneficial use categories in Figure 67. Generally, most of the TSI values (especially total phosphorus and chlorophyll- *a* TSI values) were in the partially supporting and non-supporting category. Lake Alvin is categorized as partially supporting (upper partially supporting) using ecoregion targeting (SD DENR 2000a). However, average 1999 TSI values indicated that Lake Alvin was non-supporting during this study. The mean and median for chlorophyll- *a* and total phosphorus TSI were non-supporting (hyper-eutrophic), with the mean and median Secchi TSI just into the partially supporting (eutrophic) category (Table 42). The average TSI rating over the entire project, based on observed data was 76.38.

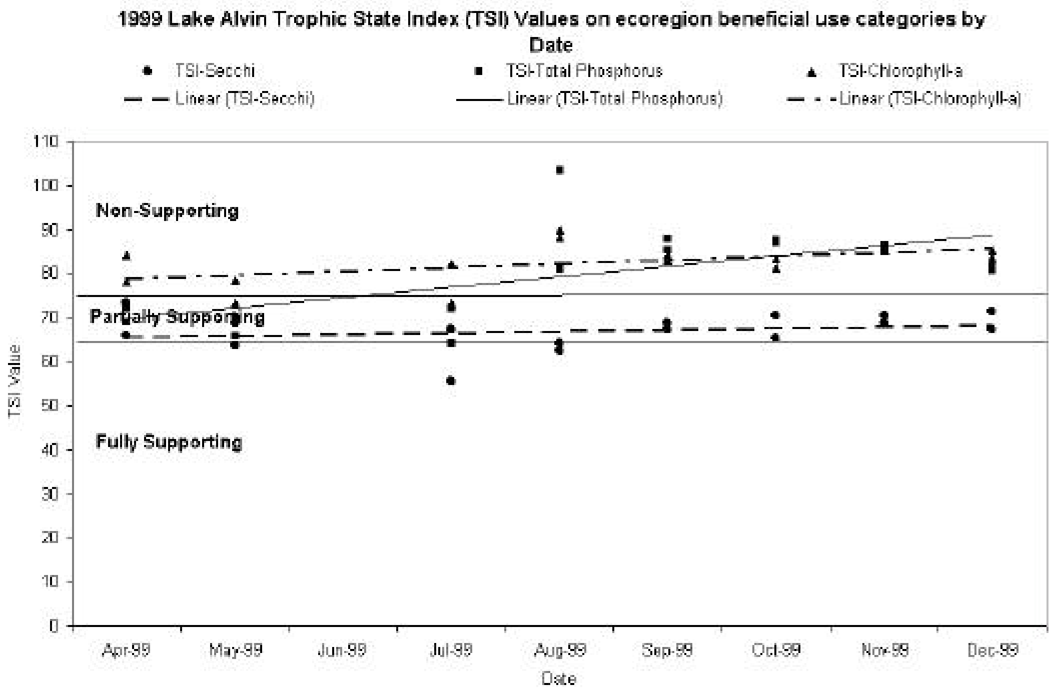


Figure 67. TSI values for phosphorus, chlorophyll-*a* and Secchi concentrations plotted by ecoregion 46 R beneficial use categories with trend lines from Lake Alvin, Lincoln County, South Dakota by date in 1999.

Table 42. Descriptive statistics for observed trophic state index values collected in Lake Alvin, Lincoln County, South Dakota in 1999.

Parameter	Chlorophyll-*a*	Total Phosphorus	Secchi Depth	Parameters Combined
Mean TSI	82.41	79.93	66.79	76.38
Median TSI	83.43	81.02	67.14	77.81
Standard Deviation	4.52	10.12	4.13	5.27

TSI trends for this study are plotted on Carlson trophic levels in Figure 66 and on ecoregion 46 R beneficial use categories in Figure 67. Secchi TSI trend increased slightly during the sampling period, which hovered around the partially supporting/fully supporting (eutrophic/hyper-eutrophic) category boundary. The chlorophyll-*a* TSI trend increased slightly over the period. Although numerically higher, the chlorophyll- *a* TSI trend increases were similar to the Secchi TSI trend (slope 0.03 and 0.01, respectively). Total phosphorus TSI trend increased from early spring through early winter 1999 (slope 0.08) which resulted in depressed total nitrogen/total phosphorus ratios in the late summer through early winter. This suggests that during 1999, phosphorus TSI values (concentrations) were more variable and had more effect on mean TSI values than Secchi or chlorophyll- *a*.

Long -Term Trends

Because there were a number of samples collected from this study and the Statewide Lake Assessment (Stueven and Stewart 1996), it is possible to make some assumptions about the water quality trends in Lake Alvin over time. Since the samples taken in 1989, 1991, 1992 and 1998 were collected in the summer, generally summer samples (May, July, August and September) collected during this project were used in the trend analysis. Long-term TSI values were plotted on both Carlson's trophic levels and ecoregion beneficial use categories for comparison (Figure 68 and Figure 69).

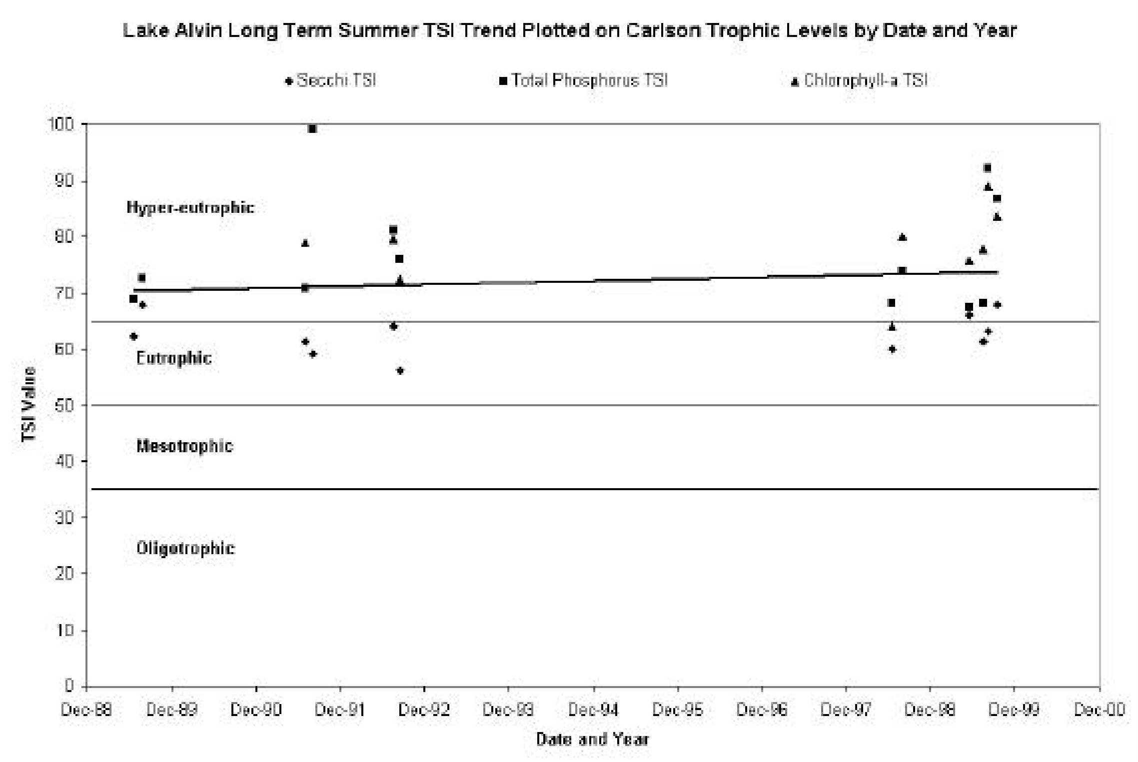


Figure 68. Long-term summer TSI trend for phosphorus, chlorophyll-*a* concentrations and Secchi depth plotted by Carlson trophic levels in Lake Alvin, Lincoln County, South Dakota by year and date.

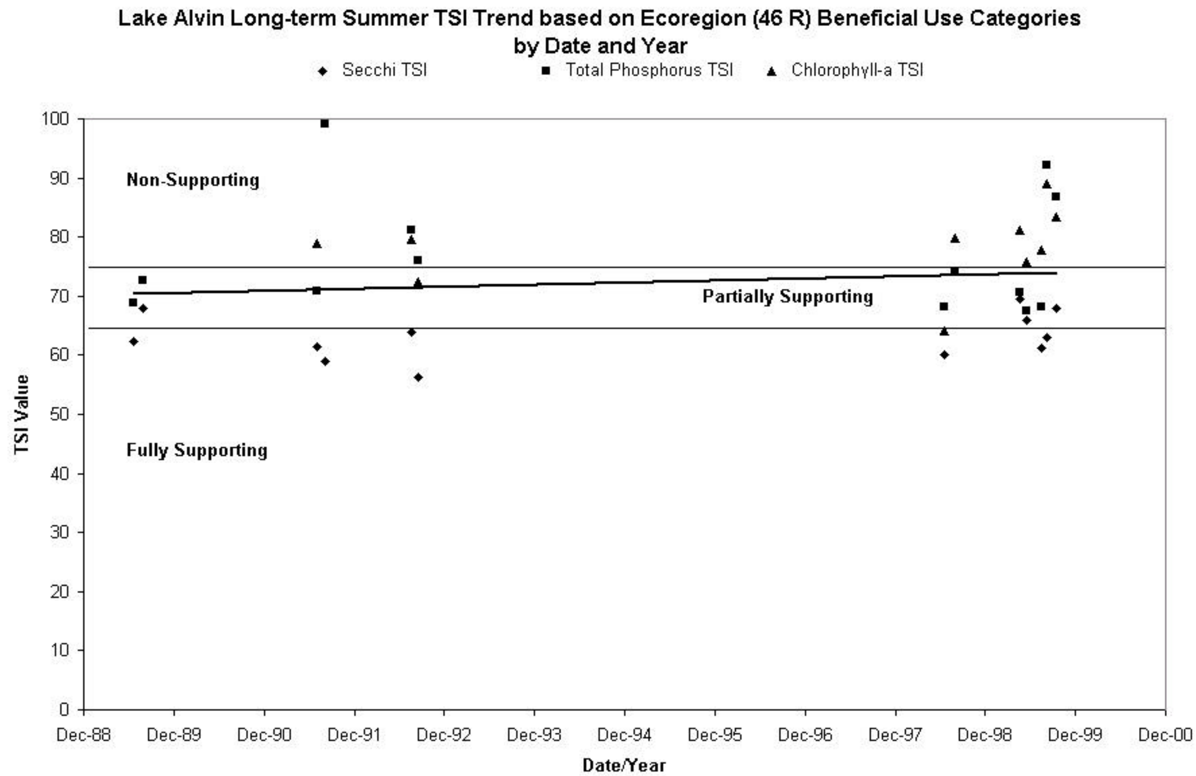


Figure 69. Long term summer TSI trend for phosphorus, chlorophyll-*a* concentrations and Secchi depth plotted by ecoregion (46 R) beneficial use categories in Lake Alvin, Lincoln County, South Dakota by year and date.

The general trend for all TSI values (Secchi, chlorophyll- *a* and total phosphorus) showed a slight increase from 1989 through 1999. No samples were collected from 1993 through 1997 in Lake Alvin. All TSI values, except for eight Secchi and one chlorophyll- *a* value were in the non-supporting and partially supporting (eutrophic/hyper-eutrophic) category (Figure 68 and Figure 69). The long-term trend for all TSI values indicates an increasing trend within the partially supporting category (Figure 69). Mitigation projects in the Lake Alvin watershed should, over time, reduce nutrient TSI values, reversing the overall trend observed from 1989 to 1999.

Reduction Response Model (BATHTUB)

The reduction response model used to predict inlake response to reductions in tributary input was BATHTUB (US ACOE 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. Inlake 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 the Lake Alvin watershed for 1999 (Table 43). Existing nitrogen and phosphorus concentrations were reduced by 10 percent successively (10 percent increments) and modeled to create an inlake reduction curve. Reductions in each TSI category

(Secchi, total phosphorus and chlorophyll-*a*) are plotted by ecoregion 46 R beneficial use categories separately in Figure 70.

Table 43. Existing and predicted tributary reductions in nitrogen and phosphorus concentrations and predicted inlake mean TSI values using 'BATHTUB'.

Percent Reduction	Total Nitrogen Concentration	Inorganic Nitrogen Concentration	Total Phosphorous Concentration	Total Dissolved Phosphorous Concentration	Estimated Inlake Mean TSI Reduction
0%	2709.6	1314.2	230.2	146.9	79.57
10%	2438.7	1182.7	207.2	132.2	78.19
20%	2167.7	1051.3	184.2	117.6	76.64
30%	1896.7	919.9	161.1	102.9	74.89
40%	1625.8	788.5	138.1	88.2	72.88
50%	1354.8	657.1	115.1	73.5	70.51
60%	1083.8	525.7	92.1	58.8	67.61
70%	812.9	394.2	69.1	44.1	63.89
80%	541.9	262.8	46.0	29.4	58.71
90%	271.0	131.4	23.0	14.7	50.05
99%	27.1	13.1	2.3	1.5	26.58

Secchi, chlorophyll-*a* and total phosphorus trophic state index reduction values all begin in the non-supporting category. TSI reduction values decline at a steady rate within the non-supporting category and run relatively parallel to one another. The predicted reduction lines within the partially supporting category begin to converge especially in the 50 to 65 percent load reduction range. This suggests that total phosphorus and chlorophyll-*a* predicted TSI reduction values decline slightly more than Secchi TSI values at the same percent reduction. Predicted TSI reduction lines for total phosphorus and chlorophyll-*a*, cross the Secchi line within the fully supporting beneficial use category, indicating total phosphorus and chlorophyll-*a* TSI values reduce more than Secchi TSI values within this category.

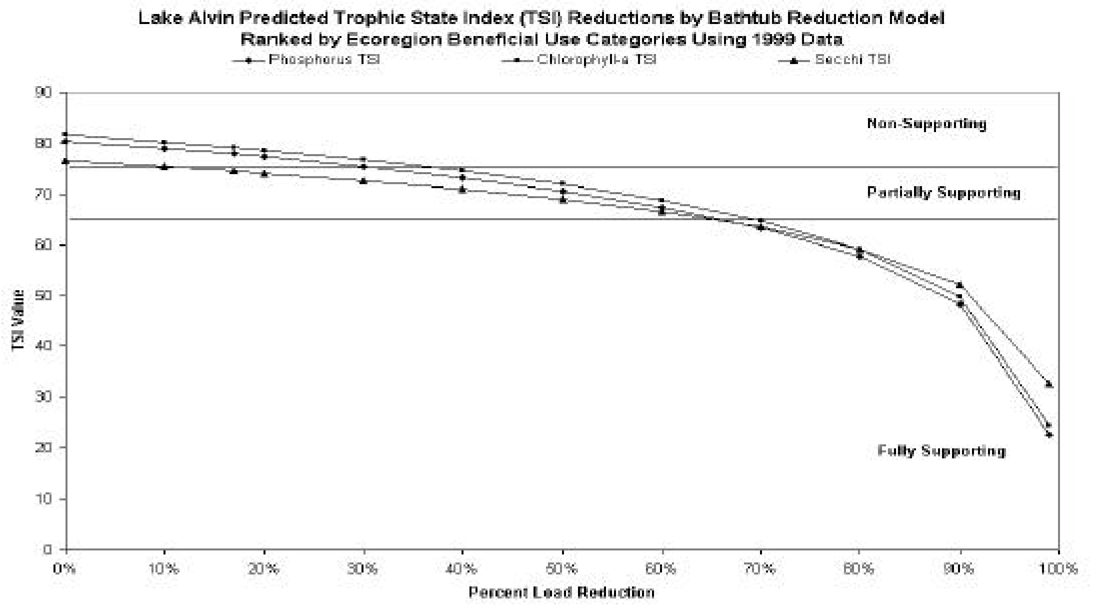


Figure 70. Predicted trophic state index (TSI) reductions using the BATHTUB reduction model ranked by ecoregion 46 R beneficial use categories for Lake Alvin, Lincoln County, South Dakota using 1999 data.

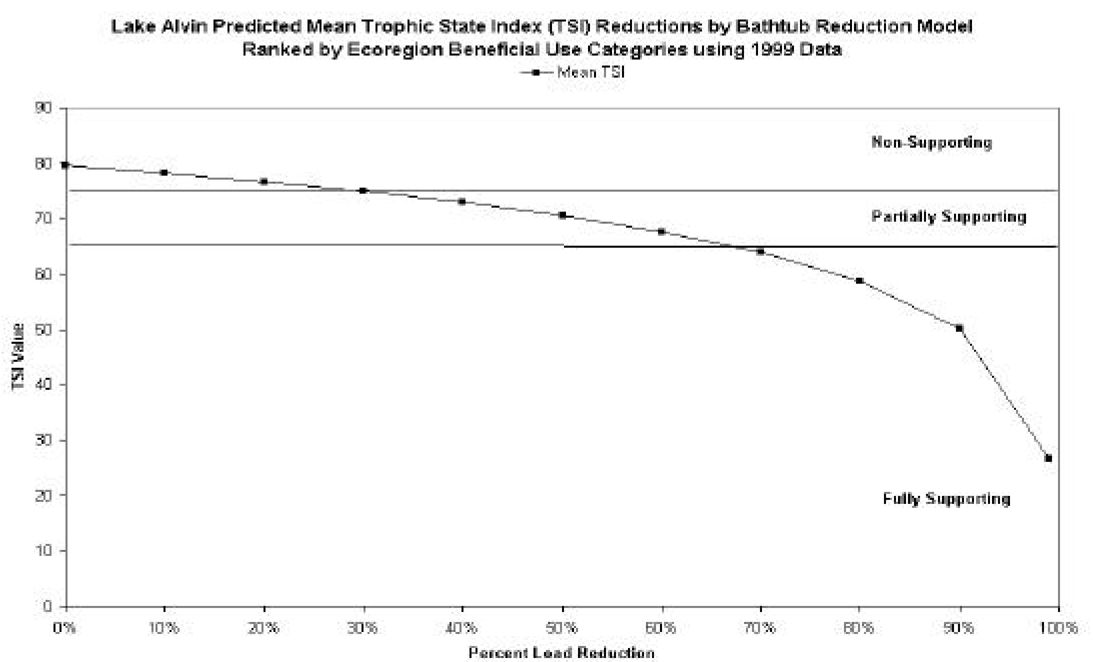


Figure 71. Predicted mean trophic state index (TSI) reductions using the BATHTUB reduction model ranked by ecoregion 46 R beneficial use categories for Lake Alvin, Lincoln County, South Dakota using 1999 loading data.

Mean TSI values were calculated for each reduction and plotted by beneficial use categories (Figure 71). Current mean TSI values for 1999 were calculated using "BATHTUB" and found to be non-supporting although Lake Alvin is ranked as partially supporting (SD DENR 2000). Using predicted TSI reductions based upon the 1999 water quality data, a 30 percent reduction in mean TSI values will bring the lake into partially supporting status and 67 percent reduction in mean TSI will bring Lake Alvin into fully supporting its beneficial uses (Figure 71).

Inlake Summary

Inlake samples from Lake Alvin were collected from April through December, 1999. Only two samples exceeded water quality standards during this period. Both exceedances (un-ionized ammonia and dissolved oxygen) were recorded at LA-2 on August 12, 1999. The un-ionized ammonia at LA-2 exceeded the water quality standard by a factor of 1.74 and dissolved oxygen was 1.6 mg/L below the water quality standard. Seven other parameters (alkalinity, ammonia, Total Kjeidahl Nitrogen (TKN), total nitrogen, total phosphorus, total dissolved phosphorus and chlorophyll-*a*) were also elevated at LA-2 in August.

Lake Alvin is listed on the 303(d) waterbody list for fecal coliform bacteria. No monthly inlake samples exceeded water quality standards for fecal coliform bacteria; however, beach samples collected by SD GF&P exceeded the fecal coliform water quality standard for public beaches (Chapter 74:04:08:07). The beach was closed from June 7, 1999 through June 23, 1999 after daily samples exceeded 1,000 colonies per 100 ml for any one sample, 300 colonies/ 100 ml for two consecutive samples and 200 colonies/ 100 ml for three consecutive samples. The beach reopened on June 23, 1999 and did not exceed the surface water quality or beach standards the rest of the season.

The Lake Alvin algal community exhibited some unusual trends during this survey that are not commonly observed in other eutrophic lakes in eastern South Dakota. For example, annual diatom peaks usually occur in spring rather than in late autumn. Maximum total algae densities are usually recorded in spring and/or summer rather than in the fall. In addition, spring blooms of *Nitzschia acicularis* and summer blooms of dinoflagellates of the *Peridinium/Glenodinium* genera did not appear to be common in other monitored state lakes. However, they were recorded previously in a few other highly eutrophic state lakes, notably, spring blooms of the diatom *Nitzschia acicularis* in Clear Lake (Deuel Co.) and Lake St. John; and summer blooms of the dinoflagellate *Peridinium* sp. (previously recorded as *Glenodinium gymnodinium*) in Lake Faulkton and Lake Campbell (Brookings Co.). Nutrients and water temperatures were at high levels in Lake Alvin during August and September, 1999, but blue-green algae, primarily, *Aphanizomenon flos-aquae* actually decreased abruptly in those months.

The lack of submerged vegetation in Lake Alvin appears to be a result of decreased light penetration due to organic and inorganic turbidity, and areas of relatively steep littoral zones. Reductions in sediment and nutrient loads to the lake, along with mechanical circulation at LA-2 should improve Secchi depth and transparency. Improving Secchi depth will allow littoral colonization of submerged macrophytes in regions of Lake Alvin conducive to colonization, which will increase the uptake of nutrients and increase habitat for fish and macroinvertebrates. Macrophyte colonization may also be affected by common carp densities.

Nutrient limitation factors can be anything physical or chemical that limits the growth or production of organisms. Although phosphorus limitation was detected in the spring, algal densities (cells/ml) increased in May and gradually decreased in August and September; however, biovolume (μm^3/ml) continued to increase through the shift in limiting factors (Figure 44 and Figure 47). At this same time *Aphanizomenon flos–aquae*, a nitrogen-fixing alga (able to fix dissolved atmospheric nitrogen N_2 via heterocysts when concentrations are reduced), declined in August (after the shift) and *Oscillatoria* sp., a non-nitrogen fixing alga (not able to fix atmospheric nitrogen), declined from 95,025 μm^3/ml in August to zero from September through November. This data tends to support the TN:TP ratio shift from phosphorus limited to nitrogen limited. Other factors were also acting on the algal population such as total suspended solids (organic and inorganic), stratification (thermal), temperature and Secchi depth (turbidity).

The benthic macroinvertebrate samples collected in Lake Alvin were compared to several other benthic lake samples collected in 1999 within ecoregion 46 R (Blue Dog and Enemy Swim Lakes). Average benthic diversity and evenness values for Lake Alvin (LA-1a and LA-2a (north)) in March 2000 was 1.72 and 0.73, respectively. Two benthic samples from Blue Dog Lake had similar diversity values (1.62 and 1.48, respectively) and were nearly equal to those of Lake Alvin site LA-1a. Species richness between Lake Alvin (10 species) and Blue Dog Lake (11 species) were also similar, however Blue Dog Lake species included amphipods, abundant nematodes, Trichoptera and water mites, groups common in eutrophic lakes. LA-2a (north) was the only site with enough data to run metrics, so no valid comparison could be made with available data. Benthic samples from Enemy Swim Lake (a lake fully supporting beneficial uses) had diversity and evenness values well above those in Lake Alvin or Blue Dog Lake (lakes partially supporting beneficial uses). At present, severe conditions at LA-2a for benthic life in the sediments of Lake Alvin are also indicated by the absence or rarity of a number of invertebrate groups usually common in eutrophic lakes and reservoirs. Conditions at LA-2a could be improved by installing an inlake circulator or aerator during the spring and summer, which would improve dissolved oxygen concentrations in the downstream half of Lake Alvin. Improving oxygen concentrations in the hypolimnion will allow benthic macroinvertebrates to re-colonize and process organic material in this area.

The dam that created Lake Alvin was finished in 1954. Based on a constant sedimentation rate of 4.27 mm per year obtained during this study, Lake Alvin would have approximately 0.19 meters of sediment built up over 45 years since its impoundment. This is 61.3 percent of the actual measured amount (0.31 meters), suggesting that yearly sedimentation rates vary.

Lake Alvin sediment (elutriate) samples were collected in February and April, 2000 at both inlake sampling sites. The sample collected from LA-2a that had detectable levels of six chemicals (insecticides and herbicides) in February and undetectable levels in April, may have resulted from sampling (spatial) variability, suggesting highly localized contamination. Another alternative is that the sample was an anomaly based upon four of the six chemicals that have half-lives longer than the period between sampling (63 days). At a minimum, Chlordane and Endrin (half-life of 4 years and 14 years, respectively) should have been detected in the April sample from LA-2a based on this premise.

Hydrologic loading to Lake Alvin was provided mainly by Nine Mile Creek at 80.3 percent of the total hydrologic load, followed by the ungauged portion of the watershed contributing 16.1 percent. Other sources of input were precipitation and groundwater contributing 3.5 and 0.2 percent of the total load, respectively.

Sediment and nutrient loadings, total suspended sediment, total nitrogen and total phosphorus from Nine Mile Creek were by far the greatest at 94.1, 86.1 and 87.2 percent, respectively. The ungauged portion of the watershed contributed 5.9 percent of the total suspended solids load, 13.9 percent of the total nitrogen load and 12.8 percent of the total phosphorus loading to Lake Alvin based on modified coefficients. The amount of total suspended sediment, total nitrogen and total phosphorus retained in Lake Alvin during this study was approximately 284,529 kg (313.6 tons) or 71.8 percent of the total suspended solids load, 2,100 kg (2.3 tons) or 9.8 percent of the total nitrogen load and 604 kg (0.67 tons), or 45.9 percent of the total phosphorus load to the lake. Reducing the influx of total suspended sediment, total nitrogen and total phosphorus will be beneficial for improving the beneficial use category (presently non-supporting) in Lake Alvin.

Generally, monthly TSI values (especially total phosphorus and chlorophyll- *a* TSI values) were in the partially and non-supporting category. The mean and median for chlorophyll- *a* and total phosphorus TSI values were non-supporting, with the mean and median Secchi TSI just into the partially supporting category. All long-term TSI values, except for eight Secchi and one chlorophyll-*a* value were in partially supporting and non-supporting beneficial use categories. The long-term trend for all TSI values indicated an increasing trend within the partially supporting category. Mitigation projects within Lake Alvin and its watershed should, over time, reduce nutrient TSI values reversing the overall trend observed from 1989 to 1999.

The reduction curve for mean TSI values using 1999 data were calculated using “BATHTUB” and found to be non-supporting, although Lake Alvin is ranked as partially supporting. Using predicted TSI reductions based upon the 1999 water quality data, a 30 percent reduction in mean TSI values would be needed to bring the lake into partially supporting status and a 67 percent reduction in mean TSI will bring Lake Alvin into the fully supporting beneficial use category.

Inlake Recommendations

Inlake recommendations are based on best management practices and best professional judgement. Reductions were estimated or calculated using water quality and/or AGNPS data collected during this study. Reduction percentages given in Table 26 are the expected percent reduction in sediment and nutrients delivered to Lake Alvin based on 1999 loading data. Inlake recommendations proposed will improve the beneficial use category and the trophic level of Lake Alvin.

Inlake Mechanical Circulator or Aerator

Installing a mechanical inlake circulator or aerator in the lower portion of the lake (LA-2) that would be operated during the spring and summer, will improve TSI values by approximately 3 percent based on limited SD GF&P Stockade Lake data (Table 44). Mechanical mixing of the lake will prevent thermal and chemical stratification (dissolved oxygen) during the spring and summer. This will improve oxygen concentrations in the hypolimnion, increasing the redox potential and preventing the release of phosphorus to the water column. Increasing dissolved oxygen concentrations in the hypolimnion will also allow benthic macroinvertebrates to re-colonize benthic substrate and process accumulating organic material in this region of the lake. Continuous vertical mixing breaks stratification in the lake should allow algae to circulate down below light transparency (compensation) depth reducing algal density (algal turbidity) and productivity. Lower algal densities and biovolume should decrease chlorophyll-a concentrations and increase Secchi transparency. It is recommended that the inlake circulator or aerator be used during watershed BMP implementation. Periodic monitoring should be implemented to document improvement using inlake circulation or aeration.

Aluminum Sulfate Treatment (Alum)

Alum treatment uses an aluminum sulfate slurry that, when applied to water, creates 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 and 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 up to ten years and is dependent upon the amount of alum applied, sedimentation rate and external phosphorus loading. The sedimentation rate in 1999 at Lake Alvin was 4.27 mm per year. Lake Alvin also received approximately 1486 kg (1.6 tons) of phosphorus (Nine Mile Creek 1,147 kg and ungauged 339 kg) in 1999. Watershed BMP techniques would have to be implemented to improve sediment and phosphorus loadings before attempting an alum treatment to attain long-term success.

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 inlake phosphorus is estimated based upon inlake concentrations prior to application. If alum treatment is initiated, it is suggested that approximately the lower 50 acres (downstream half) be treated because of favorable water depth ($\geq$ 3.0 m, 10 feet). The percent reductions (using BATHTUB) for alum treatment in Table 44 were calculated using the minimum percent reduction in phosphorus concentrations only (30 percent), making parameter specific estimated TSI reductions conservative.

If aluminum sulfate treatment (alum) is considered after watershed mitigation, the inlake circulator/aerator should be removed during application, allowing the alum time to settle out. Extensive monitoring should be maintained before and after alum application to estimate reductions and improvements. Once inlake improvements have been documented for the alum treatment, the circulator or aerator may be restarted and the lake monitored to determine the impact of hypolimnion circulation after alum treatment. If results are positive, continued water circulation is recommended; however, if marginal or no improvement is observed, circulation should be discontinued until inlake conditions once again decline.

Aquatic Macrophytes

Mechanical circulation and alum treatment should improve Secchi transparency. Once transparency improves, the maximum depth of macrophyte colonization increases, allowing submerged vegetation to re-colonize littoral zones within Lake Alvin naturally. It is estimated that because of the bathymetric morphology (subsurface shape or contour) of Lake Alvin, 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 might be initiated. Species to consider are already inhabiting Lake Alvin: floating-leaf pondweed (*Potamogeton natans*) and sago pondweed (*Potamogeton pectinatus*). Another species to consider might be clasping-leaf pondweed (*Potamogeton Richardsonii*) as this species is common to other lakes in ecoregion 46 R (Lake Oliver (Deuel County), Cresbard Lake (Faulk County) and Mina Lake (Brown County)). Because the success of submerged macrophyte plantings is not predictable, estimated TSI reductions were not included in this report (Table 44).

Table 44. Estimated reduction percentages for select inlake best management practices for Lake Alvin, Lincoln County, South Dakota.

Best Management Practice (BMP)	Estimated Percent Phosphorus Reduction	Estimated TSI Percent Reduction		
		Phosphorus	**Secchi**	**Chlorophyll-*a***
Mechanical Circulator or Aerator [1]	5	1.7	3.2	5.9
Aluminum Sulfate Application	30 to 90	6.3	5.3	6.2
Submerged Aquatic Macrophytes	Variable	I [2]	I	I
Estimated Total Reduction to Lake Alvin	**35**	**8.0**	**8.5**	**12.1**

[1] = Estimated based on limited Stockade Lake data
[2] = Conditions should improve but data was unavailable to calculate a viable response.

Implementing any or all inlake best management practices will augment tributary mitigation and have an overall positive impact on Lake Alvin over time.

Recommendations for Swimming Beach

The Lake Alvin swimming beach has had problems with high fecal coliform counts initiating beach closures (SD DENR 1998b and SD DENR 2000b) and Lake Alvin is listed on the 303(d) waterbody list for fecal coliform. South Dakota Department of Game, Fish and Parks indicated that most beach closures corresponded with precipitation events (SD GF&P personal communication). During this study, one beach closure occurred (June 7 through June 23, 1999); however, precipitation was less than 0.25 inches per day and most monthly inlake surface samples contained $\leq$ 10 fecal coliform colonies/100 ml (Figure 39). All fecal coliform loading and TMDL calculations and estimates followed US EPA 2001.

Table 45. Lake Alvin swimming beach fecal coliform concentrations (# fecal coliform bacteria colonie date.

							Year						
1992		1993		1994		1995		1996		1997		1998	
Date	**Count** [1]	**Date**	**Count**	**Date**	**Count**	**Date**	**Count**	**Date**	**Count**	**Date**	**Count**	**Date**	**Cou**
5/26	2	6/07	**310**	5/31	50	5/30	**3,500**	5/28	**360**	5/26	10	5/26	10
6/01	< 2	6/14	**540**	6/06	**48,000**	6/05	**15,000**	6/03	**1,700**	6/02	10	6/01	**58**
6/08	6	6/21	**2,200**	6/13	**2,100**	6/12	**610**	6/10	20	6/09	< 10	6/08	10
6/15	140	6/28	**60,000**	6/20	10	6/19	160	6/17	**840**	6/16	**1,400**	6/15	20
6/22	190	7/06	**6,000**	6/27	**1,000**	6/26	10	6/24	**360**	6/23	**1,100**	6/22	< 1
6/29	130	7/12	**1,800**	7/05	10	7/10	10	7/01	50	6/30	**3,900**	6/29	< 1
7/06	80	7/15	**340**	7/05	20	7/17	10	7/08	30	7/07	140	7/06	< 1
7/13	**51,000**	7/19	**470**	7/11	7	7/24	50	7/15	30	7/14	40	7/13	< 1
7/20	< 100	7/26	**690**	7/18	20	7/31	10	7/22	10	7/21	10	7/20	< 1
7/27	190	7/28	31	7/25	10	8/07	10	7/29	160	7/28	< 10	7/27	10
8/03	40	8/02	< 10	8/01	30	8/14	10	8/05	**650**	8/04	20	8/03	30
8/10	46	8/09	10	8/08	**800**	8/21	< 10	8/12	< 10	8/11	**1,000**	8/10	60
8/17	18	8/16	**80,000**	8/15	**1,300**	8/28	< 10	8/19	< 10	8/18	**1,200**	8/17	**23**
8/24	< 2	8/23	**3,600**	8/22	< 10			8/26	70	8/25	< 10	8/24	20
8/31	4	8/30	**8,000**	8/23	< 10							8/31	20
				8/29	**230**								
Samples/yr	**15**		**15**		**16**		**13**		**14**		**14**		**15**
Samples Exceeding TMDL [1]	**1**		**12**		**6**		**3**		**5**		**5**		**2**
Percent	**7%**		**80%**		**38%**		**23%**		**36%**		**36%**		**13%**

Overall Percent = 31%

[1] = Number of fecal coliform bacteria colonies/100 ml
[2] = Total Maximum Daily Load for swimming beach is 200 colonies/ 100 ml

Calculation of fecal decay rate (exponential decay)

$$C = C_o * e^{(-KX/U)}$$

Where C_O = average fecal coliform concentration at LAT-6
K = decay coefficient (nonsterile river water)
X = distance along axis of flow and
U = Average flow velocity

$C = 270_{\text{fecal coliform/100 ml}} *e^{(-0.51/\text{day} * 2.33\ \text{miles}/126.8\ \text{miles/day})}$

$C = 268_{\text{fecal coliform/100 ml}}$

Figure 72. Exponential decay rate calculation for the Lake Alvin watershed Lincoln County, South Dakota for 1999.

General fecal loading from the Nine Mile Creek watershed was calculated at tributary site LAT-6 (inlet) from May through September 1999 to determine if tributary fecal coliform loading significantly contributed to beach fecal coliform counts and closure. Current loading was calculated by multiplying the daily average fecal coliform count adjusted for decay and converted to fecal coliform/liter by the average liters per day. The average daily hydrologic volume in liters from Nine Mile Creek was 1.68×10^7; and 4.50×10^{10} for fecal coliform/ day. This translates to an average daily fecal coliform load of 268 fecal coliform/100 ml taking into account exponential decay (Figure 72 and Figure 73). This is lower than surface water quality standards ($\leq$ 400 colonies/ 100 ml for any one sample) and much lower than the public beach standard $\leq$ 1,000 colonies/ 100 ml for any one sample.

Current fecal coliform loading (fecal coliform/day at inlet)

$$CL = (C * 10)_{\text{fecal coliform/L}} * Q_S$$

Where CL = current fecal coliform load (fecal coliform/day)
C = average fecal coliform incorporating decay rate at inlet (fecal coliform/100 ml) and
Q_S = average stream discharge (liters/day)

$CL = (268_{\text{fecal coliform/100 ml}} * 10)_{\text{fecal coliform/L}} * (1.68 * 10^7)_{\text{L/day}}$

$CL = 4.50 * 10^{10}_{\text{fecal coliform/day}}$

Figure 73. Current fecal coliform loading calculation for the Lake Alvin watershed Lincoln County, South Dakota for 1999.

TMDL

$$TMDL_{\text{fecal coliform/day}} = WLA_{\text{fecal coliform/day}} + LA_{\text{fecal coliform/day}} + BC_{\text{fecal coliform/day}} + MOS$$

Where TMDL = total maximum daily load (fecal coliform/day)
WLA = waste load allocation
LA = load allocation
BC = background concentration and
MOS = margin of safety

$TMDL = 0_{\text{ fecal coliform/day}} + 2.04 * 10^{10}_{\text{ fecal coliform/day}} + 1.32 * 10^{10}_{\text{ fecal coliform/day}} + \text{Implicit}$

$TMDL = 3.36 * 10^{10}_{\text{ fecal coliform/day}}$

Fecal Coliform TMDL Calculation

$$TMDL = (WQS_{SB} * 10)_{\text{fecal coliform/L}} * Q_{S\ \text{L/day}}$$

Where TMDL = total maximum daily load (fecal coliform/day)
WQS_{SB} = water quality standard for the swimming beach (fecal coliform/100 ml) and
Q_S = average stream discharge (liters/day)

$TMDL = (200_{\text{ fecal coliform/100 ml}} * 10)_{\text{ fecal coliform/L}} * 1.68 * 10^{7}_{\text{L/day}}$

$TMDL = 3.36 * 10^{10}_{\text{ fecal coliform/day}}$

Waste Load Allocation

$$WLA = PS$$

Where WLA = waste load allocation (fecal coliform/day) and
PS = point source loading (fecal coliform/day)
BC = background concentration (fecal coliform/day)

WLA = 0

Load Allocation

$$LA = TMDL_{\text{fecal coliform/day}} - WLA - BC$$

Where TMDL = total maximum daily load (fecal coliform/day)
WLA = waste load allocation (fecal coliform/day)
BC = background concentration (fecal coliform/day)

$LA = 3.36 * 10^{10}_{\text{ fecal coliform/day}} - (0) - 1.32 * 10^{10}_{\text{ fecal coliform/day}}$

$LA = 2.04 * 10^{10}_{\text{ fecal coliform/day}}$

Background Concentration

$$BC_{\text{fecal coliform/day}} = (FCLC_{\text{fecal coliform/100 ml}} * 10)_{\text{fecal coliform/L}} * LSV_{\text{L/day}}$$

Where BC = background concentration (fecal coliform/day)
FCLC = fecal coliform lake concentration (laboratory detection limit in fecal coliform/100 ml) and
LSV = lake surface volume (acre feet converted to liters) [107 acre feet * 1.23 * 10^6]

$BC = (10_{\text{ fecal coliform/100 ml}} * 10)_{\text{fecal coliform/L}} * 1.32 * 10^{8}_{\text{ L/day}}$

$BC = 1.32 * 10^{10}_{\text{ fecal coliform/day}}$

Margin of Safety Implicit

Figure 74. Fecal coliform total maximum daily load calculation for Lake Alvin, Lincoln County, South Dakota based on 1999 hydrologic and loading data.

Fecal Coliform Reduction Calculation

Calculations used to estimate load reduction (delivered average fecal coliform load expressed in number of animals) needed to meet TMDL based upon average delivered animal load.

Total fecal coliform production

$TFCP = (TH * (4.20 * 10^{8}{}_{\text{fecal coliform/day}})) + (TDC * (1.00 * 10^{11}{}_{\text{fecal coliform/day}})) + (TSSC * (1.00 * 10^{11}{}_{\text{fecal coliform/day}})) + (TC * (1.00 * 10^{9}{}_{\text{fecal coliform/day}}))$

Where TFCP = total fecal coliform production (fecal coliform/day)
TH = total horses in the watershed (based on AGNPS)
TDC = total dairy cows in the watershed (based on AGNPS)
TSSC = total stock and slaughter cattle in the watershed (based on AGNPS) and
TC = total calves in the watershed (based on AGNPS)

$TFCP = (28 * (4.20 * 10^{8}{}_{\text{fecal coliform/ day}})) + (40 * (1.00 * 10^{11}{}_{\text{fecal coliform/day}})) + (332 * (1.00 * 10^{11}{}_{\text{fecal coliform/day}})) + (155 * (1.00 * 10^{9}{}_{\text{fecal coliform/day}}))$

$TFCP = 3.74 * 10^{13}{}_{\text{Fecal coliform/day}}$

Average fecal coliform production per animal

$$APPA_{\text{fecal coliform/day/animal}} = TFCP_{\text{fecal coliform/day}} / TA_{\text{animals}}$$

Where APPA = average fecal coliform production per animal (fecal coliform/day/animal)
TFCP = total fecal coliform production (fecal coliform/day) and
TA = total number of animals in the Lake Alvin watershed

$APPA = 3.74 * 10^{13}{}_{\text{fecal coliform/day}} / 555_{\text{animals}}$

$APPA = 6.74 * 10^{10}{}_{\text{fecal coliform/day/ animal}}$

Delivered load (fecal coliform/day at inlet)

$$DL = (C * 10)_{\text{fecal coliform/L}} * Q_S$$

Where DL = current delivered fecal coliform load based on 1999 hydrologic and loading data (fecal coliform/day)
C = average fecal coliform incorporating decay rate at inlet (fecal coliform/100 ml) and
Q_S = average stream discharge (liters/day)

$DL = (268_{\text{fecal coliform/100 ml}} * 10)_{\text{fecal coliform/L}} * (1.68 * 10^{7})_{\text{L/day}}$

$DL = 4.50 * 10^{10}{}_{\text{fecal coliform/day}}$

Delivery coefficient

$$DC = DL_{\text{fecal coliform/day}} / TFCP_{\text{fecal coliform/day}}$$

Where DC = delivery coefficient
DL = current delivered fecal coliform load based on 1999 hydrologic and loading data (fecal coliform/day) and
TFCP = total fecal coliform production (fecal coliform/day)

$DC = (4.50 * 10^{10}{}_{\text{fecal coliform/day}})_{\text{delivered load}} / (3.74 * 10^{13}{}_{\text{fecal coliform/day}})_{\text{production}}$

$DC = 1.20 * 10^{-3}$

Figure 75. Fecal coliform reduction calculations for Lake Alvin, Lincoln County, South Dakota based on 1999 hydrologic and loading data.

Fecal Coliform Reduction Calculation (continued)

Number of animals to be reduced to meet TMDL

$$NAR_{animals} = (TA_{animals}) - ((TMDL_{fecal\ coliform/day}) / (APPA_{fecal\ coliform/day/animal} * DC))$$

Where NAR = the estimated number of animals needed to reduce fecal coliform waste based on delivery load
TA = total number of animals in the Lake Alvin watershed
TMDL = total maximum daily load (fecal coliform/day)
APPA = average fecal coliform production per animal (fecal coliform/day/animal) and
DC = delivery coefficient

$NAR = (555_{animals}) - ((3.36 * 10^{10}{}_{fecal\ coliform/day}) / ((6.74 * 10^{10}{}_{fecal\ coliform/day/animal}) * (1.20 * 10^{-3})))$

$NAR = 140_{animals}$

Percent load reduction based on average delivered load

$$PLR = (NAR_{animals} / TA_{animals}) * 100$$

Where PLR = percent load reduction
NAR = the estimated number of animals needed to reduce fecal coliform waste based on delivery load and
TA = total number of animals in the Lake Alvin watershed

$PLR = (140_{animals} / 555_{animals}) * 100$

PLR = An estimated reduction of 140 animals should reduce fecal coliform/day loading by 25 percent, which would meet the fecal coliform TMDL.

Figure 75 (continued). Fecal coliform reduction calculations for Lake Alvin, Lincoln County, South Dakota based on 1999 hydrologic and loading data.

Inlake fecal coliform counts during summer (July and August) averaged 10 fecal coliform/100 ml at LA-2 (near the swimming beach), which are significantly lower than the average Nine Mile Creek tributary load $4.50 * 10^{10}$ fecal coliform/day (268 colonies/ 100 ml). The difference can be attributed to the significant dilution that occurs when the fecal coliform load enters the lake. Fecal coliform dilution and increased exposure time to ultraviolet light kills fecal coliform bacteria. This suggests that fecal coliform tributary loads from Nine Mile Creek (approximately 2.1 km west of the swimming beach) appears to have minimal impact on swimming beach fecal coliform counts during average flow conditions. Approximately 94 percent of the inlake fecal coliform samples were below the laboratory detection limit, indicating that generally, inlake fecal coliform bacteria concentrations are not a concern in Lake Alvin.

Swimming beach fecal coliform concentrations collected by SD GF&P from 1992 through 2000 is provided in Table 45. A total of 133 samples were collected over nine years, of which 41 samples exceeded 200 colonies/100 ml, the Total Maximum Daily Load (TMDL) for the Lake Alvin swimming beach (Appendix N). On average, 31 percent of the swimming beach samples exceeded the TMDL. The average fecal coliform concentration from samples that exceeded the TMDL was 7,822 fecal coliform/100 ml and the average concentration in samples that complied with the TMDL was 31 fecal coliform/100 ml.

Watershed fecal coliform loading was calculated using all AGNPS data from the entire watershed, including the ungauged area around Lake Alvin and the swimming beach (Figure 74 and Figure 75). Run-off from the ungauged area appeared to be diffuse, intermittent and sporadic. Incorporating the AGNPS feedlot data from the ungauged portion of the watershed with the gauged portion allowed a loading estimate for fecal coliform based on average flow for the entire watershed. Assuming dilution, ultraviolet light and exponential decay significantly reduce fecal coliform concentrations exclusively from Nine Mile Creek (approximately 2.1 km from the swimming beach), the sporadic increased fecal coliform concentrations at the swimming beach suggests a significant portion of the calculated fecal coliform load originated from the ungauged portion of the watershed. Using this scenario, fecal coliform bacteria originating from the ungauged portion of the watershed would have shortened exposure time and less dilution increasing concentrations near the swimming beach.

Based on these data, to meet the Lake Alvin fecal coliform TMDL of $3.36 * 10^{10}$ fecal coliform/day (200 fecal coliform/100 ml), the load from Nine Mile Creek, the ungauged portion of the watershed and the swimming beach should be reduced 25 percent. Delivered fecal coliform load should not exceed $2.04 * 10^{10}$ fecal coliform/day, with an additional $1.32 * 10^{10}$ fecal coliform/day background (Figure 74, Figure 75 and Table 47).

A load reduction of 25 percent should be attainable by implementing select tributary BMPs, specifically, animal waste management systems to eliminate waste from a minimum of 140 animals (Figure 75). Additional reductions in fecal coliform concentrations may be achieved by riparian management, buffer strips and controlling localized contamination by humans and dogs through an information and education (I&E) program to educate the public on fecal coliform and ways to prevent beach contamination utilizing signs and brochures. Public compliance/participation should reduce localized fecal coliform counts from the swimming beach at Lake Alvin.

Another consideration is to standardize fecal coliform sample collection methods (training) to reduce both sampling and sample variability, which may artificially elevate fecal coliform concentrations. Implementing any or all of these BMPs throughout the watershed should reduce (lower) fecal coliform counts.

Watershed Recommendations (Targeted Reduction)

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 46 R beneficial use categories and are shown in Figure 76 and Figure 77. Tributary and inlake TSI reductions were based on best management practices and best professional judgement. Reductions in TSI are based on tributary and inlake BMP recommendations outlined on pages 38 through 40 and 114 through 116 of this report, respectively. The margin of safety for phosphorus is both implicit and explicit. Implicit in that all reduction estimations for both tributary and inlake reductions were calculated using extremely conservative reduction percentages and explicit by an additional 14 percent phosphorus reduction over and above the 67% needed to full support beneficial uses (Appendix N).

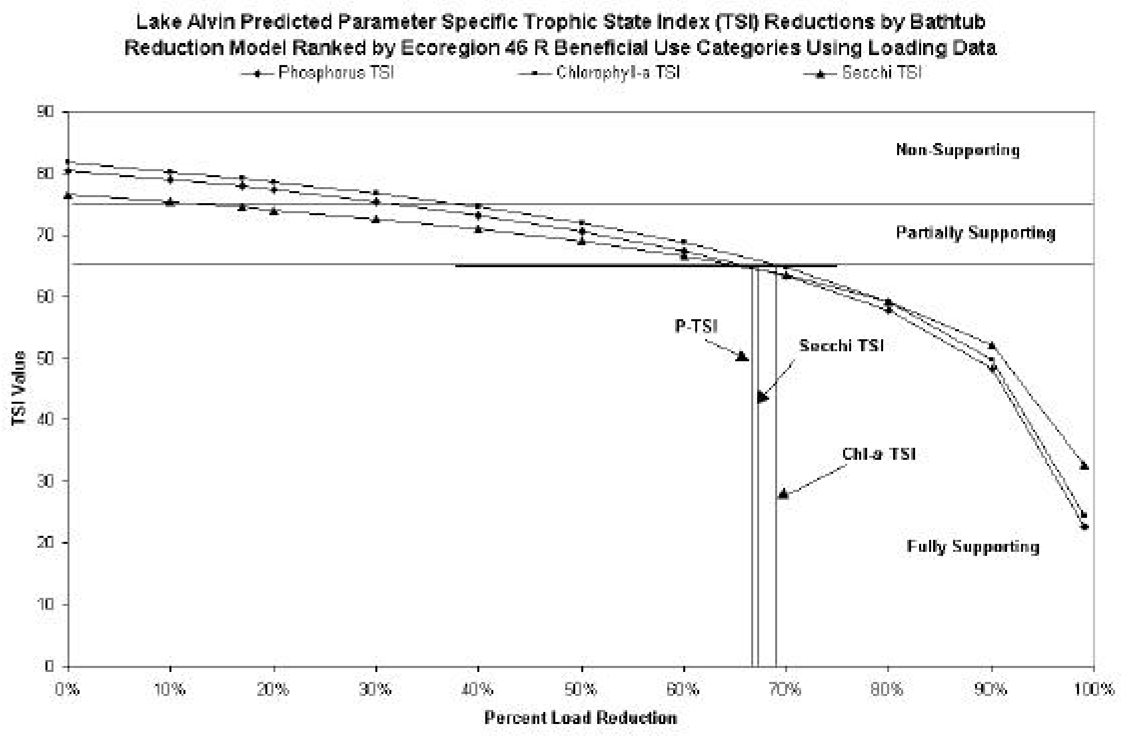


Figure 76. Predicted parameter specific trophic state index (TSI) reductions using the BATHTUB reduction model ranked by beneficial use categories for Lake Alvin, Lincoln County, South Dakota using 1999 loading data.

In 1999, phosphorus, chlorophyll-*a* and Secchi TSI values (80.47, 81.75 and 76.48, respectively) were non-supporting (Figure 76). SD DENR-recommended targets for specific TSI parameters for Lake Alvin are: 64.55 for phosphorus, 65.93 for chlorophyll-*a* and 64.38 for Secchi visibility (Table 46). To reach these goals, phosphorus loads will have to be reduced by 67 percent. These reductions should improve phosphorus TSI by 19.8 percent, chlorophyll-*a* TSI by 19.4 percent and Secchi TSI by 15.8 percent, which will improve inlake water quality. Reductions outlined above will improve the Lake Alvin beneficial use category from non-supporting to fully supporting. Both during and after implementing BMPs to reduce sediment, nitrogen and phosphorus loads to the lake, long-term tributary and inlake monitoring should be conducted to evaluate BMPs effectiveness and determine if inlake TSI targets have been reached.

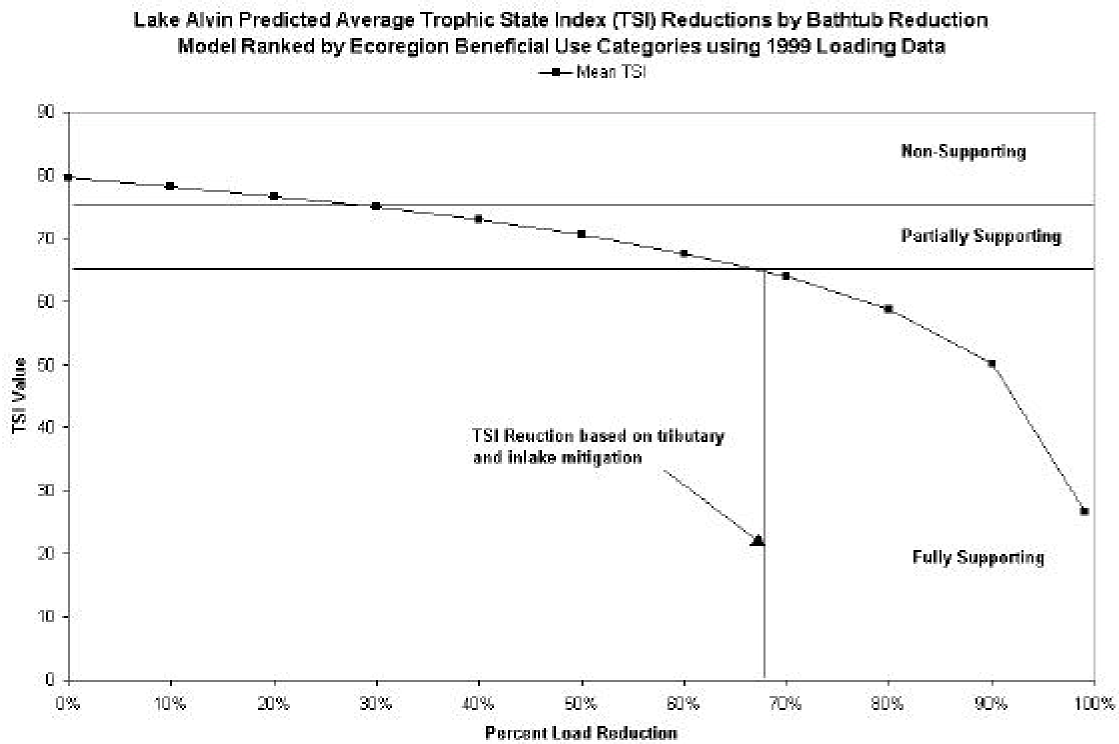


Figure 77. Predicted mean trophic state index (TSI) reductions using the BATHTUB reduction model ranked by ecoregion 46 R beneficial use categories for Lake Alvin, Lincoln County, South Dakota using 1999 loading data.

The average TSI value for phosphorus, chlorophyll-*a* and Secchi combined (79.57) was also in the non-supporting category (Figure 77). The recommended target for an average TSI value in Lake Alvin is 64.95 (Table 46). This goal can be reached if the following tributary BMPs are implemented in priority subwatersheds; minimum tillage in select areas, riparian restoration (a variety of techniques), stabilize eroded streambanks, fertilizer concentrations reduced with modified rates and application time, buffer strip planting and waste management systems implemented on animal feeding areas rated over 40. Inlake BMPs to reduce phosphorus should include installing an inlake aerator/circulator and an alum treatment.

An overall average reduction in current loadings of approximately 67 percent is expected after implementing both tributary and inlake BMPs (Figure 77). The implicit margin of safety for phosphorus is inherently conservative in both tributary and inlake BMP reductions and explicit by an additional 14 percent phosphorus reduction over and above the 67 percent should ensure TSI and TMDL attainment in Lake Alvin (Table 47). Select inlake BMPs (mechanical circulator or aerator) should be implemented during tributary mitigation and others after (alum treatment and planting of submerged aquatic macrophytes) to achieve maximum benefit.

Select tributary BMP recommendations around Lake Alvin and initiating an I&E program to reduce swimming beach contamination for fecal coliform should achieve a fecal coliform target of $3.36 * 10^{10}$ fecal coliform/day or 200 fecal coliform/100 ml (Figure 74, Figure 75 and Table

47). Implementing BMPs for fecal coliform should reduce or eliminate beach closures at the Lake Alvin swimming beach. Reductions in phosphorus and fecal coliform outlined above will improve both the esthetics and use-support category of Lake Alvin.

Table 46. Current, targeted and percent reduction for parameter specific and mean TSI values based on 1999 data for Lake Alvin, Lincoln County, South Dakota.

TSI Parameter	1999 Estimated TSI Values (BATHTUB)	Targeted TSI Value	Percent TSI Reduction
Total Phosphorus	80.47	64.55	19.8
Chlorophyll-*a*	81.75	65.93	19.3
Secchi	76.48	64.38	15.8
Average	**79.57**	**64.95**	**18.4**

Table 47. Total phosphorus and swimming beach TMDL targets and background loading for Lake Alvin, Lincoln County, South Dakota.

Parameter	Best Management Practice	Margin of Safety	TMDL	Background
Total Phosphorus	Tributary and Inlake BMPs	Implicit (conservative estimations) and Explicit (14 percent)	Mean TSI 64.95 (379 kg/year)	120 kg/year
Swimming Beach	Tributary BMPs and Fecal Coliform I&E Program	Implicit (conservative estimations)	3.36×10^{10} fecal coliform/day [1] (˜ 200 colonies/ 100 ml)	1.32×10^{10} fecal coliform/day [2] (˜ 10 colonies/ 100 ml)

[1] = Calculated based on 1999 fecal coliform loading and tributary hydrologic data
[2] = Calculated based on 1999 inlake data

The Total Maximum Daily Load (TMDL) for phosphorus in Lake Alvin is 379 kg/yr producing a mean TSI of 64.95, and 3.36×10^{10} fecal coliform/day (200 fecal coliform/100 ml) for any one sample and would prevent any South Dakota surface water quality or public beach standards violations at Lake Alvin. The load allocation for phosphorus is 206 kg/yr and 2.04×10^{10} fecal coliform/day for fecal coliform bacteria. The background load for phosphorus is 120 kg/yr and 1.32×10^{10} fecal coliform/day for fecal coliform bacteria (Appendix N and Table 47).

Conclusion

Lake Alvin is listed on the 303(d) waterbody list for elevated fecal coliform bacteria and increasing TSI trend. There were no water quality standards exceedances for Nine Mile Creek east (downstream) or west (upstream) of Lake Alvin during this study. However, three upstream tributary sites LAT-4, LAT-5 and LAT-6 had fecal coliform counts in excess of 1,000 colonies per 100 ml, the standard below Lake Alvin. No monthly inlake samples exceeded water quality standards for fecal coliform bacteria; however, three separate beach samples in June exceeded water quality standards for public beaches ($\leq$ 1,000 colonies per 100 ml for any one sample, $\leq$ 300 colonies/ 100 ml for two consecutive samples or $\leq$ 200 colonies/ 100 ml). After those events, beach samples did not exceed standards the rest of the season. Lake Alvin has had problems in the past with beach closures associated with high fecal coliform counts (SD DENR 1998b and SD DENR 2000b). During 1999, inlake fecal coliform samples did not exceed 200 colonies/ 100 mL. Based upon the assessment report, inlake fecal coliform concentrations are not a problem in Lake Alvin. However, several high tributary fecal coliform samples were collected and one beach closure in 1999 indicated there is a fecal coliform concern based on tributary runoff and localized contamination from the swimming beach. Watershed fecal coliform loading was calculated using all AGNPS data from the entire watershed, including the ungauged area around Lake Alvin and the swimming beach. Run-off from the ungauged area appeared to be diffuse, intermittent and sporadic. Incorporating the AGNPS data from the ungauged portion of the watershed with the gauged portion allowed a loading estimate for fecal coliform based on average flow for the entire watershed. Assuming dilution, ultraviolet light and exponential decay significantly reduce fecal coliform concentrations exclusively from Nine Mile Creek (2.1 km from the swimming beach), the sporadic increased fecal coliform concentrations at the swimming beach suggests a significant portion of the calculated fecal coliform load originated from the ungauged portion of the watershed. Initiating a fecal coliform I&E program and implementing select tributary BMPs will reduce fecal coliform counts from animals and humans, which in turn will reduce or eliminate the number of beach closures.

The increasing TSI trend observed in Lake Alvin from 1989 through 1999 is the result of increased nutrients by inlake (internal loading) and delivered loads. Decreasing sediment (erosion) and nutrients (nitrogen and phosphorus) inputs from Nine Mile Creek and the ungauged portion of the watershed will improve (lower) TSI values. This can be accomplished by implementing tributary and inlake BMPs on critical cells and priority areas identified by the watershed assessment and AGNPS modeling within the watershed (Figure 74, Figure 75, Figure 76 and Figure 77).

Un-ionized ammonia and dissolved oxygen water quality standards were exceeded at inlake site LA-2 in August 1999, seven other parameters were also elevated at this time. Elevated concentrations of several parameters and water quality standards exceedances were recorded when livestock (cattle) were wading in and around Lake Alvin at site LA-2 in August. This indicates that the presence of cattle in and around the lakeshore correspond to elevated chemical and biological (fecal coliform) concentrations. BMP implementation will reduce those concentrations and standards exceedances by riparian restoration and the exclusion of cattle and other livestock from Nine Mile Creek and Lake Alvin.

The Lake Alvin watershed (northeastern Lincoln County) with its close proximity to Sioux Falls is experiencing rapid growth and development with new homes and limited business construction. Current design and construction practices should incorporate modern BMP practices for runoff and septic designs in order to minimize potential impacts to the lake and watershed.

Some watershed improvements have been made recently, such as the construction of total retention wastewater treatment ponds for the City of the Harrisburg in 1999, and improvements of to the City of Tea wastewater treatment ponds in 1998 (modification of existing wastewater ponds and the addition of three new ponds). These improvements can only have a positive impact on downstream and inlake water quality.

Inlake and tributary mitigation projects should be initiated to comply with water quality standards, improve esthetics and recreational use by residents of Lincoln County and the City Sioux Falls.

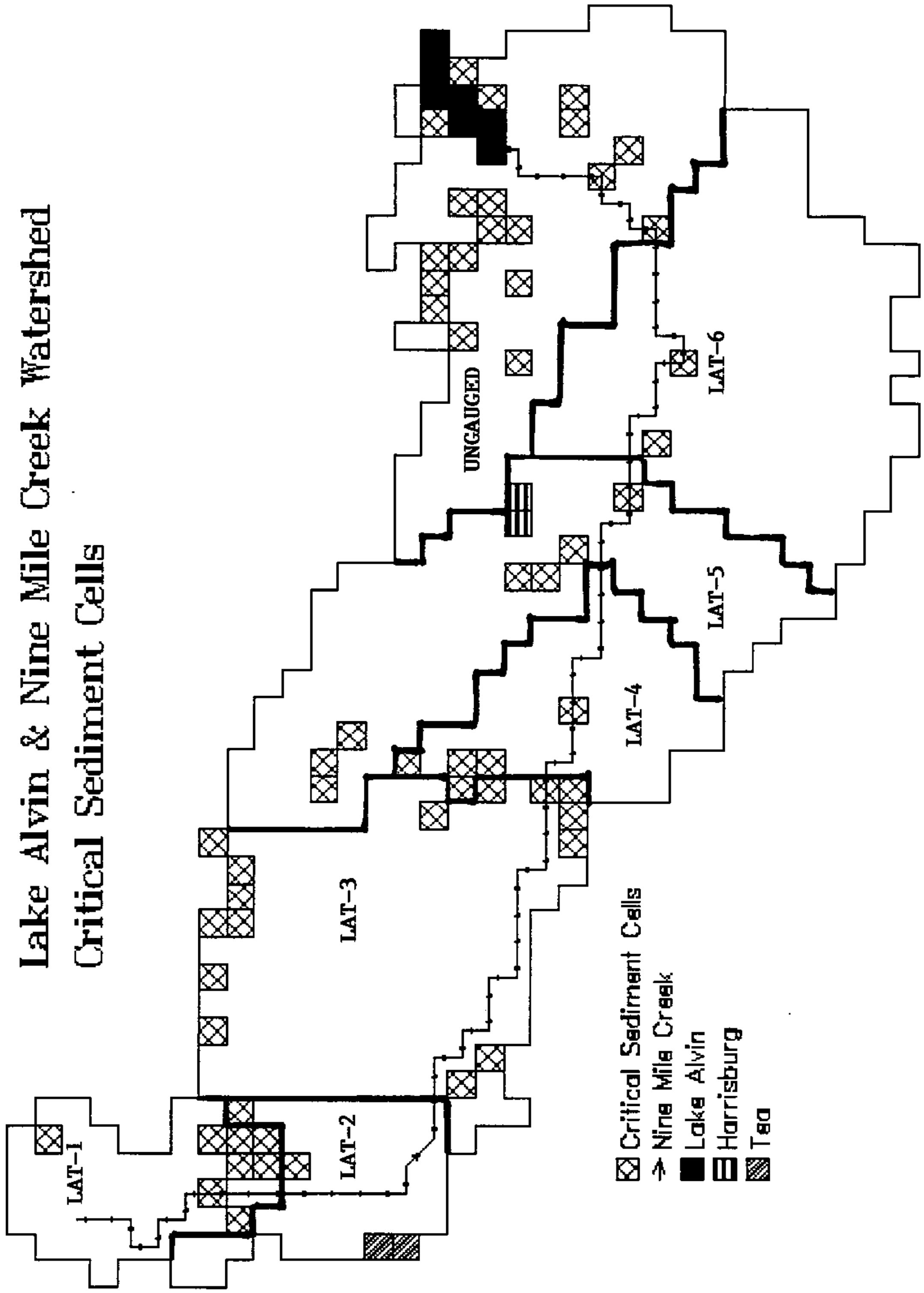


Figure 78. Critical sediment cells within the Lake Alvin watershed Lincoln County, South Dakota identified using AGNPS in 1999.

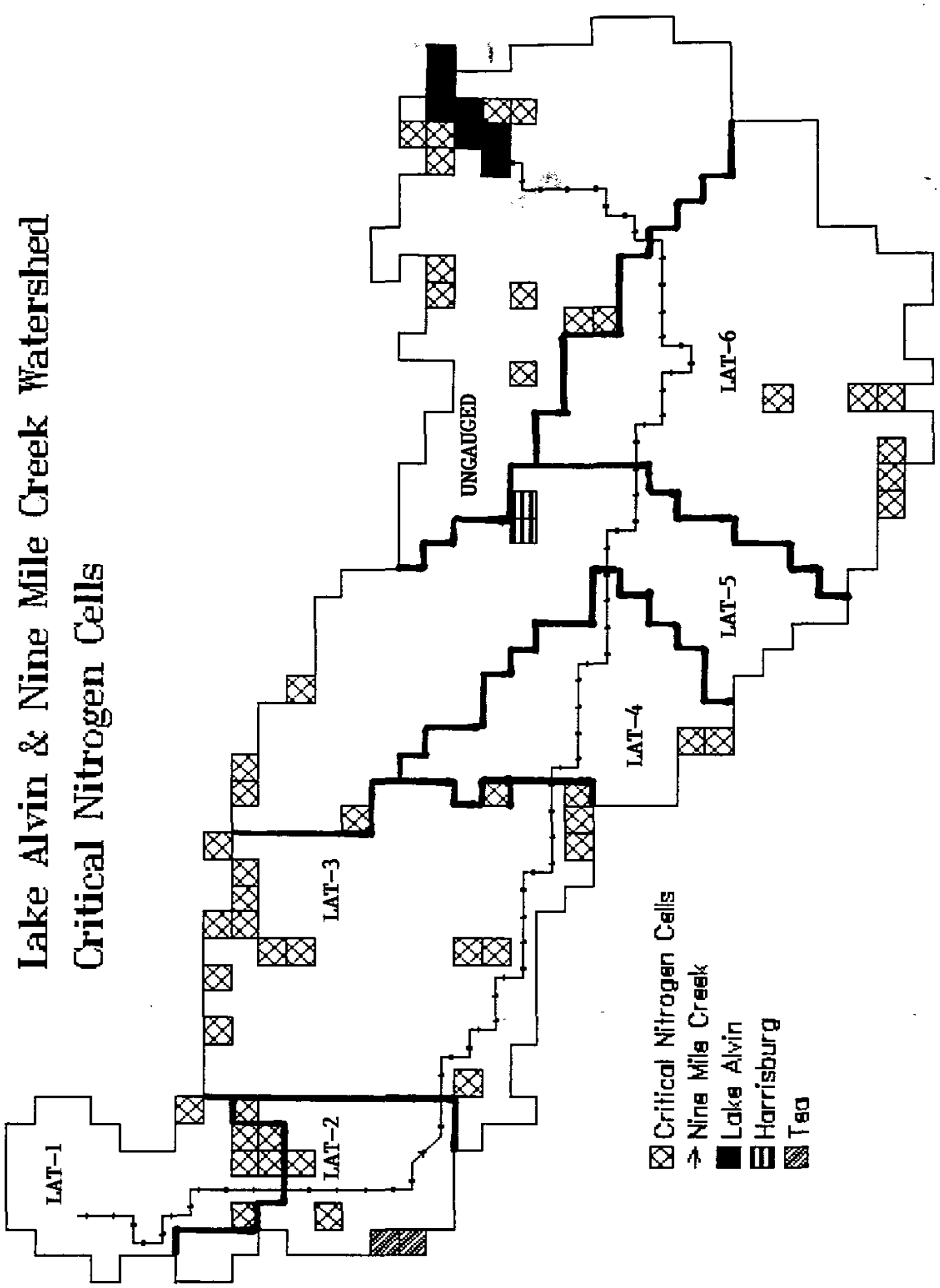


Figure 79. Critical nitrogen cells within the Lake Alvin watershed Lincoln County, South Dakota identified using AGNPS in 1999.

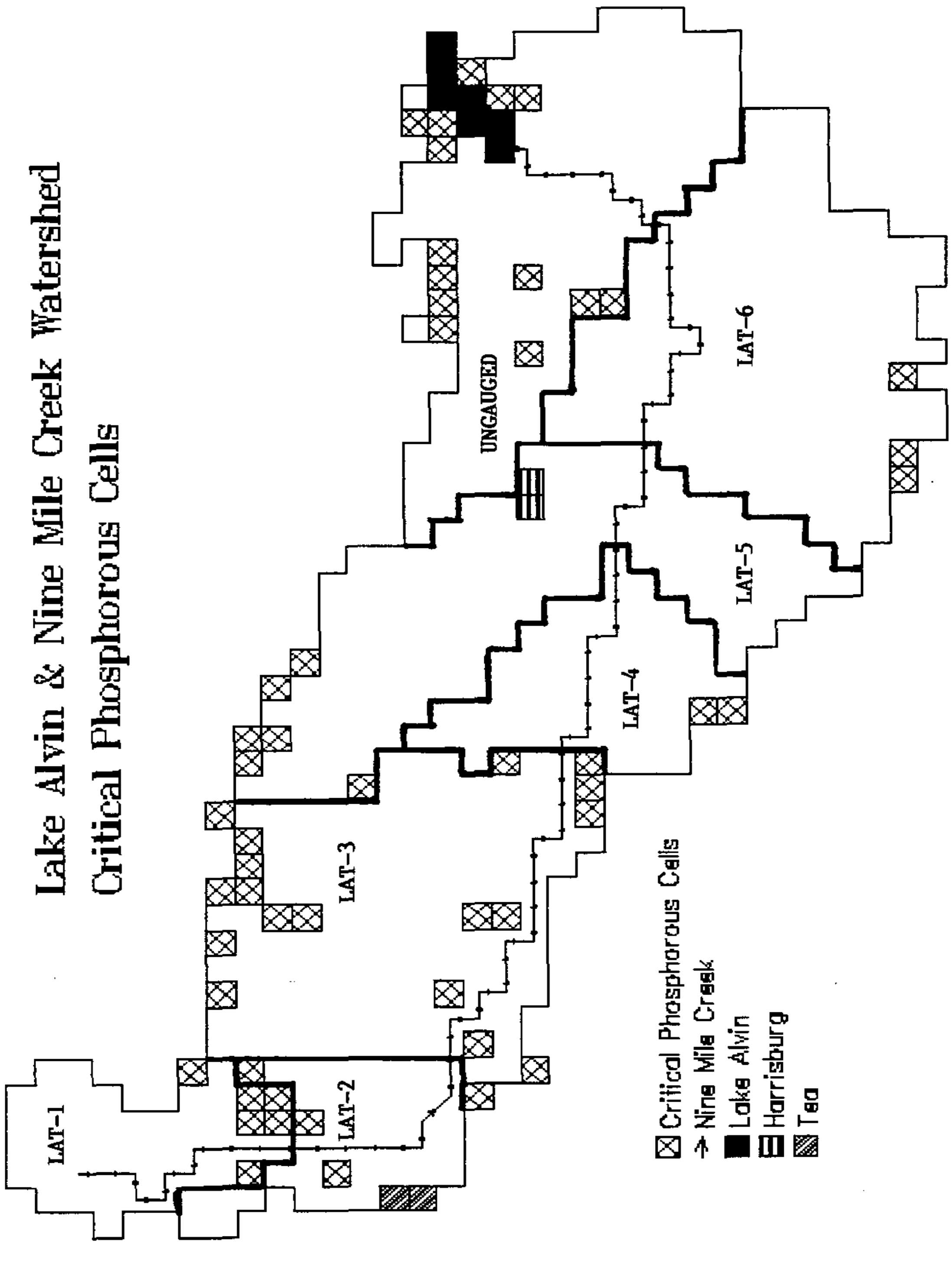


Figure 80. Critical phosphorus cells within the Lake Alvin watershed Lincoln County, South Dakota identified using AGNPS in 1999.

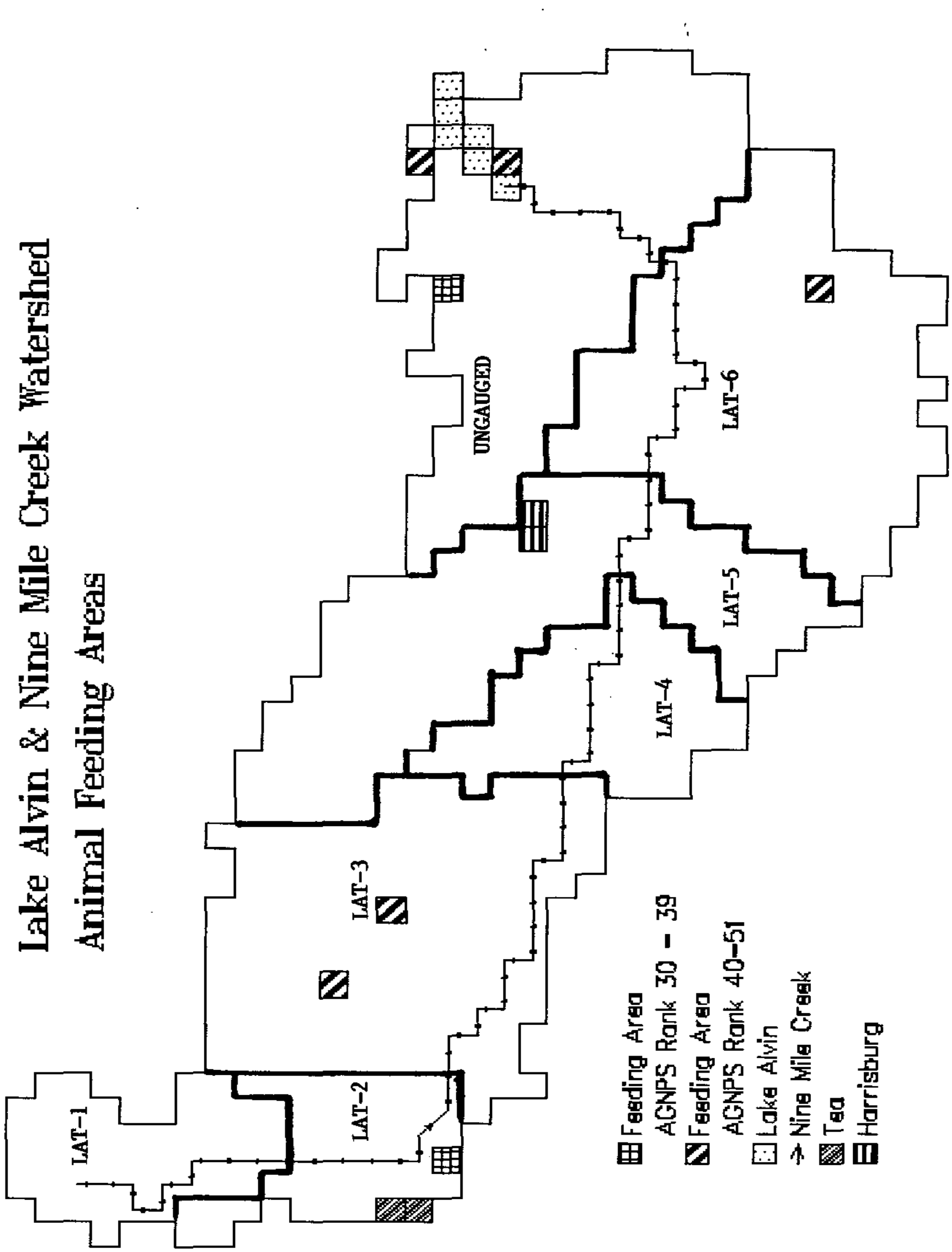


Figure 81. Animal feeding areas within the Lake Alvin watershed Lincoln County, South Dakota identified using AGNPS in 1999.

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Appendix A.

Lake Alvin South Dakota Game, Fish and Parks Fisheries Report

SOUTH DAKOTA

FISHERIES

STATEWIDE FISHERIES SURVEYS, 1998
SURVEY OF PUBLIC WATERS
Part 1
Lakes-Region III

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

Annual Report
No. 99-18

SOUTH DAKOTA STATEWIDE FISHERIES SURVEY

2102-F-21-R-31

Name: Lake Alvin **County (ies)**: Lincoln
Legal Description: Sections 33-34, Range 49W, Township 100N
Location from nearest town: 3 miles east of Harrisburg, SD.

Dates of present survey: June 29-July 1, 1998
Date last surveyed: June 30-July 2, 1997
Most recent lake management plan: F-21-R-28 Date: 1994
Management classification: Warmwater Permanent
Contour mapped: 1968

Primary Game and Forage Species	Secondary and Other Species
1. Largemouth Bass	1. Walleye
2. Black Crappie	2. Yellow Perch
3. White Crappie	3. Black Bullhead
4. Bluegill	4. Carp
5. Channel Catfish	5. White Sucker
	6. Green Sunfish
	7. Northern Pike

PHYSICAL CHARACTERISTICS

Surface Area: 90 acres **Watershed**: 24,564 acres
Maximum depth: 26 feet **Mean depth**: 11 feet
Lake elevation at time of survey (from known benchmark): Full

1. Describe ownership of lake and adjacent lakeshore property:

   Lake Alvin is owned and managed by the South Dakota Department of Game, Fish and Parks.

2. Describe watershed condition and percentages of land use:

   The watershed consists of 85 percent cropland and 15 percent pastureland. Lincoln County has been removing sediment and vegetation from the waterways feeding Lake Alvin to increase water flows off private land, through the lake and into the Big Sioux River.

3. Describe aquatic vegetative condition:

No submerged vegetation was observed in the lake this year. Cattail is still common in the west end of the lake.

4. Describe pollution problems:

Cattle pastured on the south side of the lake are causing significant damage to the shorelines. This activity combined with runoff from heavy rains in the watershed has caused turbidity problems at times.

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

The spillway and all boat ramps are in good condition but a different dock needs to be used on the west access area. The current dock is too wide for the ramp and causes difficulty with launching boats.

CHEMICAL DATA

1. Describe general water quality characteristics:

The water was quite clear in the lower (east) end of the lake but somewhat turbid in the upper (west) end.

BIOLOGICAL DATA

Methods:

1. Describe fish collection methods and show sampling locations by gear type (electrofishing, gill netting, frame nets, etc.) on the lake map.

Lake Alvin was sampled on June 29-July 1, 1998 with ten, 3/4 inch, overnight frame net sets. Netting results are listed in Table 1, length frequencies in Figure 1 and sampling locations in Figure 2.

Results and Discussion:

Table 1. Total catch of ten, 3/4 inch mesh, overnight frame net sets at Lake Alvin, Lincoln County, June 29-July 1, 1998.

Species	**Number**	**Percent**	**CPUE**	**80% C.I.**	**7 Year CPUE Avg.***	**PSD**	**Mean Wr**
Black Crappie	407	37.8	40.7	±9.2	20.7	7	114
White Crappie	270	25.1	27.0	±12.4	29.4	13	105
Bluegill	247	22.9	24.7	±8.7	43.2	57	107
White Sucker	61	5.7	6.1	±2.6	8.0	--	--
Yellow Perch	51	4.7	5.1	±3.6	0.2	--	--
Black Bullhead	19	1.8	1.9	±0.7	7.0	--	--
Carp	9	0.8	0.9	±0.6	7.3	--	--
Channel Catfish	8	0.7	0.8	±0.7	0.1	--	--
O. S. Sunfish	3	0.3	0.3	±0.4	0.1	--	--
Golden Shiner	1	0.1	0.1	±0.1	0.01	--	--
Green Sunfish	1	0.1	0.1	±0.1	0.4	--	--

* = 1991-1997

2. Brief narrative describing status of fish sampled, make references to the tables. See Appendix A for explanations of PSD, Wr and their normal values.

Table 2. Bluegill trends in frame net catch-per-unit-effort (CPUE), proportional stock density (PSD), and mean relative weight (Wr) in Lake Alvin, Lincoln County, 1992-1998.

	1992	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
CPUE	89.8	58.1	18.4	14.4	84.4	20.6	24.7
PSD	21	50	90	71	96	81	57
Mean Wr	107	91	90	94	96	104	107

Bluegill frame net CPUE increased from 20.6 in 1997 to 24.7 in 1998 while PSD decreased from 81 to 57 (Table 2). The length frequency histogram in Figure 1 shows most bluegills ranged in length from 9-20 centimeters (cm.) or 3.5-7.9 inches (in.).

Table 3. Black crappie trends in frame net catch-per-unit-effort (CPUE), proportional stock density (PSD), and mean relative weight (Wr) in Lake Alvin, Lincoln County, 1992-1998.

	1992	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
CPUE	63.2	10.9	5.2	6.7	35.0	12.6	40.7
PSD	6	6	48	27	8	73	7
Mean Wr	131	107	102	117	96	127	114

Black crappie frame net CPUE increased from 12.6 in 1997 to 40.7 in 1998 while PSD dropped from 73 to 7 indicating a year class of small fish coming into the population (Table 3). Note that generally, when crappie abundance is high, PSD is low and vise versa. Figure 1 shows there were two year classes of black crappies present during the survey; one ranging in length between 11-15 cm. (4.3-5.9 in.) and one between 17-22 cm. (6.7-8.7 in.). Average back-calculated lengths for each age class were slightly above average for South Dakota waters (Table 5).

Table 4. White crappie trends in frame net catch-per-unit-effort (CPUE), proportional stock density (PSD), and mean relative weight (Wr) in Lake Alvin, Lincoln County, 1992-1998.

	1992	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
CPUE	63.0	36.6	9.7	6.2	43.3	40.2	27.0
PSD	5	14	45	21	32	80	13
Mean Wr	108	90	95	99	104	93	105

White crappie CPUE decreased from 40.2 in 1997 to 27.0 in 1998 and PSD decreased from 80 to13 (Table 4). Average back-calculated lengths were slightly below average for South Dakota waters (Table 6). The length frequency histogram shows the white crappies were 12-29 cm. (4.7-11.4 in.) long (Figure 1).

Other species sampled during the survey included channel catfish, carp, black bullhead, white sucker, carp, green sunfish, golden shiner, yellow perch and orange-spotted sunfish. Data concerning these species can be viewed in Table 1.

Table 5. Average back-calculated lengths, in mms., for each age class of black crappie, Lake Alvin, Lincoln County, 1998.

			Back-calculation Age			
Year Class	Age	N	1	2	3	4
1997	1	18	84.71			
1996	2	16	76.83	157.02		
1995	3	3	78.83	155.38	203.54	
1994	4	3	87.82	161.28	200.99	230.67
All Classes			81.35	157.37	202.26	230.67
SD Average			77	151	198	227

Table 6. Average back-calculated lengths, in mms., for each age class of white crappie, Lake Alvin, Lincoln County, 1998.

			Back-calculation Age				
Year Class	Age	N	1	2	3	4	5
1997	1	21	90.13				
1996	2	11	75.92	159.47			
1995	3	7	82.21	156.09	206.50		
1994	4	3	77.11	143.57	185.49	219.90	
1993	5	1	85.39	168.80	221.88	255.66	291.56
All Classes			84.18	156.65	202.17	228.84	291.56
SD Average			86	189	241	268	293

RECOMMENDATIONS

1. SDSU will be continuing the analysis of the 9 inch minimum size limit in 1999. We will continue with our normal lake survey schedule for the lake and share our data with them. It needs to be determined whether natural or angling mortality explains the lack of larger crappies in our lake survey samples.

2. The South Dakota Department of Environmental Resources has started a Total Daily Load (TDL) study to determine sediment and chemical problems in Lake Alvin. We will cooperate by taking water samples in the lake. Hopefully this will help to answer questions on the low productivity that Alvin seems to display.

Table 7. Stocking record for Lake Alvin, Lincoln County, 1987-1998.

Year	Number	Species	Size
1988	6,000	Largemouth Bass	Fingerling
1989	690	Walleye	Lrg. Fingerling
1990	36,000	Fathead Minnow	Adult
	2,250	Walleye	Lrg. Fingerling
1991	525,000	Fathead Minnow	Adult
	3,000	Walleye	Lrg. Fingerling
1992	30,000	Black Crappie	Fingerling
	12,000	Channel Catfish	Fingerling
	3,212	Walleye	Lrg. Fingerling
	29,500	Yellow Perch	Fingerling
1993	3,355	Walleye	Lrg. Fingerling
1994	9,036	Black Crappie	Lrg. Fingerling
1996	1,203	Black Crappie	Adult
1997	9,000	Largemouth Bass	Fingerling

Figure 1. Length frequency histograms of selected species from Lake Alvin, Lincoln County, 1998.

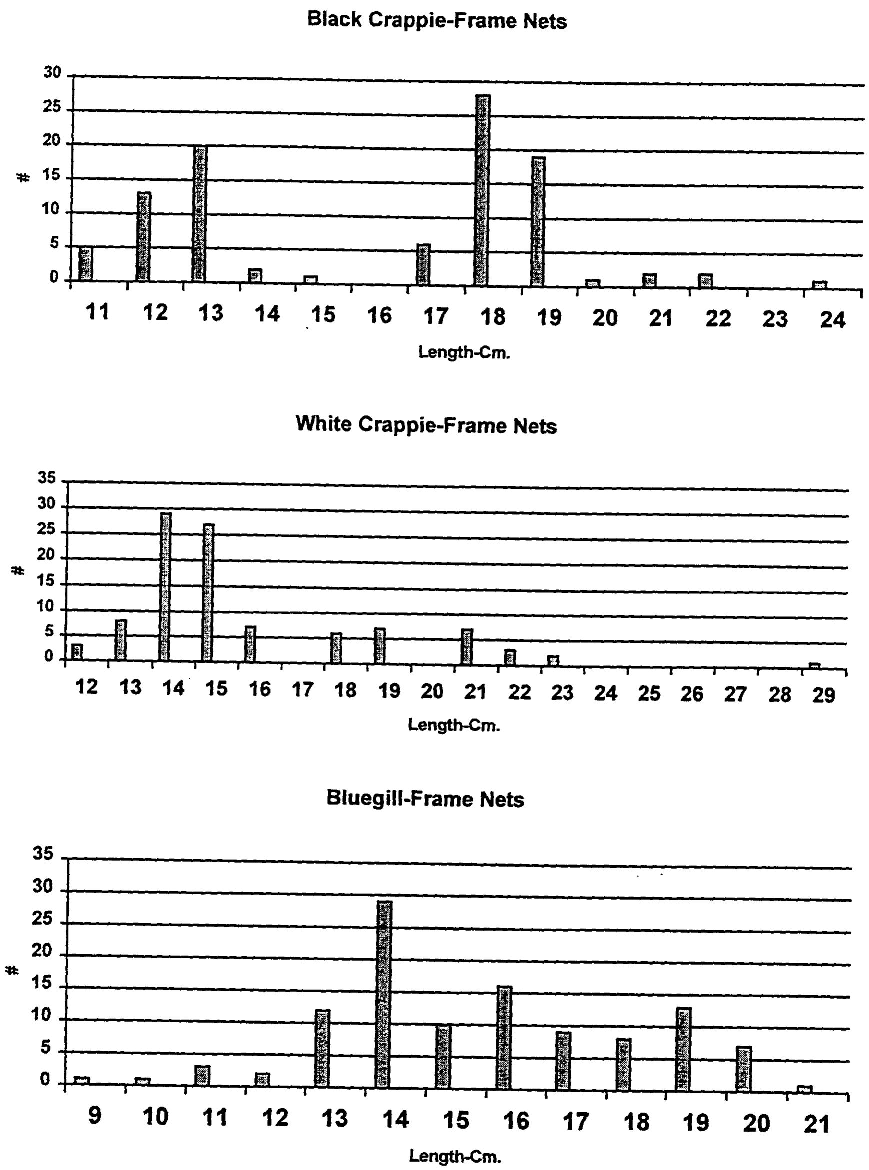
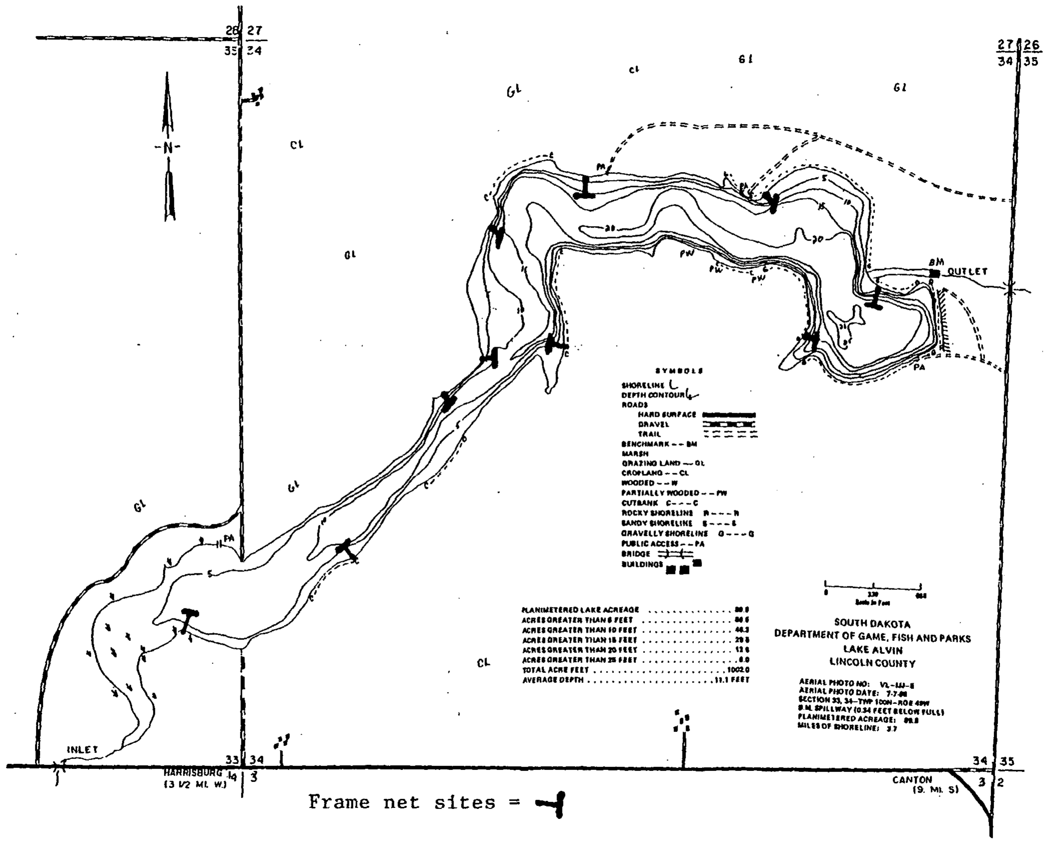


Figure 2. Sampling locations on Lake Alvin, Lincoln County, 1998.



Frame net sites =

Appendix A. A brief explanation of PSD and Wr.

Proportional Stock Density (PSD) is calculated by the following formula:

PSD = **Number of Fish > quality length x 100**
Number of Fish > stock length

PSD is unitless and usually calculated to the mearest whole digit.

Size categories for selected species used in Region 3 lake surveys, in centimeters.

Species	Stock	Quality	Preferred	Memorable	Trophy
Walleye	25	38	51	63	76
Sauger	20	30	38	51	63
Northern Pike	35	53	71	86	112
Yellow Perch	13	20	25	30	38
Largemouth Bass	20	30	38	51	63
Smallmouth Bass	18	28	35	43	51
White Crappie	13	20	25	30	38
Black Crappie	13	20	25	30	38
Bluegill	8	15	20	25	30
Channel Catfish	28	41	61	71	91
Black Bullhead	15	23	30	38	46
Carp	28	41	53	66	84

PSD vallues in the 40-70 range indicate the population is balanced. Values less than 40 indicate a population dominated by small fish and values greater than 70 indicate a population comprised mainly of large fish.

Relative weight (Wr) is a condition indice that quantifies fish condition (ie. how much a fish weighs compared to its length). When mean Wr values are well below 100 for a size group, problems may exist in food and feeding relationships. When mean Wr values are well above 100 for a size group, fish may not be making the best use of available prey.

Appendix B.

Rare, Threatened or Endangered Species Documented in the Nine Mile Creek Watershed, Lincoln County, South Dakota

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 fo und 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 i ts 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 informat ion 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 tax onomy
	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 THE NINE MILE C
LINCOLN COUNTY, SOUTH DAKOTA

South Dakota Natural Heritage Database

September 17, 2000

NAME	TOWNSHIP RANGE & SECTION	LAST OBSERVED	FEDERAL STATUS	STATE STATUS	STATE RANK	GLOBAL RANK
Downy Gentian *Gentiana puberulenta*	100N051W 27	1976			S4?	G4G5
Lilliput *Toxolasma parvus*	100N049W 34				S3	G5
Bush Clover *Lespedeza capitata*	100N049W 35	1985-07-08			S2	G5

Appendix C.

Flowmaster™ Circular Channel Analysis using Manning's Equation

Circular Channel Analysis & Design
Solved with Manning's Equation

Open Channel - Uniform flow

Worksheet Name: alvin

Description:

Solve For Actual Discharge

Given Constant Data;

Diameter...........	5.00
Slope..............	0.0005
Mannings n.........	0.013

Variable Input Data	Minimum	Maximum	Increment By
Depth	0.05	1.30	0.05

				VARIABLE	COMPUTED	COMPUTED
Diameter ft	Channel Slope ft/ft	Mannings 'n'	Discharge cfs	Depth ft	Velocity fps	Capacity Full cfs
5.00	0.0005	0.013	0.00	0.05	0.26	58.24
5.00	0.0005	0.013	0.04	0.10	0.42	58.24
5.00	0.0005	0.013	0.09	0.15	0.55	58.24
5.00	0.0005	0.013	0.17	0.20	0.66	58.24
5.00	0.0005	0.013	0.28	0.25	0.76	58.24
5.00	0.0005	0.013	0.41	0.30	0.86	58.24
5.00	0.0005	0.013	0.57	0.35	0.95	58.24
5.00	0.0005	0.013	0.76	0.40	1.03	58.24
5.00	0.0005	0.013	0.97	0.45	1.11	58.24
5.00	0.0005	0.013	1.22	0.50	1.19	58.24
5.00	0.0005	0.013	1.48	0.55	1.26	58.24
5.00	0.0005	0.013	1.78	0.60	1.33	58.24
5.00	0.0005	0.013	2.10	0.65	1.40	58.24
5.00	0.0005	0.013	2.45	0.70	1.47	58.24
5.00	0.0005	0.013	2.83	0.75	1.53	58.24
5.00	0.0005	0.013	3.23	0.80	1.59	58.24
5.00	0.0005	0.013	3.66	0.85	1.65	58.24
5.00	0.0005	0.013	4.12	0.90	1.71	58.24
5.00	0.0005	0.013	4.60	0.95	1.77	58.24
5.00	0.0005	0.013	5.10	1.00	1.82	58.24
5.00	0.0005	0.013	5.63	1.05	1.88	58.24
5.00	0.0005	0.013	6.18	1.10	1.93	58.24
5.00	0.0005	0.013	6.76	1.15	1.98	58.24
5.00	0.0005	0.013	7.36	1.20	2.03	58.24
5.00	0.0005	0.013	7.98	1.25	2.08	58.24
5.00	0.0005	0.013	8.62	1.30	2.13	58.24

Appendix D.

Nine Mile Creek Tributary Stage Discharge Regression Graphs and Equations 1999

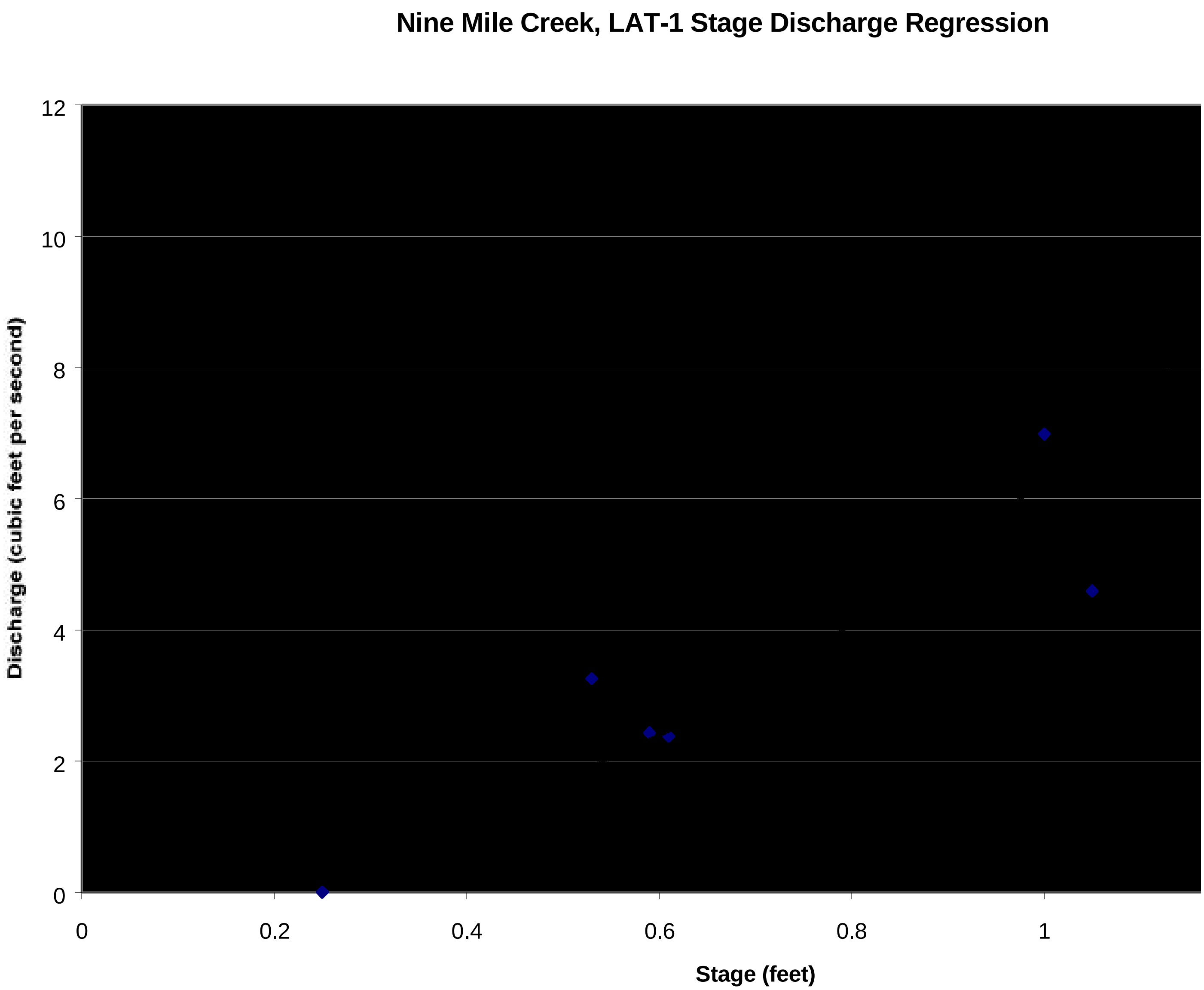


Figure D-1. LAT-1 stage discharge regression for 1999.

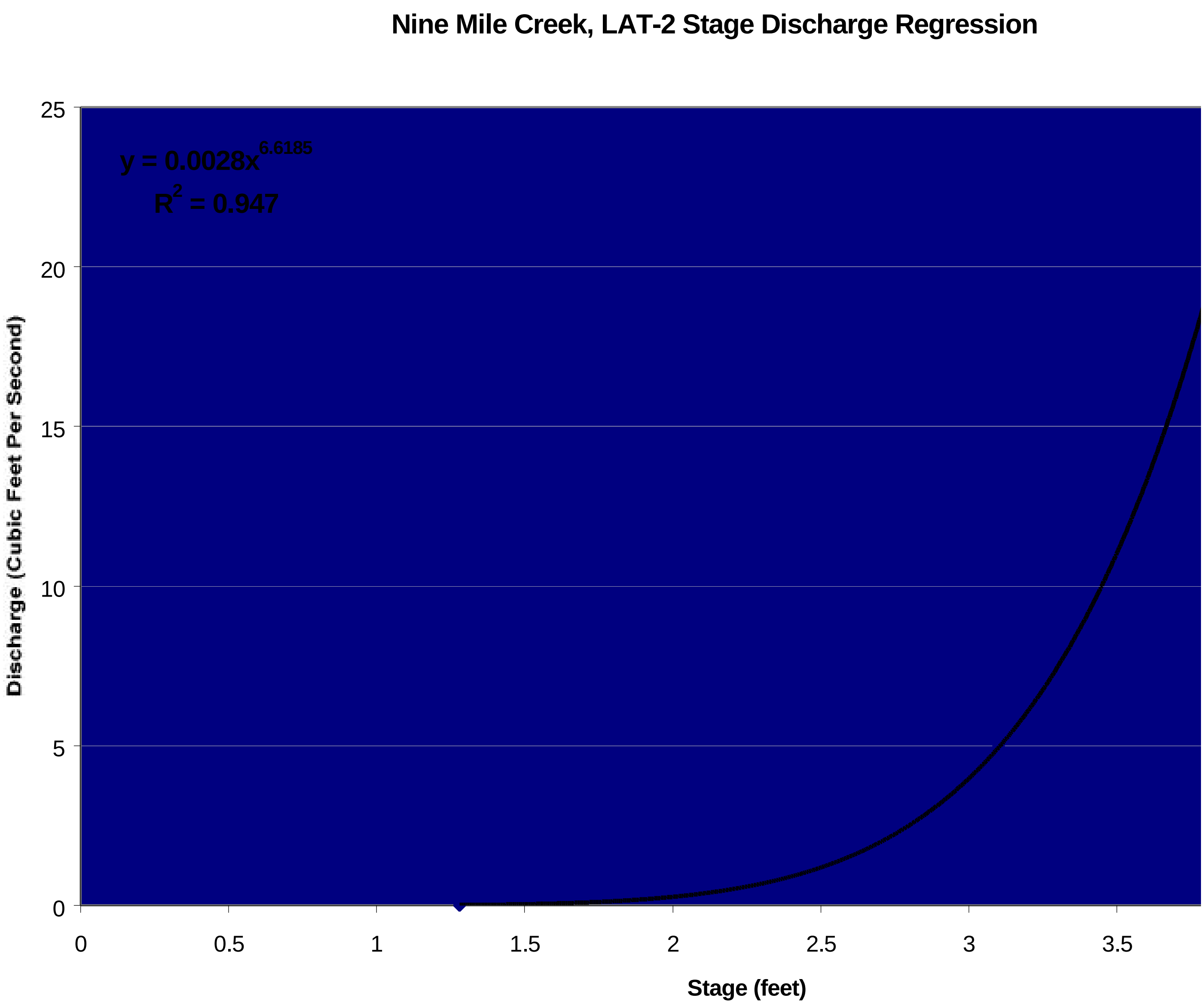


Figure D-2. LAT-2 stage discharge regression for 1999.

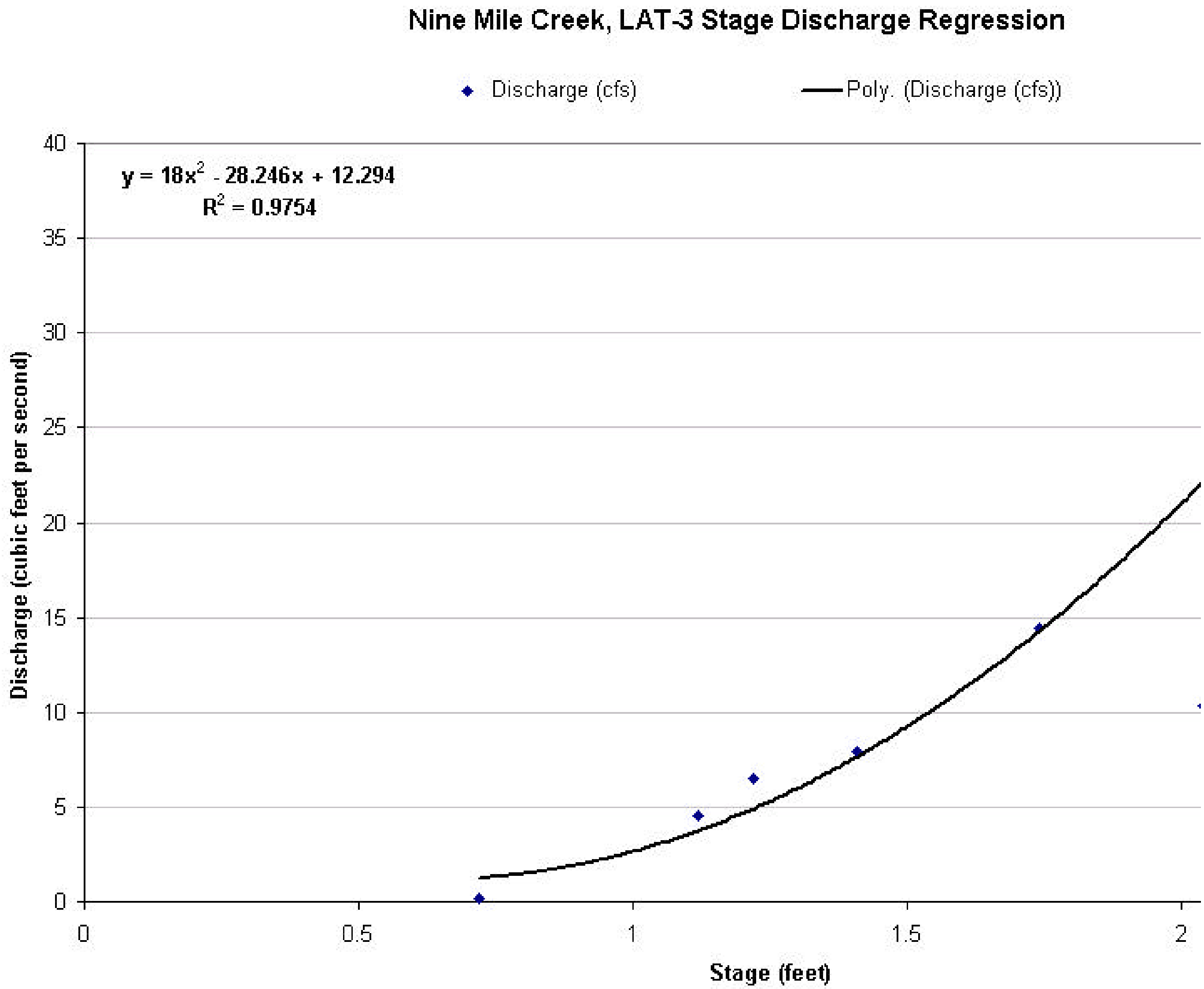


Figure D-3. LAT-3 stage discharge regression for 1999.

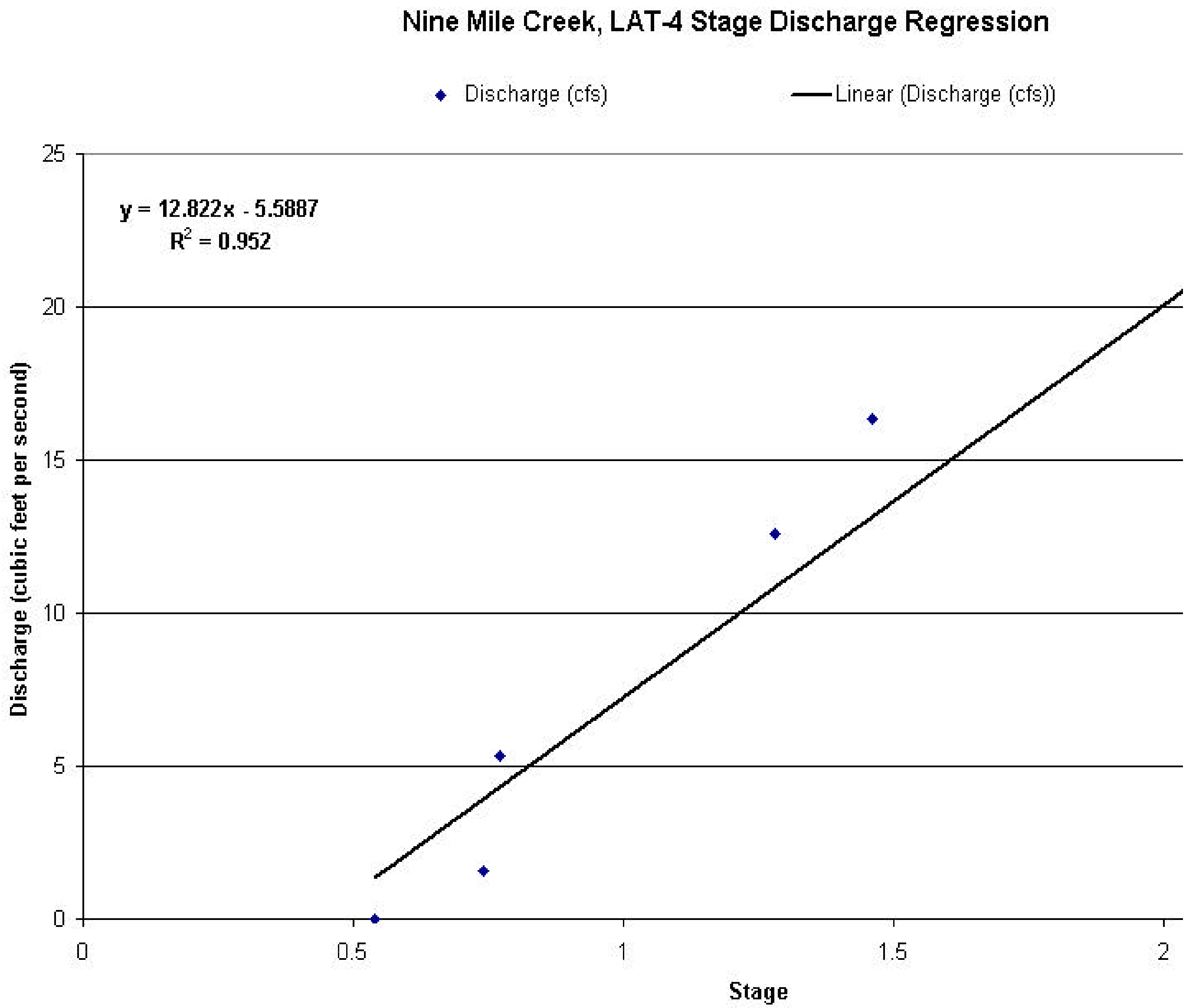


Figure D-4. LAT-4 stage discharge regression for 1999.

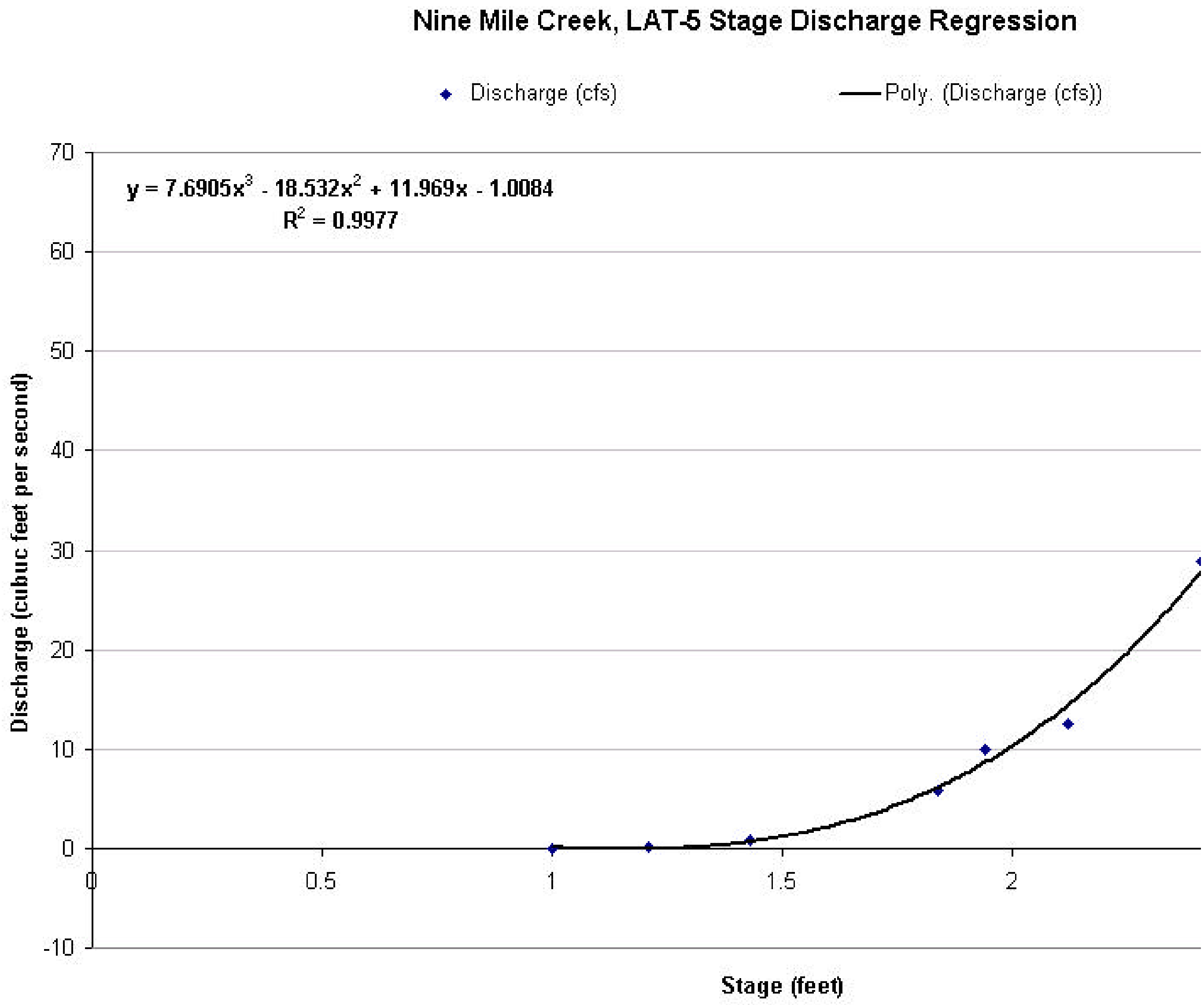


Figure D-5. LAT-5 stage discharge regression for 1999.

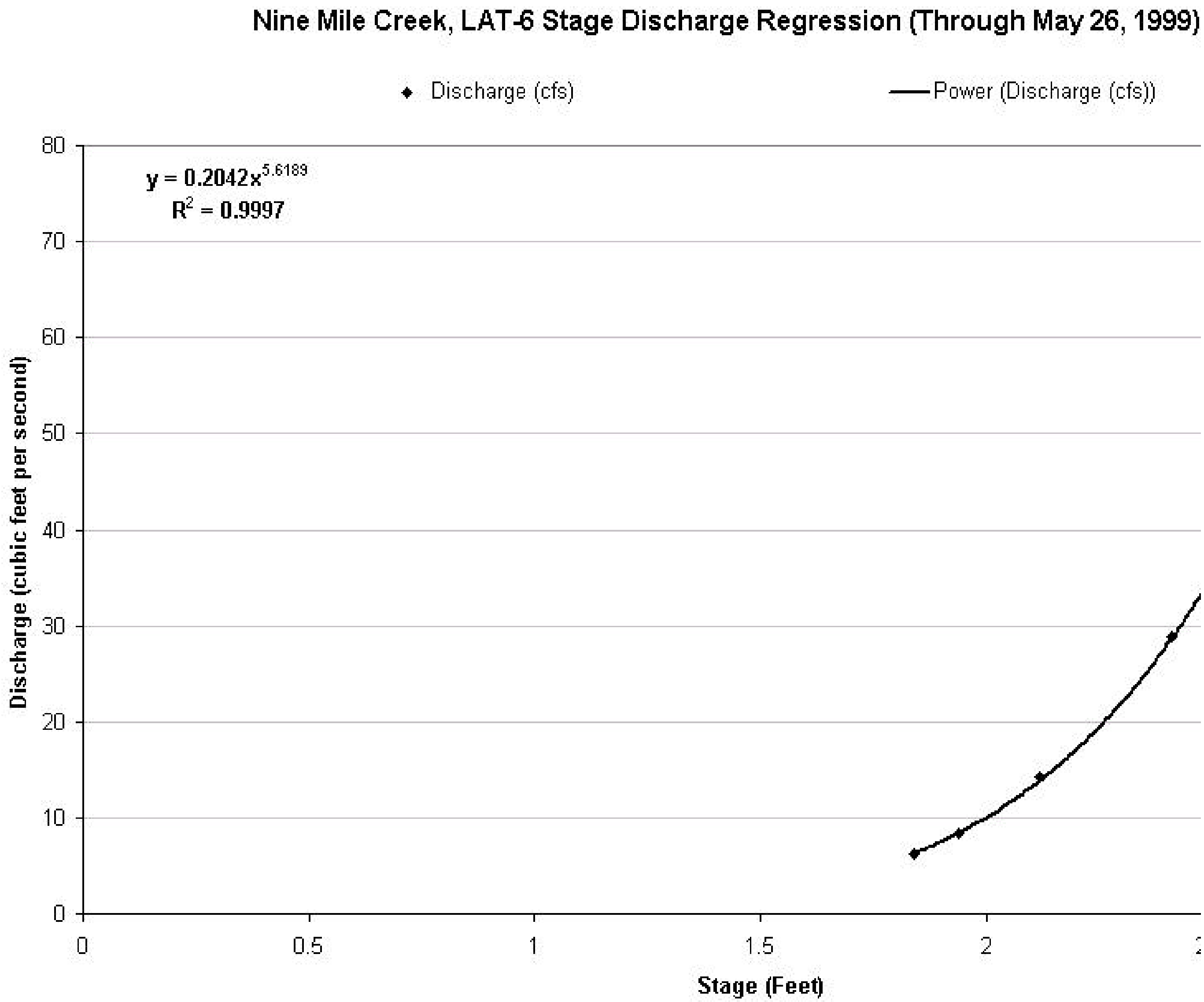


Figure D-6. LAT-6A stage discharge regression for 1999.

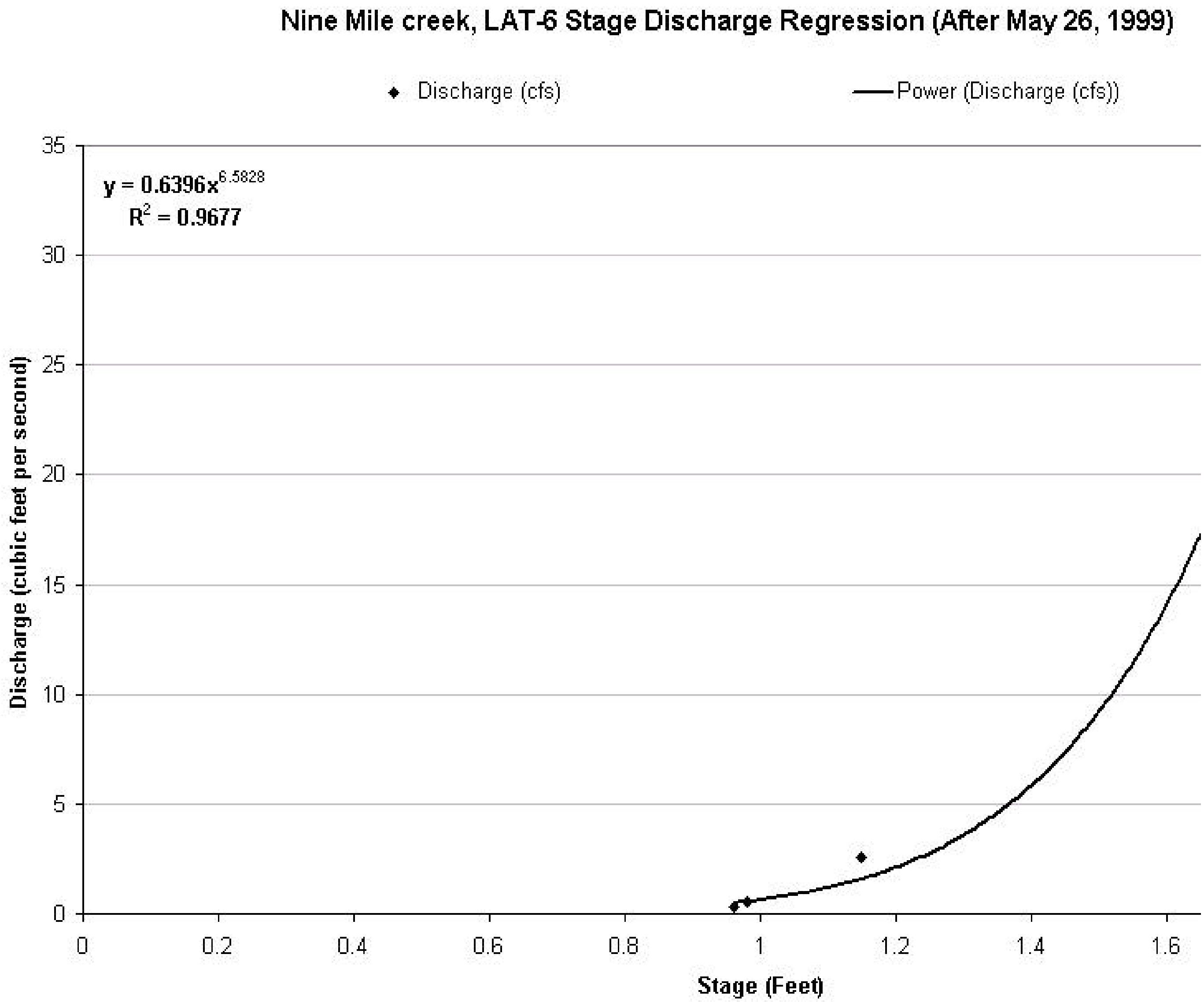


Figure D-7. LAT-6B stage discharge regression for 1999.

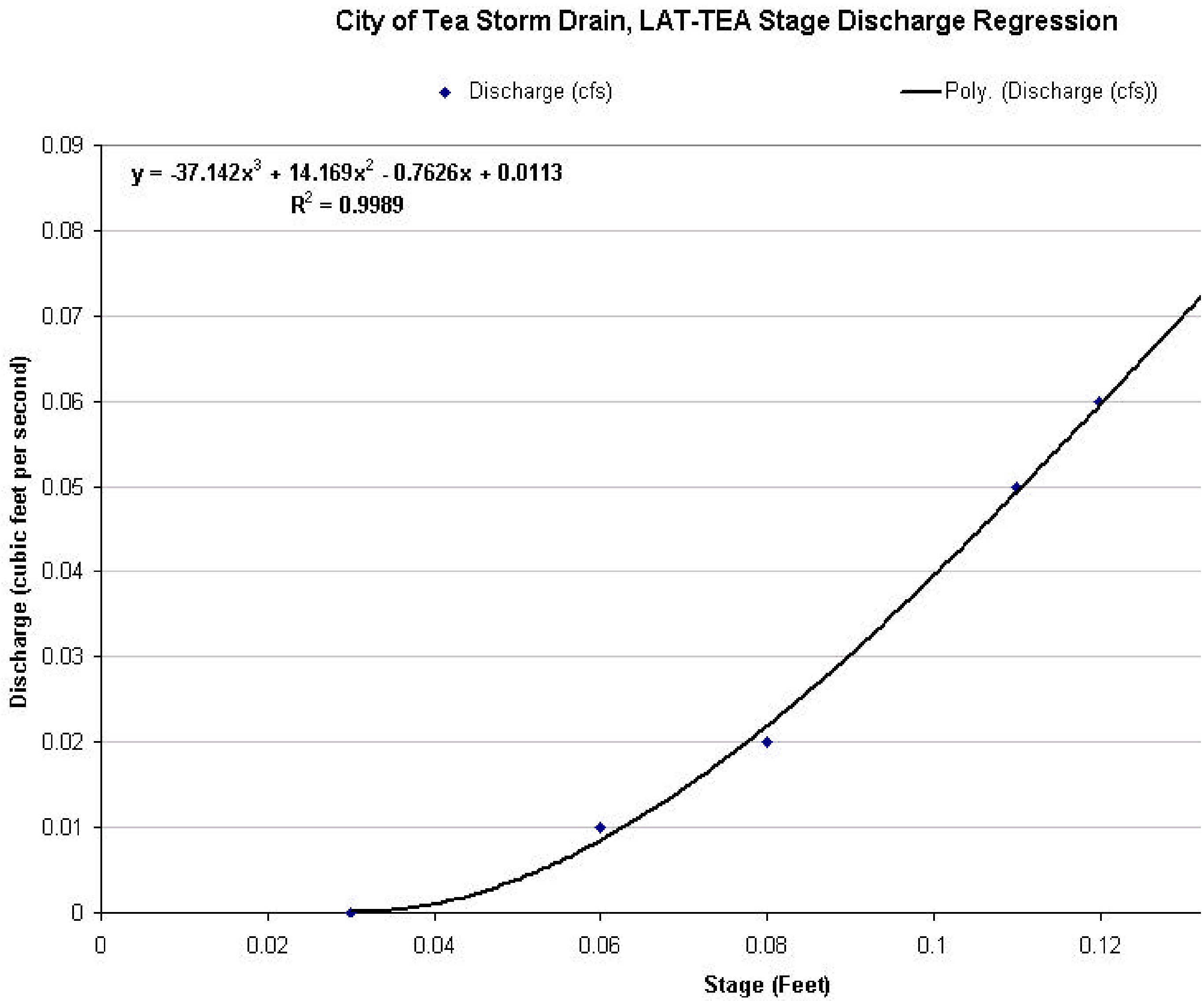


Figure D-8. LAT-TEA stage discharge regression for 1999.

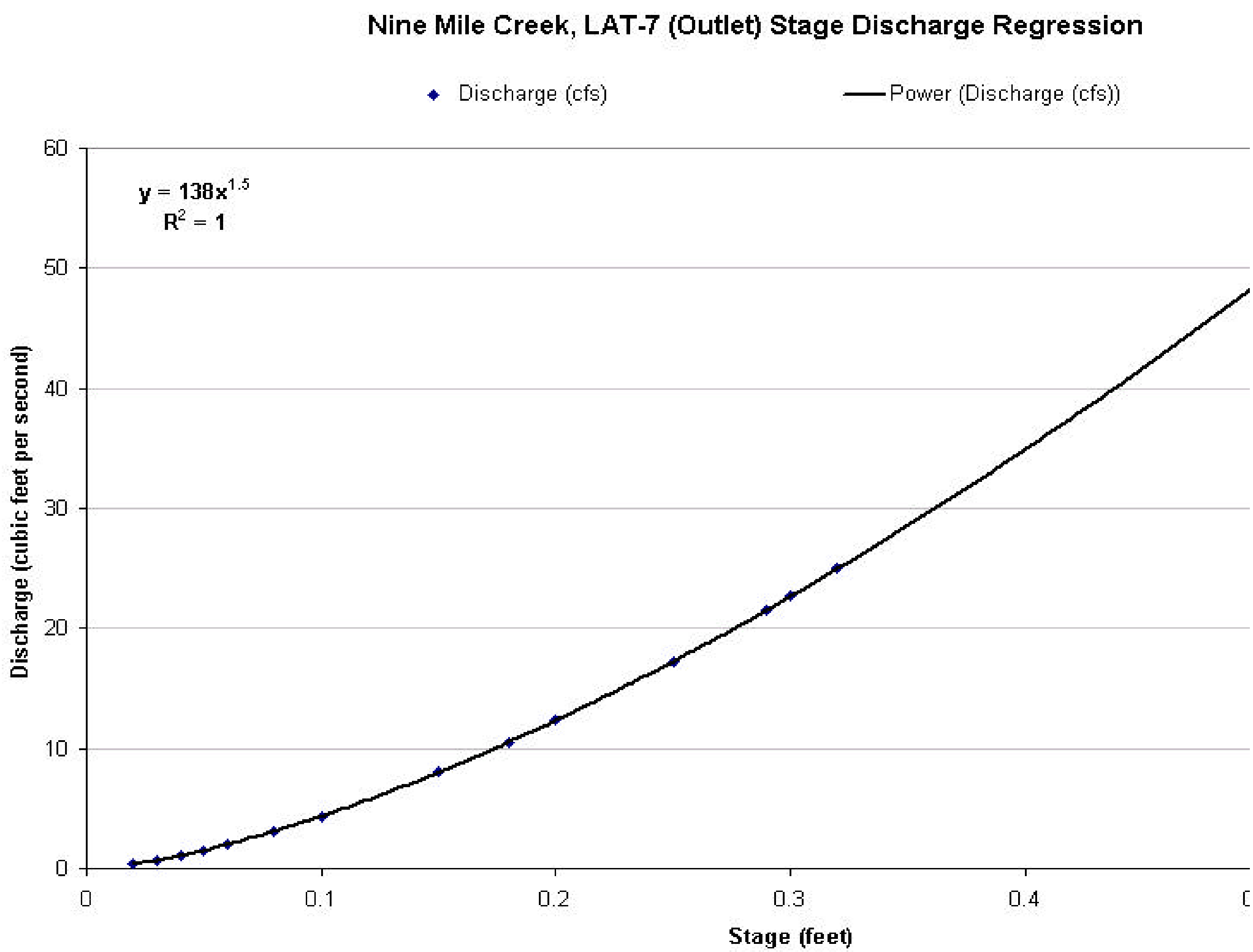


Figure D-9. LAT-7 stage discharge regression for 1999.

Appendix E.

Agricultural Non-Point Source Pollution Model (AGNPS) Final Report

PRELIMINARY REPORT ON THE
AGRICULTURAL NONPOINT SOURCE (AGNPS) ANALYSIS OF THE LAKE ALVIN WATERSHED LINCOLN COUNTY, SOUTH DAKOTA

SOUTH DAKOTA WATERSHED PROTECTION PROGRAM
DIVISION OF FINANCIAL & TECHNICAL ASSISTANCE
SOUTH DAKOTA DEPARTMENT OF
ENVIRONMENT AND NATURAL RESOURCES

December 2000

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LAKE ALVIN WATERSHED AGNPS ANALYSIS

The Lake Alvin watershed is located in Lincoln County in eastern South Dakota and includes the towns of Tea and Harrisburg, South Dakota. The Lake Alvin watershed is approximately 28,120 acres contains Nine Mile Creek. The Lake Alvin Assessment Project set up monitoring sites at five locations on Nine Mile Creek and collected water quantity and quality parameters at each site. Due to the lack of site-specific water quality data, a computer model was selected in order to assess the Nonpoint Source (NPS) loadings throughout the Lake Alvin watershed. The model selected was the Agricultural Nonpoint Source Pollution Model (AGNPS), version 3.65.

This model was developed by the USDA - Agricultural Research Service to analyze the water quality of runoff events from watersheds. The model predicts runoff volume and peak rate, eroded and delivered sediment, nitrogen, phosphorus, and chemical oxygen demand (COD) concentrations in the runoff and sediment for a single storm event for all points in the watershed. Proceeding from the headwaters to the outlet, the pollutants are routed in a step-wise fashion so the flow at any point may be examined. This model was developed to estimate subwatershed or tributary loadings to a waterbody. The AGNPS model is intended to be used as a tool to objectively compare different subwatersheds within a watershed and watersheds throughout a basin.

In order to further evaluate the water quality status of the Lake Alvin watershed, landuse and geo-technical information was compiled. This information was then incorporated into the AGNPS computer model. The primary objectives of utilizing a computer model on the Lake Alvin watershed was to:

1.) Evaluate and quantify Nonpoint Source (NPS) yields from each river reach and determinethe net loadings into Lake Alvin;
2.) Define critical NPS cells within each river reach's watershed (elevated sediment, nitrogen, phosphorus);
3.) Priority rank each animal feeding area and quantify the nutrient loadings from each area; and
4.) Use the model to estimate the percent reduction that could be achieved in the watershed by installing various Best Management Practices.

Initially, the watershed was divided into cells each of which had an area of 40 acres with dimensions of 1320 feet by 1320 feet. The AGNPS analysis of the Lake Alvin watershed consisted of the following; collection of 21 field parameters for each cell, the calculation of nonpoint source pollution yields for each cell and subwatershed, impact and ranking of each animal feeding area, and an estimated hydrology runoff volume for each of the storm events modeled.

For comparative purposes, the watershed was broken up into the six subwatersheds that the Lake Alvin Assessment Project monitored during the study. In addition, the 5160 acres that is between the last monitoring site on Nine Mile Creek and the inlet to Lake Alvin was also evaluated as a subwatershed. This 5160 acre subwatershed is referred to as the ungauged area throughout this report.

The following is a brief overview of each objective.

OBJECTIVE 1 - EVALUATE AND QUANTIFY SUBWATERSHED NPS LOADINGS

DELINEATION AND LOCATION OF SUBWATERSHEDS

The following AGNPS outlet cell numbers correlate to water quality monitoring sites that were used in the Diagnostic/Feasibility study that was performed in 1999;

D/F Study Site ID#	Total drainage area (acres)	Immediate reach drainage area (acres)	AGNPS outlet cell number
1	1880	1880	73
2	3600	1720	233
3	9200	5600	396
4	11,480	2280	465
5	16,520	5040	499
6	22,360	5840	538
Lake Alvin Outlet	28,120	5760	271

The next two tables are the AGNPS estimates for the average annual sediment, nitrogen and phosphorous loads at each of the D/F study sites. Each table also contains the AGNPS estimates for the ungauged potion of the watershed, the total load to Lake Alvin and the load leaving Lake Alvin. The first table lists the loads on a per acre basis while the second table lists the loads for each site as a total load.

Lake Alvin Subwatershed ***per acre*** loadings

D/F Study Site ID#	Drainage Area (acres)	Annual Sed. Yield (tons/acre)	Attached N (lbs/acre)	Dissolved N (lbs/acre)	Total Nitrogen (lbs/acre)	Attached P (lbs/acre)	Dissolved P (lbs/acre)	Total Phosph. (lbs/acre)
1	1880	0.25	1.63	3.57	4.77	0.64	0.67	1.31
2	1720	0.02	0.37	3.78	4.76	0.47	0.70	1.17
3	5600	0.18	1.19	4.70	6.07	0.71	0.89	1.60
4	2280	0.02	0.43	6.61	8.27	0.82	1.24	2.06
5	5040	0.17	1.12	2.29	4.46	1.09	0.44	1.53
6	5840	0.06	0.72	5.54	6.86	0.71	1.07	1.78
Ungauged Area	5160	0.33	1.71	5.04	6.75	0.90	0.92	1.82
Tot. load to Lake Alvin	27520	0.16	1.09	5.09	6.18	0.55	0.93	1.48
Lake Alvin Outlet	28120	0.03	0.34	5.20	5.54	0.11	0.94	1.05

Lake Alvin Subwatershed ***<u>total</u>*** loadings

D/F Study Site ID#	Drainage Area (acres)	Annual Sed. Yield (tons)	Attached N (tons)	Dissolved N (tons)	Total Nitrogen (tons)	Attached P (tons)	Dissolved P (tons)	Total Phosph. (tons)
1	1880	469	1.53	3.36	4.89	0.60	0.63	1.23
2	1720	37	0.32	3.25	3.57	0.40	0.60	1.00
3	5600	990	3.33	13.2	16.5	1.99	2.49	4.48
4	2280	41	0.49	7.54	8.03	0.93	1.41	2.34
5	5040	853	2.82	5.77	8.59	2.75	1.11	3.86
6	5840	355	2.10	16.2	18.3	2.07	3.12	5.19
Ungauged Area	5160	1688	4.41	13.0	17.4	2.32	2.37	4.69
Tot. load to Lake Alvin	27520	4434	15.0	70.0	85.0	7.57	12.8	20.4
Lake Alvin Outlet	28120	786	4.78	73.1	77.9	1.55	13.2	14.8

§ - **Annual loadings were estimated by calculating the NPS loadings for the cumulation of rainfall events during a average year. This includes a 1 year 24 hour event of 2.4" (E.I. = 32.4), 3 semi-annual rainfall events of 1.8" (E.I. = 17.3) and a series of 9 small rainfall events of 1.0" (E.I. = 4.8) for a total "R" factor of 127.5 . Rainfall events of less than .9" were modeled and found to produce insignificant amounts of sediment and nutrient yields.**

SEDIMENT YIELD RESULTS

The AGNPS model calculated that the sediment delivered from the Nine Mile Creek watershed to Lake Alvin is 0.16 tons/acre/year for an estimated annual load. This is equivalent to 4434 tons for an annual load. A comparison of the subwatershed total sediment yield to its aerial size is listed below for each subwatershed:

SUBWATERSHED	% OF TOTAL SEDIMENT LOADING	% OF WATERSHED AREA	# OF CRITICAL CELLS
LAT -1 (#73)	10.6%	6.8%	8 (14.3%)
LAT -2 (#233)	0.8%	6.3%	2 (3.6%)
LAT -3 (#396)	22.3%	20.3%	15 (26.8%)
LAT -4 (#465)	0.9%	8.3%	3 (5.4%)
LAT -5 (#499)	19.2%	18.3%	7 (12.5%)
LAT -6 (#538)	8.0%	21.2%	3 (5.4%)
Ungauged area	38.1%	18.8%	18 (32.1%)
Totals	100%	99.9%	56 critical cells in the watershed

SEDIMENT ANALYSIS

The ungauged watershed is delivering a large amount of sediment to the watershed and should be targeted for BMP's. This subwatershed was found to contribute over 38% of the total sediment, contain 32% of the critical erosion cells while occupying only 18.8% of the watershed surface area.

Subwatersheds for sites LAT-1, LAT-3 and LAT-5 are also contributing excess amounts of sediment to Lake Alvin. These subwatersheds were found to contribute 52% of the total sediment load, contain 54% of the critical erosion cells while occupying only 45% of the watershed area.

The high sediment yield from the ungauged watershed and sites LAT-1, LAT-3 and LAT-5 can be attributed to landuse and landslope. The source of this sediment is primarily from cropland using conventional tillage practices (C-factors > 0.20) on land with slopes greater than 4%. The conversion of this acreage to a high residue management system, installation of grassed waterways, planting of filter strips, installing other cropland BMP's or planting cropland back to native grasses will reduce the amount of sediment delivered to Lake Alvin. Efforts should first be made to target appropriate BMP's to the ungauged watershed and especially to the critical erosion cells found within this watershed.

An analysis of the sediment transport and deliverability throughout the watershed indicated during an average year, approximately 4434 tons of sediment enters Lake Alvin and 786 tons of sediment leaves the lake. This correlates to a trapping efficiency of 82.3% for Lake Alvin. Due to the trapping efficiency of the lake, the net watershed sediment deliverability rate at the outlet of Lake Alvin of .028 tons/acre/year appears to be very low. This low rate under estimates the status of erosion and sediment deliverability rates throughout the watershed, since the mean subwatershed sediment deliverability rate to Lake Alvin was estimated to be 0.16 tons/acre/year.

The impact of sediment erosion derived from gully erosion, riparian areas, shoreline erosion, wind and their deliverability to the watershed was not modeled.

NUTRIENT YIELD RESULTS

The AGNPS data indicates that the Lake Alvin watershed (at Lake Alvin outlet) has a total nitrogen (soluble + sediment bound) deliverability rate of 5.54 lbs/acre/year (equivalent to 77.9 tons) and a total phosphorus (soluble + sediment bound) deliverability rate of 1.05 lbs/acre/year (equivalent to 14.8 tons). The total nutrient load delivered from the subwatersheds to Lake Alvin is estimated to be 85 tons/year of nitrogen and 20.4 tons/year of phosphorus for an estimated annual load. A comparison of the subwatershed total nutrient yield to its aerial size for an annual load is:

SUBWATERSHED (CELL #)	% OF TOTAL NITROGEN YIELD	% OF TOTAL PHOS. YIELD	% OF WATERSHED AREA	# OF CRITICAL NUTRIENT CELLS
LAT -1 (#73)	7.1%	7.8%	6.8%	6 (10.7%)
LAT -2 (#233)	3.2%	2.9%	6.3%	3 (5.4%)
LAT -3 (#396)	17.8%	17.7%	20.3%	19 (33.9%)
LAT -4 (#465)	7.2%	6.9%	8.3%	2 (3.6%)
LAT -5 (#499)	21.4%	21.6%	18.3%	6 (10.7%)
LAT -6 (#538)	22.9%	20.1%	21.2%	6 (10.7%)
Ungauged area	20.6%	23.0%	18.8%	14 (25.0%)
Totals	100%	100%	99.9%	56 of 56 (96.8%)

TOTAL NUTRIENT ANALYSIS

Subwatersheds LAT-1 (#73), LAT-5 (#499) and the ungauged area appear to be contributing elevated levels of total nutrients. This can probably be attributed to the nutrients, which are associated with the high sediment yields from these subwatersheds. This is verified by the fact that all three of these critical nutrient subwatersheds were identified in the sediment results as subwatersheds yielding excess amounts of sediment.

The results show that 83% of the total nitrogen and 65% of the total phosphorous load coming into Lake Alvin is in the water soluble (dissolved) form. This indicates that runoff from fertilized cropland may be a large contributor of nutrients to Lake Alvin. Overall, the total nutrients delivered from the Lake Alvin watershed is average when adjusted for its watershed size and deliverability system (mean of 5.74 lbs/acre for nitrogen and 1.43 lbs/acre for phosphorus) when compared to other watrersheds in eastern South Dakota. The most likely source of nutrients is from runoff of cropland.

OBJECTIVE 2 - IDENTIFICATION OF CRITICAL NPS CELLS (25 YEAR EVENT)

Priority Erosion Cells

Cell #	Sediment (Tons/acre)	Subwater #
312	12.52	ung.
268	11.19	ung.
453	10.85	ung.
480	10.85	ung.
57	8.9	1
74	8.9	1
274	8.9	3
428	7.93	3
384	7.91	ung.
426	7.71	3
302	7.57	ung.
305	7.57	ung.
347	7.57	ung.
396	7.57	3
431	7.57	4
498	7.57	5
511	7.57	ung.
538	7.57	6
58	7.28	2
67	7.28	3
371	6.56	5
427	6.31	3
95	6.2	2
158	6.2	5
262	6.2	ung.
351	6.2	ung.
454	6.2	ung.
75	6.03	1
244	6.03	3
382	6.03	ung.
561	6.03	6
52	5.53	3
326	5.37	4
404	5.37	5
437	5.37	5
132	5.22	5
131	5.09	5
49	5.08	3
65	5.08	3
66	5.08	3
261	5.08	ung.
325	5.08	3
41	4.93	1
56	4.93	1
530	4.93	6
54	4.69	1
286	4.27	4
43	4.2	1
307	4.2	ung.
315	4.2	3
346	4.2	ung.
9	4.15	1
47	4.15	3
51	4.15	3
263	4.15	ung.
379	4.15	ung.

Priority Nitrogen Cells

Cell #	Nitrogen (Lbs/acre)	Subwater. #
268	18.29	ung.
274	15.54	3
57	15.1	1
319	14.82	3
37	13.11	1
446	12.57	ung.
382	12.3	ung.
428	12.1	3
263	12.03	ung.
262	11.62	ung.
95	11.46	2
52	11.21	3
690	11.07	6
693	10.99	6
689	10.94	6
58	10.78	2
67	10.78	3
49	10.67	3
267	10.31	ung.
75	10.28	1
325	10.25	3
54	10.12	1
74	9.96	1
427	9.88	3
51	9.81	3
379	9.73	ung.
227	9.62	ung.
82	9.57	3
47	9.46	3
426	9.31	3
155	9.3	5
56	8.4	1
475	8.18	ung.
66	8.14	3
70	8.08	5
279	8.08	3
547	8.02	4
574	8.02	4
65	7.85	3
113	7.79	5
115	7.79	2
71	7.79	5
351	7.63	ung.
631	7.53	6
103	7.35	3
682	7.33	6
691	7.13	6
389	7.08	ung.

Priority Phosphorous Cells

Cell #	Phosphorous (Lbs/acre)	Subwater. #
268	8.25	ung.
274	6.87	3
57	6.65	1
428	5.83	3
382	5.25	ung.
58	5.18	2
67	5.18	3
262	5.11	ung.
95	5.03	1
427	4.73	3
52	4.7	3
37	4.57	1
263	4.57	ung.
75	4.47	1
49	4.43	3
325	4.42	3
319	4.37	3
446	4.3	ung.
74	4.25	1
54	4.16	1
51	4.01	3
56	3.99	1
379	3.97	ung.
66	3.85	3
47	3.83	3
426	3.76	3
690	3.55	6
693	3.51	6
689	3.49	6
65	3.37	3
351	3.26	ung.
113	3.2	5
115	3.2	2
267	3.17	ung.
70	3.14	5
279	3.14	3
547	3.11	4
574	3.11	4
71	3	5
236	2.98	3
272	2.95	3
260	2.93	ung.
227	2.86	ung.
353	2.84	3
82	2.8	3
91	2.78	5
103	2.78	3
312	2.75	ung.
155	2.67	5
475	2.65	ung.
389	2.64	ung.
261	2.59	ung.
89	2.57	5

Based upon an evaluation of NPS cell yield data, the following critical cell yield criteria was established:

sediment erosion rate > 4.0 tons/acre
total nitrogen cell yields > 7.0 lbs/acre
total phosphorus cell yields > 2.5 lbs/acre

An analysis of the Lake Alvin watershed indicates that there are approximately 56 cells, which have a sediment yield greater than 7.0 tons/acre. This is approximately 8% of the cells found within the entire watershed. The yields for each of these cells are listed on page 6, and their locations are documented on page 16. These critical cells are primarily composed of lands that have a slope of 4% or greater and have a cropping factor (C-factor) of 0.20 or greater.

The model estimated that there are 48 cells, which have a total nitrogen yield greater than 7.0 lbs./acre, and 53 cells with a sediment bound phosphorus yield greater than 2.5 lbs./acre. This is approximately 7% of the cells within the watershed. The yields for each of these cells are listed on page 6, and their locations are documented on pages 17 and 18. Based upon a subwatershed area weighted to number of critical cells analysis, the most critical source of nutrients and deliverability are from subwatersheds LAT-1 (#73), LAT-5 (#499) and the ungauged area. These critical subwatersheds and identified critical NPS cells should be given high priority when installing any future BMPs. It is recommended that any targeted cells should be field verified prior to the installation of any BMPs.

OBJECTIVE 3 - PRIORITY RANKING OF ANIMAL FEEDING AREAS (25 YEAR EVENT)

A total of 10 animal feeding areas were identified as potential NPS sources during the AGNPS data acquisition phase of the project. On page 11 is a listing of the AGNPS analysis of each feeding area. Of these, five were found to have an AGNPS ranking of 40 or greater and one had an AGNPS ranking of 50 or greater. AGNPS ranks feeding areas from 0 to 100 with a 0 ranked feeding area having a smaller pollution potential and 100 ranking having a large pollution potential.

In order to determine the impact of these five feeding areas, an AGNPS run was made with these feeding areas removed and then compared to the run where the feeding areas were a part of the watershed. The results of this showed almost no change in the nutrient load to Lake Alvin. This means that currently the small feeding areas within the watershed are not contributing significant amounts of nutrients. This is probably due to the small number of animals within each of these feeding areas.

It is recommended that these five animal feeding areas be monitored for the number of animals they contain. If the animal numbers were to increase without modification to the existing facility, the potential for a significant amount of pollution to enter Nine Mile Creek would exist. Other possible sources of nutrient loadings not modeled through this study were those from septic systems and from livestock depositing fecal material directly into the lake or adjacent streams. Overall, based upon the accuracy of the watershed information gathered as part of this study, the total nutrients currently being contributed from animal feeding areas within the Lake Alvin watershed is small.

OBJECTIVE 4- EVALUATE REDUCTIONS FROM BEST MANAGEMENT PRACTICES

Several different BMP's were modeled using the AGNPS computer model. Some of these BMP's included converting conventional tilled crop ground to minimum or no-till, installing Animal Waste Management Systems (AWMS), reducing fertilization levels of crop ground, and installing grassed waterways. From the collected data for the watershed, the conversion of cropland from conventional tillage to minimum tillage will have the greatest impact on the watershed.

The model estimated that converting 50 of the 56 critical erosion cells (2000 acres) to conservation tillage practices would reduce the sediment load delivered by Nine Mile Creek from 4,400 tons/year to 3770 tons/year (15% reduction). This practice will also reduce the total phosphorous yield from 20.4 tons/year to 19.4 tons/year (5% reduction).

The data for current fertilization levels on croplands indicate that most producers are currently not putting on excessive amounts of fertilizer. An AGNPS run was performed reducing fertilization levels on 40 cells (1600 acres) that currently are using an average amount of fertilizer (100 lbs/acre nitrogen and 40 lbs/acre phosphorous) to a low amount of fertilization (50 lbs/acre nitrogen and 20 lbs/acre phosphorous). The results of this run reduced the total nitrogen delivered at the outlet of Nine Mile Creek from 85 tons/year to 83 tons/year (approximately 2%) and reduced the total phosphorous from 20.4 tons/year to 20.1 tons/year (approximately 1.5%).

The model didn't show much of a reduction when grassed waterways were installed. This lack of a response for this BMP is probably because the model lacks the capabilities to accurately simulate this practice. Grassed waterways and riparian buffers should still be included in the workplan for this watershed and should be targeted to the worst erosion reaches and erosion cells.

It is recommended that any BMP's be targeted to the priority cells listed on page 11. Priority cells that are also in the ungauged watershed will also give the greatest reductions. All cells should be field verified before BMP's are installed. The model didn't simulate gully erosion or streambank erosion and these areas should also be evaluated.

CONCLUSIONS

Sediment

Based upon the AGNPS results, the sediment delivered from the outlet of Lake Alvin is 786 tons annually (0.028 tons/acre). This rate is much lower than the calculated subwatershed mean value of 0.16 tons/acre/year. This difference can be attributed to the trapping efficiency (82.3%) of Lake Alvin. The net watershed sediment deliverability rate at the outlet of Lake Alvin of 0.028 tons/acre/year appears to be very low however, this low rate under estimates the status of erosion and sediment deliverability throughout the watershed. When a detailed subwatershed analysis was performed, one of the seven subwatersheds analyzed appeared to have a very high sediment deliverability rate. The ungauged watershed was found to be contributing 38% of the total subwatershed sediment load, contain 32% of the critical erosion cells while comprising only 18.8% of the watershed area.

An analysis of individual cell sediment yields indicated that out of the 703 cells found within the Lake Alvin watershed, 56 (8%) had sediment erosion yields greater than 4.0 tons/acre for a 25 year event. The suspected primary source of elevated sedimentation within the critical cells is from agricultural lands which have land slopes of 4% or greater which are utilized as cropland (high C-factor). In order to determine the amount of reduction in sedimentation from these critical cells, the AGNPS model was run with reduced C-factors. The AGNPS model was run with reduced C-factors to simulate conservation tillage practices to determine the amount of sediment that could be retained.

The C-factors were changed on 50 cells (2000 acres) to a value that would simulate a change from conventional tillage to conservation tillage practices. Installing these practices will reduce the amount of sediment entering Lake Alvin annually from 4434 tons to 3777 tons (14.8% reduction). Therefore, it is recommended that efforts to reduce sediment should be focused within the identified critical subwatersheds and individual critical erosion cells located throughout the watershed. It is recommended that these areas be targeted for conversion to rangeland or the implementation of a high residue management plan. It is recommended that any targeted cell should be field verified prior to the installation of any best management practices.

Nutrients

The AGNPS data indicates that 85 tons of nitrogen and 20.4 tons of phosphorous are delivered to the lake while only 78 tons of nitrogen and 14.8 tons of phosphorous leave Lake Alvin. When a detailed subwatershed analysis was performed, three of the seven subwatersheds analyzed appeared to have high nutrient deliverability rates. Subwatersheds LAT-1 (#73), LAT-5 (#499) and the ungauged watershed were found to be contributing excessive amounts of nutrients. An analysis of individual cell nutrient yields indicated that out of the 703 cells found within the watershed, 50 (7.1%) cells had total nitrogen yields greater than 7.0 lbs./acre and 55 (7.8%) cells had total phosphorus yields greater than 2.5 lbs./acre. The AGNPS output showed that most of the nitrogen and phosphorous from the critical cells is in a water soluble form.

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

<u>Animal Feeding Areas</u>

A total of ten animal feeding areas were evaluated as part of the study. Of these, five were found to have an AGNPS rating of 40 or greater and one had an AGNPS rating of 50 or greater. An analysis to evaluate the impact of feeding areas was also performed. In order to determine the impact of these five feeding areas, an AGNPS run was made with these feeding areas removed and then compared to the run where the feeding areas were a part of the watershed. The results of this showed the total phosphorous load into Lake Alvin was reduced from 20.4 tons to 20.0 tons (2% reduction) annually. For this same scenario the total nitrogen load into Lake Alvin was reduced from 85 tons to 83.9 tons (1.1% reduction) annually. These five feeding areas located within cells #123, #177, #227, #350 and #655 appear to be contributing a small amount of nutrients to Lake Alvin. Cell #655 contains a feeding area that is positioned directly above the lake and drains directly to the lake. This feeding area should be evaluated for potential operational or structural modifications in order to minimize future nutrient releases into Lake Alvin.

Best Management Practices

It is recommended that efforts to reduce sediment and nutrients be targeted to the installation of appropriate BMPs on cropland ($\geq$ 4% slope), conversion of highly erodible cropland lands to rangeland or CRP, improvement of land surface cover (C-factor) on cropland and rangeland and measures initiated to reduce nutrient runoff from animal feeding areas.

The implementation of appropriate BMPs targeting identified critical cells, priority subwatersheds and priority feeding areas upon the completion of a field verification process should produce the most cost effective treatment plan in reducing sediment and nutrient yields from the Lake Alvin watershed.

If you have any questions concerning this study, please contact the Department of Environment and Natural Resources at 605-773-4254.

FEEDING AREA ANALYSIS

Cell #	123	Cell #	177
Nitrogen concentration (ppm)	937	Nitrogen concentration (ppm)	47
Phosphorus concentration (ppm)	26	Phosphorus concentration (ppm)	13
COD concentration (ppm)	1352	COD concentration (ppm)	682
Nitrogen mass (lbs)	162	Nitrogen mass (lbs)	147
Phosphorus mass (lbs)	45	Phosphorus mass (lbs)	41
COD mass (lbs)	2369	COD mass (lbs)	2140
Animal feedlot rating number	**40**	Animal feedlot rating number	**40**
Cell #	210	Cell #	227
Nitrogen concentration (ppm)	22	Nitrogen concentration (ppm)	81
Phosphorus concentration (ppm)	5	Phosphorus concentration (ppm)	21
COD concentration (ppm)	202	COD concentration (ppm)	1385
Nitrogen mass (lbs)	49	Nitrogen mass (lbs)	174
Phosphorus mass (lbs)	10	Phosphorus mass (lbs)	44
COD mass (lbs)	456	COD mass (lbs)	2975
Animal feedlot rating number	**18**	Animal feedlot rating number	**43**
Cell #	230	Cell #	263
Nitrogen concentration (ppm)	44	Nitrogen concentration (ppm)	68
Phosphorus concentration (ppm)	17	Phosphorus concentration (ppm)	17
COD concentration (ppm)	791	COD concentration (ppm)	1128
Nitrogen mass (lbs)	82	Nitrogen mass (lbs)	121
Phosphorus mass (lbs)	32	Phosphorus mass (lbs)	30
COD mass (lbs)	1463	COD mass (lbs)	1998
Animal feedlot rating number	**34**	Animal feedlot rating number	**38**
Cell #	318	Cell #	349
Nitrogen concentration (ppm)	44	Nitrogen concentration (ppm)	21
Phosphorus concentration (ppm)	11	Phosphorus concentration (ppm)	3
COD concentration (ppm)	659	COD concentration (ppm)	151
Nitrogen mass (lbs)	57	Nitrogen mass (lbs)	44
Phosphorus mass (lbs)	15	Phosphorus mass (lbs)	7
COD mass (lbs)	853	COD mass (lbs)	317
Animal feedlot rating number	**26**	Animal feedlot rating number	**13**
Cell #	350	Cell #	655
Nitrogen concentration (ppm)	269	Nitrogen concentration (ppm)	203
Phosphorus concentration (ppm)	48	Phosphorus concentration (ppm)	52
COD concentration (ppm)	4018	COD concentration (ppm)	3356
Nitrogen mass (lbs)	390	Nitrogen mass (lbs)	252
Phosphorus mass (lbs)	70	Phosphorus mass (lbs)	65
COD mass (lbs)	5828	COD mass (lbs)	4163
Animal feedlot rating number	**51**	Animal feedlot rating number	**47**

RAINFALL SPECS FOR THE LAKE ALVIN WATERSHED STUDY

EVENT	RAINFALL	ENERGY INTENSITY
Monthly	.9	4.8
Semi-annual	1.8	17.3
1 year	2.4	32.4
5 year	3.6	78.3
10 year	4.2	109.5
25 year	4.8	146.5
50 year	5.4	189.3
100 year	6.0	238.2

NRCS R_{factor} for the Lake Alvin watershed = 130

Annual Loadings Calculations

monthly events = 9 events x 4.8 = 43.2

6 month event = 3 events x 17.3 = 51.9

1 year event = 1 event x 24.3 = 32.4

========

Modeled Cumm. R_{factor} = 127.5

OVERVIEW OF AGNPS DATA INPUTS

OVERVIEW

Agricultural Nonpoint Source Pollution Model (AGNPS) is a computer simulation model developed to analyze the water quality of runoff from watersheds. The model predicts runoff volume and peak rate, eroded and delivered sediment, nitrogen, phosphorus, and chemical oxygen demand concentrations in the runoff and the sediment for a **single** storm event for all points in the watershed. Proceeding from the headwaters to the outlet, the pollutants are routed in a step-wise fashion so the flow at any point may be examined. AGNPS is intended to be used as a tool to objectively evaluate the water quality of the runoff from agricultural watersheds and to present a means of objectively comparing different watersheds throughout the state. The model is intended for watersheds up to about 320,000 acres (8000 cells @ 40 acres/cell).

The model works on a cell basis. These cells are uniform square areas which divide up the watershed (figure 1). This division makes it possible to analyze any area, down to 1.0 acres, in the watershed. The basic components of the model are hydrology, erosion, sediment transport, nitrogen (N), phosphorus (P), and chemical oxygen demand (COD) transport. In the hydrology portion of the model, calculations are made for runoff volume and peak concentration flow. Total upland erosion, total channel erosion, and a breakdown of these two sources into five particle size classes (clay, silt, small aggregates, large aggregates, and sand) for each of the cells are calculated in the erosion portion. Sediment transport is also calculated for each of the cells in the five particle classes as well as the total. The pollutant transport portion is subdivided into one part handling soluble pollutants and another part handling sediment attached pollutants (figure 2).

PRELIMINARY EXAMINATION

A preliminary investigation of the watershed is necessary before the input file can be established. The steps to this preliminary examination are:

1) Detailed topographic map of the watershed (USGS map 1:24,000) (figure 3).
2) Establish the drainage boundaries (figure 4).
3) Divide watershed up into cells (40 acre, 1320 X 1320). Only those cells with greater than 50% of their area within the watershed boundary should be included (figure 5).
4) Number the cells consecutively from one to the number of cells (begin at NW corner of watershed and precede west to east then north to south (figure 5).
5) Establish the watershed drainage pattern from the cells (figure 5).

DATA FILE

Once the preliminary examination is completed, the input data file can be established. The data file is composed of the following 21 inputs per cell (table 1):

<u>Data input for watershed</u> (attachment 1)
1) a) Area of each cell (acres)
   b) Total number of cells in watershed
   c) Precipitation for a ___ year, 24 hour rainfall
   d) Energy intensity value for storm event previously selected

Data input for each cell

1) **Cell number** (figure 6)
2) **Receiving cell number** (figure 6)
3) **SCS number**: runoff curve number (tables 2-4), (use antecedent moisture condition II)
4) **Land slope** (topographic maps) (figure 7), average slope if irregular, water or marsh = 0
5) **Slope shape factor** (figure 8), water or marsh = 1 (uniform)
6) **Field slope length** (figure 9), water or marsh = 0, for S.D. assume slope length area 1
7) **Channel slope** (average), topo maps, if no definable channel, channel slope = 1/2 land slope, water or marsh = 0
8) **Channel sideslope**, the average sideslope (%), assume 10% if unknown, water or marsh=0 9)
9) **Manning roughness coefficient for the channel** (table 5), If no channel exists within the cell, select a roughness coefficient appropriate for the predominant surface condition within the cell
10) **Soil erodibility factor** (attachment 2),water or marsh = 0
11) **Cropping factor** (table 6), assume conditions at storm or worst case condition (fallow or seedbed periods), water or marsh = .00, urban or residential = .01
12) **Practice factor** (table 7), worst case = 1.0, water or marsh = 0 ,urban or residential = 1.0
13) **Surface condition constant** (table 8), a value based on land use at the time of the storm to make adjustments for the time it takes overland runoff to channelize.
14) **Aspect** (figure 10), a single digit indicating the principal direction of drainage from the cell (if no drainage = 0)
15) **Soil texture**, major soil texture and number to indicate each are:

Texture	Input Parameter
Water	0
Sand	1
Silt	2
Clay	3
Peat	4

16) **Fertilization level**, indication of the level of fertilization on the field.

Level	Assume Fertilization (lb./acre) N	P	Input
No fertilization	0	0	0
Low Fertilization	50	20	1
Average Fertilization	100	40	2
High Fertilization	200	80	3

avg. manure - low fertilization
high manure - avg.fertilization
water or marsh = 0
urban or residential = 0 (for average practices)

17) **Availability factor**, (table 9) the percent of fertilizer left in the top half inch of soil at the time of the
storm. Worst case 100%, water or marsh = 0, urban or residential = 100%.

18) **Point source indicator**: indicator of feedlot within the cell (0 = no feedlot, 1 = feedlot) (attachment 3).

19) **Gully source level**: tons of gully erosion occurring in the cell or input from a sub-watershed (attachment 4).

20) **Chemical oxygen demand (COD) demand**, (table 10) a value of COD for the land use in the cell.

21) **Impoundment factor**: number of impoundment's in the cell (max. 13) (attachment 5)
  a) Area of drainage into the impoundment
  b) Outlet pipe (inches)

22) **Channel indicator**: number which designates the type of channel found in the cell (Table 11)

DATA OUTPUT AT THE OUTLET OF EACH CELL

Hydrology
Runoff volume
Peak runoff rate
Fraction of runoff generated within the cell

Sediment Output
Sediment yield
Sediment concentration
Sediment particle size distribution
Upland erosion
Amount of deposition
Sediment generated within the cell
Enrichment ratios by particle size
Delivery ratios by particle size

Chemical Output
Nitrogen
Sediment associated mass
Concentration of soluble material
Mass of soluble material

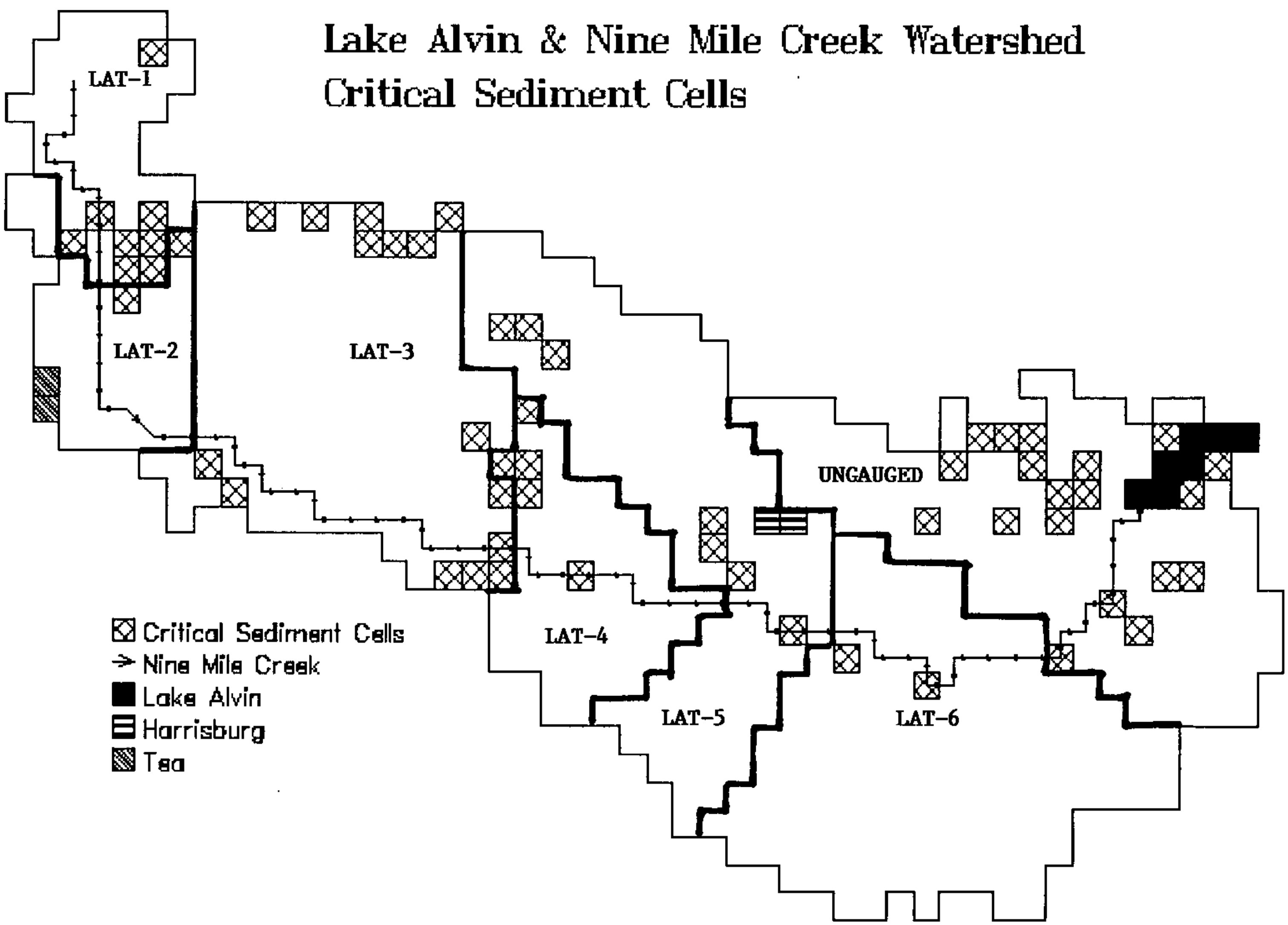
Phosphorus
Sediment associated mass
Concentration of soluble material
Mass of soluble material

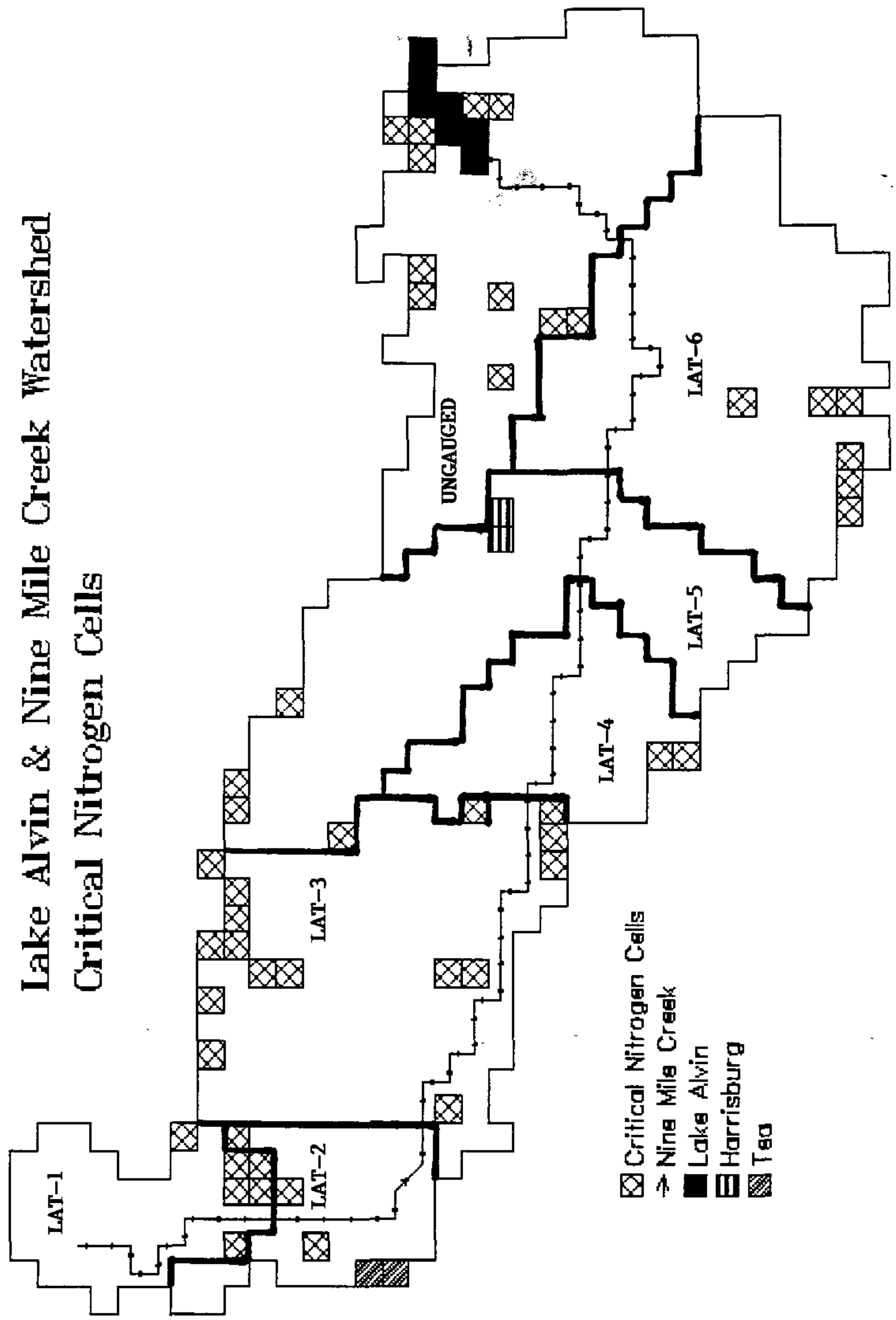
Chemical Oxygen Demand
Concentration
Mass

PARAMETER SENSITIVITY ANALYSIS

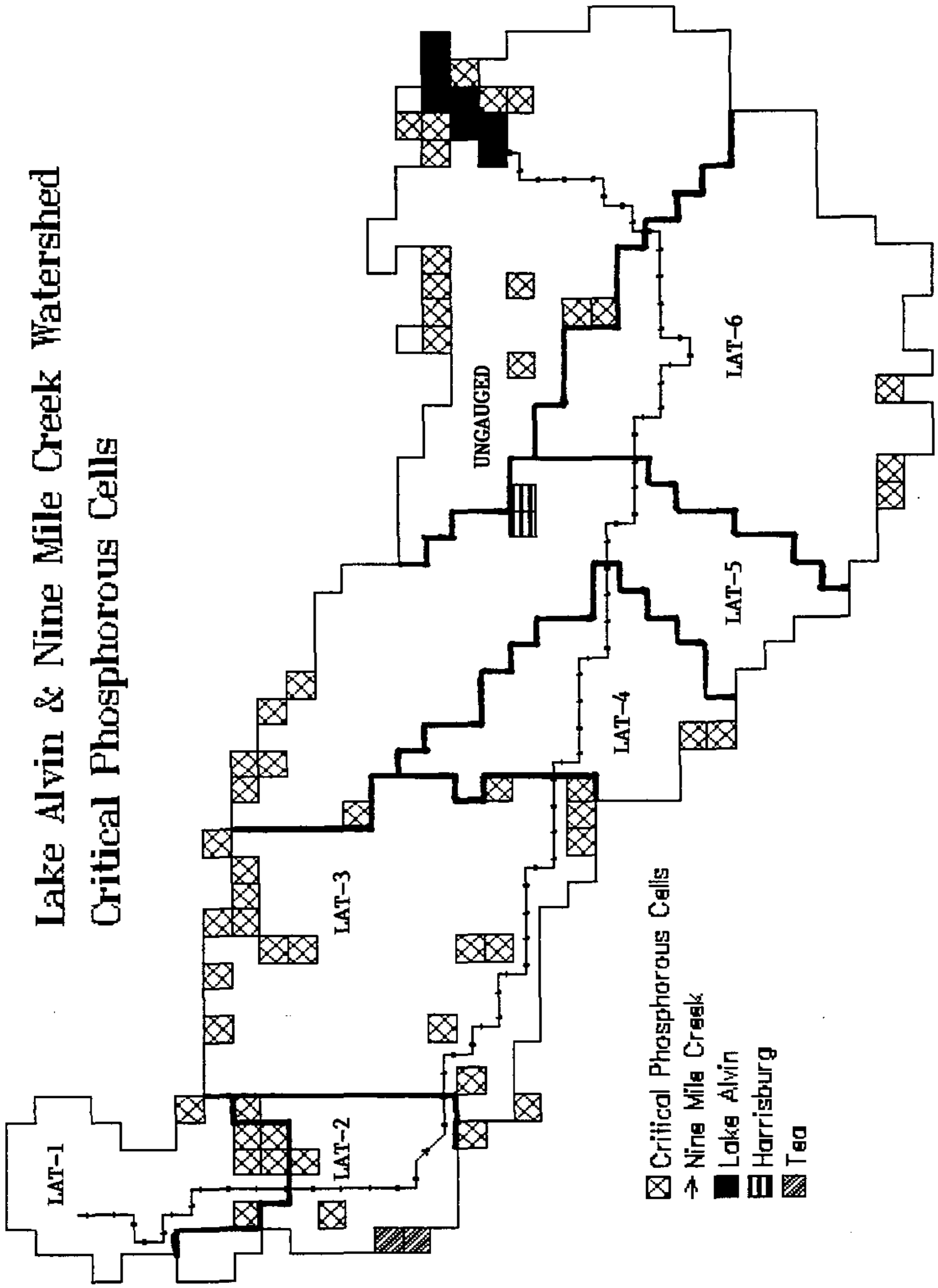
The most sensitive parameters affecting sediment and chemical yields are:
Land slope (LS)
Soil erodibility (K)
Cover-management factor (C)
Curve number (CN)
Practice factor (P)

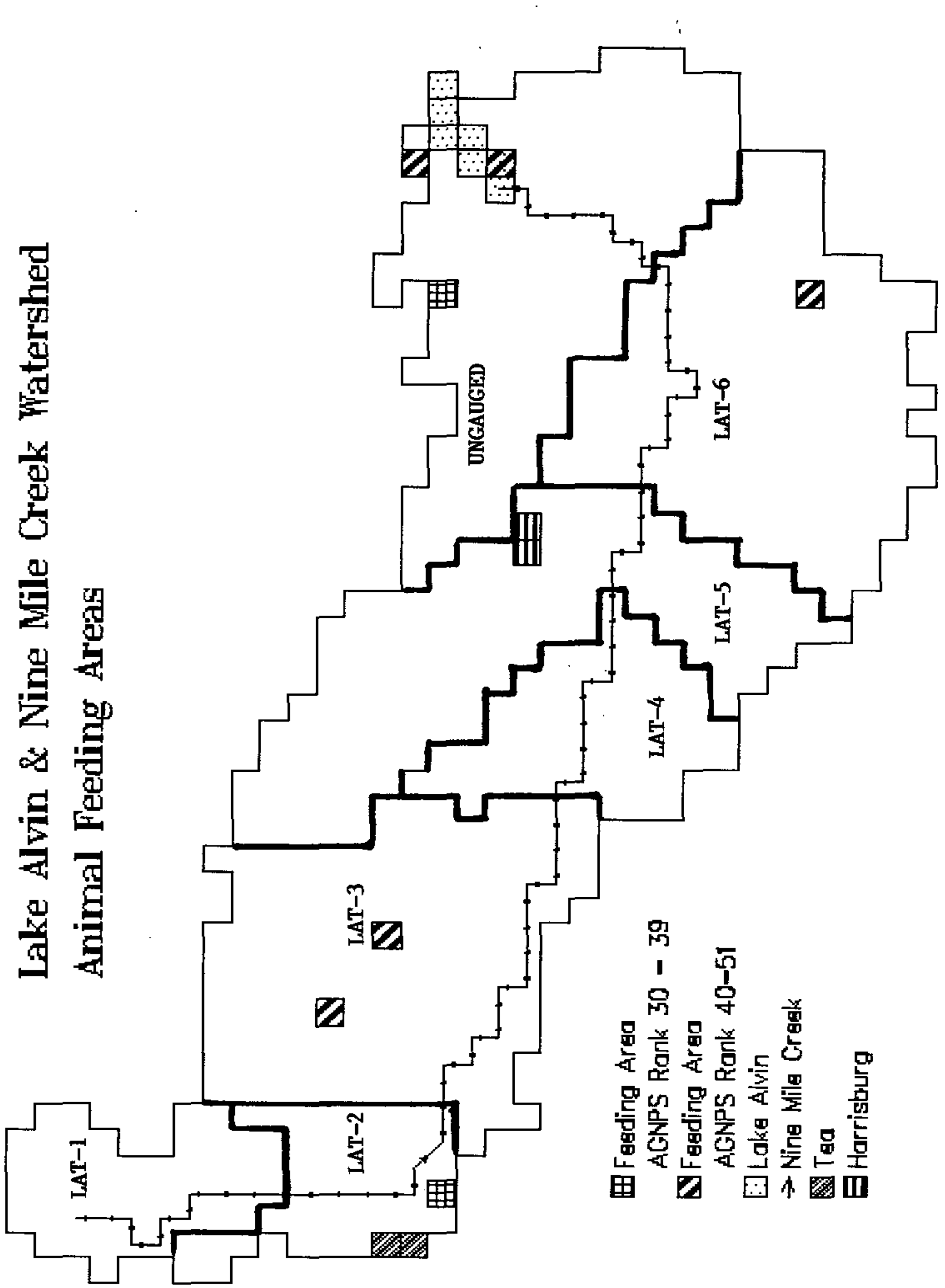
Lake Alvin & Nine Mile Creek Watershed
Critical Sediment Cells




Lake Alvin & Nine Mile Creek Watershed
Critical Nitrogen Cells
LAT-1
LAT-2
LAT-3
LAT-4
LAT-5
LAT-6
UNGAUGED
Critical Nitrogen Cells
Nine Mile Creek
Lake Alvin
Harrisburg
Tea

Lake Alvin & Nine Mile Creek Watershed
Critical Phosphorous Cells




Lake Alvin & Nine Mile Creek Watershed
Animal Feeding Areas
LAT-1
LAT-2
LAT-3
LAT-4
LAT-5
LAT-6
UNGAUGED
Feeding Area
AGNPS Rank 30 - 39
Feeding Area
AGNPS Rank 40-51
Lake Alvin
Nine Mile Creek
Tea
Harrisburg

Appendix F.

Nine Mile Creek Tributary Chemical Data for 1999

Table F-1. Chemical data concentrations for Nine Mile Creek by site and date for 1999.

Tributary	Site	Time	Date	DO: mg/L	pH: su	Water Temp. °C	Fecal Coliform #/100 ml	Total Alkalinity mg/L	Total Solids mg/L	Total Suspended Solids mg/L	Total Dissolved Solids mg/L	Ammonia mg/L	Nitrate mg/L	Organic Nitrogen mg/L	Total Nitrogen mg/L	Pho
Nine Mile	LAT1	1530	03/24/99	11.40	8.01	8.0	2	219	1556.0	1.0	1555	0.01	0.2	0.89	1.10	
Nine Mile	LAT2	1445	03/24/99	9.50	8.00	7.0	4	207	1523.0	2.0	1521	0.01	0.1	0.88	0.99	
Nine Mile	LAT3	1400	03/24/99	10.80	8.33	9.0	0	195	1418.0	5.0	1413	0.01	0.2	0.86	1.07	
Nine Mile	LAT4	1330	03/24/99	9.80	8.57	8.0	0	195	1409.0	5.0	1404	0.01	0.6	0.87	1.48	
Nine Mile	LAT5	1430	03/24/99	11.00	8.47	7.0	0	188	1359.0	6.0	1353	0.01	0.5	0.82	1.33	
Nine Mile	LAT6	1100	03/24/99	12.50	8.62	7.0	0	191	1372.0	10.0	1362	0.01	0.6	0.89	1.50	
Nine Mile	LAT7	1000	03/24/99	15.00	8.60	7.0	0	175	1272.0	22.0	1250	0.08	0.9	1.46	2.44	
Nine Mile	LAT6	1145	04/01/99	-	-	9.0	110	214	1738.0	55.0	1683	0.01	0.6	0.97	1.58	
Nine Mile	LAT1	1210	04/07/99	7.20	7.91	11.0	10	207	1608.0	18.0	1590	0.01	0.3	1.17	1.48	
Nine Mile	LAT2	1135	04/07/99	5.80	7.92	10.0	100	162	1624.0	4.0	1620	0.01	0.8	1.23	2.04	
Nine Mile	LAT3	1615	04/06/99	9.40	8.64	12.0	440	171	1539.0	35.0	1504	0.01	2.1	1.27	3.38	
Nine Mile	LAT4	1445	04/06/99	11.80	8.28	8.0	1900	156	1569.0	32.0	1537	0.01	3.2	1.23	4.44	
Nine Mile	LAT5	1400	04/06/99	10.80	8.05	8.0	1000	150	1564.0	55.0	1509	0.01	3.3	1.26	4.57	
Nine Mile	LAT6	1200	04/06/99	10.70	8.26	5.0	9300	158	1509.0	80.0	1429	0.01	3.6	1.43	5.04	
Nine Mile	LAT1	1015	04/12/99	7.20	7.92	8.0	5	161	1166.0	2.0	1164	0.01	1.2	1.17	2.38	
Nine Mile	LAT2	1045	04/12/99	6.00	7.95	8.0	140	152	1189.0	4.0	1185	0.01	1.1	1.19	2.30	
Nine Mile	LAT3	1145	04/12/99	8.10	8.04	9.0	90	150	1157.0	15.0	1142	0.01	1.5	1.17	2.68	
Nine Mile	LAT4	1215	04/12/99	8.20	8.13	9.0	120	150	1145.0	26.0	1119	0.01	2.1	1.16	3.27	
Nine Mile	LAT5	1315	04/12/99	8.20	8.04	10.0	40	149	1134.0	33.0	1101	0.01	2.1	1.19	3.30	
Nine Mile	LAT6	1400	04/12/99	8.65	8.14	10.0	130	149	1149.0	44.0	1105	0.01	2.5	1.27	3.78	
Nine Mile	LAT4	1420	04/22/99	14.80	8.85	11.0	50	202	1663.0	45.0	1618	0.01	0.8	1.39	2.20	
Nine Mile	LAT3	1335	04/22/99	10.60	8.40	11.0	30	209	1685.0	29.0	1656	0.01	0.2	1.29	1.50	
Nine Mile	LAT6	1515	04/22/99	11.80	8.58	11.0	100	210	1611.0	18.0	1593	0.01	1.2	1.13	2.34	
Nine Mile	LAT2	1345	05/13/99	3.20	-	16.0	40	234	1803.0	5.0	1798	0.01	0.1	1.21	1.27	
Nine Mile	LAT1	1330	05/13/99	5.40	-	17.0	60	254	1828.0	13.0	1815	0.01	0.1	1.29	1.40	
Nine Mile	LAT6	1145	05/13/99	7.00	-	14.0	450	240	1747.0	56.0	1691	0.01	1.2	1.04	2.25	
Nine Mile	LAT5	1200	05/13/99	7.20	-	14.0	40	233	1746.0	39.0	1707	0.01	1.0	1.20	2.21	
Nine Mile	LAT4	1230	05/13/99	7.80	-	15.0	70	232	1768.0	30.0	1738	0.01	1.1	1.17	2.28	
Nine Mile	LAT3	1250	05/13/99	7.00	-	14.0	60	239	1798.0	55.0	1743	0.01	0.3	1.11	1.42	
Nine Mile	LAT6	1100	06/02/99	6.80	8.00	16.5	40	3.5	2.5	0.1	2	0.36	3.6	2.21	6.17	

Table F-1. (Continued) Chemical data concentrations for Nine Mile Creek by site and date for 1999.

Tributary	Site	Time	Date	DO: mg/L	pH: su	Water Temp. °C	Fecal Coliform #/100 ml	Total Alkalinity mg/L	Total Solids mg/L	Total Suspended Solids mg/L	Total Dissolved Solids mg/L	Ammonia mg/L	Nitrate mg/L	Organic Nitrogen mg/L	Total Nitrogen mg/L	Pho
Nine Mile	LAT5	1020	06/02/99	6.30	8.30	16.0	5	201	1707.0	51.0	1656	0.48	2.5	2.13	5.11	
Nine Mile	LAT4	950	06/02/99	5.80	8.04	16.0	20	207	1807.0	178.0	1629	0.38	2.1	2.47	4.95	
Nine Mile	LAT3	910	06/02/99	5.00	8.01	15.0	5	200	1591.0	14.0	1577	0.14	0.8	1.53	2.47	
Nine Mile	LAT2	840	06/02/99	6.00	7.72	16.0	5	186	1578.0	1.0	1577	0.01	0.1	1.24	1.30	
Nine Mile	LAT1	740	06/02/99	3.20	7.89	15.0	350	227	1853.0	20.0	1833	0.19	0.6	2.67	3.46	
Nine Mile	LAT6	1400	06/29/99	6.80	7.89	21.0	380	252	2007.0	15.0	1992	0.34	1.3	1.09	2.73	
Nine Mile	LAT5	1320	06/29/99	9.20	8.27	20.0	280	236	1850.0	54.0	1796	0.01	3.5	0.76	4.27	
Nine Mile	LAT4	1245	06/29/99	15.00	8.60	19.0	170	239	2076.0	111.0	1965	0.01	4.4	1.20	5.61	
Nine Mile	LAT3	1130	06/29/99	15.00	8.14	19.0	320	266	2129.0	104.0	2025	0.01	1.2	1.37	2.58	
Nine Mile	LAT2	1100	06/29/99	1.40	7.46	18.0	250	206	1500.0	55.0	1445	0.02	0.1	1.14	1.21	
Nine Mile	LAT1	1000	06/29/99	4.00	7.86	16.0	260	318	2138.0	11.0	2127	0.01	0.1	1.52	1.63	
Nine Mile	LAT1	1030	07/14/99	2.00	7.60	20.0	160	373	2271.0	30.0	2241	0.01	0.2	1.02	1.23	
Nine Mile	LAT2	1100	07/14/99	1.00	7.60	24.0	800	298	2367.0	222.0	2145	0.03	0.1	1.90	1.98	
Nine Mile	LAT3	1130	07/14/99	5.50	8.10	24.0	30	277	2007.0	98.0	1909	0.01	8.3	1.07	9.38	
Nine Mile	LAT4	1200	07/14/99	5.20	8.10	25.0	30	182	1888.0	104.0	1784	0.22	3.3	1.07	4.59	
Nine Mile	LAT5	1300	07/14/99	6.00	7.82	25.0	3400	201	1884.0	174.0	1710	0.11	1.7	1.12	2.93	
Nine Mile	LAT6	1400	07/14/99	8.00	7.91	27.0	340	233	2192.0	116.0	2076	0.01	0.7	0.82	1.53	
Nine Mile	LAT7	1430	07/14/99	11.00	8.39	30.0	110	159	1669.0	25.0	1644	0.01	0.6	1.40	2.01	
Nine Mile	LAT-6	1145	08/31/99	5.30	8.09	23.0	140	256	2695.0	106.0	2589	0.02	0.2	1.03	5.45	
Nine Mile	LAT-7	0930	08/31/99	6.20	8.70	25.0	120	183	1302.0	144.0	1158	0.01	0.1	1.40	1.46	
Nine Mile	LAT TEA	1000	08/31/99	8.70	8.51	23.0	5	189	1453.0	113.0	1340	0.02	4.4	0.94	1.15	
Nine Mile	LAT2	1215	11/09/99	7.80	7.57	16.1	260	90	2318.0	4.0	2314	0.01	0.1	1.65	1.76	
Nine Mile	LAT6	1140	11/09/99	9.60	7.82	16.7	5	300	2613.0	30.0	2583	0.01	0.7	0.72	1.43	

Appendix G.

Lake Alvin Tributary Quality Assurance/Quality Control Chemical Data Tables 1999

Table G-1. Quality control quality assurance blank and duplicate samples for Nine Mile Creek by site and da

Lake	Site	Time	Date	DO: mg/L	pH: su	Water Temp. oC	Fecal Coliform #/100 ml	Total Alkalinity mg/L	Total Solids mg/L	Total Suspended Solids mg/L	Total Dissolved Solids mg/L	Ammonia mg/L	Nitrate mg/L	Organic Nitrogen mg/L	Total Nitrogen mg/L	I
Nine Mile	LAT4-B	1445	04/06/1999	-	-	-	0	3.0	1.0	0.5	0.5	0.01	0.05	0.04	0.10	
Nine Mile	LAT2-B	1300	04/22/1999	-	-	-	0	3.0	13.0	1.0	12.0	0.01	0.05	0.06	0.12	
Nine Mile	LAT1-B	740	06/02/1999	-	-	-	0	3.0	2.5	0.1	2.5	0.01	0.05	0.06	0.13	
Nine Mile	LAT5-B	1320	06/29/1999	-	-	-	0	3.0	2.5	0.5	2.0	0.01	0.05	0.06	0.12	
Mean							0.0	3.0	4.75	0.53	4.25	0.01	0.05	0.06	0.12	
Standard Deviation							0.0	0.0	5.55	0.37	5.24	0.00	0.00	0.01	0.01	
Nine Mile	LAT-4	1445	04/06/1999	11.80	8.28	8.0	1900	156	1569.0	32.0	1537	0.01	3.2	1.23	4.44	
Nine Mile	LAT-4D	1445	04/06/1999	11.80	8.28	8.0	1200	155	1600.0	35.0	1565	0.01	3.2	1.34	4.55	
Industrial Statistic (%I)				0.0%	0.0%	0.0%	22.6%	0.3%	1.0%	4.5%	0.9%	0.0%	0.0%	4.3%	1.2%	
Nine Mile	LAT-2	1300	04/22/1999	4.00	7.54	11.0	30	204	1666	9.0	1657	0.01	0.1	1.33	1.35	
Nine Mile	LAT-2D	1315	04/22/1999	-	7.76	11	80	204	1664	11	1653	0.01	0.1	1.37	1.39	
Industrial Statistic (%I)				-	1.4%	0.0%	45.5%	0.0%	0.1%	10.0%	0.1%	0.0%	0.0%	1.5%	1.5%	
Nine Mile	LAT1	740	06/02/1999	3.20	7.89	15.0	350	227	1853.0	20.0	1833	0.19	0.6	2.67	3.46	
Nine Mile	LAT1D	740	06/02/1999	3.20	7.89	15.0	200	226	1863.0	12.0	1851	0.17	0.6	2.59	3.36	
Industrial Statistic (%I)				0.0%	0.0%	0.0%	27.3%	0.2%	0.3%	25.0%	0.5%	5.6%	0.0%	1.5%	1.5%	
Nine Mile	LAT5	1320	06/29/1999	9.20	8.27	20.0	280	236	1850.0	54.0	1796	0.01	3.5	0.76	4.27	
Nine Mile	LAT5D	1320	06/29/1999	9.20	8.27	20.0	410	236	1839.0	49.0	1790	0.01	3.6	0.92	4.53	
Industrial Statistic (%I)				0.0%	0.0%	0.0%	18.8%	0.0%	0.3%	4.9%	0.2%	0.0%	1.4%	9.5%	3.0%	

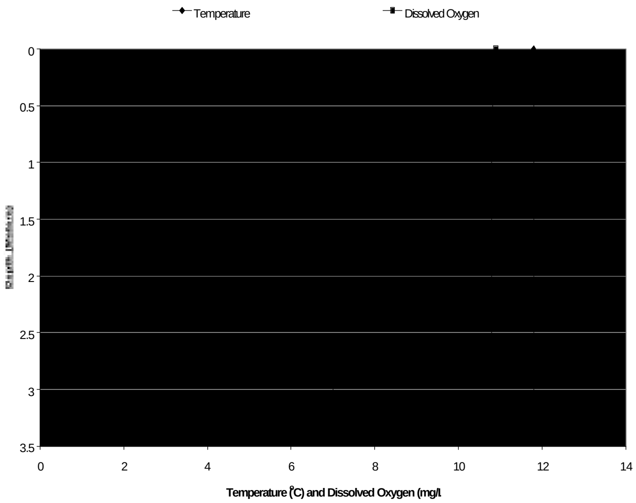
Industrial Statistic (%I) = Absolute (A-B)/ Absolute (A+B)*100

Appendix H.

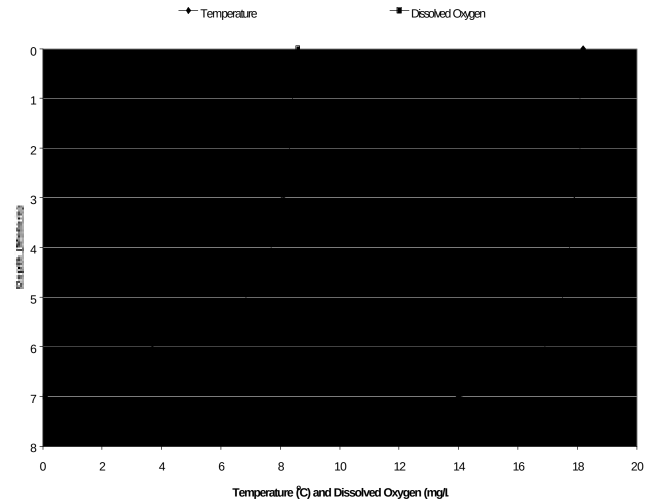
Lake Alvin Inlake Temperature and Dissolved Oxygen Profiles 1999 and Inlake Benthic Temperature and Dissolved Oxygen Profiles 2000

Inlake Sampling Profiles 1999

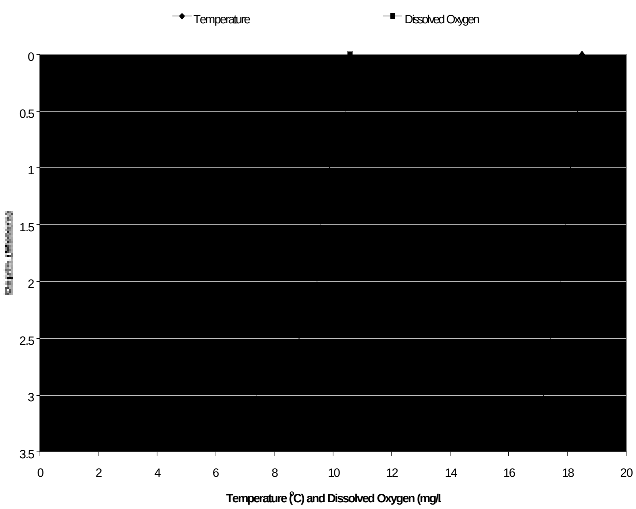
Lake Alvin LA-1 Temperature and Dissolved Oxygen Profiles for April 27, 1999



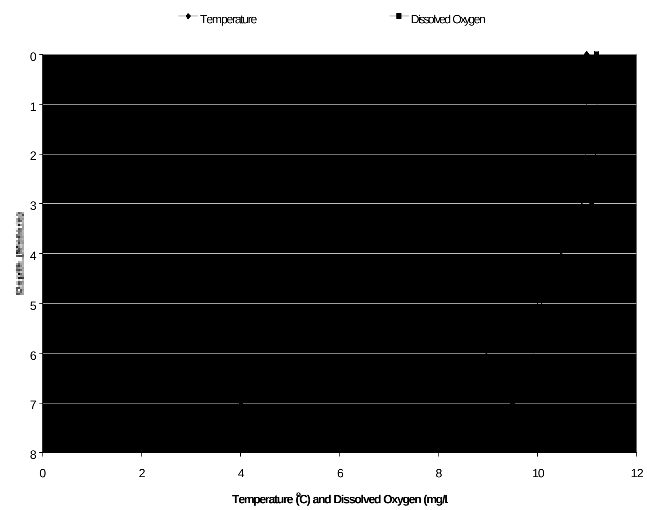
Lake Alvin LA-2 Temperature and Dissolved Oxygen Profiles for April 27, 1999



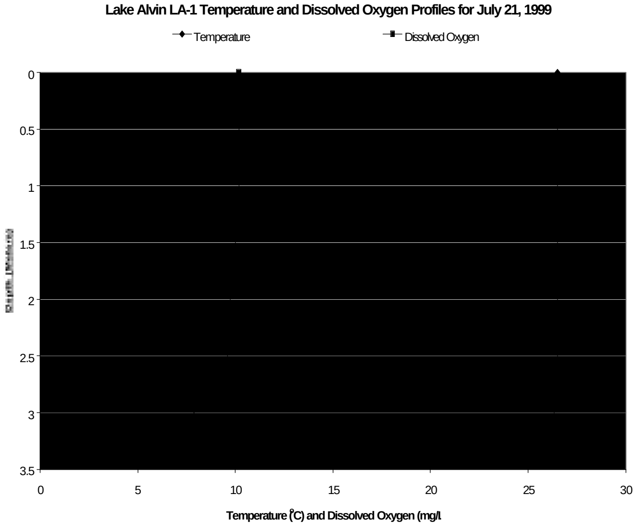
Lake Alvin LA-1 Temperature and Dissolved Oxygen Profiles for May 24, 1999



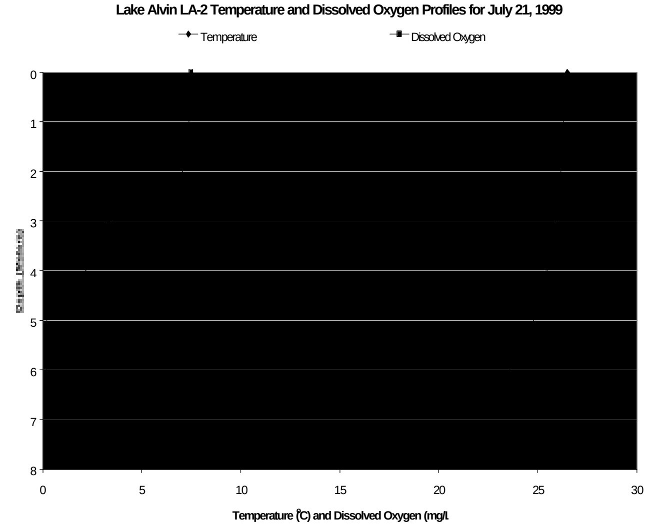
Lake Alvin LA-2 Temperature and Dissolved Oxygen Profiles for May 24, 1999



Lake Alvin LA-1 Temperature and Dissolved Oxygen Profiles for July 21, 1999

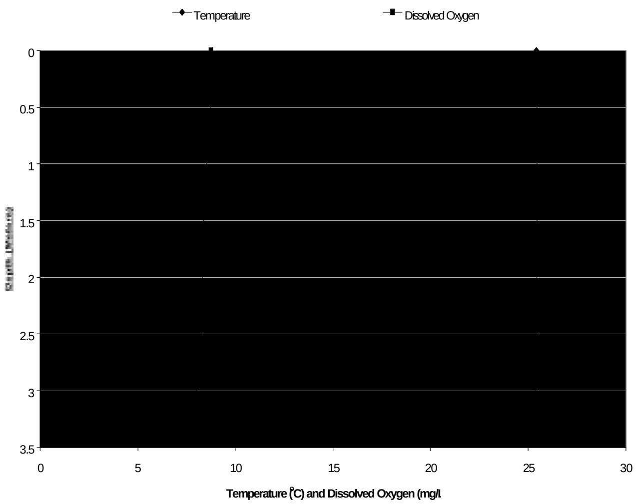


Lake Alvin LA-2 Temperature and Dissolved Oxygen Profiles for July 21, 1999

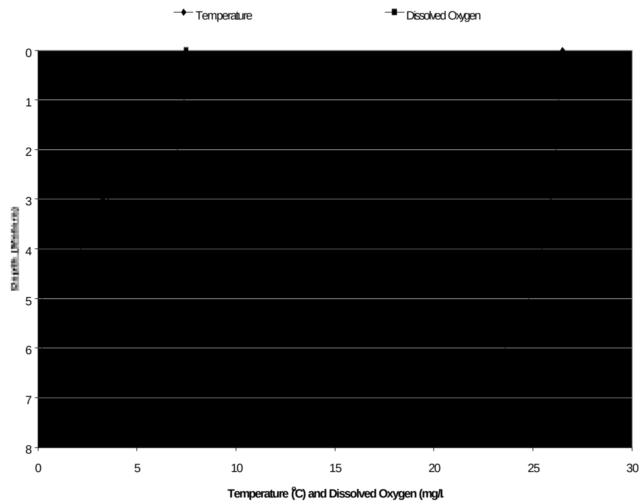


Inlake Sampling Profiles 1999

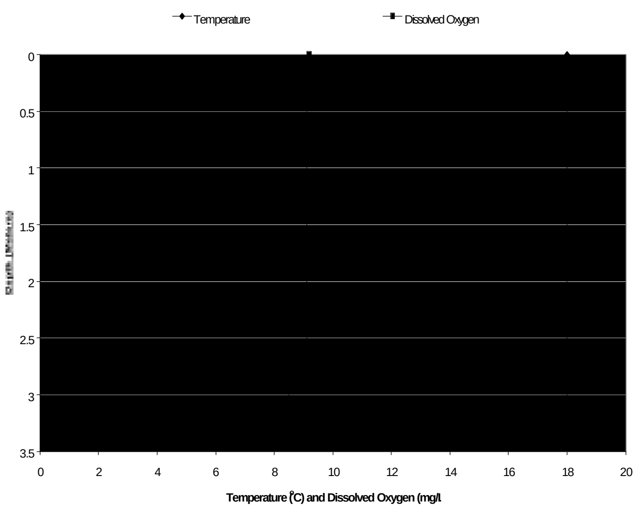
Lake Alvin LA-1 Temperature and Dissolved Oxygen Profiles for August 12, 1999



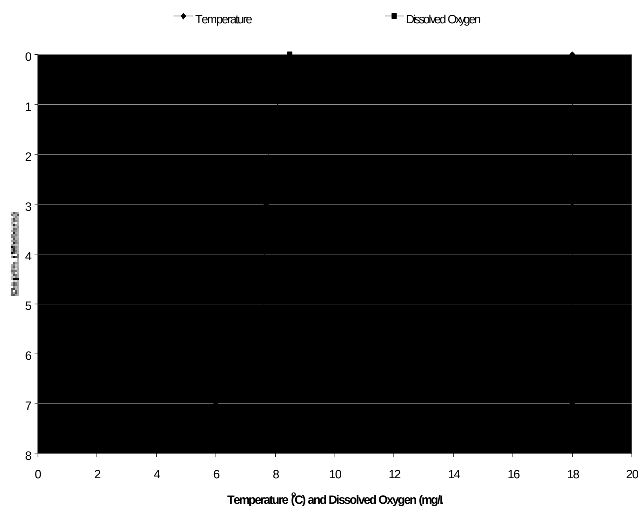
Lake Alvin LA-2 Temperature and Dissolved Oxygen Profiles for August 12, 1999



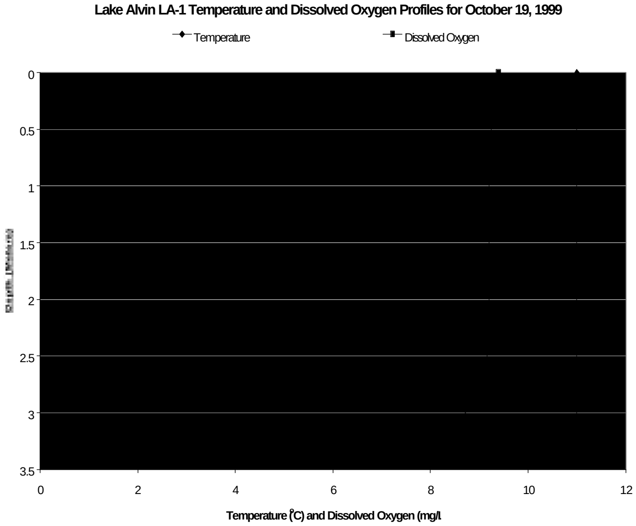
Lake Alvin LA-1 Temperature and Dissolved Oxygen Profiles for September 20, 1999



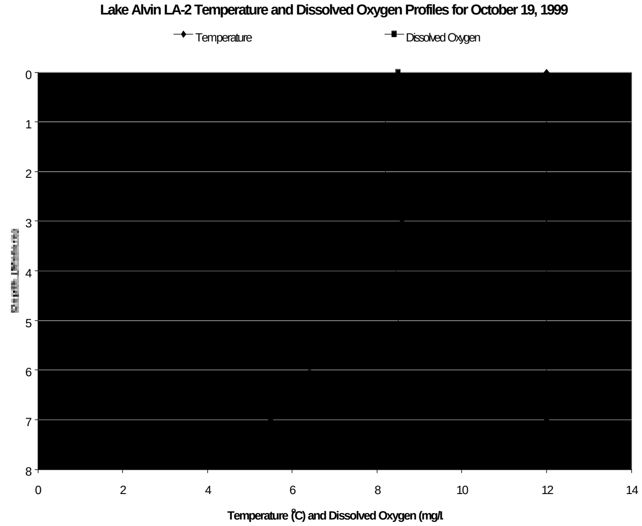
Lake Alvin LA-2 Temperature and Dissolved Oxygen Profiles for September 20, 1999



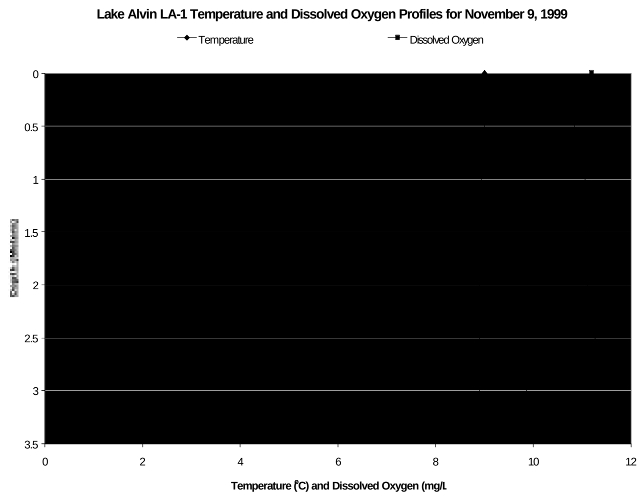
Lake Alvin LA-1 Temperature and Dissolved Oxygen Profiles for October 19, 1999

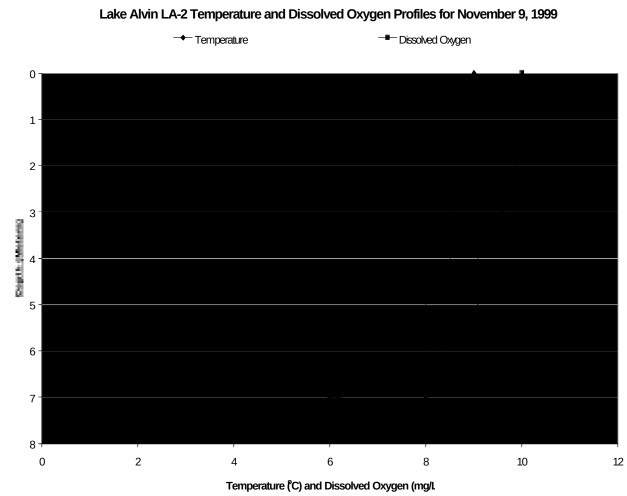


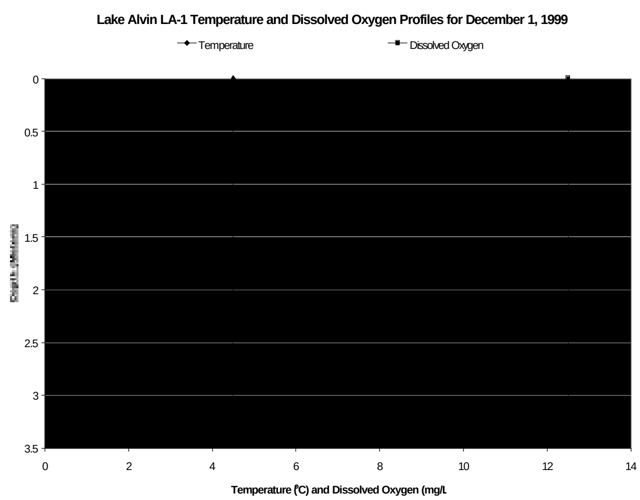
Lake Alvin LA-2 Temperature and Dissolved Oxygen Profiles for October 19, 1999

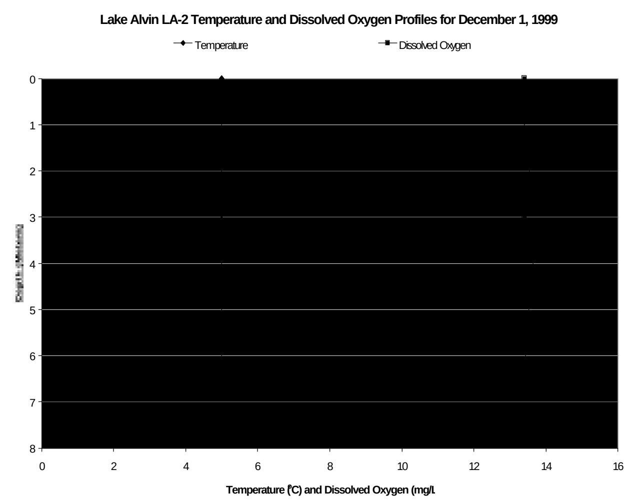


Inlake Sampling Profiles 1999

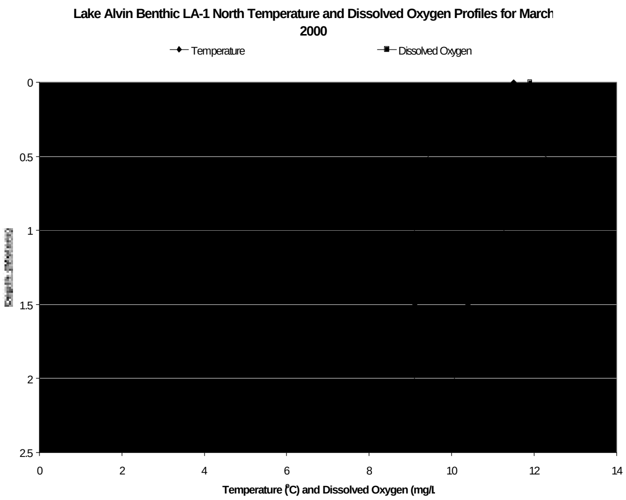


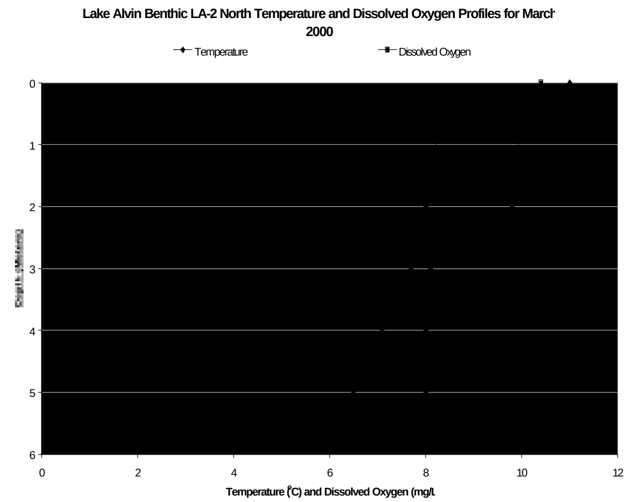


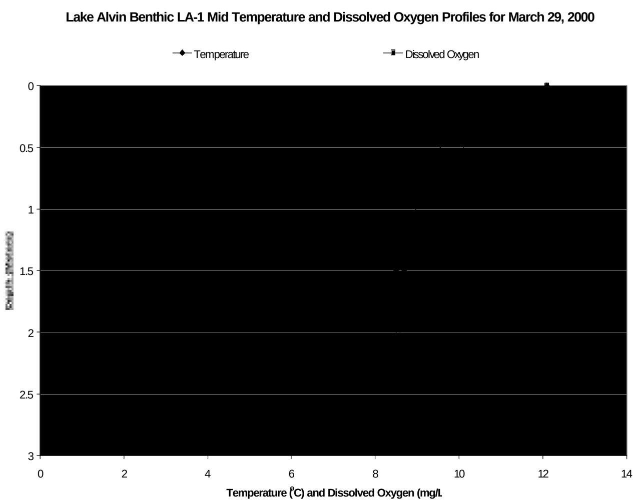


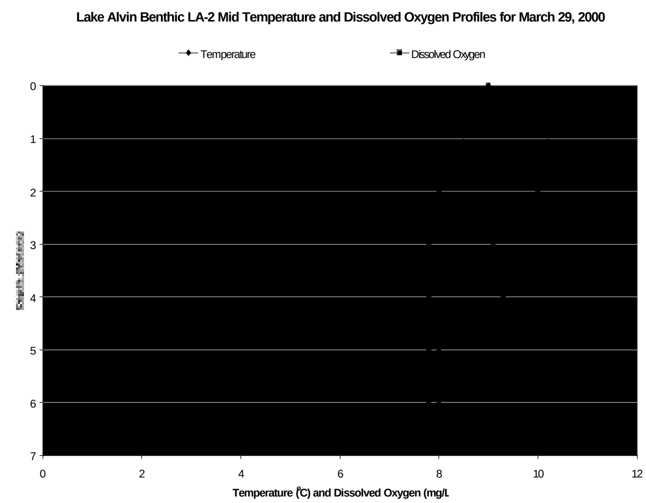


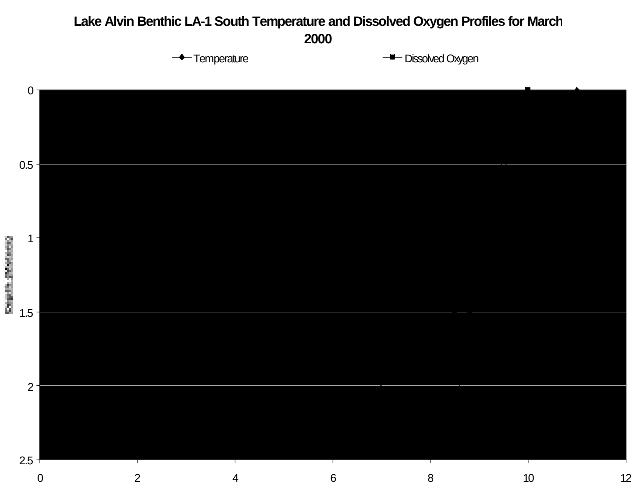
Inlake Benthic Sampling Profiles 2000

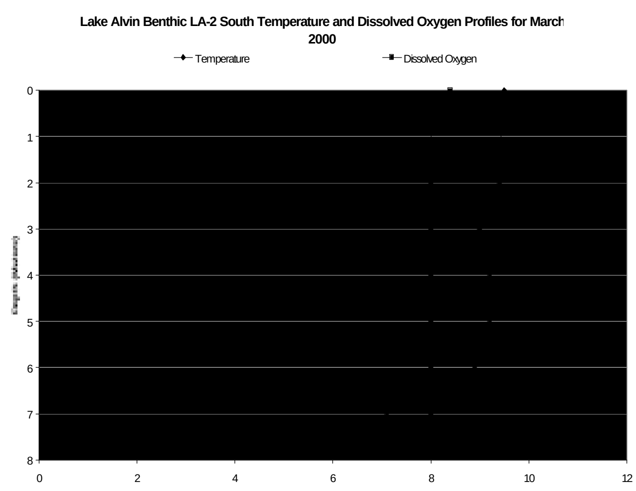






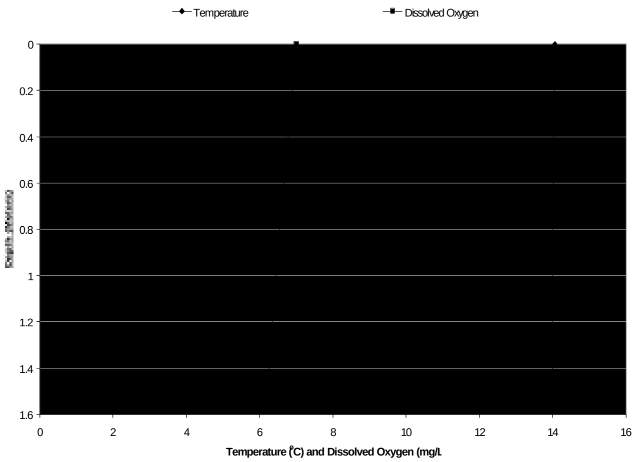




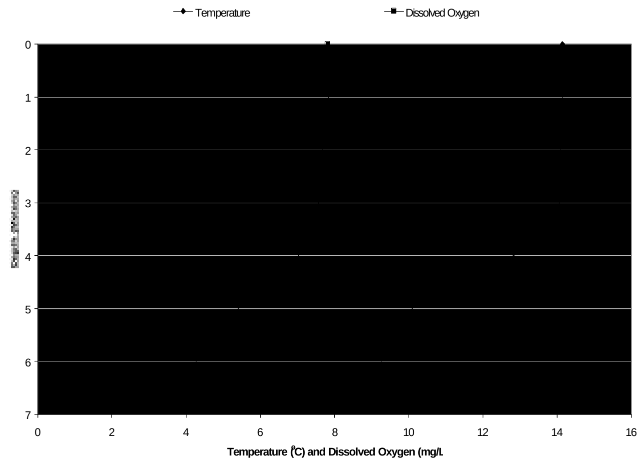


Inlake Benthic Sampling Profiles 2000

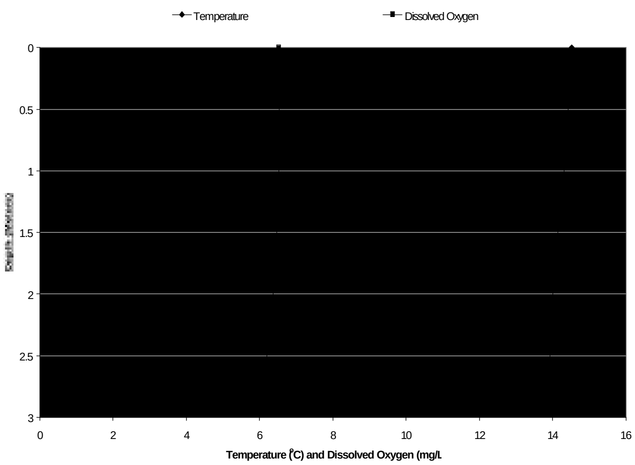
Lake Alvin Benthic LA-1 North Temperature and Dissolved Oxygen Profiles for April 27, 2000



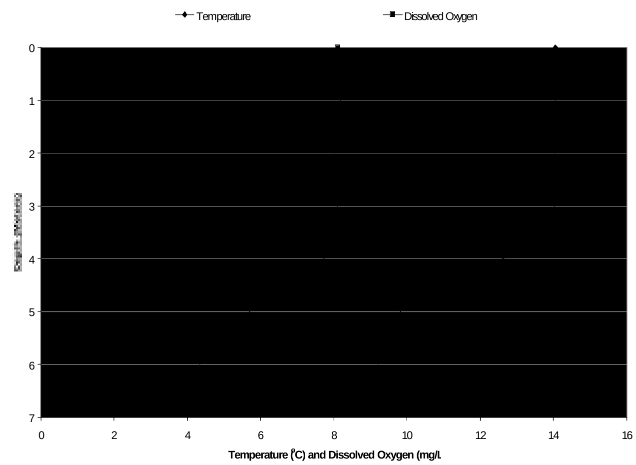
Lake Alvin Benthic LA-2 North Temperature and Dissolved Oxygen Profiles for April 27, 2000



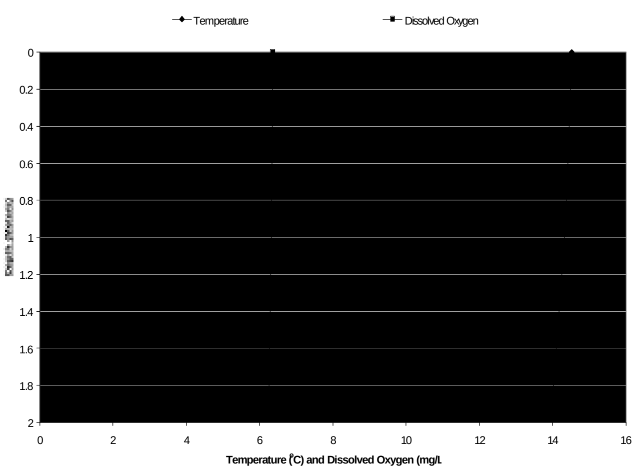
Lake Alvin Benthic LA-1 Mid Temperature and Dissolved Oxygen Profiles for April 27, 2000



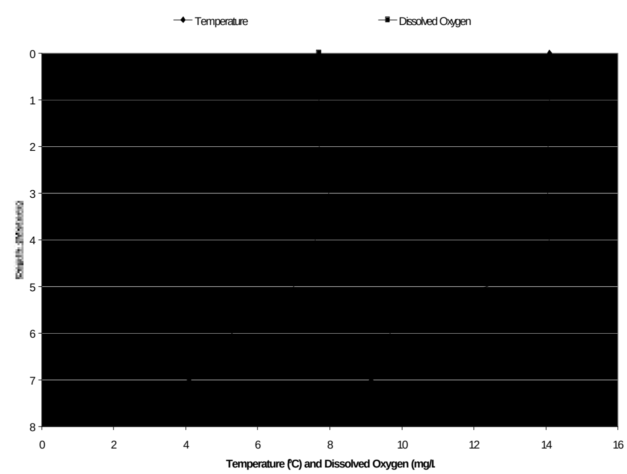
Lake Alvin Benthic LA-2 Mid Temperature and Dissolved Oxygen Profiles for April 27, 2000



Lake Alvin Benthic LA-1 South Temperature and Dissolved Oxygen Profiles for April 27, 2000



Lake Alvin Benthic LA-2 South Temperature and Dissolved Oxygen Profiles for April 27, 2000



Appendix I.

Lake Alvin Inlake Chemical Data Tables 1999

Table I-1. Surface chemical concentrations for Lake Alvin by site and date for 1999.

	27-Apr-99		24-May-99		21-July-99		12-Aug-99		20-Sept-99		19-Oct-99		09-Nov-	
	LA-1	**LA-2**	**LA-1**	**LA-2**	**LA-1**	**LA-2**	**LA-1**	**LA-2**	**LA-1**	**LA-2**	**LA-1**	**LA-2**	**LA-1**	**I**
Parameter	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**n**
Air Temp (C)	11.0	11.0	19.0	19.0	23.9	25.0	20.0	18.3	10.0	11.1	6.0	6.0	13.0	1
DO	10.9	11.2	10.6	8.6	10.2	7.5	8.3	3.4	9.2	8.5	9.4	8.5	11.2	1
PH	8.23	8.18	8.08	8.07	7.90	7.90	8.50	7.80	8.57	8.49	8.5	8.52	8.87	8
Depth	S	S	S	S	S	S	S	S	S	S	S	S	S	
Secchi Disk (m)	0.4	0.7	0.5	0.8	0.6	1.4	0.9	0.8	0.6	0.5	0.5	0.7	0.5	
Water Temp (C)	11.8	11.0	18.5	18.2	26.5	26.5	25.0	25.0	18.0	18.0	11.0	12.0	9.0	
Fecal Col.	10.0	10.0	10.0	10.0	20.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	1
Alkalinity Total	184.0	167.0	179.0	161.0	140.0	147.0	113.0	168.0	131.0	130.0	151.0	145.0	156.0	1
Alkalinity-P	3.0	4.0	4.0	0	0	0	0	0	14.0	8.0	10.0	9.0	10.0	1
Solids, Total	1413	1280	1600	1517	1647	1645	1619	1638	1682	1670	1705	1683	1720	1
Solids, Suspended	23.0	9.0	19.0	14.0	22.0	9.0	23.0	8.0	20.0	17.0	18.0	14.0	20.0	1
Total dissolved solid	1394	1266	1578	1508	1624	1637	1599	1621	1664	1656	1685	1667	1701	1
VTSS	3.0	3.0	5.0	6.0	12.0	4.0	14.0	4.0	10.0	15.0	14.0	8.0	7.0	
Ammonia	0.01	0.01	0.01	0.05	0.01	0.01	0.01	3.26	0.01	0.01	0.01	0.03	0.01	(
Nitrate	1.90	2.30	1.30	1.30	0.20	0.50	0.05	0.05	0.05	0.05	0.05	0.05	0.05	(
TKN	1.74	1.51	2.03	1.55	1.75	1.49	1.38	5.74	1.74	2.33	1.75	1.97	2.25	2
Total Nitrogen	3.64	3.81	3.33	2.85	1.95	1.99	1.43	5.79	1.79	2.38	1.80	2.02	2.30	2
Organic N2	1.73	1.50	2.02	1.50	1.74	1.48	1.37	2.48	1.73	2.32	1.74	1.94	2.24	2
Phosphorous Total	0.111	0.090	0.092	0.071	0.110	0.064	0.206	0.977	0.28	0.334	0.322	0.310	0.279	0
Phosphorous, Total Dissolved	0.020	0.031	0.011	0.013	0.025	0.018	0.047	0.438	0.136	0.151	0.195	0.238	0.116	0

Table I-2. Bottom chemical concentrations for Lake Alvin by site and date for 1999.

	27-Apr-99		24-May-99		21-July-99		12-Aug-99		20-Sept-99		19-Oct-99		09-Nov-
	LA-1	LA-2	LA-1	LA-2	LA-1	LA-2	LA-1	LA-2	LA-1	LA-2	LA-1	LA-2	LA-1
Parameter	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
Air Temp (C)	11.0	11.0	19.0	19.0	23.9	23.3	20.0	23.9	10.0	11.1	6.0	6.0	13.0
DO	7.0	4.2	7.4	0.1	7.0	0.2	7.8	0.5	8.5	6.0	8.6	5.7	9.8
PH	8.32	7.90	8.07	7.61	8.32	7.51	8.40	7.70	8.53	8.35	8.6	8.60	8.86
Depth	B	B	B	B	B	B	B	B	B	B	B	B	B
Secchi Disk (m)	-	-	-	-	-	-	-	-	-	-	-	-	-
Water Temp (C)	11.8	9.5	17.2	14.0	26.5	23.0	25.0	25.0	18.0	18.0	11.0	12.0	8.9
Fecal Col.	5.0	5.0	40.0	5.0	30.0	10.0	10.0	10.0	10.0	5.0	5.0	5.0	5.0
Alkalinity Total	180.0	178.0	190.0	176.0	141.0	207.0	111.0	118.0	131.0	129.0	152.0	143.0	158.0
Alkalinity-P	1.0	0	0	0	0	0	0	0	14.0	10.0	10.0	8.0	10.0
Solids, Total	1411	1352	1615	1502	1647	1678	1621	1632	1678	1663	1704	1680	1721
Solids, Suspended	28.0	12.0	21.0	12.0	27.0	8.0	18.0	26.0	21.0	14.0	20.0	10.0	23.0
Total dissolved solid	1390	1340	1588	1494	1629	1652	1600	1618	1658	1653	1681	1661	1698
VTSS	5.0	2.0	6.0	4.0	9.0	6.0	5.0	19.0	16.0	10.0	13.0	7.0	9.0
Ammonia	0.01	0.16	0.01	0.41	0.01	1.78	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Nitrate	1.90	2.20	1.30	1.10	0.30	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
TKN	1.62	1.72	1.54	1.94	1.33	3.32	1.33	2.62	1.9	2.02	2.05	1.77	2.26
Total Nitrogen	3.52	3.92	2.84	3.04	1.63	3.37	1.38	2.67	1.95	2.07	2.10	1.82	2.31
Organic N2	1.61	1.56	1.53	1.53	1.32	1.54	1.32	2.61	1.89	2.01	2.04	1.76	2.25
Phosphorous Total	0.138	0.116	0.088	0.074	0.099	0.588	0.173	0.264	0.266	0.305	0.314	0.319	0.274
Phosphorous, Total Dissolved	0.019	0.055	0.010	0.024	0.017	0.538	0.049	0.069	0.136	0.157	0.196	0.249	0.123

Appendix J.

Lake Alvin Algae Tables 1999

Table J-1. Algae species found in Lake Alvin by type for 1999.

Species	Algae Type
Anabaena flos-aquae	Blue-Green Algae
Ankistrodesmus falcatus	Green Algae
Aphanizomenon flos-aquae	Blue-Green Algae
Chlamydomonas sp.	Flagellated Green Algae
Chrysochromulina sp.	Flagellated Algae
Closteriopsis longissima	Green Algae
Cryptomonas erosa	Flagellated Algae
Cyclotella atomus	Diatom
Cyclotella meneghiniana	Diatom
Cyclotella pseudostelligera	Diatom
Cyclotella stelligera	Diatom
Cymatopleura solea	Diatom
Glenodinium sp.	Flagellated Algae (Dinoflagellate)
Gloeocystis ampla	Green Algae
Gymnodinium sp.	Flagellated Algae (Dinoflagellate)
Lyngbya sp.	Blue-Green Algae
Mallomonas sp.	Flagellated Algae
Melosira granulata	Diatom
Melosira varians	Diatom
Microcystis aeruginosa	Blue-Green Algae
Nitzschia acicularis	Diatom
Nitzschia dissipata	Diatom
Nitzschia hungarica	Diatom
Nitzschia palea	Diatom
Nitzschia paleacea	Diatom
Oocystis lacustris	Green Algae
Oocystis pusilla	Green Algae
Oscillatoria sp.	Blue-Green Algae
Peridinium cinctum	Flagellated Algae (Dinoflagellate)
Rhodomonas minuta (= *Chromonas* sp.[Butcher 1967])	Flagellated Algae
Scenedesmus quadricauda	Green Algae
Selenastrum minutum	Green Algae
Sphaerocystis schroeteri	Green Algae
Stephanodiscus astraea	Diatom
Stephanodiscus astraea minutula	Diatom
Stephanodiscus hantzschii	Diatom
Surirella ovata	Diatom
Synedra acus	Diatom
Synedra radians	Diatom
Trachelomonas hispida	Flagellated Algae
Trachelomonas volvocina	Flagellated Algae
Unidentified flagellates	Flagellated Algae
Total Species	**42**

Table J-2. Lake Alvin average total cells/ml by species and date for 1999.

Taxa	Apr-99 cells/ml	May-99 cells/ml	Jul-99 cells/ml	Aug-99 cells/ml	Sep-99 cells/ml	Oct-99 cells/ml	Nov-99 cells/ml	Dec-99 cells/ml	Grand Total cells/ml
Anabaena flos-aquae	0	0	1,206	1,008	0	0	0	0	2,214
Ankistrodesmus falcatus	0	0	27	24	21	29	0	0	101
Aphanizomenon flos-aquae	0	0	111,588	28,654	40,341	127,883	57,197	39,092	404,753
Chlamydomonas spp.	2,163	545	34	73	42	112	417	0	3,384
Chrysochromulina	123	374	0	0	0	0	0	0	497
Closteriopsis longissima	0	0	0	24	0	0	0	0	24
Cryptomonas erosa	255	3,993	34	52	42	376	833	442	6,026
Cyclotella atomus	0	0	0	0	0	0	166	498	664
Cyclotella meneghiniana	1,903	1,068	0	659	158	1,289	4,495	5,472	15,043
Cyclotella pseudostelligera	0	289	0	0	0	0	0	0	289
Cyclotella stelligera	1,571	790	0	0	0	0	35,815	26,917	65,092
Cymatopleura solea	0	86	0	0	0	0	0	0	86
Glenodinium sp.	67	0	0	0	21	0	251	0	338
Gloeocystis ampla	56	0	0	0	0	0	0	0	56
Gymnodinium	0	86	0	0	0	0	0	0	86
Lyngbya	1,120	0	0	0	0	0	0	0	1,120
Mallomonas sp.	0	0	0	0	0	0	417	0	417
Melosira granulata	0	0	0	314	232	0	0	0	546
Melosira varians	67	0	0	0	0	0	0	0	67
Microcystis aeruginosa	0	0	3,952	0	0	0	0	0	3,952
Nitzschia acicularis	480	12,813	0	0	0	0	501	0	13,793
Nitzschia dissipata	56	0	0	0	0	0	0	0	56
Nitzschia hungarica	56	0	0	0	0	0	0	0	56
Nitzschia palea	0	353	0	0	0	0	0	0	353
Nitzschia paleacea	0	0	0	0	0	0	417	387	804
Oocystis lacustris	0	0	53	0	0	0	0	0	53
Oocystis pusilla	0	846	210	194	0	1,297	2,329	2,266	7,141
Oscillatoria sp.	0	0	988	4,525	0	0	0	11,050	16,563
Peridinium cinctum	0	0	114	2,764	2,461	0	0	0	5,338
Rhodomonas minuta	1,291	1,922	127	77	67	112	1,747	1,161	6,501
Scenedesmus quadricauda	0	0	67	0	0	0	0	0	67
Selenastrum minuta	0	0	159	0	0	0	0	0	159
Sphaerocystis schroeteri	0	0	237	0	198	331	0	0	766
Stephanodiscus astraea	245	321	0	0	0	58	914	884	2,421
Stephanodiscus astraea minutula	1,352	118	13	0	0	29	1,168	3,150	5,829
Stephanodiscus hantzschii	2,693	470	0	0	0	0	748	3,040	6,951
Surirella ovata	179	0	0	0	0	0	0	0	179
Synedra radians	133	86	0	0	0	0	0	0	218
Synedra acus	123		0	0	0	0	0	0	123
Trachelomonas hispida	0	0	0	0	0	182	0	0	182
Trachelomonas volvocina	0	0	0	0	0	29	0	0	29
Unidentified flagellates	112	257	13	0	204	0	501	387	1,473
Grand Total	**14,040**	**24,412**	**118,818**	**38,366**	**43,786**	**131,724**	**107,911**	**94,744**	**573,800**

Table J-3. Lake Alvin average total biovolume (µm^3/ml) by species and date for 1999.

Taxa	Apr-99 µm³/ml	May-99 µm³/ml	Jul-99 µm³/ml	Aug-99 µm³/ml	Sep-99 µm³/ml	Oct-99 µm³/ml	Nov-99 µm³/ml	Dec-99 µm³/ml	Grand Total µm³/ml
Anabaena flos-aquae	0	0	141,102	117,936	0	0	0	0	259,038
Ankistrodesmus falcatus	0	0	663	600	525	725	0	0	2,513
Aphanizomenon flos-aquae	0	0	13,055,796	3,352,460	4,719,897	14,962,253	6,691,991	4,573,706	47,356,101
Chlamydomonas spp.	324,450	81,675	5,025	10,875	6,300	16,725	62,475	0	507,525
Chrysochromulina	9,800	29,920	0	0	0	0	0	0	39,720
Closteriopsis longissima	0	0	0	8,544	0	0	0	0	8,544
Cryptomonas erosa	128,010	2,004,486	16,817	26,104	21,084	188,501	417,915	221,884	3,024,801
Cyclotella atomus	0	0	0	0	0	0	3,320	9,950	13,270
Cyclotella meneghiniana	475,625	267,000	0	164,750	39,375	322,125	1,123,750	1,368,000	3,760,625
Cyclotella pseudostelligera	0	47,603	0	0	0	0	0	0	47,603
Cyclotella stelligera	243,505	122,450	0	0	0	0	5,551,248	4,172,058	10,089,260
Cymatopleura solea	0	1,385,100	0	0	0	0	0	0	1,385,100
Glenodinium sp.	46,550	0	0	0	14,700	0	175,350	0	236,600
Gloeocystis ampla	29,344	0	0	0	0	0	0	0	29,344
Gymnodinium	0	230,850	0	0	0	0	0	0	230,850
Lyngbya	6,720	0	0	0	0	0	0	0	6,720
Mallomonas sp.	0	0	0	0	0	0	208,250	0	208,250
Melosira granulata	0	0	0	172,700	127,600	0	0	0	300,300
Melosira varians	43,225	0	0	0	0	0	0	0	43,225
Microcystis aeruginosa	0	0	130,400	0	0	0	0	0	130,400
Nitzschia acicularis	134,260	3,587,500	0	0	0	0	140,280	0	3,862,040
Nitzschia dissipata	15,064	0	0	0	0	0	0	0	15,064
Nitzschia hungarica	29,680	0	0	0	0	0	0	0	29,680
Nitzschia palea	0	185,063	0	0	0	0	0	0	185,063
Nitzschia paleacea	0	0	0	0	0	0	40,817	37,926	78,743
Oocystis lacustris	0	0	16,170	0	0	0	0	0	16,170
Oocystis pusilla	0	45,657	11,313	10,476	0	70,038	125,739	122,364	385,587
Oscillatoria sp.	0	0	20,738	95,025	0	0	0	232,050	347,813
Peridinium cinctum	0	0	476,700	11,606,700	10,336,200	0	0	0	22,419,600
Rhodomonas minuta	25,810	38,440	2,540	1,530	1,330	2,230	34,930	23,210	130,020
Scenedesmus quadricauda	0	0	10,519	0	0	0	0	0	10,519
Selenastrum minuta	0	0	3,180	0	0	0	0	0	3,180
Sphaerocystis schroeteri	0	0	63,516	0	53,064	88,574	0	0	205,154
Stephanodiscus astraea	836,435	1,096,431	0	0	0	198,418	3,125,084	3,024,164	8,280,531
Stephanodiscus astraea minutula	473,025	41,125	4,550	0	0	10,150	408,800	1,102,500	2,040,150
Stephanodiscus hantzschii	810,593	141,470	0	0	0	0	225,148	915,040	2,092,251
Surirella ovata	51,765	0	0	0	0	0	0	0	51,765
Synedra radians	47,700	30,780	0	0	0	0	0	0	78,480
Synedra acus	232,750	0	0	0	0	0	0	0	232,750
Trachelomonas hispida	0	0	0	0	0	382,200	0	0	382,200
Trachelomonas volvocina	0	0	0	0	0	54,665	0	0	54,665
Unidentified flagellates	2,240	5,130	260	0	4,070	0	10,020	7,740	29,460
Grand Total	**3,966,551**	**9,340,679**	**13,959,288**	**15,567,700**	**15,324,145**	**16,296,604**	**18,345,116**	**15,810,591**	**108,610,671**

Table J-4. Lake Alvin density (cells/ml), total biovolume (µm^3/ml) by percent, species, site and date fo

	27-Apr-99		27-Apr-99		24-May-99		24-May-99		21-July-99		21-July-99	
	LA-1		LA-1		LA-1		LA-1		LA-1		LA-1	
Taxa	**Density**	**PCT**	**Bio Vol**	**PCT**	**Density**	**PCT**	**Bio Vol**	**PCT**	**Density**	**PCT**	**Bio Vol**	**PC**
Ankistrodesmus falcatus	0	0	0	0	0	0	0	0	0	0	0	
Aphanizomenon flos-aqua	0	0	0	0	0	0	0	0	9,772	92.4	5,863,000	[illegible]
***Chlamydomonas* sp.**	3,316	22.7	1,077,758	18.0	235	0.8	76,341	0.6	67	0.6	21,812	[illegible]
Chrysochromulina	133	0.9	2,653	0	235	0.8	4,698	0	0	0	0	
Closteriopsis longissima	0	0	0	0	0	0	0	0	0	0	0	
Cryptomonas erosa	398	2.7	206,929	1.9	4,228	14.4	2,198,625	18.2	67	0.6	34,899	[illegible]
Cyclotella meneghiniana	2,122	14.5	806,494	13.5	940	3.2	357,042	2.9	0	0	0	
Cyclotella pseudostelligera	0	0	0	0	235	0.8	15,268	0.1	0	0	0	
Cyclotella stelligera	1,459	10.0	80,251	1.3	1,409	4.8	77,516	0.6	0	0	0	
***Glenodinium* sp.**	133	0.9	92,853	1.6	0	0	0	0	0	0	0	
Mallomonas	0	0	0	0	0	0	0	0	0	0	0	
Melosira granulata	0	0	0	0	0	0	0	0	0	0	0	
Melosira varians	663	2.7	431,103	3.5	0	0	0	0	0	0	0	
Nitzschia acicularis	398	1.8	111,424	35.6	18,792	64.0	5,261,668	43.4	0	0	0	
Nitzschia palea	0	0	0	0	705	2.4	126,844	1.0	0	0	0	
Oocystis pusilla	0	0	0	0	0	0	0	0	0	0	0	
***Oscillatoria* sp.**	0	0	0	0	0	0	0	0	0	0	0	
Peridinium cinctum	0	0	0	0	0	0	0	0	201	1.9	845,625	[illegible]
Rhodomonas minuta	1,459	10.0	29,182	0.5	940	3.2	18,792	0.2	201	1.9	4,027	[illegible]
Scenedesmus quadricauda	0	0	0	0	0	0	0	0	134	1.3	8,725	[illegible]
Selenastrum minutum	0	0	0	0	0	0	0	0	134	1.3	2,685	
Stephanodiscus astraea	265	1.8	2,133,495	1.6	470	1.6	3,778,065	31.2	0	0	0	
Stephanodiscus astraea minutula	796	5.5	278,559	4.7	235	0.8	82,214	0.7	0	0	0	
Stephanodiscus hantzschii	2,918	20.0	350,188	5.8	940	3.2	112,750	0.9	0	0	0	
Surirella ovata	133	0.9	38,468	0.6	0	0	0	0	0	0	0	
Synedra radians	265	4.5	95,506	7.2	0	0	0	0	0	0	0	
Synedra acus	133	0.9	252,029	4.2	0	0	0	0	0	0	0	
Total Density cells/ml	**14,591**				**29,362**				**10,577**			
Total Biovolume mm/ml	**5,986,893**				**1.21 x 10^7**				**6,780,772**			
Trophic State index	**62.8**				**67.8**				**63.7**			
Diversity index	**3.11**				**1.95**				**0.69**			

Table J-4. (Continued) Lake Alvin density (cells/ml), total biovolume (µm ^{3}/ml) by percent, species, sit
(Sweet 1999).

	20-Sep-99		20-Sep-99		19-Oct-99		19-Oct-99		09-Nov-99		09-Nov-99	
	LA-1		LA-1		LA-1		LA-1		LA-1		LA-1	
Taxa	**Density**	**PCT**	**Bio Vol**	**PCT**	**Density**	**PCT**	**Bio Vol**	**PCT**	**Density**	**PCT**	**Bio Vol**	**PC**
Ankistrodesmus falcatus	42	0.7	1,044	0	0	0	0	0	0	0	0	
Aphanizomenon flos-aqua	2,689	36.0	1,613,578	81.8	8,326	63.5	4,995,693	75.7	1,954	2.4	1,172,600	[illegible]
***Chlamydomonas* sp.**	84	1.5	27,144	0.4	165	5.0	53,690	0.4	501	0.8	162,861	[illegible]
Cryptomonas erosa	84	3.0	43,430	0.9	578	1.9	300,667	7.9	1,002	0.8	521,155	[illegible]
Cyclotella meneghiniana	167	1.5	63,474	0	1,652	12.6	627,766	9.5	5,011	7.9	1,904,222	[illegible]
Cyclotella stelligera	0	0	0	0	0	0	0	0	45,100	70.9	2,480,500	[illegible]
***Glenodinium* sp.**	42	0.7	29,231	0.3	0	0	0	0	501	0.8	350,778	[illegible]
***Mallomonas* sp.**	0	0	0	0	0	0	0	0	501	0.8	190,422	[illegible]
Melosira granulata	167	3.0	91,870	0.6	0	0	0	0	0	0	0	
Nitzschia acicularis	0	0	0	0	0	0	0	0	1,002	1.6	280,622	[illegible]
Nitzschia paleacea	0	0	0	0	0	0	0	0	501	0.8	49,109	[illegible]
Oocystis pusilla	0	0	0	0	1,322	4.4	71,367	4.6	2,004	3.2	108,240	[illegible]
***Oscillatoria* sp.**	0	0	0	0	0	0	0	0	0	0	0	
Peridinium cinctum	2,004	48.3	8,418,665	15.7	0	0	0	0	0	0	0	
Rhodomonas minuta	84	1.5	1,670	0.3	165	1.3	3,304	0.8	1,503	1.6	30,067	[illegible]
Sphaerocystis schroeteri	0	0	0	0	661	10.1	23,128	1.1	0	0	0	
Stephanodiscus astraea	0	0	0	0	0	0	0	0	501	3.2	4,029,936	[illegible]
Stephanodiscus astraea minutula	0	0	0	0	0	0	0	0	2,004	3.1	701,555	[illegible]
Stephanodiscus hantzschii	0	0	0	0	0	0	0	0	501	0.8	60,133	[illegible]
Trachelomonas hispida	0	0	0	0	248	1.3	520,385	0.1	0	0	0	
Unidentified flagellate	209	3.7	4,176	0	0	0	0	0	1,002	1.6	20,044	[illegible]
Total Density cells/ml	**5,571**				**13,117**				**63,591**			
Total Biovolume mm/ml	**1.03 x 10^7**				**6,595,999**				**1.21 x 10^7**			
Trophic State index	**66.7**				**63.5**				**67.8**			
Diversity index	**1.96**				**1.69**				**1.73**			

Table J-4. (Continued) Lake Alvin density (cells/ml), total biovolume (μm^3/ml) by percent, species, sit (Sweet 1999).

	27-Apr-99		27-Apr-99		24-May-99		24-May-99		21-July-99		21-July-99	
	LA-2		LA-2		LA-2		LA-2		LA-2		LA-2	
Taxa	**Density**	**PCT**	**Bio Vol**	**PCT**	**Density**	**PCT**	**Bio Vol**	**PCT**	**Density**	**PCT**	**Bio Vol**	**PC**
Anabaena flos-aquae	0	0	0	0	0	0	0	0	134	0.6	134,352	3
Ankistrodesmus falcatus	0	0	0	0	0	0	0	0	53	61.6	1,317	2
Aphanizomenon flos-aqua	1,010	8.3	328,153	7.3	0	0	0	0	3,356	1.4	2,013,694	0
***Chlamydomonas* sp.**	112	0.9	2,244	0	854	8.7	277,604	1.0	0	0	0	
Chrysochromulina	0	0	0	0	513	2.6	10,250	0.1	0	0	0	
Cryptomonas erosa	112	3.7	58,338	0.6	3,758	19.3	1,954,333	20.6	0	0	0	
Cyclotella meneghiniana	1,683	13.8	639,478	14.2	1,196	4.4	454,417	2.9	0	0	0	
Cyclotella pseudostelligera	0	0	0	0	342	1.8	22,208	0.2	0	0	0	
Cyclotella stelligera	1,683	13.8	92,556	2.1	171	0.9	9,396	0.1	0	0	0	
Cymatopleura solea	0	0	0	0	171	0.9	2,767,500	29.2	0	0	0	
Gloeocystis ampla	449	1.8	28,720	40.0	0	0	0	0	0	0	0	
***Gymnodinium* sp.**	0	0	0	0	171	0.9	461,250	4.9	0	0	0	
***Lyngbya* sp.**	112	0.9	39,266	0.9	0	0	0	0	0	0	0	
Melosira granulata	0	0	0	0	0	0	0	0	0	0	0	
Microcystis aeruginosa	0	0	0	0	0	0	0	0	7,903	26.1	63,224	80
Nitzschia acicularis	561	4.6	157,065	3.5	6,833	35.1	1,913,333	20.2	0	0	0	
Nitzschia dissipata	112	0.9	30,179	0.7	0	0	0	0	0	0	0	
Nitzschia hungarica	112	0.9	59,460	1.3	0	0	0	0	0	0	0	
Oocystis lacustris	0	0	0	0	0	0	0	0	105	0.4	32,455	0
Oocystis pusilla	0	0	0	0	1,691	6.1	91,328	4.8	419	3.7	22,618	0
***Oscillatoria* sp.**	0	0	0	0	0	0	0	0	79	0.4	79,030	
Peridinium cinctum	0	0	0	0	0	0	0	0	26	0.2	110,643	4
Rhodomonas minuta	1,122	9.2	22,438	0.5	2,904	14.9	58,083	0.6	53	0.2	1,054	0
Selenastrum minutum	0	0	0	0	0	0	0	0	184	3.3	3,688	0
Sphaerocystis schroeteri	0	0	0	0	0	0	0	0	474	1.0	16,596	5
Stephanodiscus astraea	224	1.8	1,804,449	1.4	171	0.9	1,373,841	14.5	0	0	0	
Stephanodiscus astraea minutula	1,907	15.6	667,525	14.8	0	0	0	0	26	0.8	9,220	1
Stephanodiscus hantzschii	2,468	20.2	296,179	6.6	0	0	0	0	0	0	0	
Surirella ovata	224	1.8	65,070	0.1	0	0	0	0	0	0	0	
Synedra acus	112	0.9	213,159	4.7	0	0	0	0	0	0	0	
Synedra radians	0	0	0	0	171	0.9	61,500	0.6	0	0	0	
Unidentified flagellate	224	0.9	4,488	1.3	513	2.6	10,250	0.1	26	0.2	527	
Total Density cells/ml	**12,229**				**19,458**				**12,840**			
Total Biovolume mm/ml	**4,508,766**				**9,465,293**				**2,488,420**			
Trophic State index	**60.7**				**66.1**				**56.4**			
Diversity index	**3.29**				**2.74**				**1.48**			

Table J-4. (Continued) Lake Alvin density (cells/ml), total biovolume (µm ^{3}/ml) by percent, species, sit
(Sweet 1999).

	20-Sep-99		20-Sep-99		19-Oct-99		19-Oct-99		09-Nov-99		09-Nov-99	
	LA-2		LA-2		LA-2		LA-2		LA-2		LA-2	
Taxa	**Density**	**PCT**	**Bio Vol**	**PCT**	**Density**	**PCT**	**Bio Vol**	**PCT**	**Density**	**PCT**	**Bio Vol**	**PC**
Ankistrodesmus falcatus	0	0	0	0	58	0.6	1,446	0	0	0	0	
Aphanizomenon flos-aqua	2,057	33.9	1,234,316	9.0	6,719	69.9	4,031,247	68.7	4,775	8.9	2,865,177	
***Chlamydomonas* sp.**	0	0	0	0	58	0.6	18,792	0.3	332	0.7	107,776	
Cryptomonas erosa	0	0	0	0	173	13.2	90,200	1.2	663	5.9	344,882	
Cyclotella atomus	0	0	0	0	0	0	0	0	332	0.7	6,632	
Cyclotella meneghiniana	148	0.8	56,375	0	925	1.8	351,549	1.5	3,979	10.6	1,512,177	
Cyclotella stelligera	0	0	0	0	0	0	0	0	26,529	59.1	1,459,118	
***Mallomonas* sp.**	0	0	0	0	0	0	0	0	663	1.5	252,029	
Melosira granulata	297	2.4	163,191	0.4	0	0	0	0	0	0	0	
Nitzschia paleacea	0	0	0	0	0	0	0	0	332	0.7	32,499	
Oocystis pusilla	0	0	0	0	1,272	9.6	68,691	6.0	2,653	4.4	143,259	
Peridinium cinctum	2,918	48.1	1,2254,147	89.3	0	0	0	0	0	0	0	
Rhodomonas minuta	49	6.5	989	0.1	0	0	0	0	1,990	3.0	39,794	
Sphaerocystis schroeteri	396	3.3	13,846	0	0	0	0	0	0	0	0	
Stephanodiscus astraea	0	0	0	0	116	1.2	929,985	15.9	1,326	2.2	10,667,479	
Stephanodiscus astraea minutula	0	0	0	0	58	0.6	20,237	0.3	332	0.7	116,066	
Stephanodiscus hantzschii	0	0	0	0	0	0	0	0	995	1.5	119,382	
Rhodomonas minuta	0	0	0	0	58	0.6	1,156	0	0	0	0	
Trachelomonas hispida	0	0	0	0	116	1.2	242,846	4.1	0	0	0	
Trachelomonas volvocina	0	0	0	0	58	0.6	108,992	1.9	0	0	0	
Unidentified flagellate	198	4.9	3,956	1.2	0	0	0	0	0	0	0	
Total Density cells/ml	**6,063**				**9,610**				**44,901**			
Total Biovolume mm/ml	**1.37 x 10^7**				**5,865,139**				**1.77 x 10^7**			
Trophic State index	**68.7**				**62.6**				**70.6**			
Diversity index	**1.59**				**1.48**				**2.06**			

Appendix K.

Lake Alvin Aquatic Macrophyte Tables for 1999

Table K-1. Lake Alvin inlake submerged macrophyte transects results for 1999.

Transect	Point Depth (m)	Secchi Depth (m)	Shoreline Submergent Species	Transect Species	Transect Density
1A	0.61	0.37	No	None	0
1B	0.61	0.34	No	None	0
1C	0.55	0.30	No	None	0
2A	0.94	0.34	No	None	0
2B	1.13	0.37	No	None	0
2C	1.16	0.37	No	None	0
3A	1.62	0.49	No	None	0
3B	1.52	0.49	No	None	0
3C	1.62	0.49	No	None	0
3D	1.52	0.49	No	None	0
4A	2.59	0.55	No	None	0
4B	2.44	0.58	No	None	0
4C	1.30	0.55	No	None	0
5A	2.80	0.61	No	None	0
5B	2.90	0.61	No	None	0
6A	2.10	0.61	No	None	0
6B	3.51	0.67	No	None	0
6C	3.35	0.67	No	None	0
7A	3.29	0.64	No	None	0
7B	3.05	0.85	No	None	0
8A	2.71	0.76	Potamogeton natans	None	0
9A	1.16	0.91	No	None	0
9B	2.44	0.85	No	None	0
9C	3.66	0.82	No	None	0
9D	3.96	0.76	No	None	0
10A	3.96	0.91	No	None	0
10B	4.57	0.91	No	None	0
10C	4.51	0.67	No	None	0
10D	3.02	0.85	No	None	0
11A	2.47	0.88	No	None	0
11B	3.72	0.85	No	None	0
11C	4.72	0.76	No	None	0
11D	2.74	0.85	No	None	0
12A	2.26	0.85	No	None	0
12B	5.36	0.88	No	None	0
12C	5.58	0.70	No	None	0
12D	1.68	0.88	No	None	0
13A	2.44	0.79	Potamogeton *pectinatus*	None	0
13B	5.18	0.76	No	None	0
13C	5.82	0.88	No	None	0
13D	3.05	0.85	No	None	0
14A	0.88	0.85	No	None	0
14B	6.86	0.82	No	None	0
14C	1.22	0.85	No	None	0
15A	3.63	0.85	*Potamogeton natans*	None	0
16A	1.89	0.76	No	None	0
16B	7.10	0.82	No	None	0
16C	6.80	0.91	No	None	0
16D	1.37	0.91	No	None	0
Mean	**2.87**	**0.69**			

Appendix L.

Lake Alvin Benthic Macroinvertebrate Tables 2000

Table L-1. Lake Alvin benthic macroinvertebrates counts by species, site and date collected in March

	Mid		Mid		South		South		N
	29-Mar	27-Apr	29-Mar	27-Apr	29-Mar	27-Apr	29-Mar	27-Apr	29-Mar
Taxon	**LA-1a**	**LA-1a**	**LA-2a**	**LA-2a**	**LA-1a**	**LA-1a**	**LA-2a**	**LA-2a**	**LA-1a**
Chironomus plumosus gr.	23	4	0	0	24	4	1	3	24
C. plumosus gr. pupae	0	0	0	0	0	0	0	0	2
Cryptochironomus sp.	0	0	0	0	1	0	0	0	1
Procladius sp.	1	2	0	0	7	3	1	0	2
Procladius sp. pupae	0	0	0	0	1	0	0	0	0
Ostracods	0	0	0	0	0	1	0	0	0
Ceratopogonids	3	2	0	0	8	6	0	0	7
Oligochaetes	10	11	0	0	77	48	0	0	14
Cladotanytarsus sp.	0	0	0	0	0	0	0	1	0
Cladopelma sp.	0	1	0	0	1	5	0	0	0
Fingernail clam shells	1[2]	0	0	0	0	0	0	0	0
Hexagenia sp.	0	0	0	0	2	1	0	0	0
Chaoborus sp.	1	1	0	0	0	0	0	0	0
Paratendipes sp.	0	0	0	0	0	0	0	0	0
Nematodes	0	0	0	0	0	1	0	0	0
Paratanytarsus sp.	0	0	0	0	0	0	0	0	0
Total	**38**	**21**	**0**	**0**	**121**	**69**	**2**	**4**	**50**
Depth (m)	**2.40**	**2.74**	**7.00**	**6.40**	**1.70**	**1.98**	**7.30**	**7.01**	**1.80**
Organisms per m^2	**546**	**301**	**0**	**0**	**1739**	**990**	**28**	**57**	**719**

[1] = Entire sample identified
[2] = Fingernail clam shells older and not included in total count

Table L-2. Lake Alvin benthic macroinvertebrates (#/m^2) by species, site and date collected in March

	Mid		Mid		South		South		N
	29-Mar	27-Apr	29-Mar	27-Apr	29-Mar	27-Apr	29-Mar	27-Apr	29-Mar
Taxon	**LA-1a**	**LA-1a**	**LA-2a**	**LA-2a**	**LA-1a**	**LA-1a**	**LA-2a**	**LA-2a**	**LA-1a**
Chironomus plumosus gr.	330	57	0	0	345	57	14	43	345
C. plumosus gr. Pupae	0	0	0	0	0	0	0	0	29
Cryptochironomus sp.	0	0	0	0	14	0	0	0	14
Procladius sp.	14	29	0	0	101	43	14	0	29
Procladius sp. Pupae	0	0	0	0	14	0	0	0	0
Ostracods	0	0	0	0	0	14	0	0	0
Ceratopogonids	43	29	0	0	115	86	0	0	101
Oligochaetes	144	158	0	0	1106	690	0	0	201
Cladotanytarsus sp.	0	0	0	0	0	0	0	14	0
Cladopelma sp.	0	14	0	0	14	72	0	0	0
Fingernail clam shells	14[2]	0	0	0	0	0	0	0	0
Hexagenia sp.	0	0	0	0	29	14	0	0	0
Chaoborus sp.	14	14	0	0	0	0	0	0	0
Paratendipes sp.	0	0	0	0	0	0	0	0	0
Nematodes	0	0	0	0	0	14	0	0	0
Paratanytarsus sp.	0	0	0	0	0	0	0	0	0
Total	**545**	**301**	**0**	**0**	**1738**	**990**	**28**	**57**	**719**
Depth (m)	**2.40**	**2.74**	**7.00**	**6.40**	**1.70**	**1.98**	**7.30**	**7.01**	**1.80**

[1] = Entire sample identified
[2] = Fingernail clam shells older and not included in total count

Table L-3. Shannon base (2) diversity and Evenness values for Blue Dog and Enemy Swim Lakes by site and date in 1999.

	Blue Dog Lake		Enemy Swim Lake	
Metric	**East**	**West**	**North**	**South**
Shannon Base (2) Diversity	1.62	1.48	2.47	1.99
Evenness	0.49	0.44	0.82	0.59
Average Diversity	1.62		2.23	
Average Evenness	0.46		0.70	

Table L-4. Benthic macroinvertebrate counts collected from Blue Dog and Enemy Swim Lakes by site and date in February 1999.

	Blue Dog		Enemy Swim	
	West	**East**	**North**	**South**
Taxon	**10-Feb-99**	**10-Feb-99**	**10-Feb-99**	**10-Feb-99**
***Chironomus plumosus* gr.**	3	4	5	20
***Coelotanypus* sp.**	61	55	0	1
Hyalella azteca	1	0	0	0
***Placobdella* sp**	0	0	18	0
***Procladius* sp.**	2	2	20	163
***Micropsectra* sp.**	0	0	21	4
Oecetis inconspicua	4	6	0	0
Oligochaetes	50	57	8	130
***Palpomyia* sp.**	3	1	0	0
***Caenis* sp.**	0	1	0	0
***Sphaerium* spp.**	2	8	4	4
***Pisidium* sp.**	0	0	0	1
Unid. Water mite sp.	9	4	0	2
***Chaoborus* sp.**	0	0	0	11
***Polypedilum* sp.**	0	0	1	0
***Harnischia* sp.**	0	0	1	0
Nematodes	308	260	0	38
Total	**443**	**398**	**78**	**374**
Depth (m)	**2.44**	**2.44**	**3.66**	**6.71**
Organisms per m^2	**6,363**	**5,717**	**1,120**	**5,372**

Table L-5. Benthic macroinvertebrate (#/m^2) by species, site and date collected from Blue Dog and Enemy Swim Lakes in February 1999.

	Blue Dog		**Enemy Swim**	
	West	**East**	**North**	**South**
Taxon	**10-Feb-99**	**10-Feb-99**	**10-Feb-99**	**10-Feb-99**
***Chironomus plumosus* gr.**	43	57	72	287
***Coelotanypus* sp.**	876	790	0	14
Hyalella azteca	14	0	0	0
***Placobdella* sp.**	0	0	259	0
***Procladius* sp.**	29	29	287	2,342
***Micropsectra* sp.**	0	0	302	57
Oecetis inconspicua	57	86	0	0
Oligochaetes	718	819	115	1,868
***Palpomyia* sp.**	43	14	0	0
***Caenis* sp.**	0	14	0	0
***Sphaerium* spp.**	29	115	57	57
***Pisidium* sp.**	0	0	0	14
Unid. Water mite sp.	129	57	0	29
***Chaoborus* sp.**	0	0	0	158
***Polypedilum* sp.**	0	0	14	0
***Harnischia* sp.**	0	0	14	0
Nematodes	4,425	3,736	0	546
Total	**6,363**	**5,717**	**1,120**	**5,372**
Depth (m)	**2.44**	**2.44**	**3.66**	**6.71**

Appendix M.

Lake Alvin Elutriate and Receiving Water Tables 2000

Table M-1. Lake Alvin receiving water chemical concentrations collected in February and April 2000 by s

	Date Collected: 2/24/2000 Time Collected: 0845 LA-1a	Date Collected: 2/24/2000 Time Collected: 1530 LA-2a	Date Collected: 4/27/2000 Time Collected: 1405 LA-1a	Date Coll Time C
COD	10.0	10.0	26.8	
Phosphorous, total	0.067	0.054	0.044	
TKN	0.60	0.52	1.08	
Hardness	480	480	1080	
Nitrate	0.1	0.1	0.1	
Nitrite	-	-	0.02	
Aluminum	0.8	1.5	1.3	
Zinc	5	3	4	
Silver	0.2	0.2	0.2	
Selenium	1.7	1.5	1.3	
Nickel	4.3	4.9	10.1	
Mercury, total	0.1	0.1	0.1	
Lead	0.1	0.1	0.1	
Copper	6.0	2.2	4.2	
Cadmium	0.2	0.2	0.2	
Arsenic	1.9	2.0	3.0	
Ammonia	0.18	0.02	0.02	
Alachlor	0.500	1.55	0.100	
Chlordane	0.500	1.52	0.500	
Endrin	0.500	0.500	0.500	
Heptachlor	0.500	0.500	0.400	
Heptachlor Epoxide	0.500	1.48	0.500	
Methoxychlor	0.500	1.94	0.500	
Toxaphene	ND	ND	ND	
Aldrin	0.500	0.500	0.500	
Dieldrin	0.500	0.500	0.500	
Aroclor 1016	ND	ND	0.100	
Aroclor 1221	ND	ND	0.100	
Aroclor 1232	ND	ND	0.100	
Aroclor 1242	ND	ND	0.100	
Aroclor 1248	ND	ND	0.100	
Aroclor 1254	ND	ND	0.100	
Aroclor 1260	ND	ND	0.100	
Diazinon	0.500	0.500	0.500	
DDD	0.500	0.500	0.500	
DDT	0.500	0.500	0.500	
DDE	0.500	0.500	0.500	
BETA BHC	0.500	0.500	0.500	
GAMMA BHC	0.500	0.959	0.500	
ALPHA BHC	0.500	0.500	0.500	

Table M-2. Lake Alvin elutriate chemical concentrations collected in February and April 2000 by site and

	Date Collected: 2/24/2000 Time Collected: 0845 LA-1	Date Collected: 2/24/2000 Time Collected: 0930 LA-2	Date Collected: 4/27/2000 Time Collected: 1405 LA-1	Date Coll Time C
COD	39.7	17.1	34.6	
Phosphorous, total	1.55	0.670	0.124	
TKN	10.5	3.48	4.24	
Hardness	560	560	1120	
Nitrate	0.1	0.1	0.1	
Nitrite	-	-	0.02	
Aluminum	2.4	2.4	1.6	
Zinc	4	4	3	
Silver	0.2	0.2	0.2	
Selenium	1.3	1.6	1.0	
Nickel	7.5	6.4	9.7	
Mercury, total	0.1	0.1	0.1	
Lead	0.1	0.1	0.1	
Copper	2.0	10.0	1.6	
Cadmium	0.2	0.2	0.2	
Arsenic	139	39.5	14.2	
Ammonia	9.92	2.73	2.52	
Alachlor	0.500	1.98	0.100	
Chlordane	0.500	1.89	0.500	
Endrin	0.500	1.39	0.500	
Heptachlor	0.500	0.939	0.400	
Heptachlor Epoxide	0.500	1.60	0.500	
Methoxychlor	0.500	2.37	0.500	
Toxaphene	ND	ND	ND	
Aldrin	0.500	0.500	0.500	
Dieldrin	0.500	0.500	0.500	
Aroclor 1016	ND	ND	0.100	
Aroclor 1221	ND	ND	0.100	
Aroclor 1232	ND	ND	0.100	
Aroclor 1242	ND	ND	0.100	
Aroclor 1248	ND	ND	0.100	
Aroclor 1254	ND	ND	0.100	
Aroclor 1260	ND	ND	0.100	
Diazinon	0.500	0.500	0.500	
DDD	0.500	0.500	0.500	
DDT	0.500	0.500	0.500	
DDE	0.500	0.500	0.500	
BETA BHC	0.500	0.500	0.500	
GAMMA BHC	0.500	0.500	0.500	
ALPHA BHC	0.500	0..500	0.500	

Appendix N

Lake Alvin Total Maximum Daily Load Summary Document

TOTAL MAXIMUM DAILY LOAD EVALUATION

For

TOTAL PHOSPHORUS (TSI TREND) AND FECAL COLIFORM

In

LAKE ALVIN

NINE MILE CREEK WATERSHED

(HUC 10170203)

LINCOLN COUNTY, SOUTH DAKOTA

SOUTH DAKOTA DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES

March, 2001

Lake Alvin Total Maximum Daily Load March, 2001

Waterbody Type: Lake (Impounded)
303(d) Listing Parameters: Total phosphorus (TSI trend), fecal coliform bacteria
Designated Uses: Warmwater permanent fish life p ropagation water;
Immersion recreation water;
Limited contact recreation waters
Size of Waterbody: 107 acres
Size of Watershed : 28,013 acres
Water Quality Standards: Narrative and numeric
Indicators: Average TSI, Beach closures
Analytical Approach: AGNPS and BATHTUB
Location: HUC Code: 10170203
TMDL Goal
Total Phosphorus: 67% reduction in total phosphorus (768 kg/yr.)
Fecal Coliform
(Swimming Beach): 25% reduction in fecal coliform
($1.12 * 10^{10}$ fecal coliform/day) or (67 fecal coliform/100 mL)

TMDL Target
Total Phosphorus: 64.95 mean TSI (379 kg/yr.)
Fecal Coliform
(Swimming Beach): 3.36×10^{10} fecal coliform/day or (200 fecal coliform/100 ml)

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

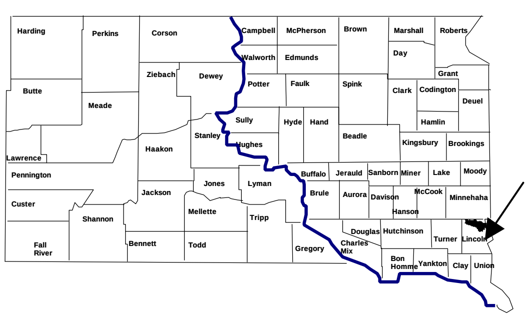


Figure 1. Watershed location in South Dakota

Lake Alvin is a 107-acre man-made impoundment located in northeastern Lincoln County, South Dakota. The 1998 South Dakota 303(d) Waterbody List (page 19) identified Lake Alvin for TMDL development for trophic state index (TSI), increasing eutrophication trend and fecal coliform bacteria.

The damming of Nine Mile Creek 0.80 km (0.5 mile) upstream of the confluence of the Big Sioux River created the lake, which has an average depth of 3.38 meters (11.1 feet) and over 5.95 kilometers (3.7 miles) of shoreline. The lake has a maximum depth of 7.01 meters (23 feet), holds 1,002 acre-feet of water, and is subject to periods of stratification during the summer. The outlet for the lake empties back into Nine Mile Creek, which eventually reaches the Big Sioux River south of Sioux Falls.

Problem Identification

Nine Mile Creek is the primary tributary to Lake Alvin and drains predominantly agricultural land (85 percent). Winter feeding areas for livestock are present within the watershed. The stream carries nutrient (total phosphorus) loads, which degrade the water quality of the lake, and cause increased eutrophication. Currently, the total phosphorus load to Lake Alvin is 1,147 kilograms per year, which does not allow the lake to meet designated uses. Total phosphorus loads need to be reduced by 768 kilograms (67 %), resulting in a total phosphorus TMDL of a mean Trophic State Index (TSI) of 64.95 (379 kilogram per year) that fully supports beneficial uses.

Sporadic beach closures occur due to elevated fecal coliform counts. Three consecutive samples exceeded 200 colonies/ 100 mL in June, resulting in one beach closure (June 7 through June 23, 1999). Swimming beach fecal coliform bacteria will have to be reduced $1.12 * 10^{10}$ fecal coliform/day or 67 fecal coliform/100 mL (25 %) through selective Best Management Practices (BMPs) that will result in the beach complying with South Dakota Water Quality for Public Beach Standards ($\leq$ 200 colonies/100 mL for three consecutive samples or $3.36 * 10^{10}$ fecal coliform/day), that would fully support beneficial uses.

Description of Applicable Water Quality Standards & Numeric Water Quality Targets

Lake Alvin 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:

(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.

Individual parameters, including the lake's mean TSI value, determine the support of beneficial uses and compliance with standards. Lake Alvin experiences nutrient enrichment, sporadic beach closures and some nuisance algal blooms which are typical signs of the eutrophication process. Lake Alvin was identified in both the 1998 South Dakota 303(d) Waterbody List and "Ecoregion Targeting for Impaired Lakes in South Dakota" as not supporting its beneficial uses.

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.

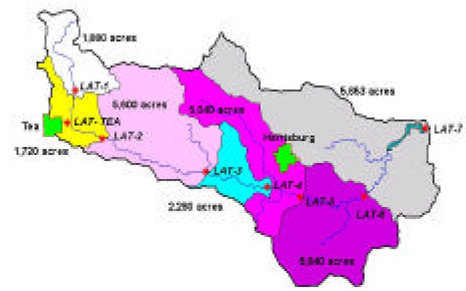


Figure 2. Lake Alvin and Nine Mile Creek watershed

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 Lake Alvin.

Lake Alvin currently has a total phosphorus TSI of 80.47, a chlorophyll-*a* TSI of 81.75 and a Secchi TSI of 76.48 and a mean TSI of 79.57, which is indicative of high levels of primary productivity. Assessment monitoring indicates that the primary cause of high productivity is high total phosphorus loads from the watershed.

SD DENR-recommended specific TSI parameters for Lake Alvin are: 64.55 for total phosphorus, 65.93 for chlorophyll-*a* and 64.38 for Secchi visibility. The TMDL numeric target established to improve the eutrophic status of Lake Alvin is a mean TSI of 64.95 (assessment final report, pages 121-124).

South Dakota Surface Water Quality Standards for immersion recreation is $\leq$ 400 colonies/100 mL for any one sample or a geometric mean of $\leq$ 200 colonies per 100 mL for a minimum of five samples collected during separate 24-hour periods in a 30-day period. They may not exceed the geometric mean value in more than 20 percent of the samples in any 30-day period (Chapter 74:51:01:50). The South Dakota Water Quality for Public Beaches are $\leq$ 1,000 colonies/ 100 mL for any one sample, $\leq$ 300 colonies/ 100 mL for two consecutive samples or $\leq$ 200 colonies/ 100 mL for three consecutive samples (Chapter 74:04:08:07).

During 1999, one beach closure event occurred in June due to three separate samples. Two of the three samples exceeded 1,000 colonies/ 100 mL and all three exceeded 300 colonies/ 100 mL for two consecutive samples or 200 colonies/ 100 mL for three consecutive samples.

Pollutant Assessment

Point Sources

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

Nonpoint Sources/ Background Sources

Analysis of the watershed through the use of the Agricultural Non-Point Source (AGNPS) model indicated that approximately 2% of the total phosphorus load was the result of livestock feeding area discharge, 5% from inadequate cropland tillage practices and 1.5% from fertilizer. See the AGNPS section of the final report, Appendix E, pages 8, 10 and 11.

Other tributary total phosphorus loads were estimated using published percent reductions expected for Best Management Practices (BMPs) on priority subwatersheds. BMPs included inadequate buffers (28.1%), riparian management (8.5%) and streambank stabilization (0.9%) which contributes to the total phosphorus load to Lake Alvin (assessment final report, pages 38 through 40).

Inlake total phosphorus reduction percentages were estimated using in-house and published data. Total phosphorus reduction recommendations include mechanical aerator/circulator, 5%, and aluminum sulfate treatment, 30% (assessment final report, pages 113 through 115).

The remaining total phosphorus loading (120 kg/yr) was attributed to background sources in the Lake Alvin watershed.

The fecal coliform load from Nine Mile Creek appeared to have minimal impact on swimming beach fecal coliform concentrations. The majority of the loading was attributed (localized) to the ungauged portion of the watershed and the swimming beach. The current load from the watershed was estimated at $4.50 * 10^{10}$ fecal coliform/day or 268 fecal coliform/100mL, based on average observed fecal coliform concentrations and average daily flow in liters/day for 1999 (assessment final report, pages 115 through 121).

Fecal coliform bacteria background sources in the watershed were estimated at $1.32 * 10^{10}$ (10 fecal coliform/ 100 mL).

Linkage Analysis

Water quality data was collected from 10 monitoring sites within the Lake Alvin/ Nine Mile Creek watershed. Samples collected at each site were taken according to South Dakota's EPA-approved Standard Operating Procedures for Field Samplers. Water samples were sent to the State Health Laboratory in Pierre for analysis. Quality Assurance/Quality Control samples were collected on 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 4 through 11 and 41 through 44 of the assessment final report.

In addition to water quality monitoring, data was collected to complete a watershed landuse model. The AGNPS (Agricultural Nonpoint Source) model was used to estimate potential nutrient load reductions from feedlots, minimum tillage and fertilizer reduction within the watershed through the implementation of various BMPs. See the AGNPS section of the final report, Appendix E.

Other watershed (buffer strips, riparian management and streambank stabilization) and inlake (aerator/circulator and aluminum sulfate treatment) BMPs were also used to estimate total phosphorus reductions. Estimates were based on conservative percent reductions applied to priority subwatersheds (assessment final report, pages 38 through 40 and 112 through 115).

Reducing the current total phosphorus load (1147 kg/yr) a minimum of 67% (768 kg/yr.) will reduce the mean TSI value from 79.57 (non-supporting), to 64.95 (fully supporting). This can be accomplished by implementing tributary and inlake BMPs including a 14% margin of safety to support the TMDL target.

Fecal coliform loading was mainly attributed to the ungauged portion of the watershed and the swimming beach. Reductions in fecal coliform through selected tributary BMPs in Nine Mile Creek and the ungauged portion of the watershed (animal waste management systems (reducing waste from 140 animals 25%), riparian management and buffer strips) and implementing an information and education (I&E) program at the swimming beach should reduce fecal coliform loads. Reductions should reduce fecal coliform load from $4.50 * 10^{10}$ fecal coliform/day (268 fecal coliform/100 mL) to $3.36 * 10^{10}$ fecal coliform/day (200 fecal coliform/100 mL) (25%), which fully supports beneficial uses (assessment final report, pages 115 through 121).

An estimated $1.32 * 10^{10}$ fecal coliform/day (10 fecal coliform/100 mL) was attributed to background sources based on inlake fecal coliform concentrations and surface water volume (acre feet of Lake Alvin converted to liters per day) (assessment final report, page 118)

TMDL and Allocations

TMDL

Total phosphorus (kg) = 67% reduction

0 kg/yr	(WLA)
+ 206 kg/yr	(LA)
+ 120 kg/yr	(Background)
+ 53 kg/yr Implicit and Explicit	(MOS)
379 kg/yr	(TMDL) [1]

[1] = TMDL Equation implies a 81% total phosphorus reduction with all possible implementation BMPs. A 67% total phosphorus reduction is needed to restore beneficial uses. Thus, the TMDL includes a 14% margin of safety.

Fecal Coliform (Lake Alvin)

During 1999, inlake fecal coliform samples did not exceed 200 colonies/ 100 mL. Based upon the assessment report, inlake fecal coliform concentrations are not a problem in Lake Alvin.

Fecal Coliform (swimming beach)

0 fecal coliform/day	(WLA)
+ $2.04 * 10^{10}$ fecal coliform/day	(LA)
+ $1.32 * 10^{10}$ fecal coliform/day	(Background)
+ Implicit	(MOS)
$3.36 * 10^{10}$ fecal coliform/day	(TMDL) [1]

[1] = The TMDL was estimated using swimming beach water quality standards (200 fecal coliform/ 100 ml was used to ensure compliance) converted to fecal coliform per liter times the acre feet of Lake Alvin converted to liters per day (assessment final report page 118).

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 results of the AGNPS model indicates that a 4.3% (49 kg/yr) and 3.4% (39 kg/yr) reductions in total phosphorus loading to the lake could be achieved by minimum tillage (2,000 acres) and reduced fertilizer application (1,600 acres), respectively, within the watershed.

Removal of five animal feeding operations within the watershed would account for an additional 2% (23 kg/yr) of the total phosphorus load to the lake.

Tributary total phosphorus reductions for riparian management 8.5% (97 kg/yr), streambank stabilization 0.9% (10 kg/yr) and buffer strips 28.1% (322 kg/yr) were estimated using various methods and best professional judgement.

Inlake total phosphorus reductions were also estimated for Lake Alvin. They include mechanical circulator/ aerator, 5% (57 kg/yr) and an alum treatment, 30% (344 kg/yr).

A total phosphorus reduction of 67% is needed to restore the beneficial uses of Lake Alvin.

Reductions in fecal coliform through selected tributary BMPs in Nine Mile Creek and the ungauged portion of the watershed (animal waste systems (25%), riparian management and buffer strips) and implementing an information and education (I&E) program at the swimming beach should reduce fecal coliform loads approximately 25%. ($3.36 * 10^{10}$ fecal coliform/day or 200 fecal coliform/100 mL), which fully supports beneficial uses (assessment final report, pages 119 through 121).

An estimated fecal coliform reduction of 25% is needed to restore the beneficial uses of the Lake Alvin swimming beach.

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, Lake Alvin samples were separated into spring (March-May), summer (June-August), fall (September-November) and winter (December).

Margin of Safety

All total phosphorus reductions were calculated based on extremely conservative estimations built into the model and conservative total phosphorus reduction percentages using best professional judgement. Total phosphorus reductions were also explicit in that an 81% total phosphorus reduction is possible using all possible BMPs. Lake Alvin needs only a 67% total phosphorus reduction to restore beneficial uses. The additional 14% is the explicit margin of safety (assessment final report, pages 38 through 40, 113 through 115, and 121 through 124).

The margin of safety for fecal coliform was considered implicit because load reduction calculations were based on conservative delivery coefficients and loading estimates.

Critical Conditions

Based upon the 1999 assessment data, impairments to Lake Alvin are most severe during the late summer and early fall. This is the result of warm water temperatures, stratification and increased algal growth. Most beach closures tend to occur in early summer.

Follow-Up Monitoring

Lake Alvin should remain on the round robin statewide lake assessment project and on the South Dakota Game, Fish and Parks normal lake survey and swimming beach sampling to monitor and evaluate long-term trophic status, biological communities and ecological trends. It is recommended that the statewide lake assessment survey for Lake Alvin include fecal coliform samples to periodically monitor long-term fecal coliform concentrations.

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

Public Participation

The water quality assessment project was initiated during the spring of 1999 with EPA Section 604(b) and 104 (b)(3) funds. Lake Alvin was on the priority list of Section 319 Nonpoint Pollution Control projects. The Lincoln Conservation District agreed to sponsor the project and provided local matching funds and in-kind services. The federal grant funds totaled $44,675, and the local in-kind match totaled $18,576. Funds were used for water quality analyses, equipment, supplies, travel, and wages for the local coordinator.

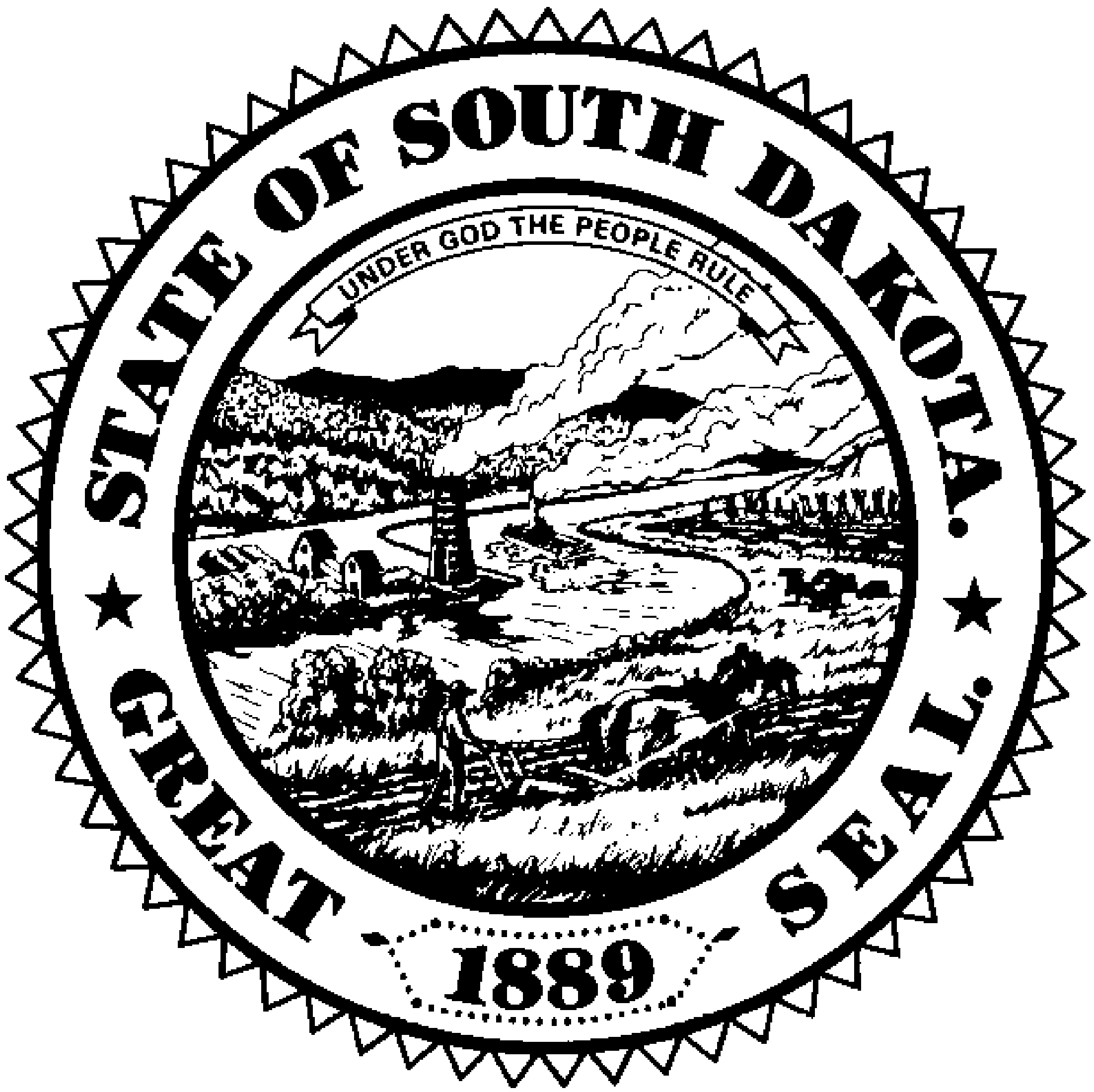
Efforts taken to gain public education, review, and comment during development of the TMDL involved:

1. Lincoln County Conservation District Board Meetings (14)
2. Lincoln County Commission Meeting (1)
3. City of Tea Board Meetings (1)
4. City of Harrisburg Board Meetings (1)
5. Individual contact with landowners in the watershed.
6. Articles in the Canton Sioux Valley News (3) and The Argus Leader (3)

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

Implementation Plan

The South Dakota DENR is working with the Lincoln County Conservation District to initiate an implementation project beginning in 2002. It is expected that a local sponsor will request project assistance during the spring 2002 EPA Section 319 funding round.


STATE OF SOUTH DAKOTA.
UNDER GOD THE PEOPLE RULE
GREAT SEAL.
1889

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NOV -9 2001

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 Alvin
Cottonwood Lake
Lake Louise
Lake Oliver

Dear Mr. Pirner:

We have completed our review of 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,

Jerry Anderson, Acting

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 Alvin*	phosphorus	TSI ≤ 64.95	67% reduction in total phosphorus	Section 303(d)(1)	▪ Phase I Watershed Assessment Final Report, Lake Alvin, Lincoln County, South Dakota (SD DENR, January 2001)
	fecal coliform	3.36×10^{10} fecal coliform/day 200 fecal coliform/100 mL	25% reduction in fecal coliform loads	Section 303(d)(1)	
Cottonwood Lake*	phosphorus	TSI ≤ 68 and phosphorus limited	30% reduction in tributary phosphorus loads	Section 303(d)(1)	▪ Phase I Watershed Assessment & TMDL Final Report, Cottonwood Lake, Faulk, Hand and Spink Counties, South Dakota (SD DENR, Feb 2001)
Lake Louise*	phosphorus	TSI < 70 average during growing season	10% reduction of phosphorus load	Section 303(d)(1)	▪ Phase I Watershed Assessment Final Report, Lake Louise/Wolf Creek, Hand and Hyde Counties, South Dakota (SD DENR, March 2001)
Lake Oliver*	phosphorus	TSI < 60	50% reduction of inlake phosphorus	Section 303(d)(1)	▪ Phase I Watershed Assessment Final Report, Lake Cochrane/Lake Oliver, Deuel County, South Dakota (SD DENR, October 2000)

* 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 Alvin, Lincoln County
Point Source-control TMDL: Nonpoint Source-control TMDL: X (check one or both)
Date Received: October 5, 2001 Date Review completed: October 19, 2001 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 permanent fish life propagation, immersion recreation, and limited contact recreation.
■ **Water Quality Standards Target**	X	One water quality target was established based on trophic status. This is a reasonable approach because the trophic status of the waterbody relates to the uses of concern. Also, the numeric standard for fecal coliform was used as a quantified endpoint.
■ **TMDL**	X	The TMDL is expressed in terms of annual phosphorus and fecal coliform load reductions. These are reasonable ways to express the TMDL for this lake because they provides an effective measure or 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, AGNPS 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 by performing ongoing monitoring to assure water quality goals are achieved and by application of additional nonpoint source BMPs for croplands within the watershed. Seasonality was adequately considered by evaluating the cumulative impacts of the various seasons on water quality and by tailoring the BMPs to seasonal needs.
■ **Allocation**	X	The allocation for the TMDL was a "load allocation" attributed to nonpoint sources. The allocation for phosphorous was attributed to such sources as animal feeding areas and inadequate cropland tillage practices. The fecal coliform allocation was attributed to localized sources (e.g., grazing animals, and pets) within the area of the swimming beach, and to a lesser extent to background sources (animal grazing and feeding) within the watershed.
■ **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: Cottonwood Lake, Faulk, Hand, Spink Counties
Point Source-control TMDL: Nonpoint Source-control TMDL: X (check one or both)
Date Received: October 5, 2001 Date Review completed: October 19, 2001 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 marginal 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 targets were established based on trophic status. 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 reduction. 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.
■ **Technical Analysis**	X	Monitoring, empirical relationships, AGNPS, PSIAC 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 by performing ongoing monitoring to assure water quality goals are achieved and by application of additional nonpoint source BMPs. Seasonality was adequately considered by evaluating the cumulative impacts of the various seasons on water quality and by tailoring the BMPs 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, animal feeding operations and individual wastewater treatment systems..
■ **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: Lake Louise, Hand County
Point Source-control TMDL: Nonpoint Source-control TMDL: X (check one or both)
Date Received: October 5, 2001 Date Review completed: October 19, 2001 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 targets were established based on trophic status. 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 reduction. 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.
■ **Technical Analysis**	X	Monitoring, empirical relationships, AGNPS, PSAIC 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 by performing ongoing monitoring to assure water quality goals are achieved and possibly by application of additional nonpoint source BMPs. Seasonality was adequately considered by evaluating the cumulative impacts of the various seasons on water quality and by tailoring the BMPs to seasonal needs.
■ **Allocation**	X	The allocation for the TMDL was a "load allocation" attributed to nonpoint sources. Allocation was attributed to sources such as animal feeding operations, and range and cropland management practices.
■ **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: Lake Oliver, Deuel County
Point Source-control TMDL: Nonpoint Source-control TMDL: X (check one or both)
Date Received: October 5, 2001 Date Review completed: October 19, 2001 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 permanent fish life propagation, immersion recreation, limited contact recreation and fish and wildlife propagation, recreation and stock watering.
■ **Water Quality Standards Target**	X	Water quality targets were established based on trophic status. 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 inlake phosphorus load reduction. 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.
■ **Technical Analysis**	X	Monitoring, empirical relationships, modeling (e.g., AGNPS, BATHTUB, Reduction Response), 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 by performing ongoing monitoring to assure water quality goals are achieved and by application of additional nonpoint source BMPs. Seasonality was adequately considered by evaluating the cumulative impacts of the various seasons on water quality and by tailoring the BMPs to seasonal needs.
■ **Allocation**	X	The allocation for the TMDL was a "load allocation" attributed to nonpoint sources. Allocation was attributed to inlake recycling of phosphorous from sources such as disturbed bottom sediments and from the water column.
■ **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.