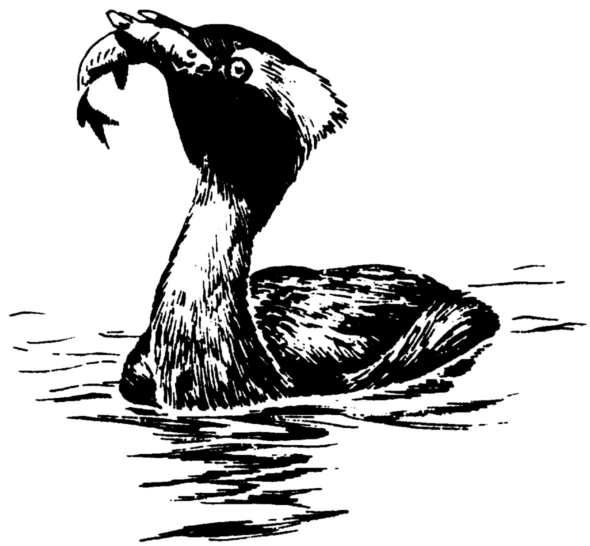
Phase I Watershed Assessment
Final Report and TMDL

Sylvan Lake Watershed
Custer County, South Dakota



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

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

Sylvan Lake
Custer County, SD

By

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

Sponsor

Black Hills Resource Conservation and Development Association, Inc.

November 2005

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

Executive Summary

Sylvan Lake was included in the 1998 South Dakota 303(d) list as an impairment-related TMDL waterbody (SD DENR 1998). Information supporting this listing was derived from statewide lake assessment data (Stueven and Stewart 1996) and the 1996 305(b) report (SD DENR 1996). According to the 1996 305(b) report, causes for impaired beneficial uses include nutrients, siltation, and noxious aquatic plants. More recently, Sylvan Lake was also identified in the 2002 and 2004 South Dakota Waterbody Lists as impaired due to its eutrophic state, and is listed as high priority waterbody in terms of Total Maximum Daily Load (TMDL) development (SD DENR 2002, 2004).

Because Sylvan Lake has been identified as an impaired waterbody, a watershed assessment project was initiated. The primary objectives of this assessment project were to (1) evaluate current physical, chemical, and biological integrity of Sylvan Lake and its watershed (2) determine non-point source critical areas within the watershed, (3) define management practices to improve the water quality, and (4) develop a TMDL for Sylvan Lake.

Physical, chemical, and biological data for this project was collected over a 2-year period. Scott Environmental, a local consultant, conducted monthly and event-based water quality sampling at two inlet sites, one outlet site, and two lake sites from August 2001 to August 2002. Continuous discharge data was also collected from the inlet and outlet sites during this time period. South Dakota Department of Environment and Natural Resources (SD DENR) performed monthly water quality sampling, temperature and dissolved oxygen profiles at the same two lake sites from January to August 2003. Some additional historic water quality data was also available for Sylvan Lake.

Almost 90% of samples collected in Sylvan Lake were considered phosphorus-limited. Due to phosphorus assimilation by algae, samples collected during late summer revealed the highest cases of phosphorus limitation. For this reason, phosphorus loads to Sylvan Lake will be targeted for reduction to allow the lake to support its designated beneficial uses and decrease the likelihood of algae blooms.

Carlson's (1977) Trophic State Index (TSI) was used to determine the approximate trophic state of Sylvan Lake and to determine the lake's beneficial use support status. During the project period, approximately 84% of phosphorus TSI values indicate eutrophic conditions, and 13% were in the mesotrophic range. One phosphorus sample collected in October 2001 was considered hyper-eutrophic. Individual parameter and mean TSI values span all beneficial use support categories throughout the project period. Nearly half of all TSI values fell within the partially supporting category. However, no phosphorus TSI values were considered fully supporting during the project period. Only 9% of mean TSI values were considered fully supporting beneficial uses.

Approximately 12.4 kg of total phosphorus are delivered to Sylvan Lake from its watershed annually. Modeling results indicate an accumulation of 5.1 kg of total phosphorus per year. The models also predicted that greater than 90% reduction of total phosphorus load from the watershed is required to meet the TMDL goal (phosphorus TSI = 45).

These results indicate that internal phosphorus loading from lake sediment is a significant source of phosphorus in Sylvan Lake. According to model results and a lake total phosphorus mass balance, lake sediments contribute a significant amount of the total phosphorus load to Sylvan Lake. Approximately 7.3 kg/yr of total phosphorus (37% of the overall phosphorus load) originates from recycling of phosphorus in the lake's sediment. This load will also be targeted for reductions to meet the TMDL goal.

As the oxygen content of the water near the sediment interface declines, phosphorus and other nutrients can be released into the water. Concentrations of total phosphorus in lake sediment samples ranged from 610 to 5,100 mg/kg. Higher sediment phosphorus concentrations were observed in the deeper embayment. Dissolved oxygen and temperature profiles taken in the deeper embayment displayed seasonal stratification and oxygen depletion in the lower depths of the lake. During summer stratification, dissolved oxygen concentrations begin to decrease drastically at depths of approximately 3-4 m until concentrations reach anoxia at approximately 5-6 m of water depth. Anoxic conditions in the hypolimnion of the deeper embayment were observed as early as April and persist throughout the summer months until fall turnover.

Based on sediment survey data collected during this study, Sylvan Lake has accumulated approximately 49,400 cubic yards of sediment. The majority of the accumulated sediment is shown to have been deposited in the deeper embayment. Approximately 15,000 cubic yards of sediment was removed from the shallower embayment in 1982.

To slow sedimentation rates and reduce nutrient loads, the construction of artificial wetlands is recommended at each of the inlet streams. Current total phosphorus loads are 3.8 and 7.1 kg/yr for SLT-3 and SLT-4, respectively. The proposed wetland areas should reduce this total phosphorus load from 10.9 to 1.1 kg/year, approximately a 90% reduction (Fischer et al. 2004).

Five lake treatment options were considered to reduce internal phosphorus loading. Of these options, two were deemed most likely to succeed: hydraulic dredging and aluminum sulfate application. Of the two, alum treatment is recommended as the primary lake treatment and will allow the lake to reach the TMDL numeric target (i.e. phosphorus TSI = 45; 0.02 mg/L of total phosphorus).

It should be noted that water quality data presented in this report may not be representative of a typical year, as the study period was during a time of drought. Nonetheless, lake and watershed management recommendations presented in this report will improve water quality. To evaluate the level of improvement, water quality monitoring is recommended following the implementation of management activities.

Acknowledgements

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

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

South Dakota Department of Game, Fish, and Parks – Regional Office in Rapid City, SD

South Dakota Department of Game, Fish, and Parks – Custer State Park

United States Environmental Protection Agency – Non-Point Source Program

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Introduction

The purpose of the Custer State Park Lakes Assessment was to determine sources of impairment for three waterbodies, Sylvan Lake, Center Lake, and Legion Lake. This report discusses the current condition, possible restoration alternatives, and a Total Maximum Daily Load (TMDL) summary for one of the three lakes, Sylvan Lake, and its watershed.

Lake and Watershed Description

The Sylvan Lake watershed is located in north central Custer County, South Dakota. The watershed consists of nearly 565 acres of Harney Peak Granite outcrop with dense pine forest; predominately Ponderosa Pine with some Black Hills Spruce and Aspen (Figure 1).

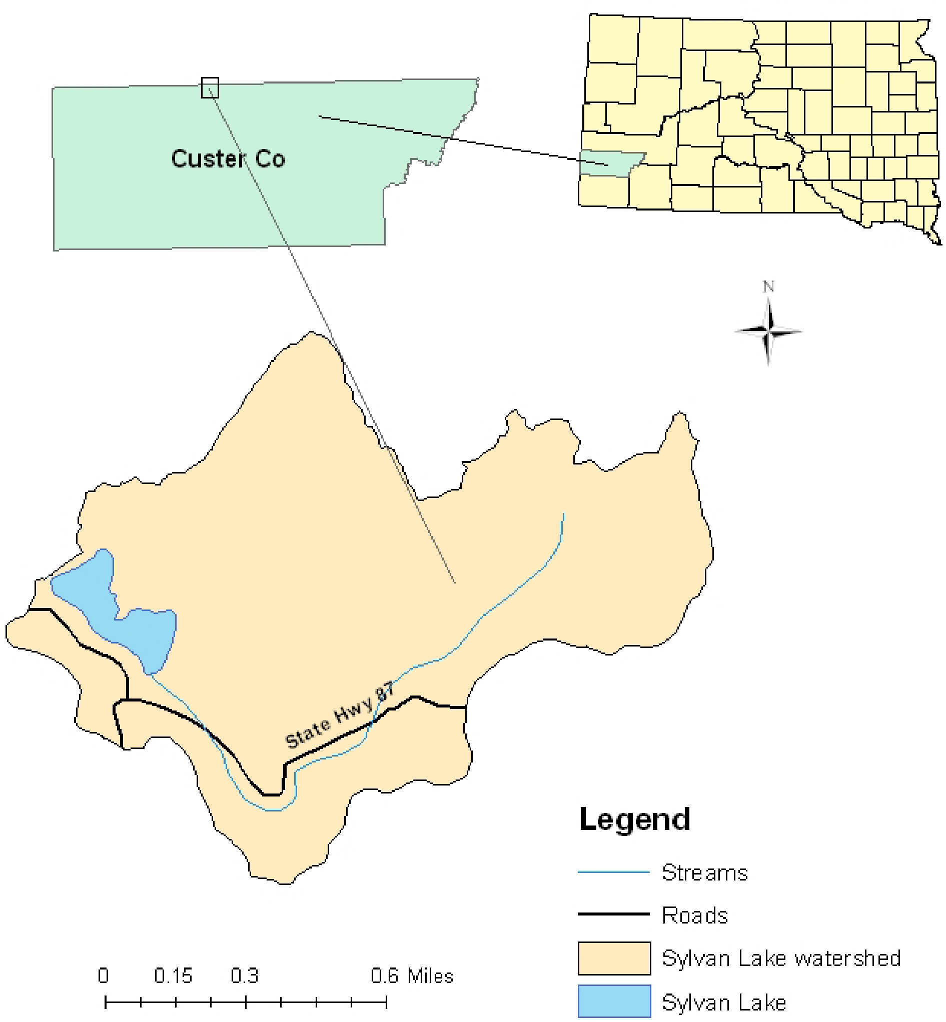

Figure 1. Location of the Sylvan Lake watershed and Sylvan Lake, Custer County, SD.

The Sylvan Lake watershed falls within the Middle Rockies Level III Ecoregion. A majority of the watershed area is in the Black Hills Plateau Level IV Ecoregion, with only a small portion in the Black Hills Core Highlands Level IV Ecoregion. The Black Hills Plateau is characterized by plateau topography with broad ridges and entrenched canyons. The Black Hills Core Highlands have mountainous topography with highly eroded outcrops and broad valleys.

The lake is recharged by natural precipitation, which is quite variable in the study area. Average annual precipitation for the Black Hills of South Dakota is approximately 19 inches (Driscoll et al. 2000). Typically, most precipitation falls from early spring to late summer (Figure 2).

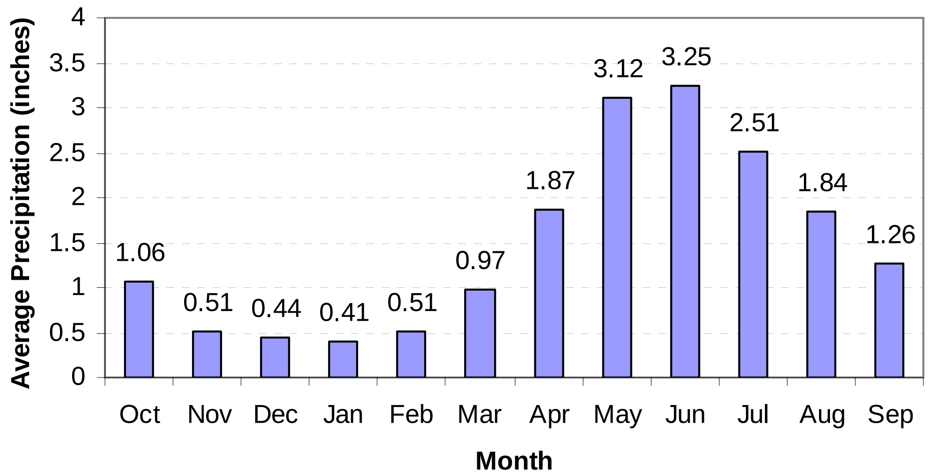

Figure 2. Average monthly precipitation for Custer County, SD (water years 1931-1998). (source: Driscoll et al., 2000)

The lake volume is depleted by evaporation and seepage. Excess runoff spills over the concrete dam during periods of high inflow, however, only seepage through the concrete dam structure and igneous rock was discharged during this study period.

Sylvan Lake, the oldest lake in the Black Hills, was originally built by a private landowner in 1893. A natural dam site exists between massive granite outcroppings, which is where the original dam was constructed (predominantly timber construction). This dam was replaced with the existing concrete gravity arch dam, which was constructed by the Civilian Conservation Corps in the mid-1930's.

After Custer State Park was formed in the 1920's, Sylvan Lake came under public ownership and is presently managed by the South Dakota Department of Game, Fish, and Parks (SDGFP). The lake has been an extremely popular recreational area in which to enjoy a variety of outdoor activities including swimming, boating, hiking, fishing, and rock climbing. Annual revenue is approximately $1.25 million (Goebel 2003).

The lake has a surface area of approximately 18 acres and volume of approximately 214 acre feet. The lake has two embayments. The shallow fore bay has a mean depth of 9 ft, and the deeper bay has a mean depth of 12 ft. The two are joined by a moderately sized channel formed by granite outcropping.

The source of nonpoint source pollution loading from the Sylvan Lake watershed is likely a combination of recreational uses, forest management, as well as background sources (i.e. wildlife, natural weathering, etc.). However, degraded water quality in Sylvan Lake is primarily attributed to recreational activity within the watershed. According to Wierenga and Payne (1987), 5% of the total watershed area has been converted to commercial or developed recreational use. Approximately 90% of the watershed land area is managed by the SD Department of Game, Fish and Parks (Custer State Park), while the remaining 10% is managed by the US Forest Service. Although much of the watershed remains in its natural state, the intense usage of recreational facilities within Custer State Park (e.g. fishing, camping, hiking, swimming, boating, rock climbing, automobile touring, etc.) has degraded the watershed condition.

Watershed Geology

Sylvan Lake lies within a basin of granite and is bounded to the south by metamorphic rock (Figure 3). Deposition of alluvial material has taken place in three drainage areas within the watershed. Gaging stations were set up on two of those drainages (sites SLT-3 and SLT-4); the additional alluvial channel was located in an ungaged portion of the watershed.

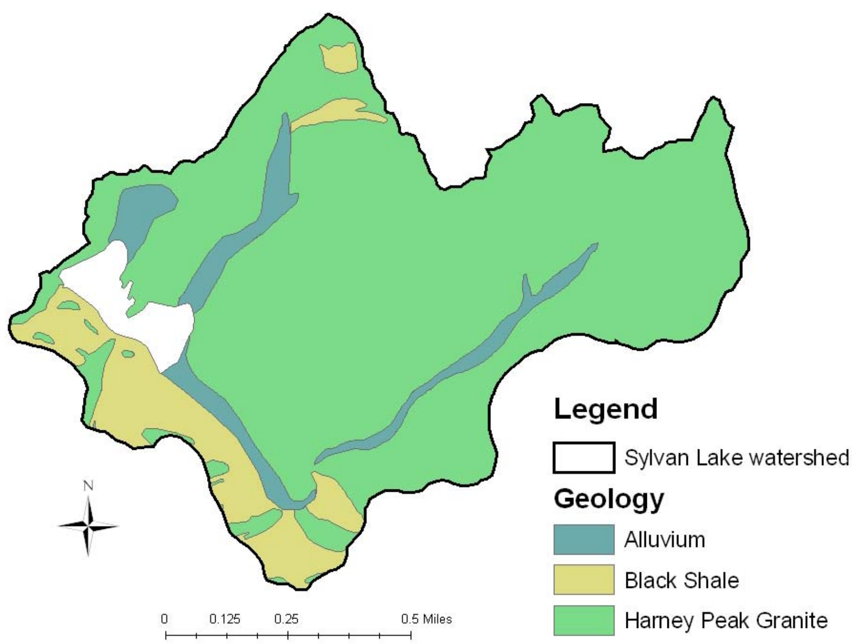

Figure 3. Geology of Sylvan Lake watershed. The watershed was formed within a basin of Harney Peak Granite and bounded to the south by metamorphic rock. Alluvium has formed within the three drainage areas of the basin.

The host rock, Harney Peak Granite, has many pegmatitic and coarse-grained mineral deposits which consist largely of quartz and feldspar (USGS 1986). The larger deposits have central cores of quartzite surrounded by concentric layers of accessory minerals (tourmaline, garnet, apatite, etc.) that contain calcium, iron, lithium, manganese, and phosphorus. The principle phosphate deposits include apatite, amblygonite (USGS 1986), triphylite (Fahrenbach 2003), and other rare phosphate minerals (Page et al. 1953, Roberts and Rapp 1965).
The crystalline nature of the host rock made it unlikely that any type of groundwater storage or springflow from outside the watershed would occur. Analysis of classical flow-net studies (ASCE 1985), and rock fractures at the study site indicated that leakage from under the toe of the dam was unlikely. Flow from the dam typically occurred through a fracture in the dam face, and flow over the spillway occurs when the water level was sufficiently high.

Beneficial Use Assignment and Water Quality Standards

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

Sylvan Lake has been assigned the following beneficial uses: (2) coldwater permanent fish life propagation, (7) immersion recreation, (8) limited contact recreation, and (9) wildlife propagation, recreation, and stock watering. Table 1 lists the criteria that must be met to maintain the above beneficial uses. When multiple standards exist for a particular parameter, the most stringent standard is used.

Table 1. State surface water quality standards for Sylvan Lake, Custer State Park, SD.

Parameter	Criteria	Beneficial Use Requiring Criteria
Nitrate – N	≤88 mg/L, daily maximum	Wildlife propagation, recreation, and stock watering
Un-ionized Ammonia[1]	≤0.02 mg/L, 30-day average	Coldwater permanent fish propagation
Alkalinity ($CaCO_3$)	≤750 mg/L, 30-day average ≤1,313 mg/L, daily maximum	Wildlife propagation, recreation, and stock watering
pH	6.6 – 8.6 (standard units)	Coldwater permanent fish propagation
Conductivity	≤4,000 umhos/cm, 30-day average; ≤7,000 umhos/cm, daily maximum	Wildlife propagation, recreation, and stock watering
Total Dissolved Solids	≤2,500 mg/L, 30-day average; ≤4,375 mg/L, daily maximum	Wildlife propagation, recreation, and stock watering
Total Suspended Solids	≤30 mg/L, 30-day average; ≤53 mg/L, daily maximum	Coldwater permanent fish propagation
Temperature	≤65 º F	Coldwater permanent fish propagation
Dissolved Oxygen[2]	≥6.0 mg/L; per sample	Coldwater permanent fish propagation
Fecal Coliform Bacteria[3]	≤200 colonies/100mL, geomean: ≤400 CFU/100mL, per sample	Immersion recreation
Chlorides[4]	≤100 mg/L, 30-day average; ≤175 mg/L, daily maximum	Coldwater permanent fish propagation
Undisassociated hydrogen sulfide[4]	≤0.002 mg/L, per sample	Coldwater permanent fish propagation

[1] Un-ionized ammonia is the fraction of ammonia toxic to aquatic life. The concentration of un-ionized ammonia is calculated and dependent on temperature and pH. The daily maximum of un-ionized ammonia standard is 1.75 times the calculated criterion for the single sample (SD DENR, 1997).
[2] Dissolved oxygen concentrations must be ≥ 7.0 mg/L in spawning areas during the spawning season.
[3] The fecal coliform standard is in effect from May 1 to September 30.
[4] Parameters not measured during this project.

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

Table 2. Surface water quality criteria and designated beneficial uses for streams in the Sylvan Lake watershed study area, Custer State Park, SD.

Parameter	Criteria	Beneficial Use Requiring Criteria
Alkalinity ($CaCO_3$)	≤750 mg/L, 30-day average; ≤1,313 mg/L, daily maximum	Wildlife propagation, recreation, and stock watering
pH	6.0 – 9.5 (standard units)	Wildlife propagation, recreation, and stock watering
Conductivity	≤2,500 umhos/cm, 30-day average; ≤4,375 umhos/cm, daily maximum	Irrigation
Total Dissolved Solids	≤2,500 mg/L, 30-day average; <4,375 mg/L, daily maximum	Wildlife propagation, recreation, and stock watering
Nitrate-N	≤50 mg/L, 30-day average; ≤88 mg/L, daily maximum	Wildlife propagation, recreation, and stock watering
Total Petroleum Hydrocarbons[1]	≤10 mg/L, per sample	Wildlife propagation, recreation, and stock watering
Oil and grease[1]	≤10 mg/L, per sample	Wildlife propagation, recreation, and stock watering
Sodium adsorption ration[1,2]	≤10	Irrigation

[1] Parameters not measured during this project.
[2] The SAR is used to evaluate the sodium hazard of irrigation water based on the Gapon equation.

Threatened and Endangered Species

No threatened or endangered species have been documented in the Sylvan Lake watershed. However, the U. S. Forest Service Region 2 Sensitive Species List has documented the Selkirk's violet as a sensitive species in the Sylvan Lake area. Selkirk's violet (Viola selkirkii) has been observed in the rocky area beneath the Sylvan Lake dam and also in some stream riparian areas. During the course of our study, the violets were not encountered. Care should be taken when considering management activities in this watershed.

Project Goals, Objectives, and Activities

Project Goals

The purpose of this assessment project was to determine and document sources of impairments to Sylvan Lake and the watershed and to develop feasible alternatives for restoration. The primary goal of this project was to complete a phosphorus TMDL for Sylvan Lake.

Project Objectives

Objective 1: Lake Sampling

The first objective was to determine current water quality conditions in the lake and calculate the lake's trophic state. This information was used to determine the amount of nutrient trapping, the amount of phosphorus released from the hypolimnion, and the amount of nutrient reduction required to improve the trophic condition of the lake.

Physical, chemical, and biological parameters were examined for Sylvan Lake on a monthly basis, excluding the months November and March. Samples were collected from surface and bottom depths at two sites (Figure 4). All samples were analyzed by Energy Laboratories in Rapid City, SD. Air and water temperature, dissolved oxygen, conductivity, field pH, and water depth were measured using a Yellow Springs Instruments (YSI) meter. As with stream sampling, all samples and measurements were collected using methods described in *Standard Operating Procedures for Field Samplers* for the South Dakota Water Resources Assistance Program (Stueven et al. 2000a). Table 3 lists all parameters measured for Sylvan Lake.

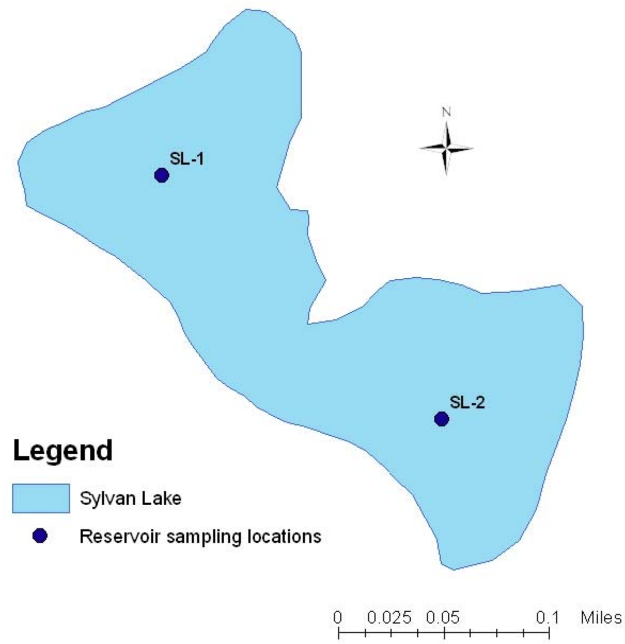

Figure 4. Location of inlake sampling sites for Sylvan Lake, Custer County, SD.

Table 3. Parameters measured at lake sites.

Physical	Chemical	Biological
Air temperature	Total alkalinity	Fecal coliform bacteria
Water temperature	Un-ionized ammonia	E. coli
Secchi transparency	Total Kjeldahl Nitrogen	Phytoplankton
Visual observations	Nitrate+Nitrite	
Total solids	Total Phosphorus	
Total suspended solids	Total Dissolved Phosphorus	
Depth	Dissolved oxygen	
	Conductivity	
	Field pH	

Objective 2: Stream Sampling

The second objective was to estimate the sediment and nutrient loadings from streams in the watershed through hydrologic and chemical monitoring. The information was used to locate critical areas in the watershed to be targeted for implementation.

OTT Thalimedes water level recorders were installed on two inlet streams sites (SLT-3 and SLT-4) and one outlet stream site (SLO-5) to maintain a continuous stage record for those streams for a period of one year. Figure 5 shows the location of the stream monitoring sites.

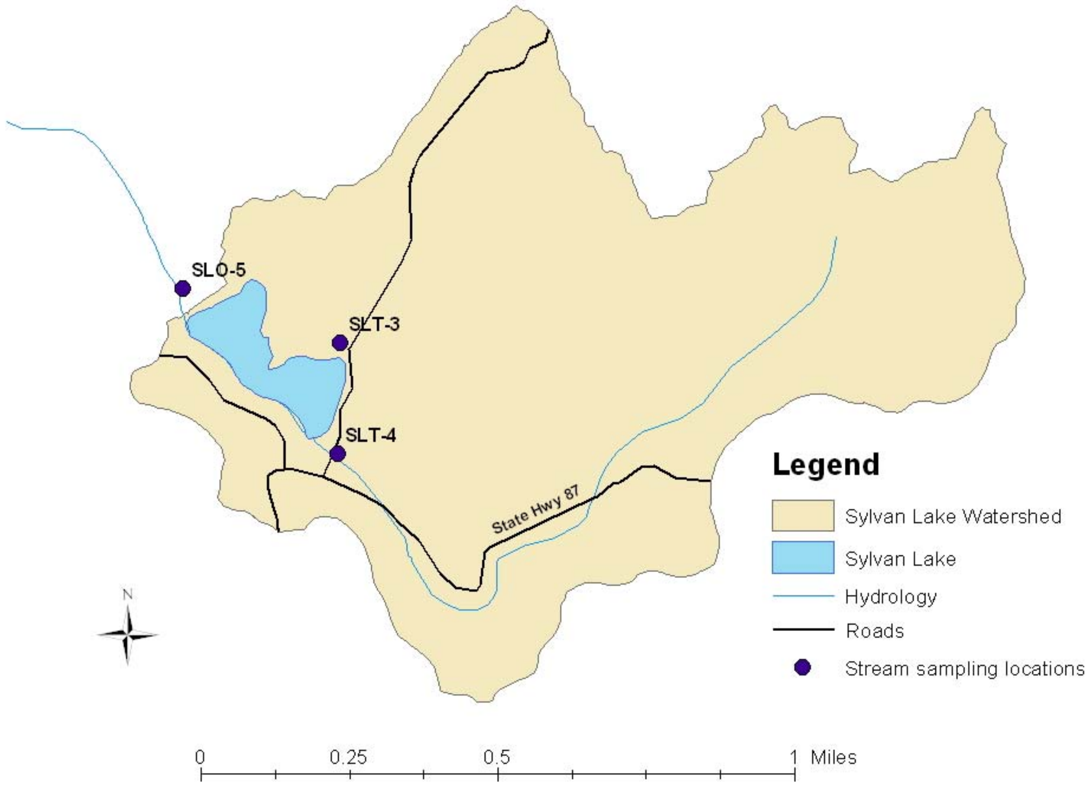

Figure 5. Location of stream sampling sites for the Sylvan Lake watershed assessment, Custer County, SD.

Instantaneous discharge measurements were taken with a hand-held current velocity meter. A regression equation was developed from the relationship between instantaneous discharge measurements and stage data to estimate continuous discharge and a hydrologic budget for the drainage system. Watershed loads were determined from discharge measurements and sample concentrations of sediment and nutrients. FLUX, a eutrophication model developed by the Army Corps of Engineers (US ACOE 1999) was used to estimate nutrient and sediment loading.

All stream samples and measurements were collected using methods described in *Standard Operating Procedures for Field Samplers* for the South Dakota Water Resources Assistance Program (Stueven et al. 2000a). Grab samples were collected mid-stream from the same location with same method at each visit. After each water sample was collected, water and air temperature, pH, conductivity, and dissolved oxygen measurements were taken using a YSI meter. Table 4 lists all parameters assessed at stream sites.

Table 4. Parameters measured at stream sites.

Physical	Chemical	Biological
Air temperature	Dissolved oxygen	Fecal coliform bacteria
Water temperature	Ammonia	E. coli
Discharge	Un-ionized ammonia	Benthic macroinvertebrates
Depth	Nitrate+Nitrite	
Visual observations	TKN	
Water level	Total phosphate	
Total solids	Total dissolved phosphate	
Total suspended solids	Field pH	
Conductivity		

Benthic macroinvertebrate samples were collected from both inlet stream sites in November 2001. All benthic samples were collected in accordance the *Standard Operating Procedures for Field Samplers* for the South Dakota Water Resources Assistance Program (Stueven et al. 2000a).

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

All QA/QC activities were conducted in accordance with the Water Resource Assistance Program Quality Assurance Project Plan. QA/QC samples consisted of field blanks and field duplicate samples. The activities involved with QA/QC procedures and the results of QA/QC monitoring are reported in a subsequent section of this report.

Objective 4: Watershed Modeling

Sylvan Lake and its streams were modeled using the BATHTUB and FLUX models. FLUX is a program used to estimate loadings of nutrients or other water quality constituents passing a stream sampling station over a period of time.

The BATHTUB program was used to estimate water and nutrient balances and identify factors controlling algal production. The model was also used to determine the nutrient load reduction required for Sylvan Lake to support its beneficial uses. The model performs calculations on a steady state, spatially segmented hydraulic network and accounts for advective transport, diffusive transport, and nutrient sedimentation.

Results

Stream Physical and Chemical Parameters

Annual Loading

FLUX, a eutrophication model developed by the Army Corps of Engineers (US ACOE 1999), was used to determine hydrologic, nutrient, and sediment loadings at monitoring sites based on the flow and water quality parameter concentration data collected at the site. FLUX can calculate loadings using several available models (e.g. average flow, flow-weighted, etc.).

The drainage area was divided into four subwatersheds (Figure 6). Two of the larger subwatersheds are those that drain to stream sites SLT-3 and SLT-4. Two subwatersheds adjoined the lake directly, where flows could not be recorded. Flows were estimated from these areas, and are referred to as Ungaged North and Ungaged South.

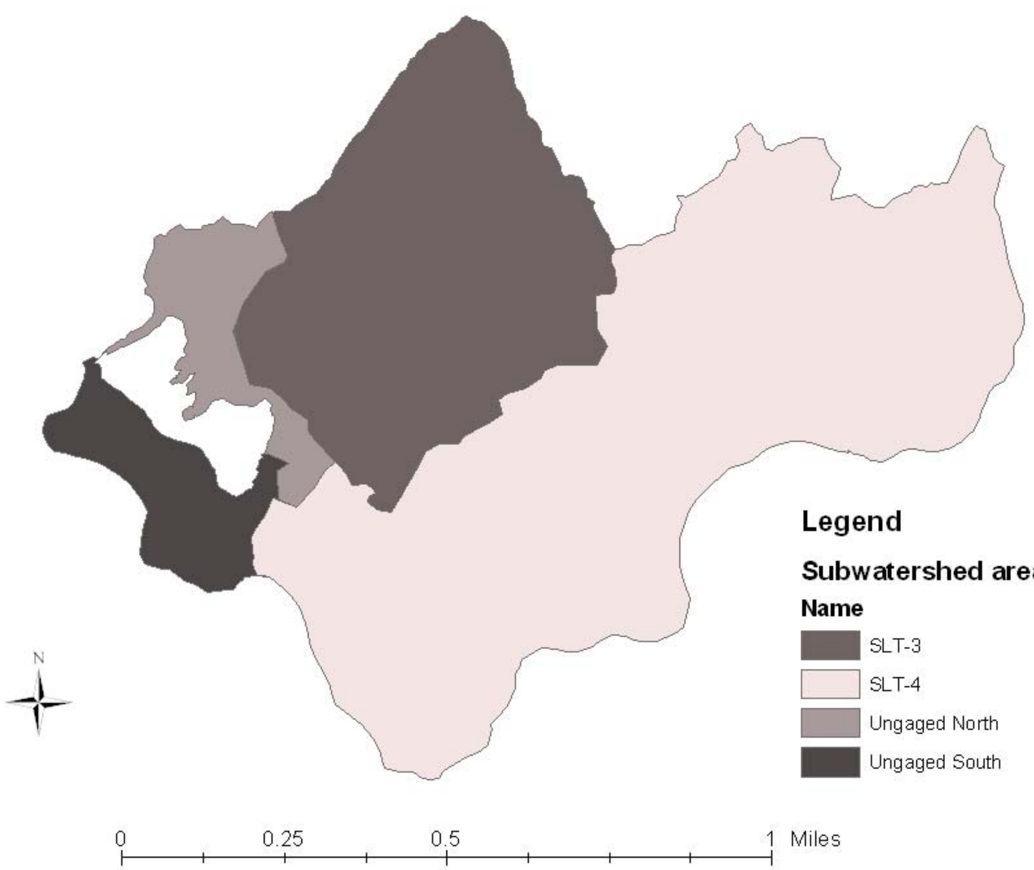

Figure 6. Delineation of subwatershed areas for the Sylvan Lake watershed assessment.

The monthly hydrologic contributions from each gaged subwatershed area were calculated by the FLUX modeling program. Estimates of hydrologic load were calculated for each season by summing three months of hydrologic load per season (i.e. the winter season was the total of December, January, and February monthly loads; spring was the total of March, April, and May monthly loads; summer was the total of June, July, and August monthly loads; and fall was the total of September, October, and November monthly loads) (Table 5). Subwatershed SLT-4 contributed the largest hydrologic load. Subwatershed SLT-4 also contributed the largest nutrient loads and the largest loads for all sampled parameters, excluding total suspended solids. Subwatershed SLT-3 contributed the largest total suspended solids load (Table 6).

Table 5. Subwatershed Hydrologic Contributions. The following table lists the FLUX-modeled hydrologic contributions for each site/subwatershed in the Sylvan Lake watershed.

Site	Season	Seasonal Volume in Liters (L)	Seasonal Volume (acre-ft)	Percent of Total (%)	Subwatershed Area	Units	Subwatershed Hydrologic Export Coefficient (ac ft/ac)
INLETS							
SLT3	Winter	7,712,078	6.3	8%	162	ac	0.04
	Spring	9,990,982	8.1	11%	7,036,350	sq ft	0.05
	Summer	6,645,985	5.4	7%	0.25	sq mi	0.03
	Fall	7,330,634	5.9	8%			0.04
	Total	**31,679,679**	**25.7**	**34%**			**0.16**
SLT4	Winter	13,971,727	11.3	15%	320	ac	0.04
	Spring	10,616,947	8.6	11%	13,940,894	sq ft	0.03
	Summer	9,968,977	8.1	11%	0.50	sq mi	0.03
	Fall	15,309,237	12.4	16%			0.04
	Total	**49,866,888**	**40.4**	**54%**			**0.13**
Ungaged (N)	Winter	1,446,518	1.2	2%	31.7	ac	0.04
	Spring	1,503,898	1.2	2%	1,378,788	sq ft	0.04
	Summer	1,144,125	0.9	1%	0.05	sq mi	0.03
	Fall	1,475,287	1.2	2%			0.04
	Total	**5,569,828**	**4.5**	**6%**			**0.14**
Ungaged (S)	Winter	1,528,742	1.2	2%	33.5	ac	0.04
	Spring	1,589,384	1.3	2%	1,457,162	sq ft	0.04
	Summer	1,209,161	1.0	1%	0.05	sq mi	0.03
	Fall	1,559,146	1.3	2%			0.04
	Total	**5,886,432**	**4.8**	**6%**			**0.14**
Lake					18.2	ac	
					794,407	sq ft	
							Average
Inlet Total		**93,002,828**	**75.4**	**100%**	565	ac	**0.06**
OUTLET							
SLO5	Winter	21,101,854	17.1	22%	565	ac	0.03
	Spring	23,867,349	19.3	25%	24,607,601	sq ft	0.03
	Summer	23,260,946	18.9	25%	0.88	sq mi	0.03
	Fall	25,992,210	21.1	28%			0.04
	Total	**94,222,359**	**76.4**	**100%**			**0.14**

Table 6. Parameter annual loads (kg) delivered from subwatersheds and total loads for the entire watershed.

Parameter	SLT-3	SLT-4	Ungaged N	Ungaged S	Total
Alkalinity	885.1	1,082.7	173.4	113.2	**2,254.4**
TKN	3.6	15.1	0.7	1.6	**21.0**
Nitrate+Nitrite	2.5	6.1	0.5	0.6	**9.7**
Ammonia	1.2	2.4	0.2	0.3	**4.1**
Organic Nitrogen	0.0	12.7	0.0	1.3	**14.0**
Inorganic Nitrogen	3.8	8.3	0.7	0.9	**13.7**
Total Nitrogen	7.1	21.1	1.4	2.2	**31.8**
Total Phosphorus	3.8	7.1	0.7	0.7	**12.4**
Total Dissolved Phosphorus	2.5	4.8	0.5	0.5	**8.3**
Total Suspended Solids	210.6	260.4	51.0	22.0	**544.0**
Total Dissolved Solids	1,794.4	2986.0	351.6	312.1	**5,444.1**
Total Solids	2,053.8	3,202.8	402.4	334.8	**5,993.8**

After the hydrologic and parameter loadings for all sites were calculated, export coefficients were developed for each of the subwatershed water quality parameters. Export coefficients were calculated by taking the annual nutrient and sediment loads (kg) at a particular site and dividing by the total area of the sub-watershed (in acres) for that site. This calculation resulted in the determination of the kilograms of sediment and nutrient per acre per year (kg/acre/year) delivered from the respective subwatershed area. Similar to the hydrologic export coefficient, these values represent a fraction of the parameter mass that might be expected from each acre in the watershed annually. Higher values indicate higher export potentials, and are signs that priority problems exist within the subwatershed. Nitrogen export coefficients for the SLT-4 subwatershed were greater than those for the SLT-3 subwatershed. Export coefficients for the solids parameters (i.e. total, total dissolved, and total suspended solids) and total phosphorus were greater in the SLT-3 subwatershed (Table 7).

Table 7. Export coefficients (kg/acre/year) for gaged subwatersheds and total watershed area. Ungaged areas were assigned export coefficients of the closest gaged area.

Parameter	SLT-3 and Ungaged North	SLT-4 and Ungaged South	Total Watershed
Alkalinity	5.479	3.383	3.990
TKN	0.022	0.047	0.037
Nitrite/Nitrate	0.015	0.019	0.017
Ammonia	0.007	0.007	0.007
Organic Nitrogen	0.000	0.040	0.025
Inorganic Nitrogen	0.024	0.026	0.024
Total Nitrogen	0.044	0.066	0.056
Total Phosphorus	0.024	0.022	0.022
Total Dissolved Phosphorus	0.015	0.015	0.015
Total Suspended Solids	1.300	0.814	0.963
Total Dissolved Solids	11.109	9.330	9.636
Total Solids	12.715	10.008	10.609

Water Temperature

Water temperature is an influential variable in biological, chemical, and physical processes. Temperature can influence metabolic rates of aquatic organisms, toxicity of pollutants, and levels of dissolved oxygen. Stream water temperature is influenced by natural environmental conditions/events, including atmospheric temperatures, precipitation, and vegetation (shade). The greatest source of heat in freshwaters is solar radiation, especially waterbodies that are directly exposed to the sun (Hauer and Lamberti 1996); however, the streams that flow into Sylvan Lake drain heavily forested areas.

As expected, temperature measurements were extremely variable due to seasonal atmospheric temperature differences (Table 8 and Figure 7). Temperatures at the main inlet site (SLT-4) ranged from 1.5 to 18.4 degrees Celsius (mean = 8.7), while the outlet site (SLO-5) ranged from 5.0 to 22.5 degrees Celsius (mean = 13.8). Lower mean water temperatures at inlet sites could be attributed to the water source, which is predominantly snow-melt runoff. Spring snow-melt water can keep stream water temperatures below air temperatures for several days (Hynes 1970).

Table 8. Descriptive statistics of water temperature (degrees Celsius) for Sylvan Lake stream sites.

	Number of Measurements	Mean	Min	Max	Standard Deviation	Lower Quartile	Median	Upper Quartile
SLT-3	10	8.7	1.5	18.4	5.4	3.2	9.0	11.4
SLT-4	10	8.9	4.0	14.1	3.9	5.4	8.4	12.2
SLO-5	8	13.8	5.0	22.5	6.6	7.0	15.7	18.7

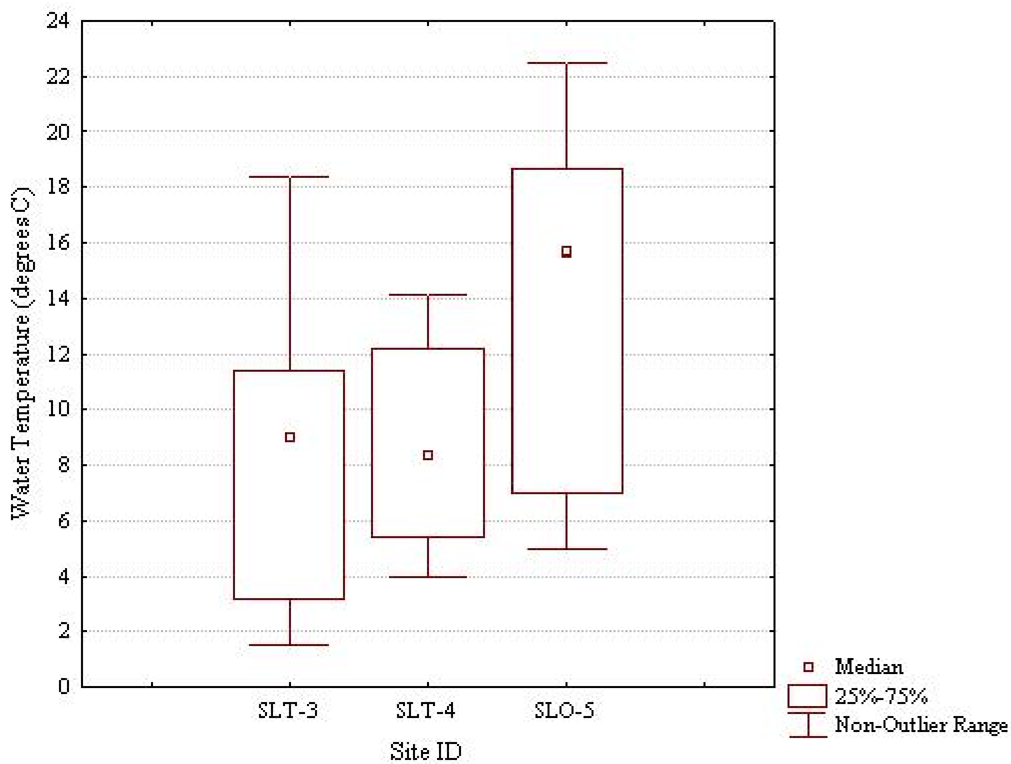

Figure 7. Box plot of temperature by site for Sylvan Lake stream sites. SLT-3 and SLT-4 are inlet stream sampling sites, and SLO-5 is the outlet stream sampling site.

Dissolved Oxygen

Concentrations of dissolved oxygen (DO) often vary both spatially and temporally. Seasonal loadings of organic matter greatly influence DO concentrations (Wetzel 2001). Physical factors, such as temperature and pressure, also influence concentrations of DO. Atmospheric oxygen solubility is most affected by temperature; DO increases considerably in colder water.

Concentrations of DO at both inlet stream sites were similar. Average DO concentrations were 8.1 mg/L and 8.2 mg/L for sites SLT-3 and SLT-4, respectively. Average DO concentration was 6.63 mg/L at the outlet site (Table 9 and Figure 8). Lower DO concentrations at the outlet are probably due to warmer water temperatures and the water source at this sampling site. Typically, water flows from the reservoir over the spillway to the outlet site during spring and summer months. During low flow periods, which includes this study period, only water that seeps through the concrete dam structure is discharged from the reservoir.

Table 9. Descriptive statistics of dissolved oxygen (mg/L) for Sylvan Lake stream sites.

	Number of Measurements	Mean	Min	Max	Standard Deviation	Lower Quartile	Median	Upper Quartile
SLT-3	10	8.1	5.5	9.5	1.5	6.9	8.8	9.2
SLT-4	10	8.2	7.1	10.0	1.0	7.4	7.8	9.0
SLO-5	8	6.6	5.0	8.0	1.2	5.8	6.4	7.8

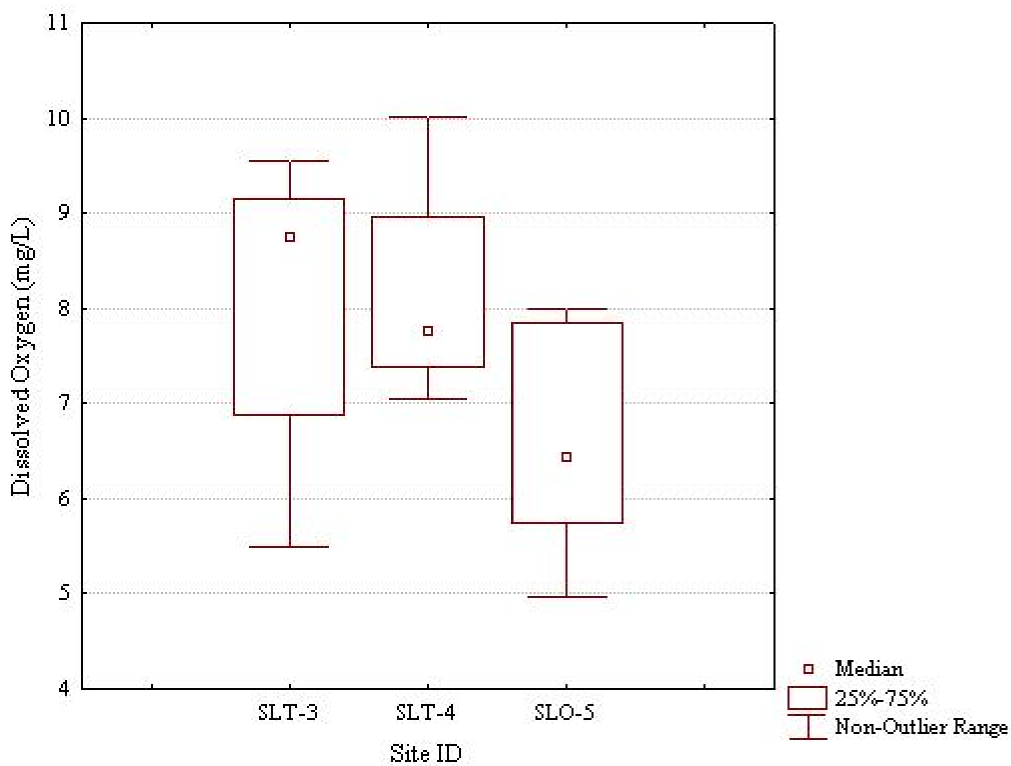

Figure 8. Box plot of dissolved oxygen by site for Sylvan Lake streams sites.

Acidification and Alkalinity

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

Streams in the Sylvan Lake watershed are designated with the beneficial use of fish and wildlife propogation and stock watering, which requires pH levels to be maintained between 6.0 and 9.5. All pH measurements fell within this range. Average field pH at all sites was comparable with an average of 7.5, 7.4, and 7.6 at sites SLT-3, SLT-4, and SLO-5, respectively (Table 10). Relatively little variability in pH values was observed throughout the sampling period (Figure 9).

Table 10. Descriptive statistics of field pH (standard units) for the Sylvan Lake stream sites.

	Number of Measurements	Mean	Min	Max	Standard Deviation	Lower Quartile	Median	Upper Quartile
SLT-3	10	7.5	6.9	8.0	0.4	7.3	7.5	7.7
SLT-4	10	7.4	6.8	8.4	0.5	6.9	7.3	7.6
SLO-5	8	7.6	6.8	7.9	0.4	7.5	7.6	7.9

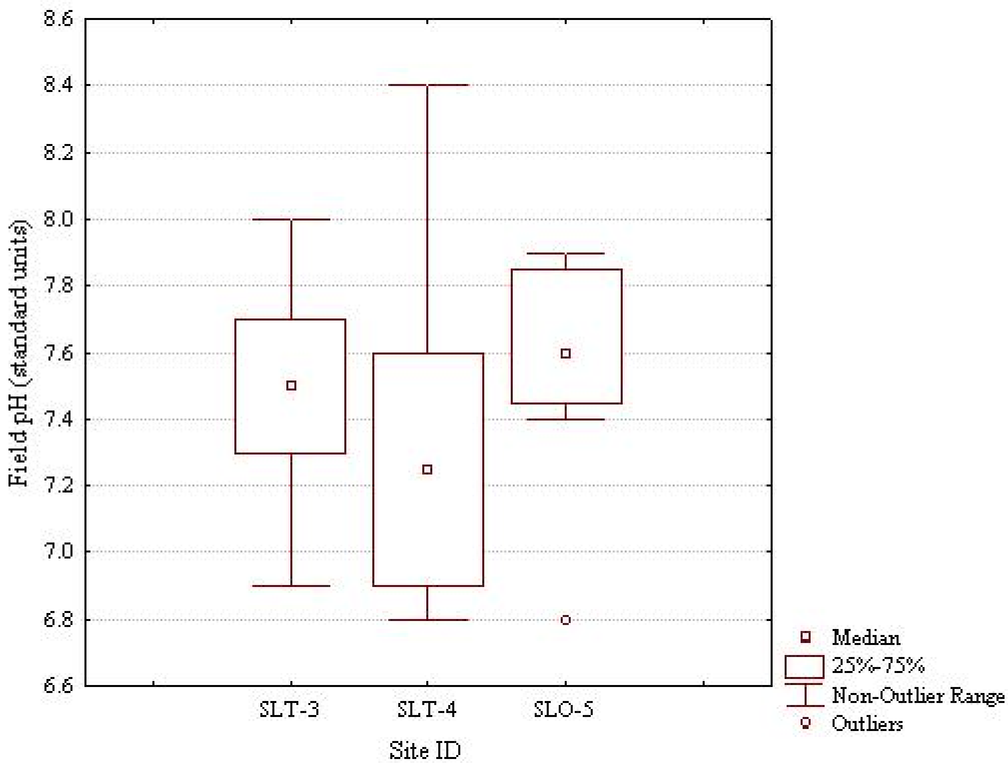

Figure 9. Box plot of field pH by site for Sylvan Lake stream sites.

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

Inlet and outlet samples were similar, although somewhat higher concentrations were observed at the outlet site (Table 11). Average alkalinity concentrations were 23.0 mg/L and 28.2 mg/L for sites SLT-3 and SLT-4, respectively. Average alkalinity concentration was 39.0 mg/L at the outlet site (Table 11 and Figure 10). Greatest variability in sample concentrations was observed at inlet stream sites, particularly at site SLT-4. The alkalinity standard of ≤ 1313 mg/L was not exceeded.

Table 11. Descriptive statistics of alkalinity (mg/L) for Sylvan Lake stream sites.

	Number of Measurements	Mean	Min	Max	Standard Deviation	Lower Quartile	Median	Upper Quartile
SLT-3	10	23.0	18.0	36.0	5.3	20.0	22.0	24.0
SLT-4	10	28.2	14.0	80.0	19.9	16.0	24.0	26.0
SLO-5	8	39.0	34.0	44.0	3.2	37.0	39.0	41.0

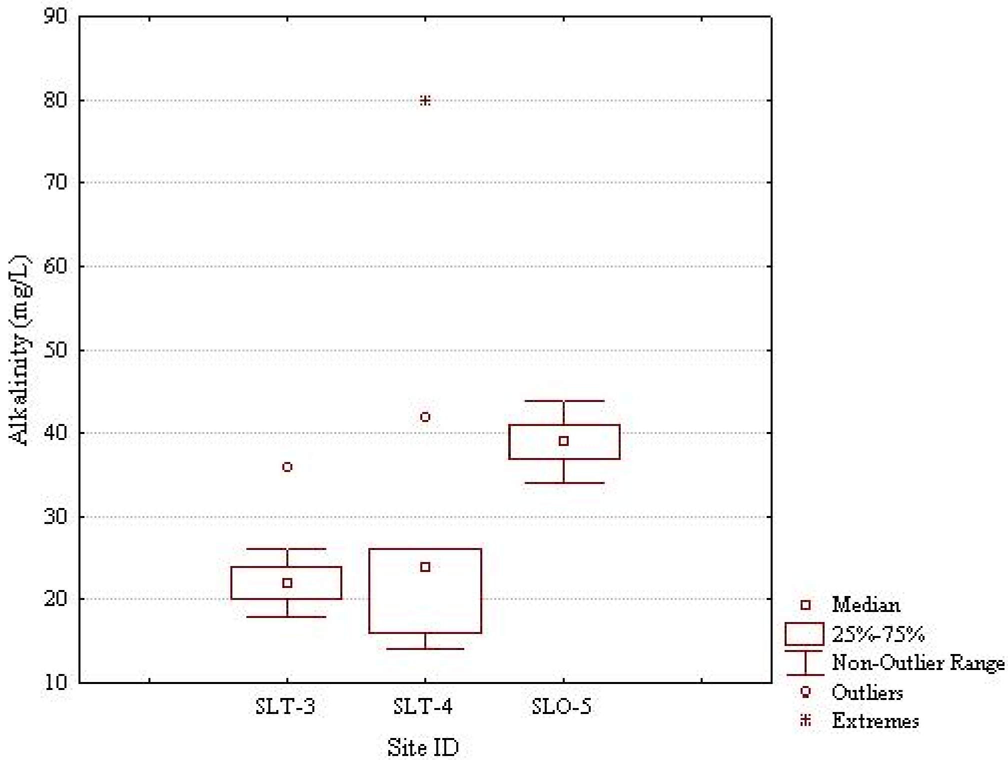

Figure 10. Box plot of alkalinity by site for Sylvan Lake stream sites.

Solids

"Solids" is a general term that refers to suspended or dissolved materials that are present in the waterway. Two solids parameters were examined in this assessment: total solids and total suspended solids. Total solids include the sum of dissolved and suspended solids. Suspended solids consist of larger materials that do not pass through the filter; this material is also referred to as the residue. These materials include both organic and inorganic forms.

Concentrations of total solids were comparable at the two inlet sites. Average total solids concentrations were 68.8 mg/L and 64.3 mg/L for sites SLT-3 and SLT-4, respectively. Average total solids concentration was 79.8 mg/L at the outlet site (Table 12 and Figure 11).

Annual total solids load from the Sylvan Lake watershed is approximately 5,994 kg/year. Total solids export coefficient for the watershed was 10.609 kg/acre/year. The export coefficient was slightly higher for SLT-3 subwatershed (12.715 kg/acre/year) than for SLT-4 subwatershed (10.008 kg/acre/year).

Table 12. Descriptive statistics of total solids (mg/L) for Sylvan Lake stream sites.

	Number of Measurements	Mean	Min	Max	Standard Deviation	Lower Quartile	Median	Upper Quartile
SLT-3	10	68.8	44.0	110.0	19.9	52.0	67.0	80.0
SLT-4	10	64.3	38.0	82.0	15.2	52.0	68.5	76.0
SLO-5	8	79.8	68.0	100.0	10.3	72.0	78.0	85.0

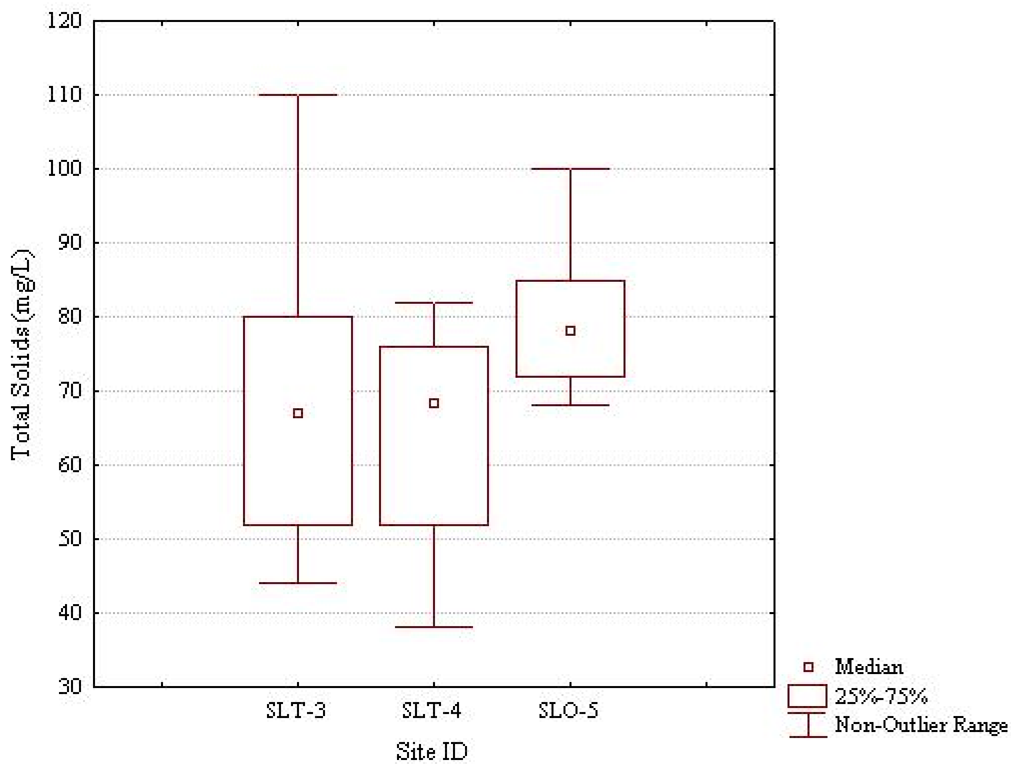

Figure 11. Box plot of total solids by site for Sylvan Lake stream sites.

Concentrations of total suspended solids (TSS) were slightly higher at SLT-4 than at SLT-3. At SLO-5, sample concentrations of TSS were always highest and displayed the greatest variability (Table 13 and Figure 12). Average TSS concentrations were 4.2 mg/L and 8.0 mg/L for sites SLT-3 and SLT-4, respectively. Average TSS concentration was 14.6 mg/L at the outlet site. Higher TSS concentrations at the outlet site are possibly due to contributions from algae die-off.

Annual TSS load from the Sylvan Lake watershed is approximately 544 kg/year. TSS export coefficient for the watershed was 0.963 kg/acre/year. Similar to total solids, the TSS export coefficient was slightly higher for SLT-3 subwatershed (1.300 kg/acre/year) than for SLT-4 subwatershed (0.814 kg/acre/year). Annual loads are greater from SLT-4, but this subwatershed is also larger. As a result, the export coefficient for SLT-4 subwatershed was less than SLT-3 subwatershed.

Table 13. Descriptive statistics of total suspended solids (mg/L) for Sylvan Lake stream sites.

	Number of Measurements	Mean	Min	Max	Standard Deviation	Lower Quartile	Median	Upper Quartile
SLT-3	10	4.2	2.5	7.0	1.8	2.5	3.8	6.0
SLT-4	10	8.0	2.5	18.0	5.8	2.5	7.0	11.0
SLO-5	8	14.6	6.0	26.0	7.9	8.0	12.5	22.0

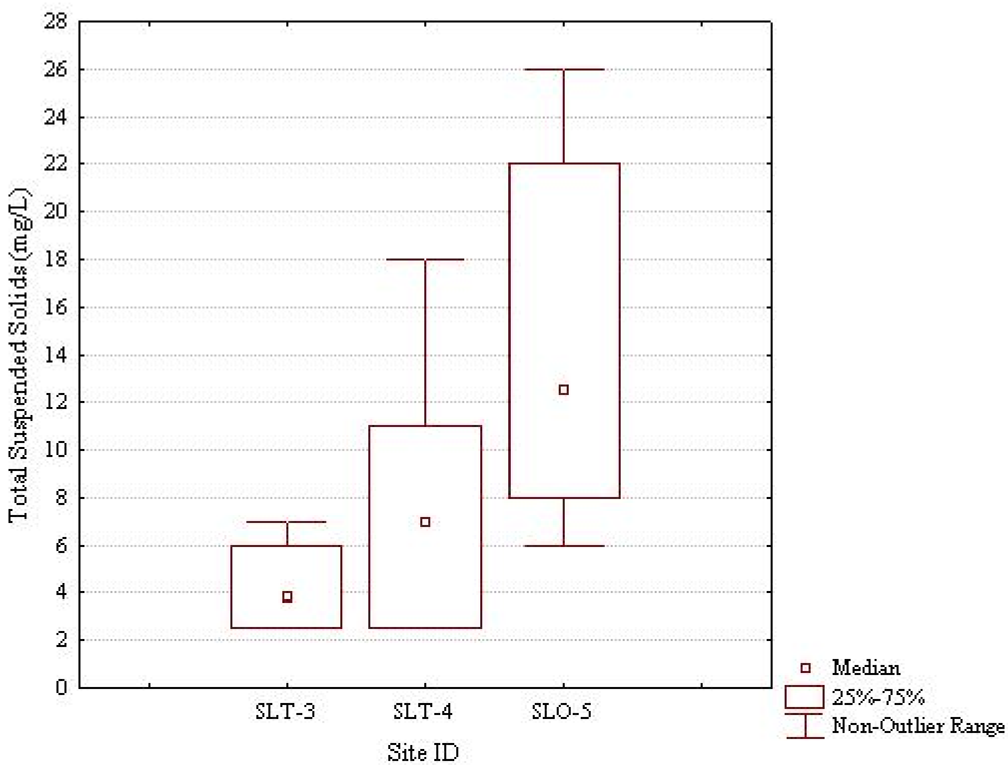

Figure 12. Box plot of total suspended solids (TSS) by site for Sylvan Lake stream sites.

Nitrogen

Three types of nitrogen were assessed in stream samples: (1) nitrate/nitrite, (2) ammonia, and (3) Total Kjeldahl Nitrogen (TKN). With these three parameters, relative concentrations of organic and inorganic nitrogen can be determined, as well as total nitrogen concentrations. Organic nitrogen was calculated as TKN minus ammonia. Inorganic nitrogen was calculated as the sum of ammonia and nitrate/nitrite. Total nitrogen was calculated by totaling inorganic and organic nitrogen.

Concentrations of all forms of nitrogen were highest at SLO-5. Average total nitrogen concentrations were 0.34 mg/L and 0.21 mg/L for sites SLT-3 and SLT-4, respectively, while average total nitrogen concentration was 1.18 mg/L at SLO-5 (Table 14 and Figure 13). The lake appears to be a significant source of the total nitrogen load. Total nitrogen annual load entering Sylvan Lake was approximately 32 kg, while the total nitrogen annual load leaving Sylvan Lake is approximately 108 kg. Annual loads for all assessed forms of nitrogen are listed in Table 6.

Table 14. Descriptive statistics of total nitrogen (mg/L) for Sylvan Lake stream sites.

	Number of Measurements	Mean	Min	Max	Standard Deviation	Lower Quartile	Median	Upper Quartile
SLT-3	10	0.34	0.28	0.69	0.12	0.28	0.31	0.32
SLT-4	10	0.21	0.05	0.75	0.26	0.05	0.12	0.16
SLO-5	8	1.18	0.73	2.13	0.48	0.83	1.09	1.40

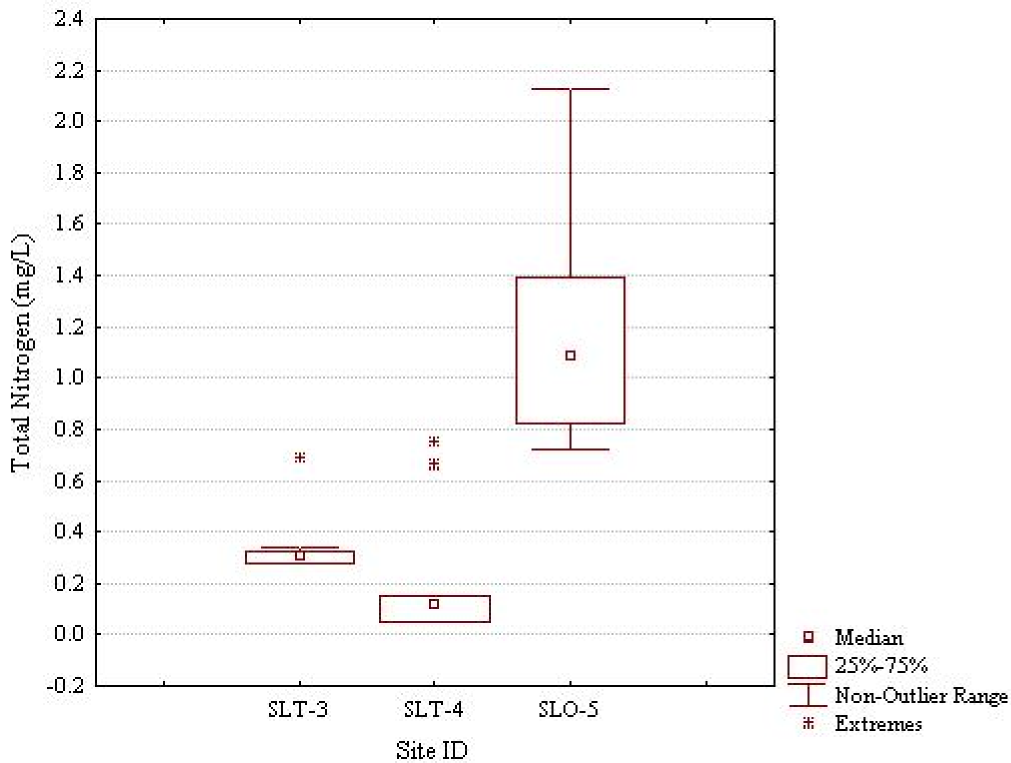

Figure 13. Box plot of total nitrogen by site for Sylvan Lake stream sites.

Quantities of inorganic (nitrate, nitrite, and ammonia) and organic nitrogen compounds in streams are highly diverse and variable due to the variety of inputs from natural and anthropogenic sources. Ammonia is usually the dominant constituent of inorganic nitrogen, and nitrate and nitrite concentrations are typically low in unpolluted waters. Organic nitrogen concentrations usually constitute a large portion of the total nitrogen in river systems (Wetzel 2001).

Average concentrations of organic nitrogen were 0.24, 0.27, and 0.99 mg/L at sites SLT-3, SLT-4, and SLO-5, respectively (Table 15). Average concentrations of inorganic nitrogen were 0.11, 0.12, and 0.20 mg/L at sites SLT-3, SLT-4, and SLO-5, respectively (Table 16). Concentrations of organic nitrogen were markedly higher than inorganic nitrogen at the outlet site (Figure 14).

Table 15. Descriptive statistics of organic nitrogen (mg/L) for Sylvan Lake stream sites.

	Number of Measurements	Mean	Min	Max	Standard Deviation	Lower Quartile	Median	Upper Quartile
SLT-3	10	0.24	0.20	0.55	0.11	0.25	0.25	0.25
SLT-4	10	0.27	0.20	0.55	0.24	0.03	0.03	0.03
SLO-5	8	0.99	0.60	2.05	0.50	0.80	1.00	1.30

Table 16. Descriptive statistics of inorganic nitrogen (mg/L) for Sylvan Lake stream sites.

	Number of Measurements	Mean	Min	Max	Standard Deviation	Lower Quartile	Median	Upper Quartile
SLT-3	10	0.11	0.08	0.14	0.02	0.08	0.11	0.12
SLT-4	10	0.12	0.08	0.20	0.05	0.08	0.12	0.16
SLO-5	8	0.20	0.08	0.45	0.14	0.10	0.13	0.30

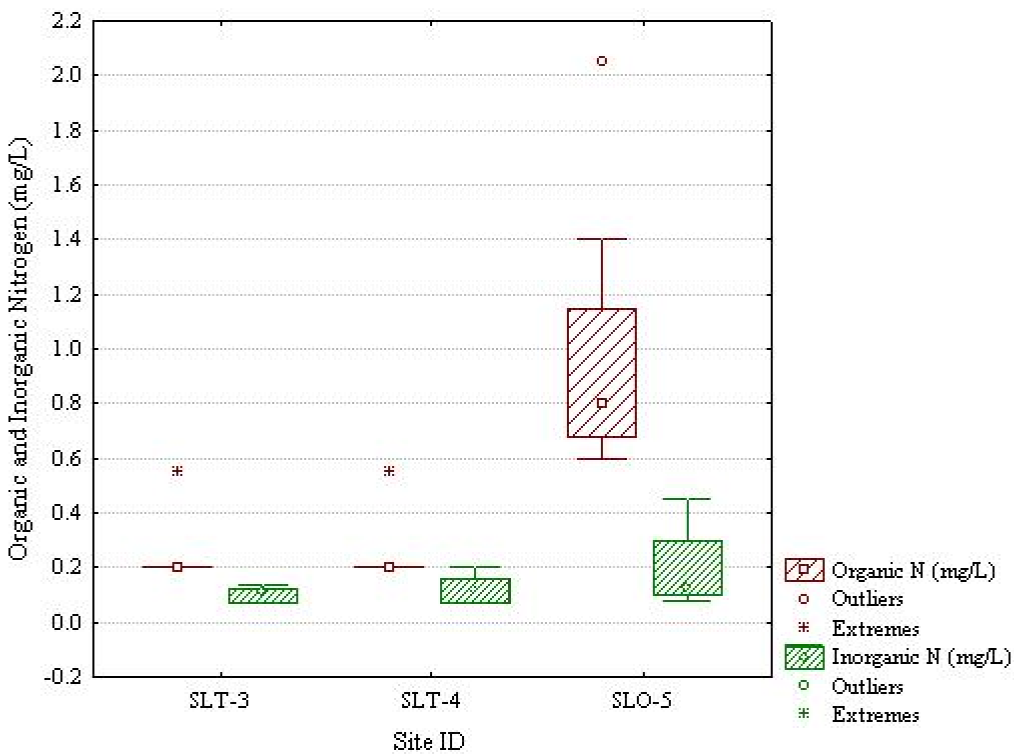

Figure 14. Box plot of organic and inorganic nitrogen by site for Sylvan Lake stream sites.

Ammonia is the nitrogen end-product of bacterial decomposition of organic matter. This form of nitrogen is most readily available to algae and aquatic plants for uptake and growth. Concentrations of ammonia in fresh water are highly variable geographically, temporally, and spatially. Ammonia concentrations can range from 0-5 mg/L in unpolluted surface waters. Ammonia levels in streams and lakes are primarily influenced by the amount of primary productivity and the extent of pollution from organic matter. In general, concentrations of ammonia in well-oxygenated waters are low due to rapid utilization by the algae community (Wetzel 2001).

Average ammonia levels at the inlet stream sites were less than reporting limits (< 0.1 mg/L), however, detectable levels were observed at the outlet site (Table 17).

Table 17. Descriptive statistics of ammonia (mg/L) for Sylvan Lake stream sites.

	Number of Measurements	Mean	Min	Max	Standard Deviation	Lower Quartile	Median	Upper Quartile
SLT-3	10	0.05*	0.05*	0.05*	0.00	0.05*	0.05*	0.05*
SLT-4	10	0.05*	0.05*	0.05*	0.00	0.05*	0.05*	0.05*
SLO-5	8	0.14	0.05*	0.30	0.10	0.08	0.10	0.20

*Note: For statistical purposes, half of the reporting limit was used for sample results less than the reporting limit (e.g. ammonia concentrations < 0.1 mg/L were assigned a value of 0.05 mg/L).

Ammonia is present in water primarily in two forms: NH_4^+ (ionized form) and NH_4OH (un-ionized form). The un-ionized or "undissociated" form is highly toxic to many organisms, especially fish (Wetzel 2001). For this reason, the state water quality standard for ammonia is limited specifically to un-ionized ammonia. Un-ionized ammonia concentrations for all stream sites were below the water quality criterion.

Nitrate/nitrite concentrations were similar among all stream sites and ranged from less than detection to 0.15 mg/L. Slightly higher concentrations were observed at SLT-4 (Table 18). To protect the beneficial use of fish and wildlife propagation and stock watering, the state water quality standard for nitrates is ≤ 88 mg/L. All samples were well below this limit.

Table 18. Descriptive statistics of nitrate/nitrite (mg/L) for Sylvan Lake stream sites.

	Number of Measurements	Mean	Min	Max	Standard Deviation	Lower Quartile	Median	Upper Quartile
SLT-3	10	0.06	0.03*	0.09	0.02	0.03*	0.06	0.07
SLT-4	10	0.07	0.03*	0.15	0.05	0.03*	0.07	0.11
SLO-5	8	0.06	0.03*	0.15	0.05	0.03*	0.03*	0.10

*Note: For statistical purposes, half of the reporting limit was used for sample results less than the reporting limit (e.g. nitrate/nitrite concentrations < 0.05 mg/L were assigned a value of 0.025 mg/L).

Phosphorous

Phosphorus is present in all aquatic systems. Natural sources include the leaching of phosphate-bearing rocks and organic matter decomposition. Potential anthropogenic sources of phosphorus include fertilizers and sewage.

Effects of the reservoir are apparent when comparing inlet and outlet phosphorus concentrations. Average total phosphorus concentrations were 0.11, 0.12, and 0.08 mg/L at sites SLT-3, SLT-4, and SLO-5, respectively (Table 19 and Figure 15). Total phosphorus annual load from the watershed was 12.4 kg, which is equivalent to 0.022 kg per watershed acre. Total phosphorus annual load measured at the outlet site was 7.4 kg. Based on these loading estimates, roughly 5 kg of phosphorus is stored in Sylvan Lake each year. It is expected that much of the external phosphorus load is either incorporated into aquatic plant and algal biomass or attached to suspended solids that eventually settles to the bottom of the lake.

Table 19. Descriptive statistics of total phosphorus (mg/L) for Sylvan Lake stream sites.

	Number of Measurements	Mean	Min	Max	Standard Deviation	Lower Quartile	Median	Upper Quartile
SLT-3	10	0.11	0.03	0.19	0.06	0.06	0.11	0.18
SLT-4	10	0.12	0.05	0.18	0.05	0.08	0.13	0.16
SLO-5	8	0.08	0.04	0.13	0.03	0.06	0.08	0.09

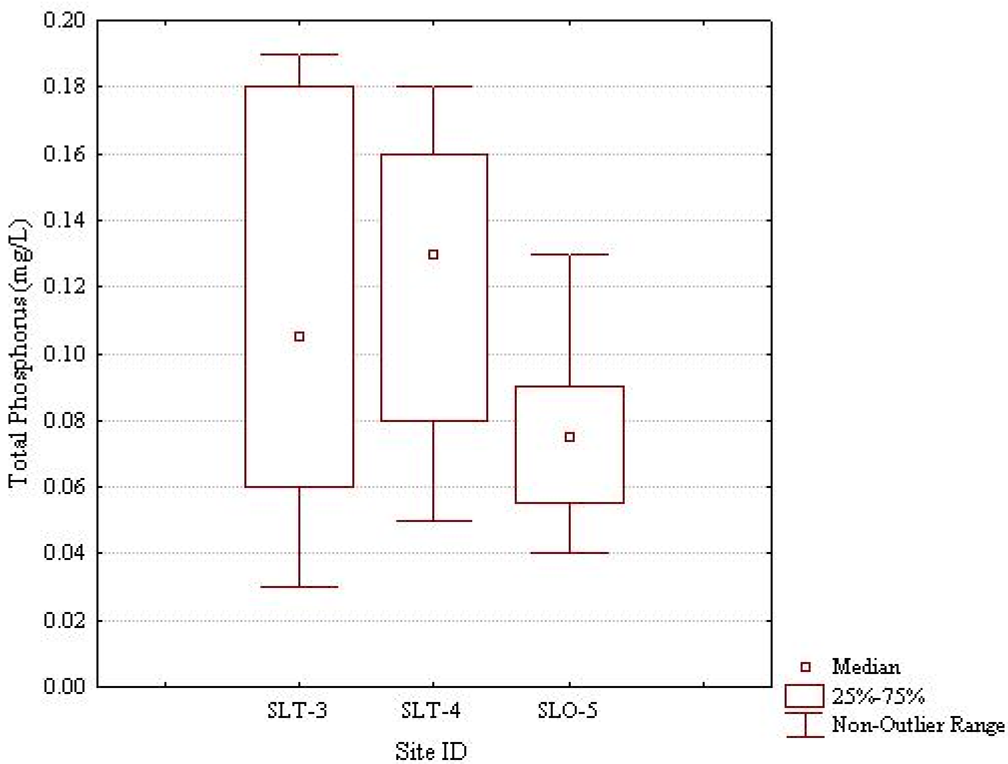

Figure 15. Box plot of total phosphorus by site for Sylvan Lake stream sites.

It appears that similar phosphorus loads are delivered from both gaged subwatersheds. Approximately 0.024 kg/acre/year of total phosphorus is delivered from SLT-3 subwatershed, and 0.026 kg/acre/year is delivered from SLT-4 subwatershed.

Similar to total phosphorus concentrations, Total dissolved phosphorus (TDP) concentrations at the inlet were higher and more variable than the outlet. TDP concentrations were 0.07, 0.08, and 0.01 mg/L at sites SLT-3, SLT-4, and SLO-5, respectively (Table 20 and Figure 16). Estimated TDP annual load was 8.3 kg, which is equivalent to 0.015 kg per watershed acre.

Table 20. Descriptive statistics of total dissolved phosphorus (mg/L) for Sylvan Lake stream sites.

	Number of Measurements	Mean	Min	Max	Standard Deviation	Lower Quartile	Median	Upper Quartile
SLT-3	10	0.07	0.01	0.15	0.06	0.03	0.06	0.13
SLT-4	10	0.08	0.02	0.15	0.04	0.03	0.09	0.11
SLO-5	8	0.01	0.01	0.02	0.01	0.01	0.01	0.02

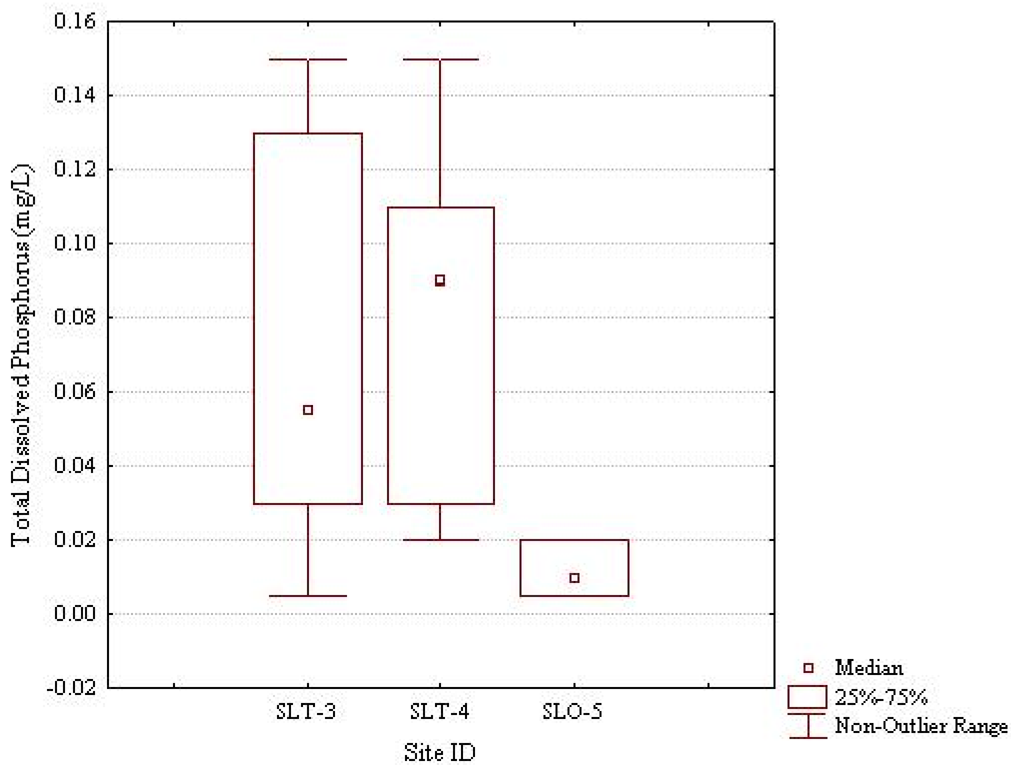

Figure 16. Box plot of total dissolved phosphorus by site for Sylvan Lake stream sites.

Stream Biological Parameters

Benthic Macroinvertebrate Survey

Three benthic macroinvertebrate samples were collected at each monitored inlet stream (sites SLT-3 and SLT-4). A D-framed net (500 µm mesh size) was used to collect composite samples at three locations in a 100 m reach immediately upstream of the water quality sampling site.

Polypedilum sp. was the dominant taxon among all samples and belongs to the order Diptera (true flies) and the family Chironomidae. Chironomidae is an ecologically important group of aquatic insects and often occur in high densities and diversity. Chironomidae was the most abundant family in all stream samples. Approximately 45% of all individuals were chironomids.

Ceratopogonidae, which also belongs to the order Diptera, was the second most abundant family among all samples (approximately 9% of all individuals). Ceratopogonidae are known as "biting midges," as the adults of a few aquatic species are known to bite people and become annoying pests in some areas.

In general, Diptera taxa are considered moderately tolerant of pollution in comparison to other aquatic insect groups. The orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) are considered to be more sensitive or intolerant to pollution. These more sensitive orders are often combined and measured as total "EPT" taxa. Higher numbers of EPT taxa indicate good water quality, while higher numbers of Diptera can indicate poorer water quality. A common measure or metric used to examine the relative abundances of these indicator groups is the ratio of EPT:Chironomidae. Good biological health is reflected in communities with an even distribution among all four major groups and with substantial representation in the sensitive groups (i.e. Ephemeroptera, Plecoptera, and Trichoptera).

The EPT:Chironomidae metric was one of many used to compare sites SLT-3 and SLT-4. Higher values for this metric were observed at site SLT-3, indicating larger numbers of more sensitive groups and potentially better water quality than site SLT-4 (Figure 17). However, the difference between the two sites was not statistically significant (Kruskal-Wallis test, $p > 0.05$).

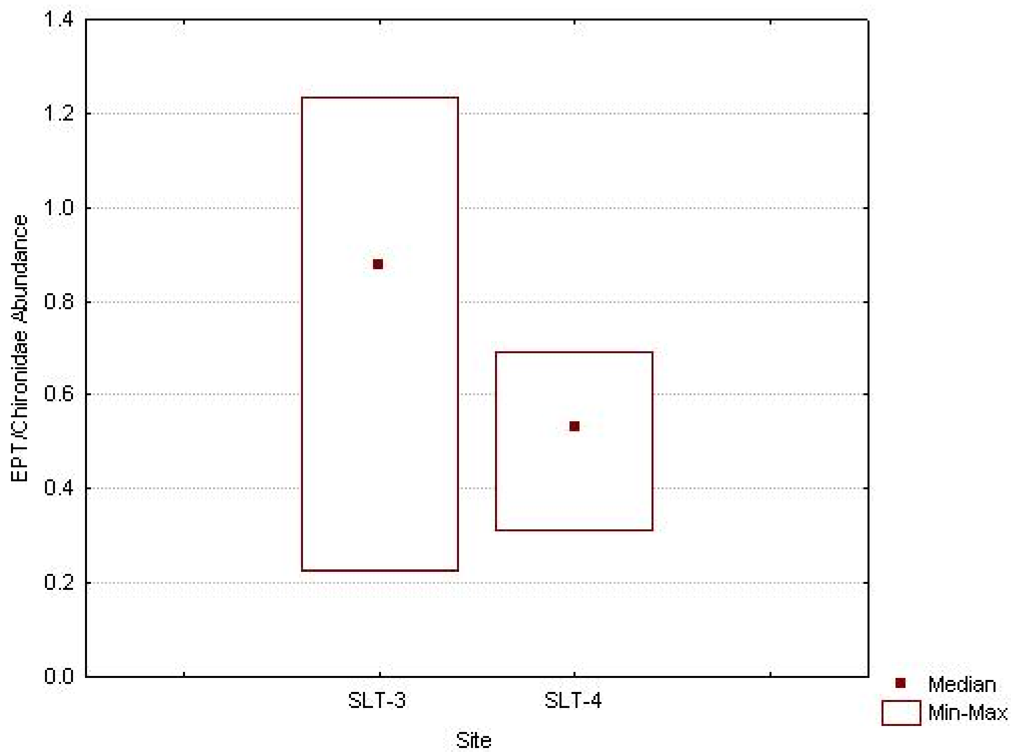

Figure 17. Ratio of Ephemeroptera, Plecoptera, and Trichoptera (EPT) to Chironomidae abundances for stream sites SLT-3 and SLT-4. Box represents minimum and maximum values, and point represents median value (three samples per site).

The relative abundance of Plecoptera, one of the most sensitive groups, was also calculated. A larger number of Plecoptera were collected at site SLT-3 than at SLT-4 (Figure 18). For this metric, the difference between the two sites was statistically significant (Kruskal-Wallis test, $p < 0.05$).

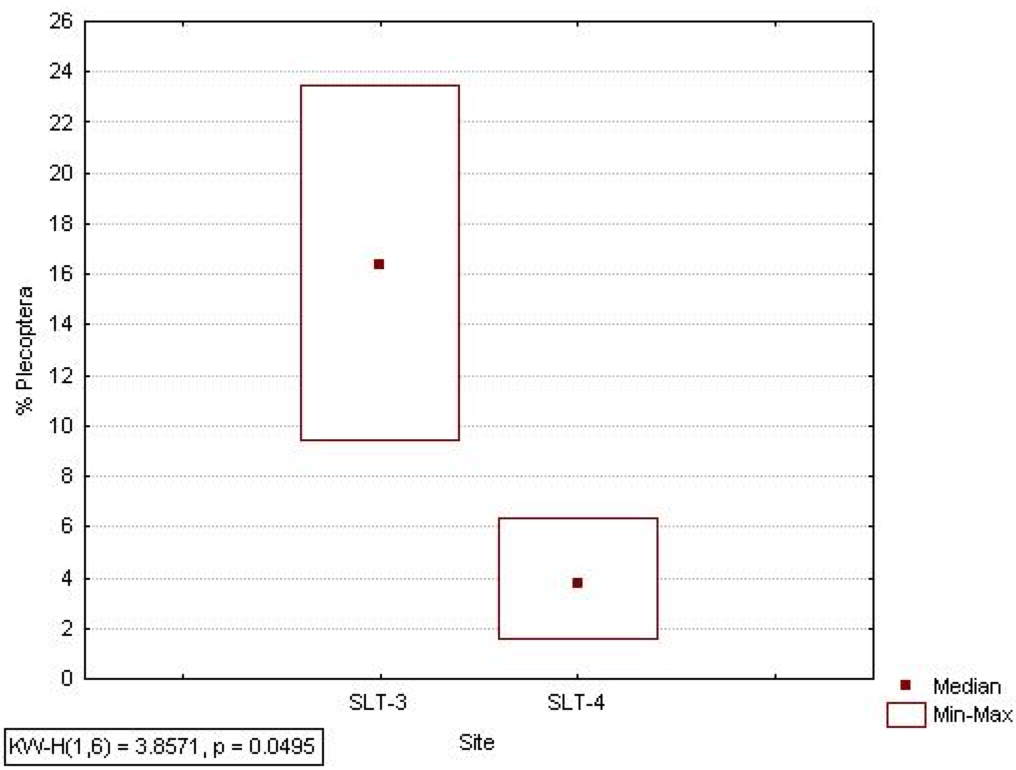

Figure 18. Plecoptera abundances for stream sites SLT-3 and SLT-4. This metric displayed a statistically significant difference between the two sites (Kruskal-Wallis, $p < 0.05$).

The relative percent of sediment tolerant taxa was calculated for each site. Sediment tolerant taxa metric was calculated by summing the relative percent abundance of taxa belonging to the following groups: oligochaetes, burrowers, gastropods, non-insects, and one tribe of chironomids (Orthocladinae). Higher numbers of sediment tolerant individuals were observed at SLT-4 (Figure 19). However, the difference between the two sites was not statistically significant (Kruskal-Wallis test, $p > 0.05$).

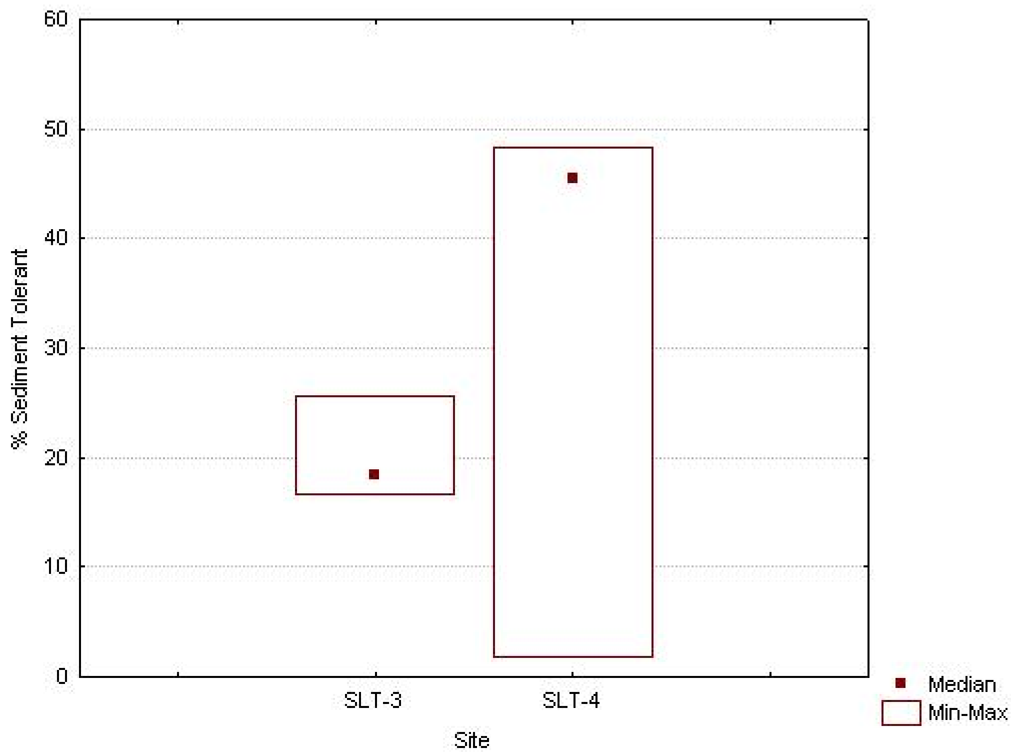

Figure 19. Percent sediment tolerant organisms for stream sites SLT-3 and SLT-4.

The Hilsenhoff Biotic Index (HBI) metric was used to examine the average tolerance to pollution of macroinvertebrates sampled at each site. The scale of tolerance values range from 0 to 10 and increase as water quality decreases (i.e. higher values indicate more tolerant biological communities). Slightly higher HBI values were observed at site SLT-4 (Figure 20). Again, the difference between the two sites was not statistically significant (Kruskal-Wallis test, $p > 0.05$).

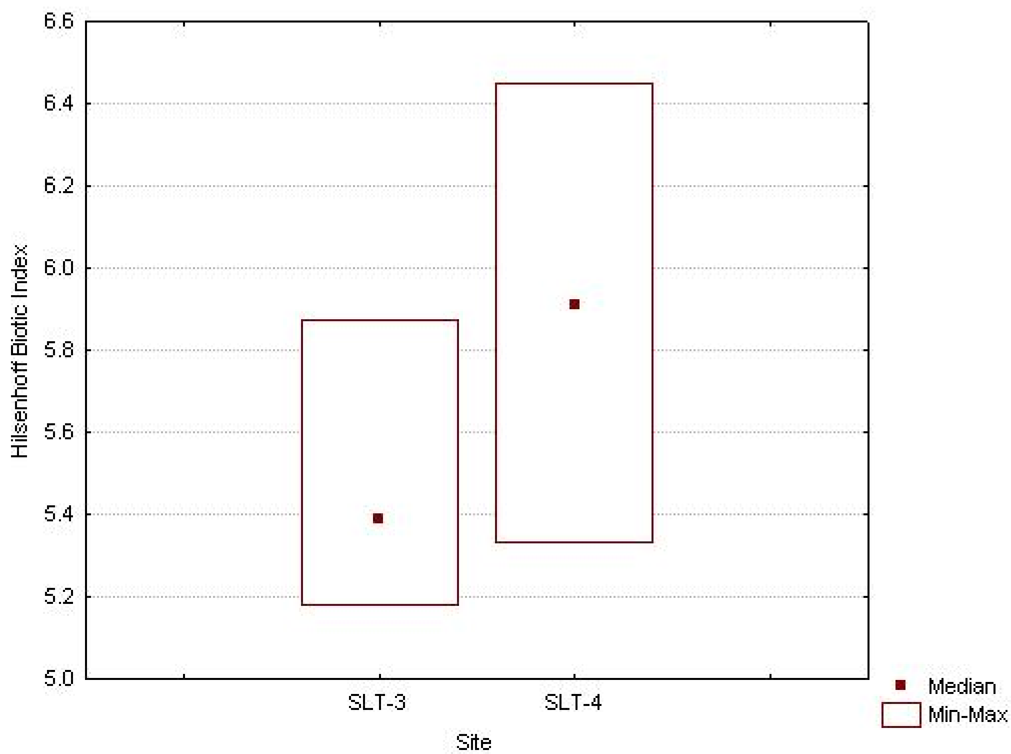

Figure 20. Hilsenhoff Biotic Index (HBI) abundances for stream sites SLT-3 and SLT-4.

Overall, macroinvertebrate data indicates average water quality at both stream sites based on the number and tolerance to pollution of organisms found in samples. Because the differences in metric values between the two sites were rarely statistically significant, only generalizations can be made concerning which of the two sites is more biologically impaired. Biological condition was slightly better at site SLT-3 than SLT-4. Results indicate potential sediment impairment at site SLT-4, possibly due to runoff from nearby paved areas. This correlates to the higher total suspended solids concentrations and load measured at SLT-4. All results, including metrics and taxa list, are presented in Appendix E.

Fecal Coliform Bacteria

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

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

Average fecal coliform bacteria concentrations were 82, 90, and 41 colony forming units CFU/100 ml at sites SLT-3, SLT-4, and SLO-5, respectively (Table 21). Highest bacteria concentrations were sampled at all stream sites in July 2002. The streams in the study watershed do not have a water quality standard for fecal coliform bacteria. However, Sylvan Lake waterbody does have a water quality standard of ≤ 400 CFU/100 ml.

Concentrations of *E. coli* were also analyzed. Excluding three samples collected in June 2002, *E. coli* was not detected. Detectable concentrations were very small (6, 12, and 10 CFU/100ml at sites SLT-3, SLT-4, and SLO-5, respectively). Detectable concentrations of *E. coli* and higher concentration of fecal coliform bacteria during the summer months may be an indicator of the seasonal human activity in the watershed.

Table 21. Descriptive statistics of fecal coliform bacteria (CFU/100 ml) for Sylvan Lake stream sites.

	Number of Measurements	Mean	Min	Max	Standard Deviation	Lower Quartile	Median	Upper Quartile
SLT-3	10	82	1	690	214	2	5	35
SLT-4	10	90	1	780	243	1	4	30
SLO-5	8	41	1	250	86	1	2	34

Lake Physical and Chemical Parameters

Water Temperature

Water temperature in Sylvan Lake ranged from 1.4 to 22.5 (mean = 12.3) degrees Celsius (Figure 21). Maximum temperature was reached in July. State standards require water temperatures to be maintained below 18.3 degrees Celsius to support the beneficial use of coldwater permanent fish life propagation. In July and August, the temperature limit was exceeded at surface sample depths. At depths greater than 2 meters, the temperature limit was not exceeded.

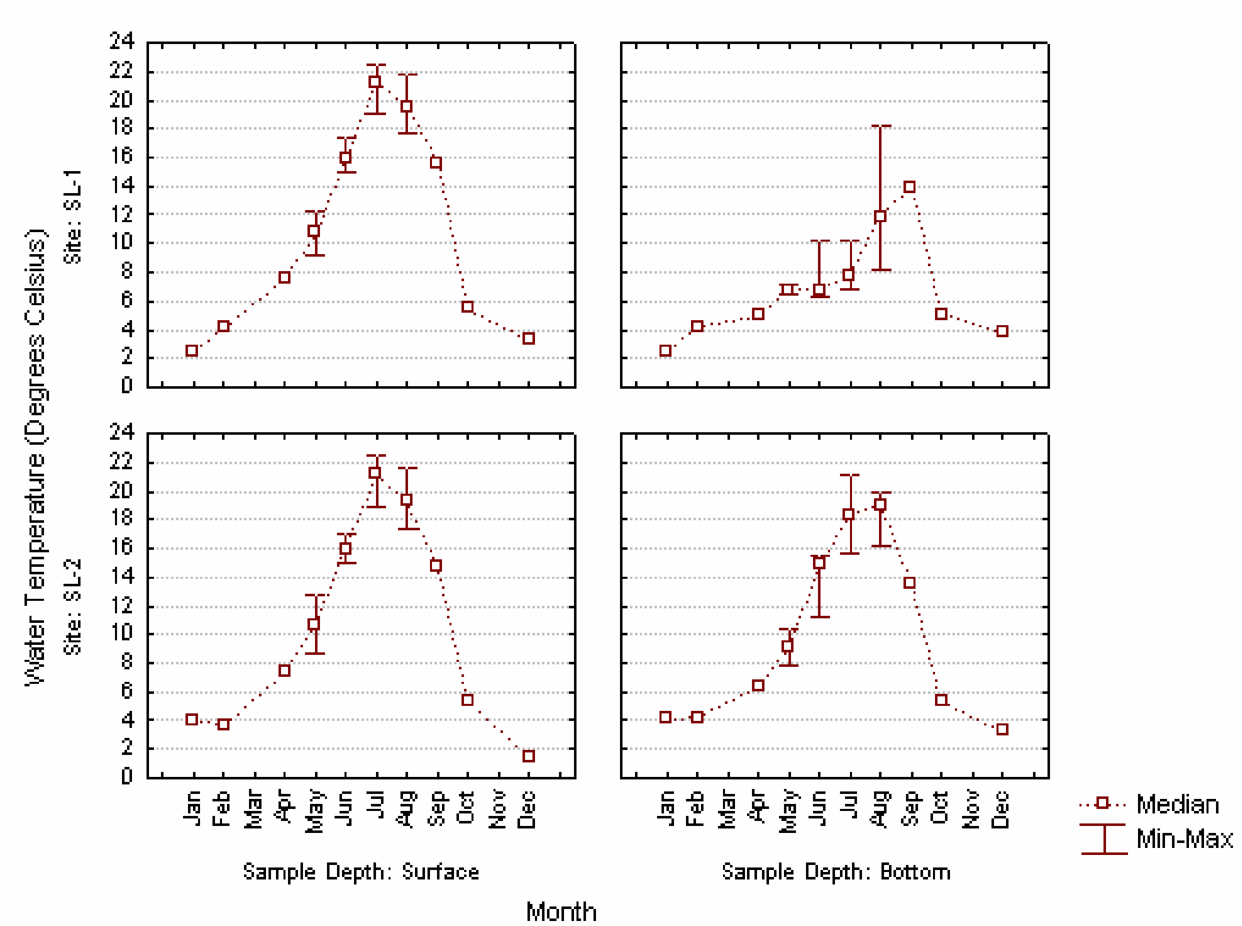

Figure 21. Water temperature by month for Sylvan Lake categorized by site and sample depth. Temperature measurements were collected from August 2001-August 2003 (no samples collected during March or November).

Dissolved Oxygen

Dissolved oxygen (DO) is made available, in part, by photosynthetic inputs from algae and aquatic plants. Conversely, microbial degradation of dead algae and aquatic plants consumes oxygen. In eutrophic lakes (i.e. high in nutrient loading with high organic production), an elevated rate of production and subsequent decomposition of organic matter can result in low or no oxygen in the lower depths of the lake (i.e. hypolimnion) (Monson 2000). The hypolimion can become anoxic as quickly as a few weeks after the onset of summer stratification and can remain anaerobic throughout this stratification period (Wetzel 2001).

This trend was observed in Sylvan Lake during the spring and summer months. Sylvan Lake experiences stratification as early as April and typically remains stratified until the end of September. During the summer months, DO deficient and anoxic conditions occur at bottom depths. DO levels at near-surface depths were sufficient to support coldwater fish populations throughout most of the sampling season. However, levels significantly decreased during the summer months when sunlight penetration was impeded by algae growth (Figure 22).

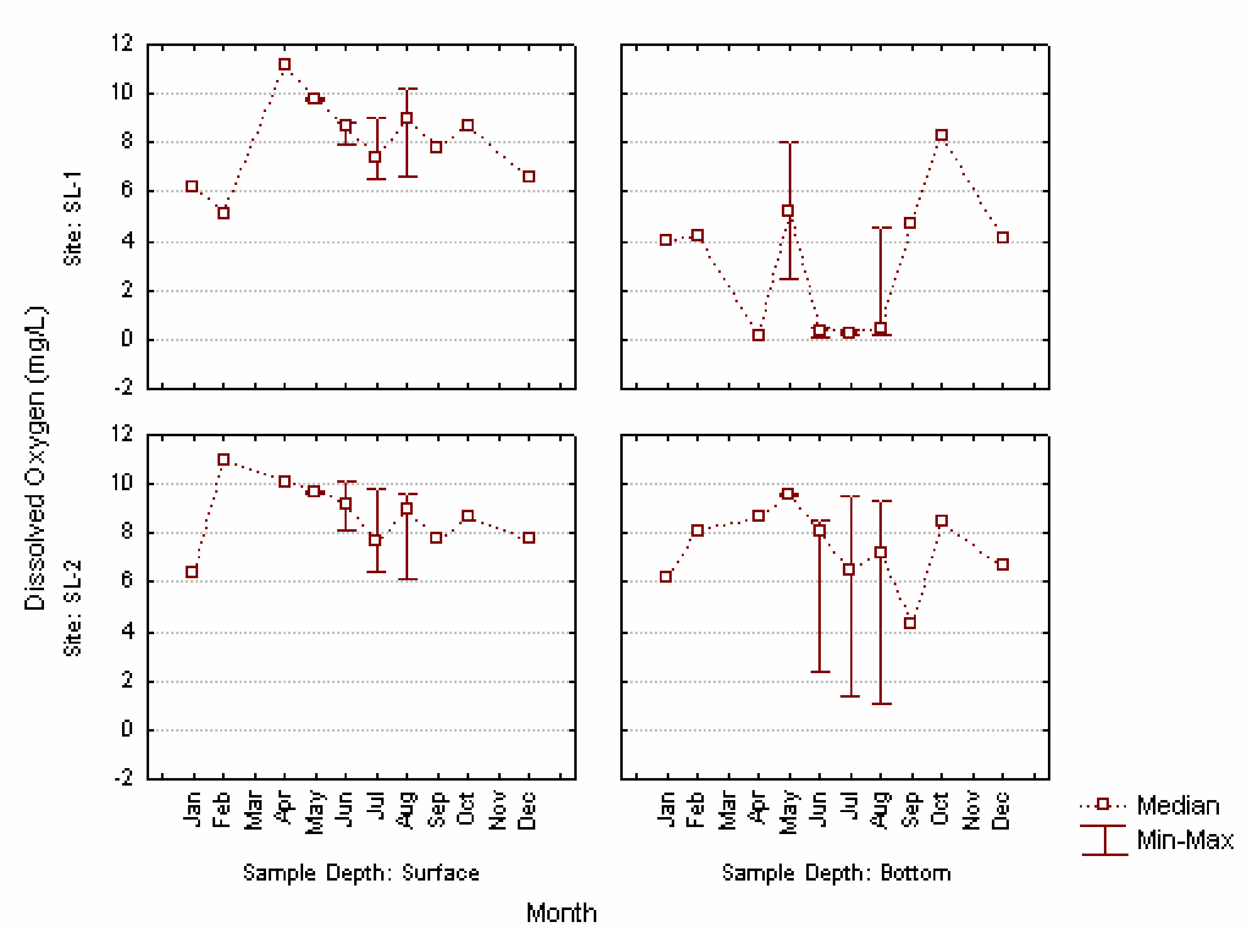

Figure 22. Dissolved oxygen by month for Sylvan Lake categorized by site and sample depth. No samples collected during March or November.

State water quality standards require DO concentrations to be maintained at or above 6.0 mg/L to support the coldwater permanent fish propagation use. Surface DO values ranged from 5.1 to 11.4 mg/L (mean = 8.4). All surface DO measurements, except one measurement in February 2002, were above this criterion. Bottom DO measurements ranged from 0.1 to 9.7 mg/L (mean = 4.55). Approximately 60% of the bottom DO measurements were below this criterion.

Temperature and DO profiles were measured to determine oxygen availability and temperature conditions throughout the water column and to detect stratification. Summer stratification occurs annually in Sylvan Lake. Figure 23 is a temperature and DO profile at site SL-1 collected in August 2004. This graph demonstrates typical summer stratification observed in the deeper bay of Sylvan Lake. DO concentrations were less than 0.3 mg/L (i.e. anoxic) at or below a depth of 6 meters. Site SL-2 displayed no stratification due to its shallow depth.

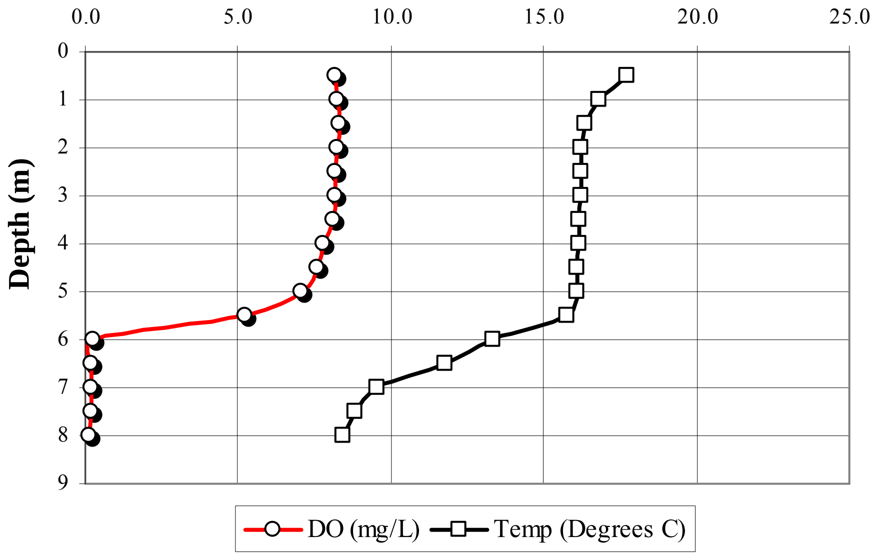

Figure 23. Temperature and dissolved oxygen profile for Sylvan Lake at site SL-1 on August 30, 2004.

Excessive nutrient loading to Sylvan Lake has contributed to a higher oxygen demand and thus lower hypolimnetic DO levels. The proposed management practices to reduce phosphorus concentrations are expected to also improve the DO levels in Sylvan Lake.

Acidification and Alkalinity

As previously stated, the primary measurements of acidification are alkalinity and pH. In Sylvan Lake, pH values ranged from 6.63 to 9.90 (mean = 7.94). The pH water quality standard for Sylvan Lake is a range of 6.6 to 8.6. The upper limit of this standard was exceeded during the months of June, July, August, and September (Figure 24). This increase in pH values can be attributed to the photosynthetic utilization of CO_2 by algae and aquatic plants. Approximately 8% of all pH measurements exceeded the upper limit of the pH standard. The pH standard was never exceeded at the deepest sampling location (SL-1, bottom).

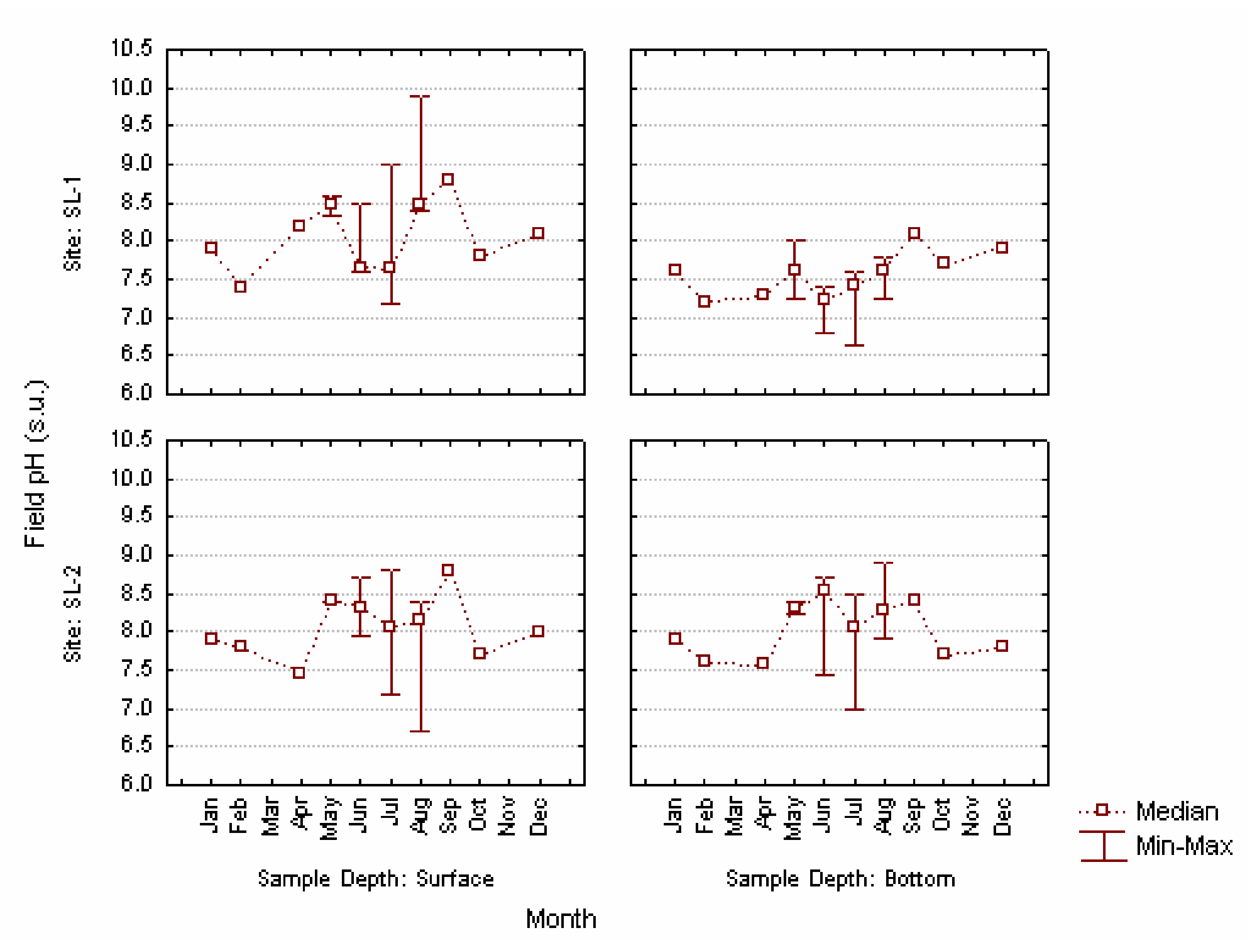

Figure 24. pH by month for Sylvan Lake categorized by site and sample depth.

Alkalinity concentrations ranged from 30 to 62 mg/L (mean = 39). The alkalinity concentrations in Sylvan Lake are well below the water quality standard, which is ≤1,313 mg/L. Concentrations were low throughout the sampling period with minimum concentrations occurring in February at each sampling location (Figure 25).

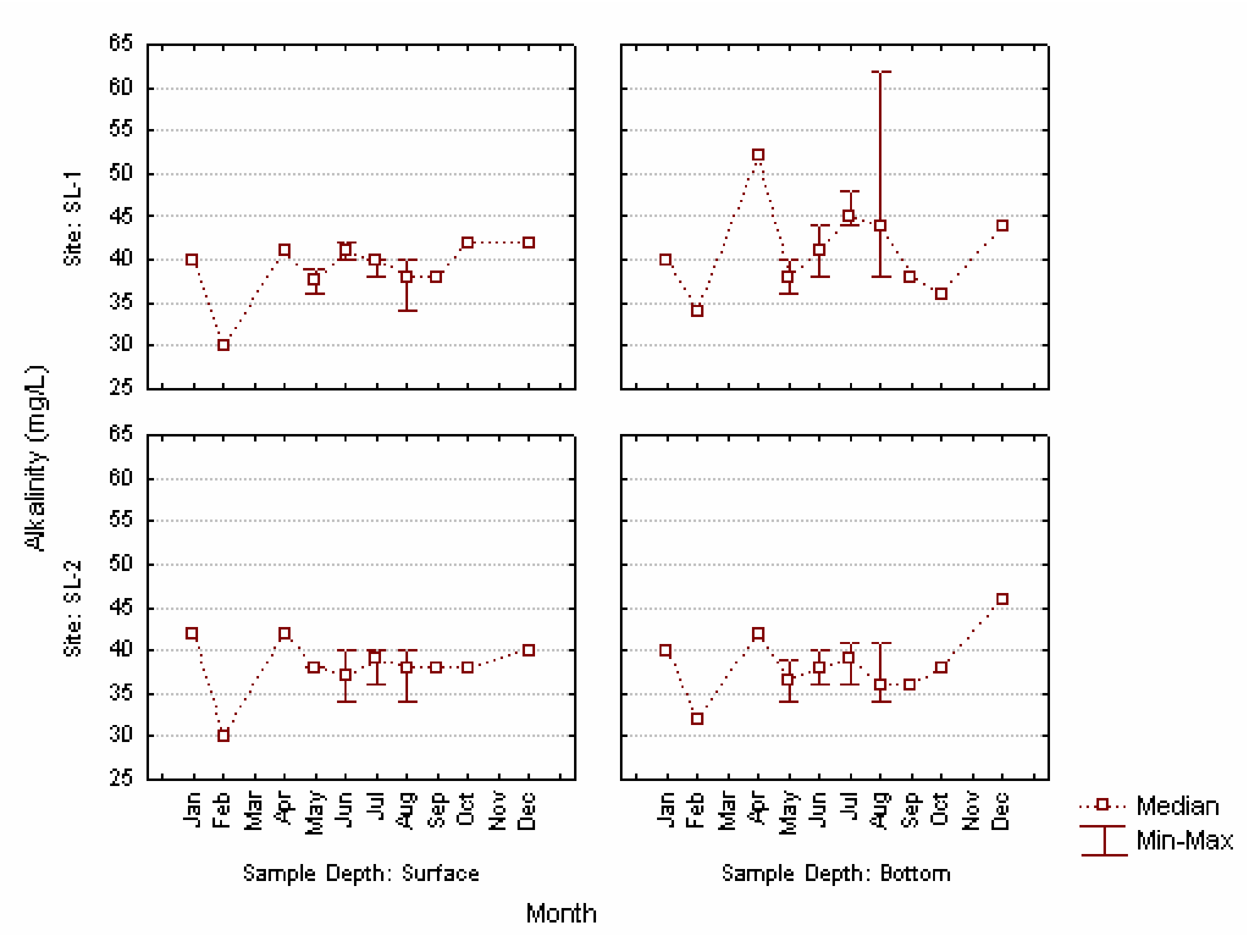

Figure 25. Alkalinity concentrations by month for Sylvan Lake categorized by site and sample depth.

Solids

Total solids concentrations in Sylvan Lake ranged from 50 to 105 mg/L (mean = 71). In general, variation throughout the sampling period was not significant, with the exception of the month of August. Ice contamination is suspected to be the cause of the elevated surface sample concentrations in January (Figure 26).

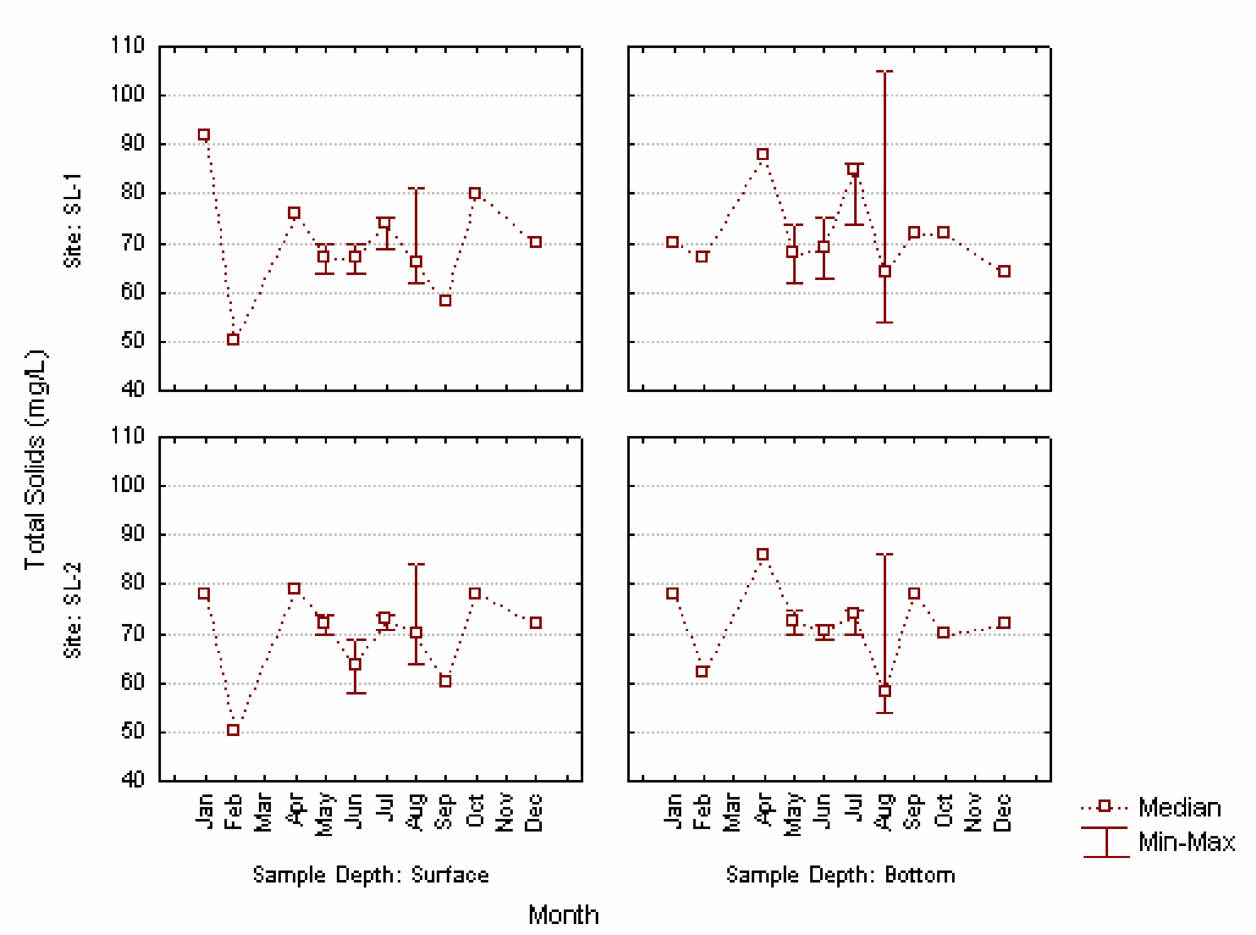

Figure 26. Total solids concentrations by month for Sylvan Lake categorized by site and sample depth.

Typical of most waterways, total solids were mostly comprised of dissolved solids. Concentrations of dissolved solids ranged from 8 to 99 mg/L (mean = 63). Minimum concentrations of dissolved solids were observed in May at all lake sampling locations (Figure 27).

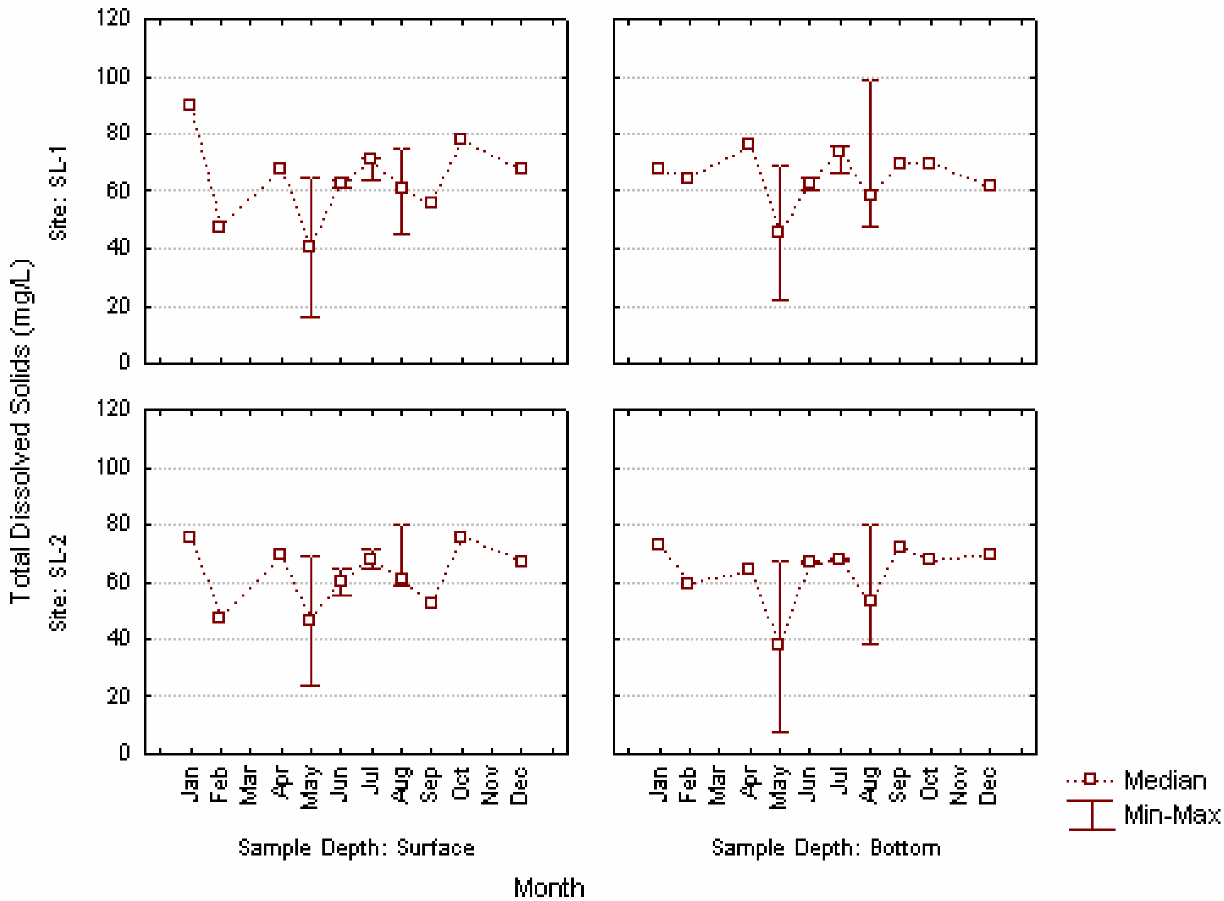

Figure 27. Total dissolved solids concentrations by month for Sylvan Lake categorized by site and sample depth.

Total suspended solids (TSS) concentrations ranged from non-detectable levels to 62 mg/L (mean = 3). TSS concentrations displayed marked seasonality at all sampling locations. Concentrations increased in the spring due to precipitation and snow-melt runoff, with the maxima occurring in May (Figure 28).

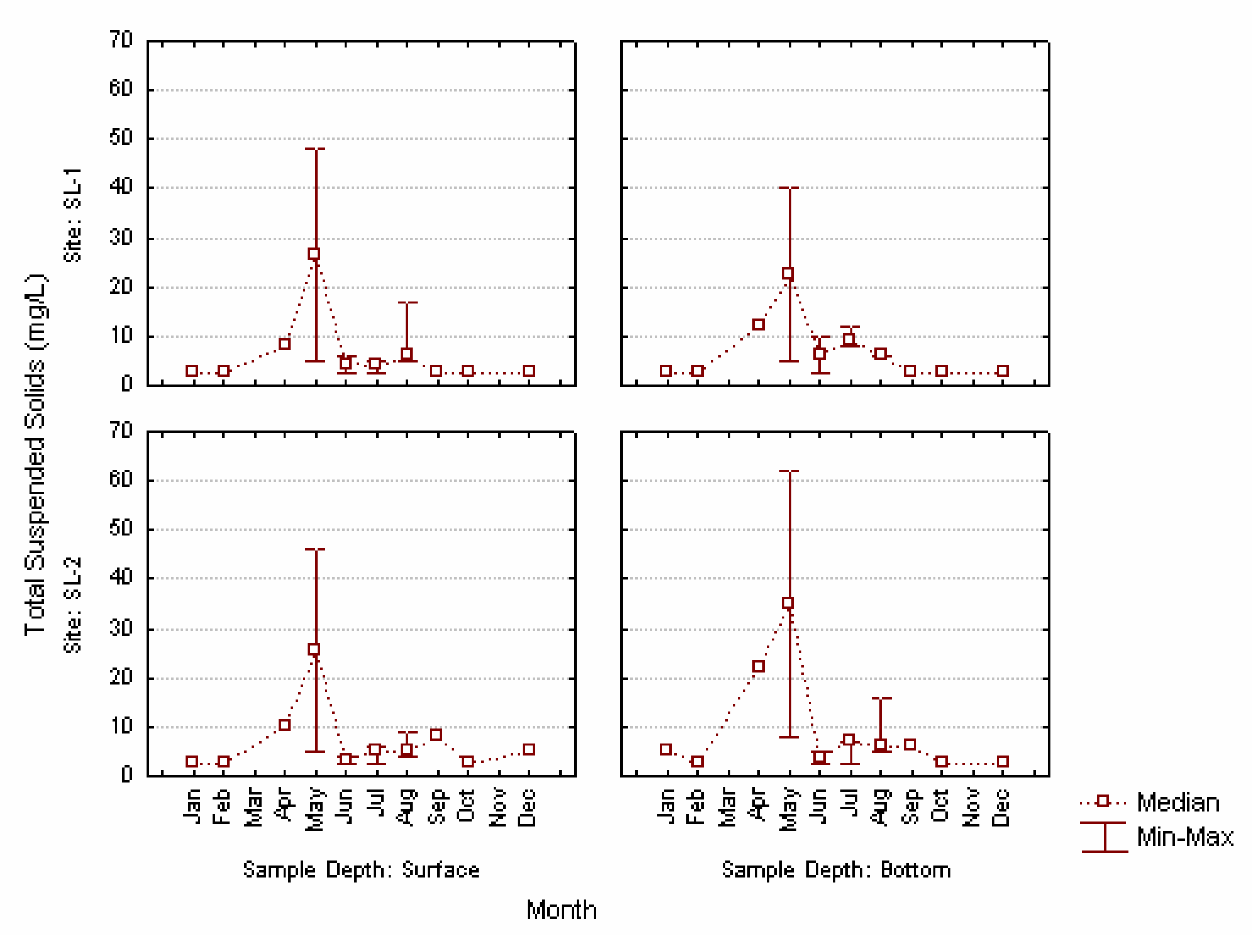

Figure 28. Total suspended solids concentrations by month for Sylvan Lake categorized by site and sample depth.

Nitrogen

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

Ammonia levels were below the detection limit (0.02 mg/L) in nearly one-third of the samples collected in Sylvan Lake. All values below detection limits were assigned half of the limit to allow calculation of statistics. Ammonia concentrations ranged from below detection limits to 1.04 mg/L (mean = 0.14). Ammonia appears to accumulate under ice cover and during summer stratification in Sylvan Lake (Figure 29). Elevated ammonia concentrations in the winter months are most likely due to the lack of plant and algae utilization of this nutrient. Elevated ammonia concentrations at bottom sampling depths during the summer months is caused by anoxic conditions in the hypolimnion, which inhibits bacterial nitrification of ammonia.

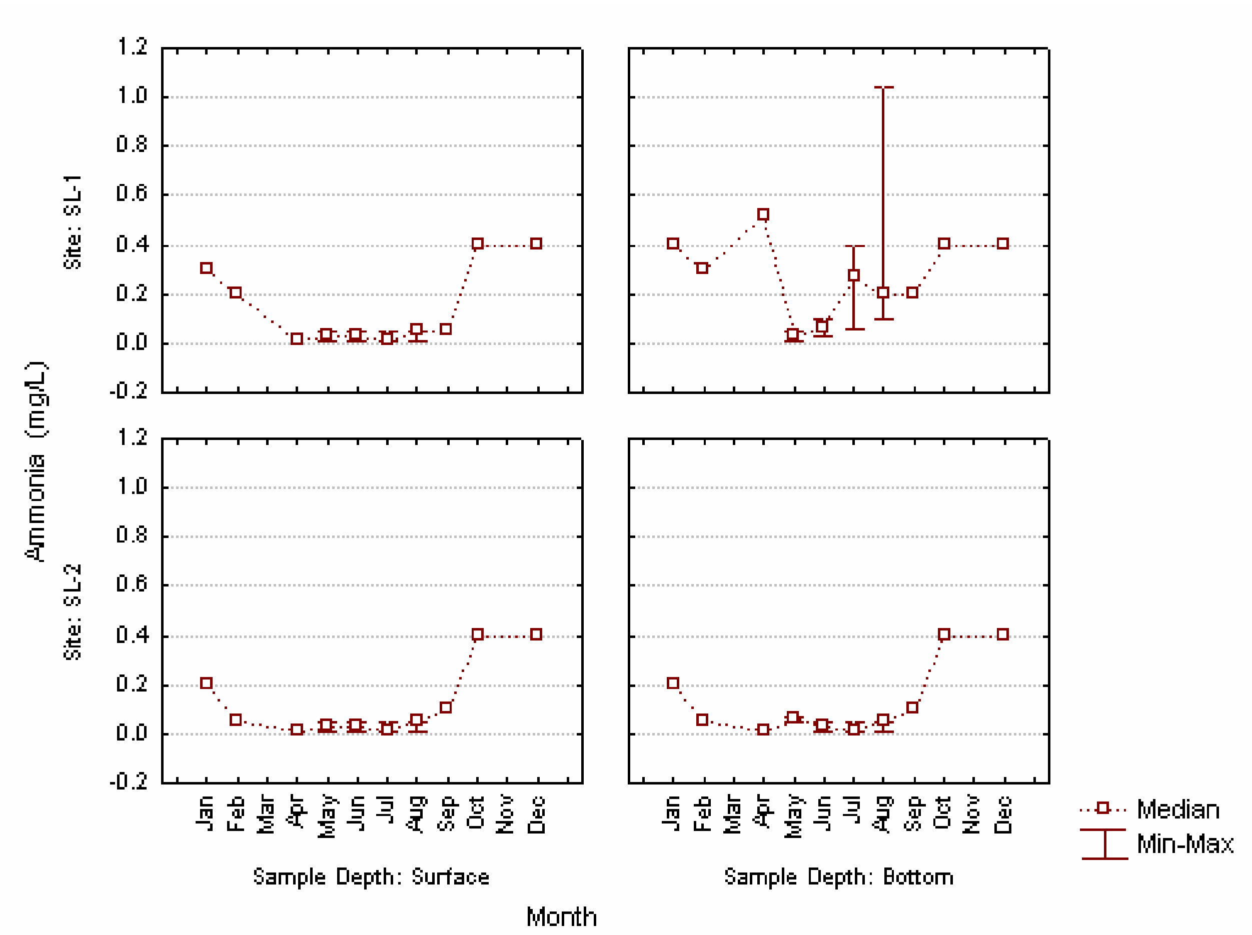

Figure 29. Ammonia concentrations by month for Sylvan Lake categorized by site and sample depth.

Corrected for pH and temperature, un-ionized ammonia concentrations were all below the water quality standard.

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

Nitrate/nitrite concentrations were below detection limits (0.05, Energy Laboratories; 0.1, State Health Laboratory) in approximately 80% of samples. Nitrate/nitrite concentrations in Sylvan Lake ranged from less than detection to 0.17 mg/L (mean = 0.05) (Figure 30).

Maximum nitrate concentrations were observed during the winter months. All sample concentrations were well below the nitrate standard (≤ 88 mg/L).

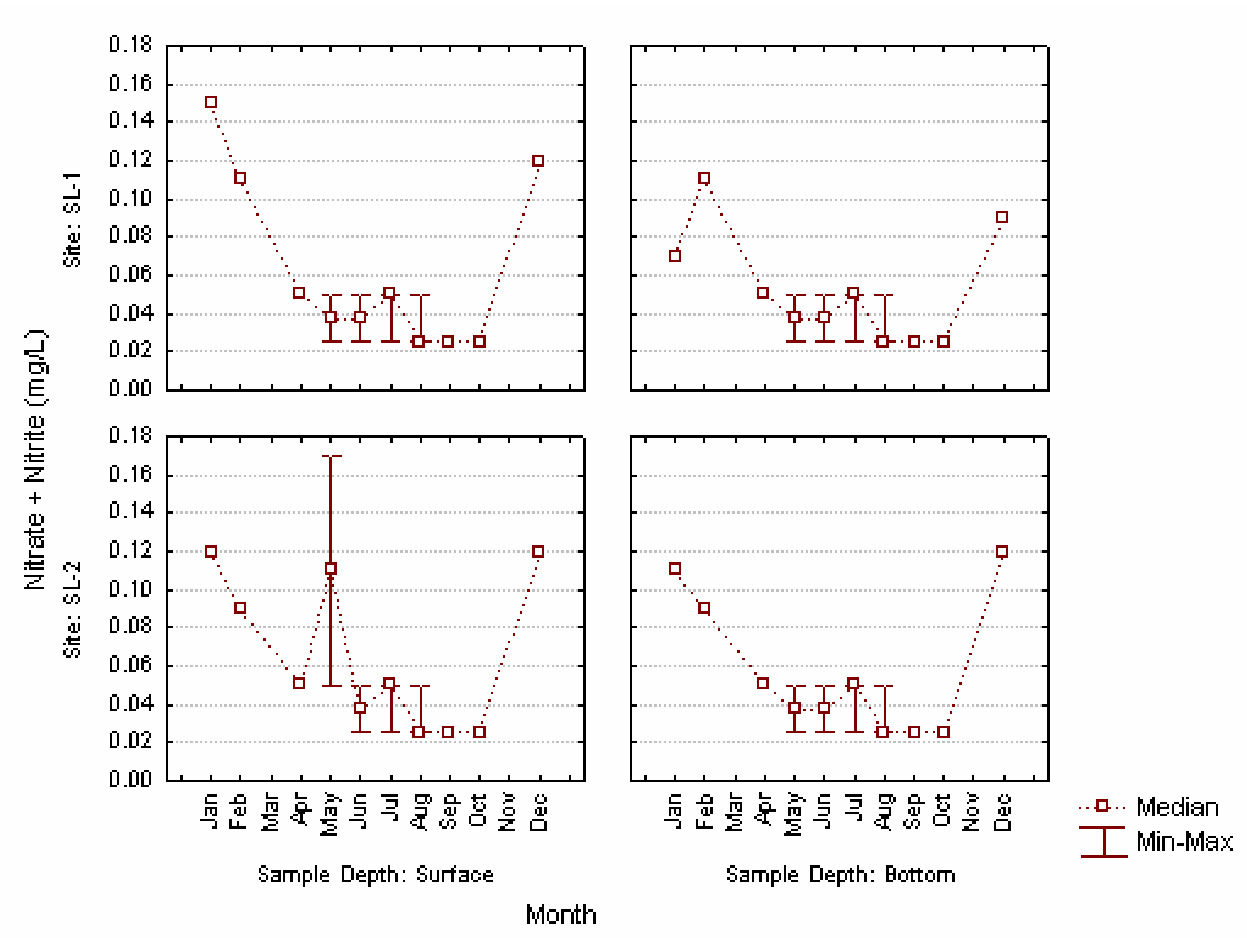

Figure 30. Nitrate plus nitrite concentrations by month for Sylvan Lake categorized by site and sample depth.

Total nitrogen was calculated for each sample by adding TKN and nitrate/nitrite concentrations. Total nitrogen values were used to determine whether nitrogen is a limiting nutrient in Sylvan Lake (see limiting nutrient section). Total nitrogen in Sylvan Lake ranged from 0.11 to 18.67 mg/L (mean = 1.15) (Figure 31).

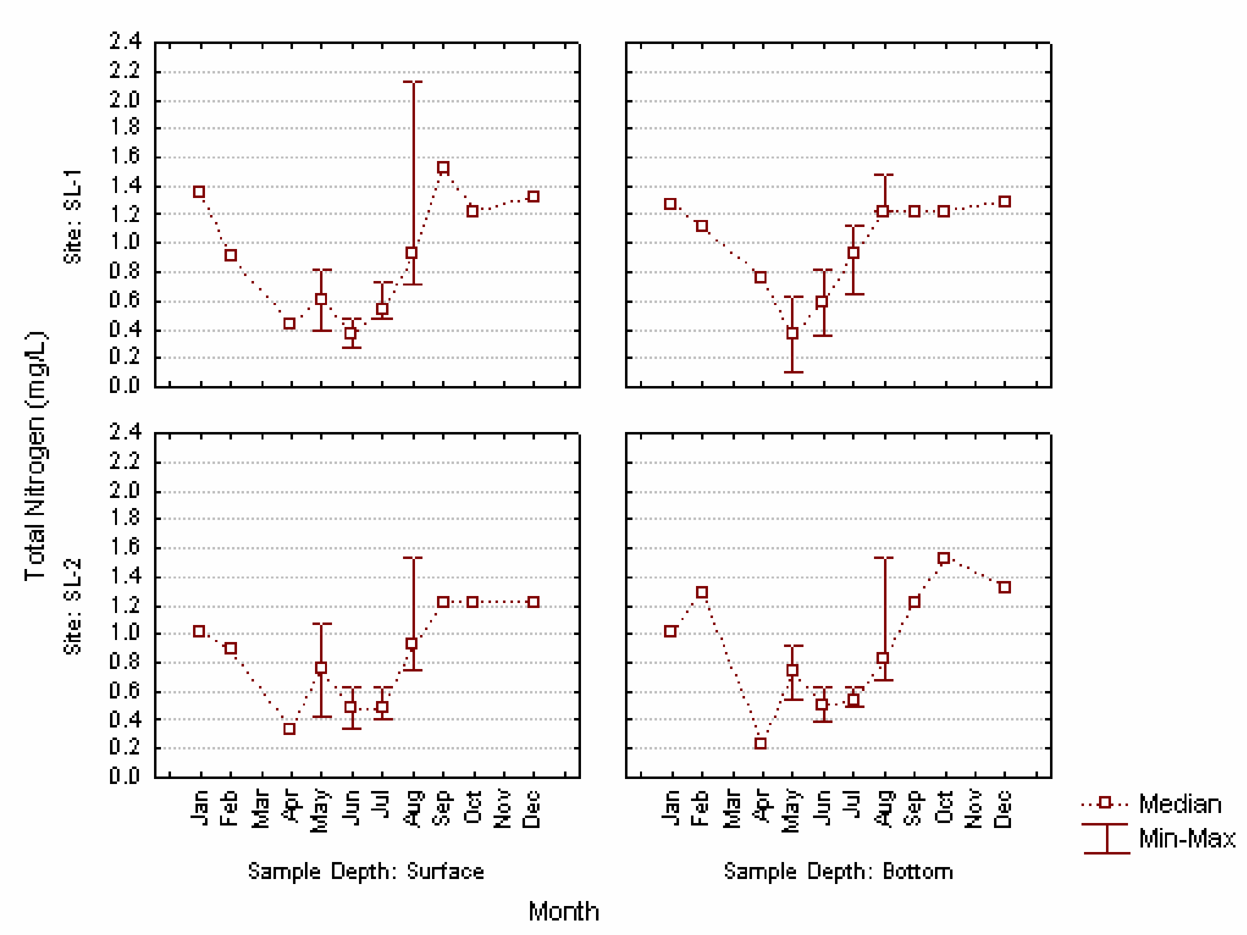

Figure 31. Total nitrogen concentrations by month for Sylvan Lake categorized by site and sample depth.

Phosphorus

Like nitrogen, phosphorus is a biologically active element. It cycles through different states in the aquatic environment, and its concentration in any one state depends on the degree of biological assimilation or decomposition occurring in that system. The predominant inorganic form of phosphorus in lake systems is orthophosphate. Concentrations of orthophosphate were measured as total dissolved phosphorus (TDP) in this study. Phosphorus is often a limiting nutrient to algae and macrophyte production within many aquatic systems. Loading of this nutrient presents an increased eutrophication (primary production) risk.

Total phosphorus concentrations of non-polluted waters are usually less than 0.1 mg/L (Lind 1985). Total phosphorus values in Sylvan Lake ranged from less than detection to 0.08 mg/L (mean = 0.05). At most lake sampling locations, maximum concentrations of phosphorus were observed in October. Due to anoxic conditions in the hypolimnion, the bottom sampling depth of site SL-1 experienced the highest total phosphorus concentrations of all sampling locations in July and August (Figure 32).

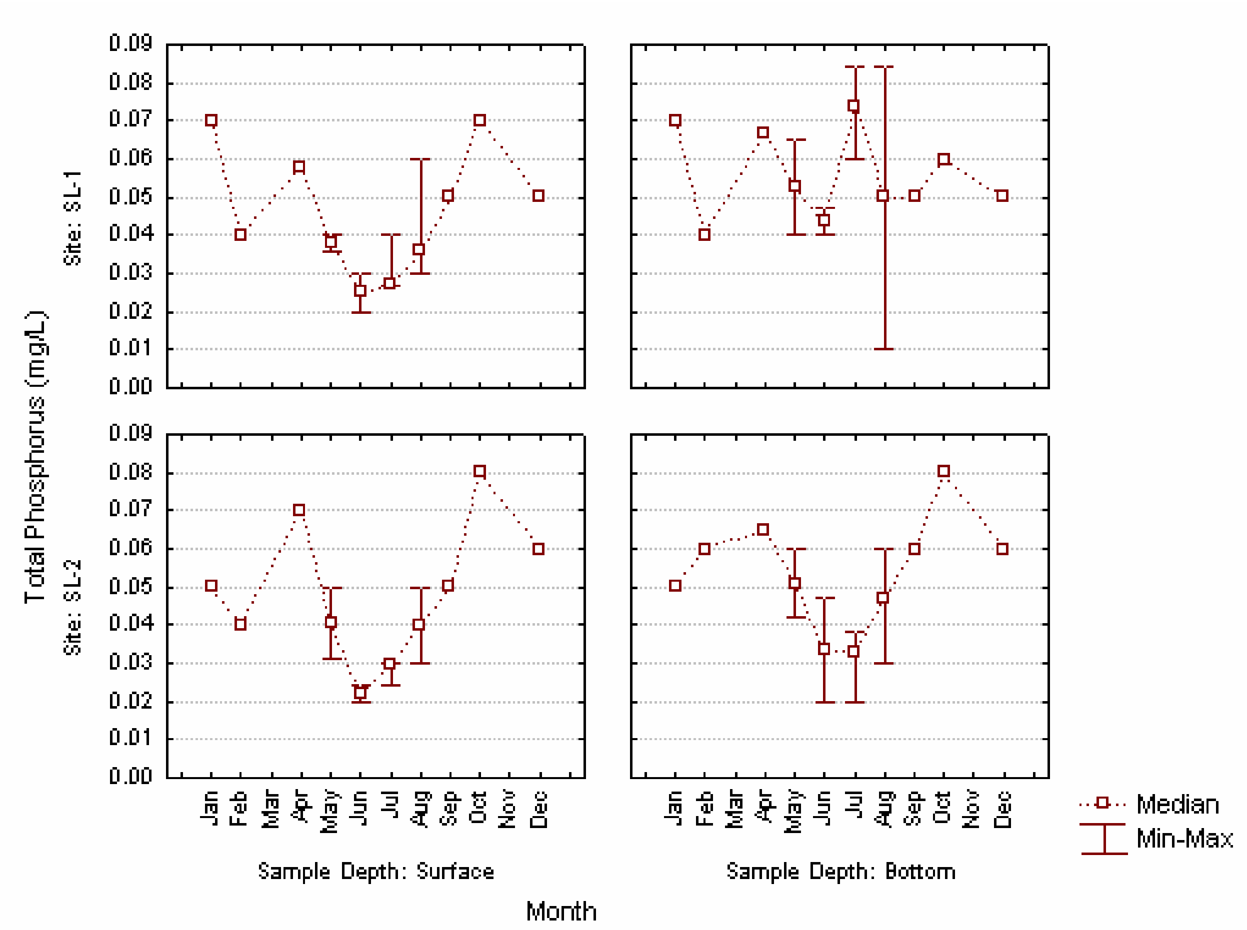

Figure 32. Total phosphorus concentrations by month for Sylvan Lake categorized by site and sample depth.

TDP is the portion of total phosphorus that is readily available for plant and algae utilization. TDP concentrations in non-polluted waters are usually less than 0.01 mg/L (Lind 1985). TDP concentrations in Sylvan Lake ranged from below detection limits to 0.04 mg/L (mean = 0.02). Concentrations were above the minimum amount for rapid algal growth in April, which requires only 0.02 mg/L, but decreased through the growing season (Figure 33).

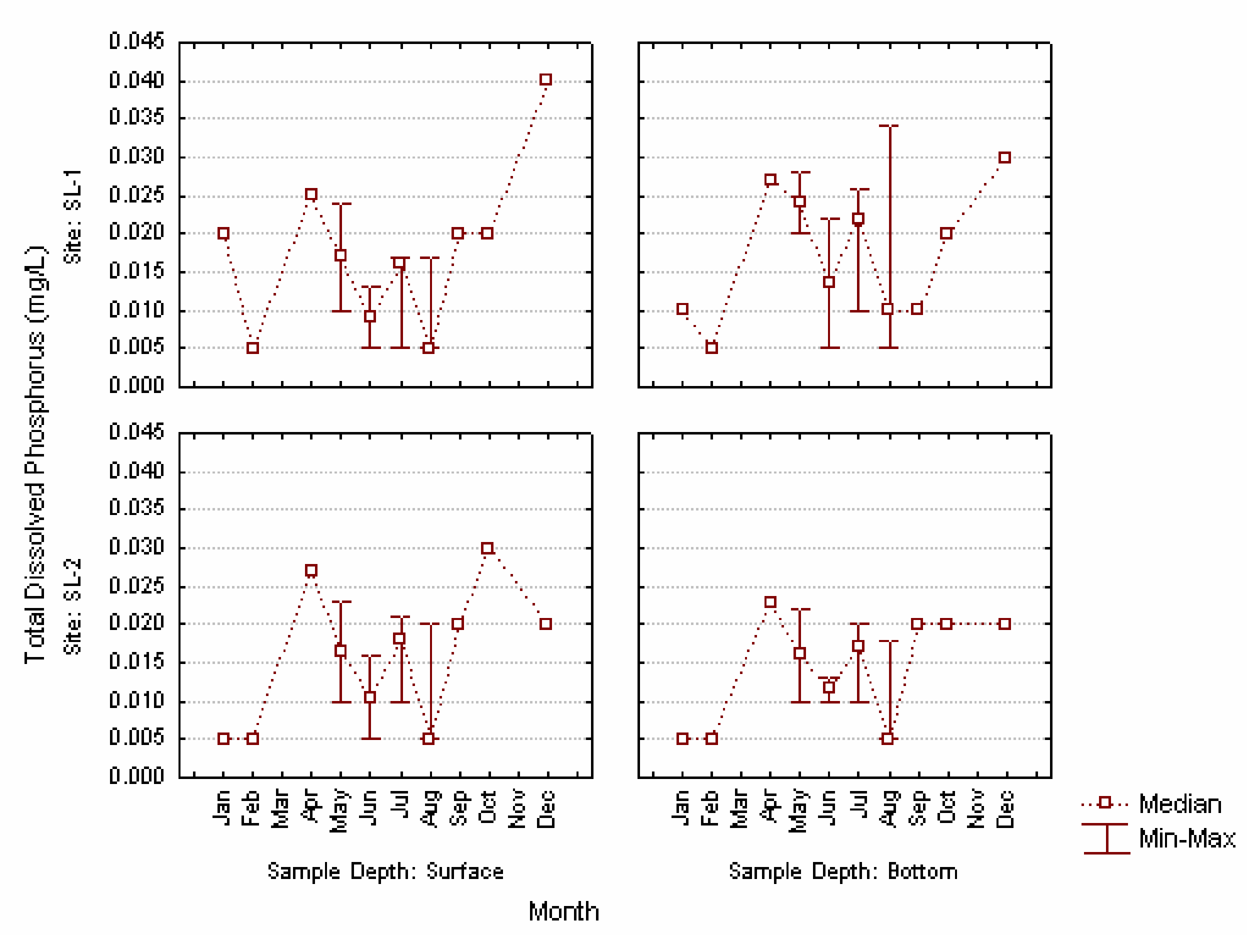

Figure 33. Total dissolved phosphorus concentrations by month for Sylvan Lake categorized by site and sample depth.

Limiting Nutrients

Great emphasis is placed on regulating nutrient loading to waterbodies to control aquatic productivity (i.e eutrophication). In aquatic systems, the most significant nutrient factors causing the shift from a lesser to a more productive state are phosphorus and nitrogen. Nitrogen is difficult to control because of its highly soluble nature, but phosphorus is easier to manipulate from a management perspective. Consequently, it is most often the nutrient targeted for reduction when attempting to control lake eutrophication.

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

N:P ratios for Sylvan Lake ranged from approximately 2 to 588 (mean = 29). Almost 90% of samples collected in Sylvan Lake were considered phosphorus-limited. N:P ratios were generally lower in the spring and increased throughout the summer months (Figure 34). Samples collected in July, August, and September revealed the highest cases of phosphorus limitation. With the exception of one sample collected in August 2002, the ratios displayed little variability. The extreme phosphorus-limited sample (N:P = 123) was collected at the deepest sampling location (SL-1, bottom), which correlates with the high ammonia concentration observed in this sample.

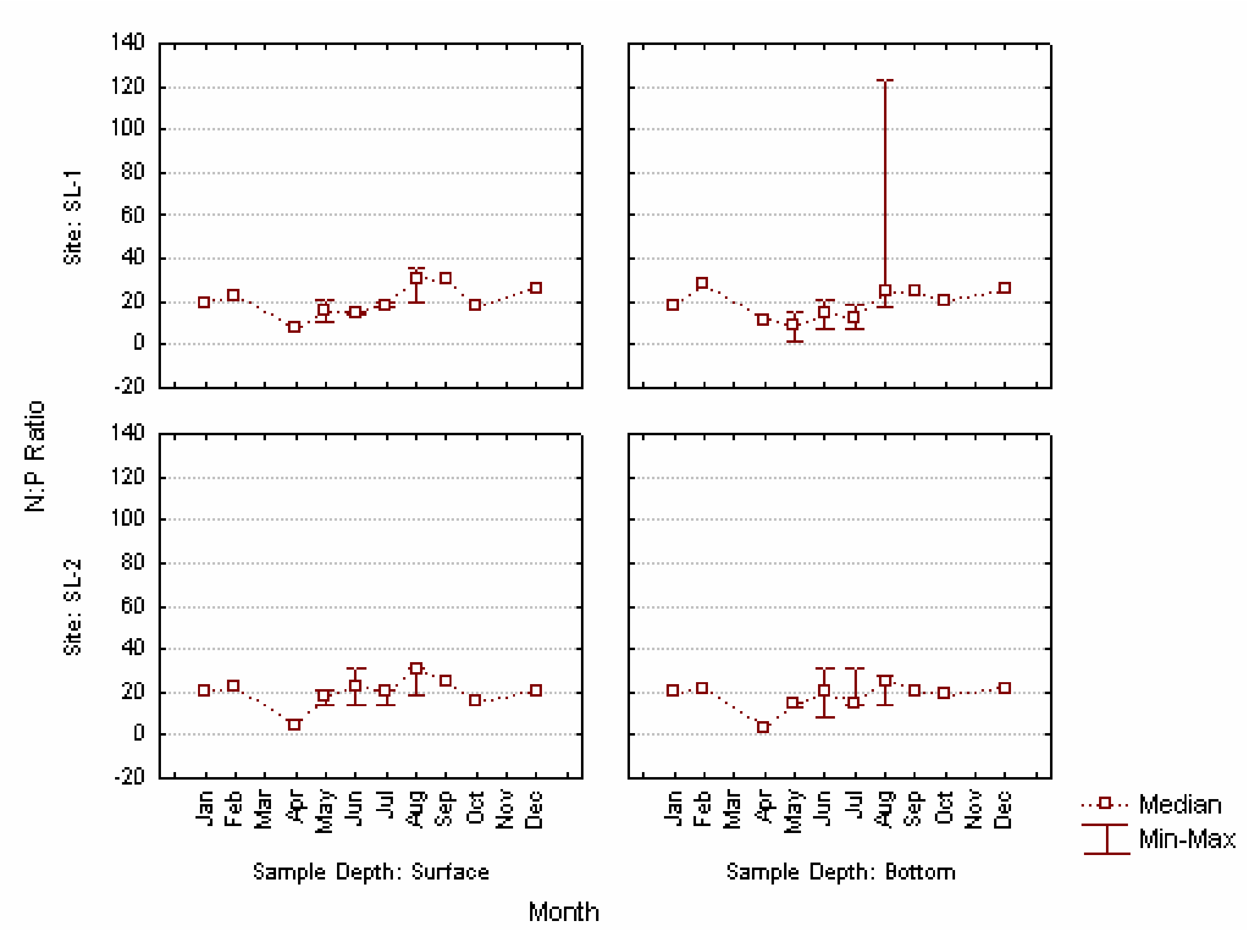

Figure 34. Nitrogen:phosphorus ratios by month for Sylvan Lake categorized by site and sample depth.

Trophic State

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

An index incorporating several of these parameters is best suited to determine trophic state.

Carlson's (1977) Trophic State Index (TSI) was used to determine the approximate trophic state of Sylvan Lake. This index incorporates measures of Secchi disk transparency, chlorophyll *a*, and total phosphorus into scores ranging from 0 to 100 with each 10-unit increase representing a doubling in algal biomass. Four ranges of index values (Table 22) define Carlson's trophic levels, which include oligotrophic, mesotrophic, eutrophic, and hyper-eutrophic (in order of increasing productivity).

Table 22. Carlson's trophic levels and index ranges for each level.

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

TSI values were calculated for each of the index parameters individually. The number of samples/measurements used to calculate individual TSI values varied by parameter and year. Only surface samples/measurements from sites SL-1 and SL-2 were used for TSI calculations. Phosphorus samples were collected monthly from August through December 2001 (n = 8); January, February, and May through August 2002 (n = 12); and April through August of 2003 (n = 12, two measurements collected in July). Chlorophyll *a* samples were collected monthly from April through August of 2003 (n = 12, two measurements collected in July). Secchi depth measurements were taken monthly from August through October 2001 (n = 6), May through August 2002 (n = 8), and April through August of 2003 (n = 12, two measurements collected in July).

Phosphorus TSI values ranged from 37.4 to 67.3 (mean = 57.3), chlorophyll *a* TSI values ranged from 30.6 to 64.2 (mean = 55.0), and Secchi depth TSI values ranged from 39.1 to 70.0 (mean = 53.7). Approximately 84% of phosphorus TSI values indicate eutrophic conditions, and 13% were in the mesotrophic range. One phosphorus sample collected in October 2001 was considered hyper-eutrophic. Half of the Secchi depth measurements indicated eutrophic conditions, and 46% were in the mesotrophic range. One Secchi depth measurement collected in August 2001 was considered hyper-eutrophic. Of the nine chlorophyll samples, one-third were considered eutrophic, while the other two-thirds were in the mesotrophic range.

Secchi disk transparency, chlorophyll *a*, and total phosphorus concentrations were used to calculate a mean TSI value for each site on each sampling date. Chlorophyll *a* data was not available to include in the index in 2001 and 2002, because the chlorophyll samples were unknowingly stored past the holding time allowed for this analysis. Chlorophyll *a* data was included in the mean TSI calculations in 2003. A total of 26 mean TSI values were calculated for this study period.

Mean TSI values indicate trophic levels comparable to individual TSI parameters (Table 23). Mean TSI values ranged from 42.3 to 66.6 (mean = 54.7). Average TSI values for the study period indicate eutrophic conditions. Approximately 70% of mean TSI values were considered eutrophic, 26% were considered mesotrophic, and only 4% were in the hyper-eutrophic range.

Table 23. Descriptive statistics for trophic state index (TSI) values calculated from direct measurements and samples collected from Sylvan Lake in 2001-2003.

	Secchi TSI	Phosphorus TSI	Chlorophyll TSI*	Mean TSI
Number of Samples	14	32	9	26
Average	53.6	57.3	49.9	54.7
Median	54.2	57.3	49.1	55.1
Minimum	39.2	47.4	30.6	42.3
Maximum	70.0	67.3	64.2	66.6
Standard Deviation	7.3	5.5	9.9	6.2

* Chlorophyll data was available for 2003 only.

Phosphorus, chlorophyll *a*, Secchi depth, and mean TSI values, displayed seasonal variation. In general, values decrease in the spring, increase during the summer, and decrease again during the fall months (Figure 35).

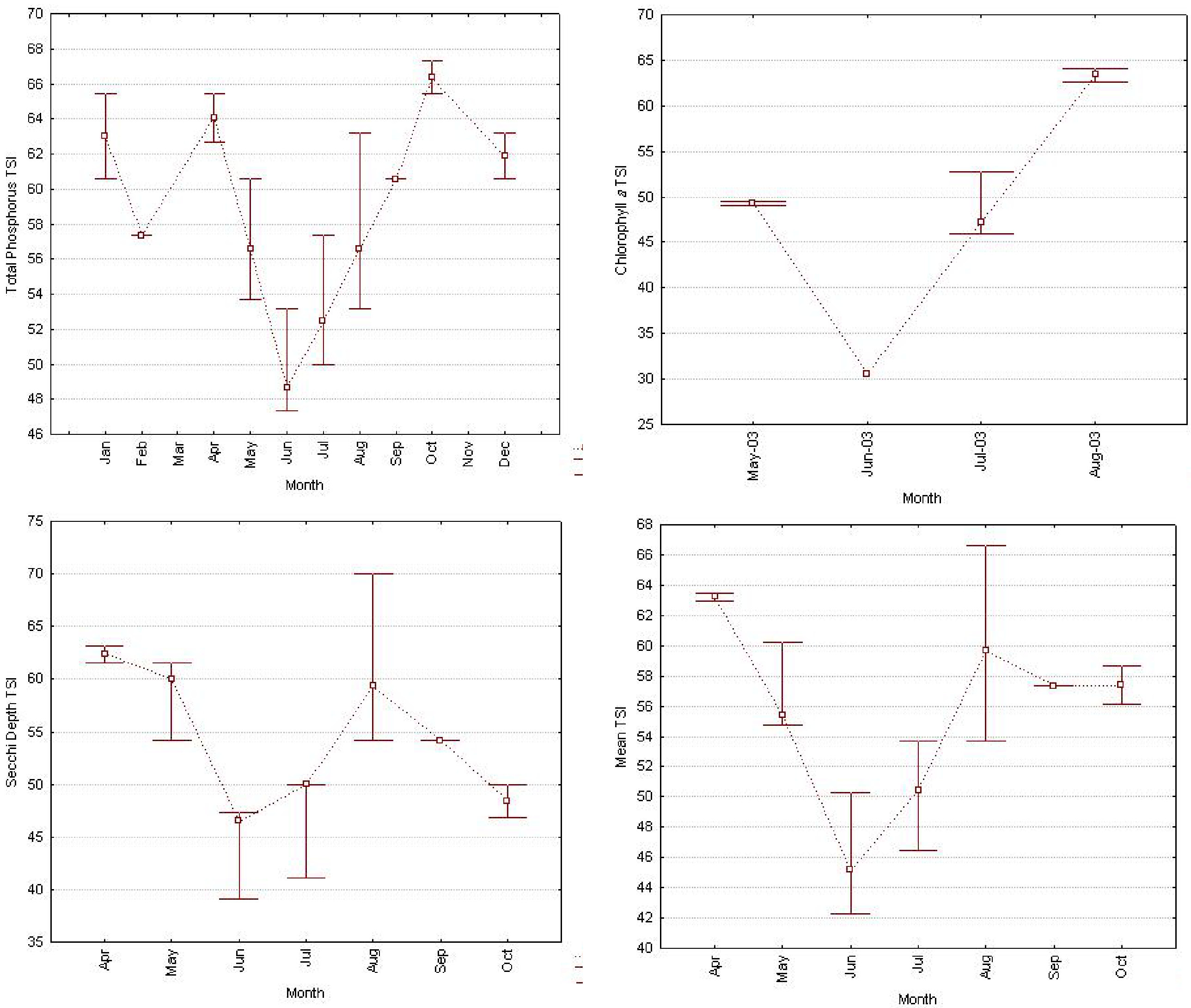

Figure 35. Sylvan Lake phosphorus, chlorophyll, Secchi depth, and mean TSI values by month showing seasonal variation. Phosphorus and Secchi depth data is from 2001-2003. Chlorophyll data was available for 2003 only. Points represent median values and whiskers represent minimum and maximum values for each month.

Beneficial use attainment for Sylvan Lake was also assessed using TSI values. SD DENR uses ecoregion specific criteria to evaluate beneficial use attainment. Stueven et al. (2000b) determined TSI criteria for support classifications that are specific to each South Dakota ecoregion. Sylvan Lake is located in the Middle Rockies Ecoregion. Numeric TSI criteria for beneficial use support categories for the Middle Rockies Ecoregion are listed in Table 24.

Table 24. Beneficial use categories for the Middle Rockies Ecoregion with TSI criteria.

Beneficial Use Category	TSI Criteria
Not supporting	>60
Partially Supporting	45-60
Fully Supporting	<45

Individual parameter and mean TSI values span all beneficial use support categories throughout the project period. Nearly half of all TSI values fell within the partially supporting category. However, no phosphorus TSI values were considered fully supporting during the project period. Only 9% of mean TSI values were considered fully supporting (Figure 36).

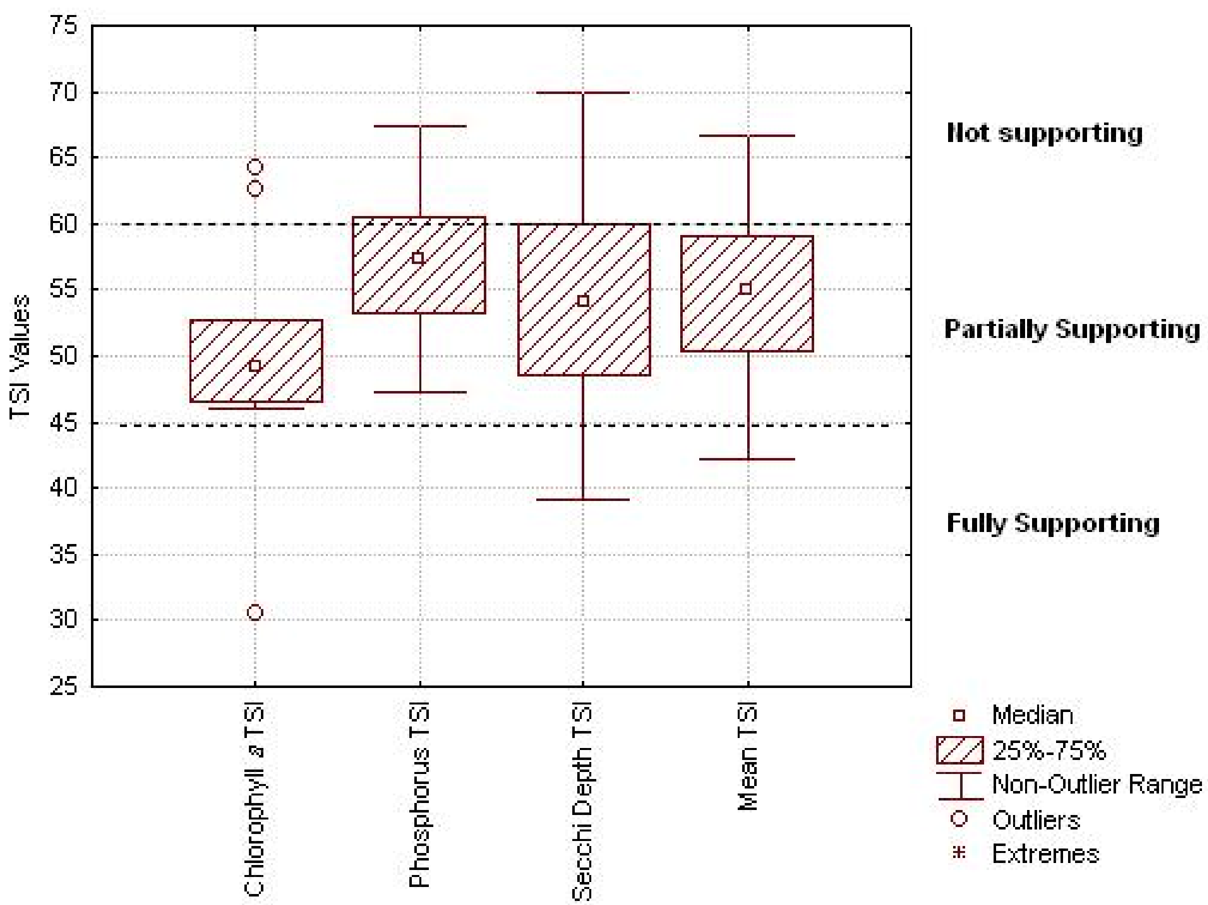

Figure 36. Phosphorus, chlorophyll, Secchi depth, and mean TSI values for Sylvan Lake. Dashed horizontal lines represent beneficial use support categories (i.e fully, partially, and not supporting beneficial use). Phosphorus and Secchi depth data is from 2001-2003. Chlorophyll data was available for 2003 only.

Historic TSI data was compiled from Wierenga and Payne (1987), SD DENR Statewide Lakes Assessment, and this study to examine trends in trophic state. TSI values appear to be declining since 1991. Using the current TSI beneficial use support categories, yearly average phosphorus and mean TSI values were considered partially supporting or not supporting beneficial uses (Table 25 and Figure 37).

Table 25. Historic TSI values for Sylvan Lake. Values represent averages for each year.

Year	Total Phosphorus	Secchi Depth	Chlorophyll *a*	Mean*
1979	59.8	m	m	59.8
1981	63.2	57.3	m	60.3
1982	69.2	63.3	58.3	63.6
1983	64.2	55.9	49.9	56.7
1984	63.8	57.5	36.8	52.7
1989	64.9	62.1	m	63.5
1991	69.9	61.2	78.1	69.7
1993	65.2	62.5	63.0	63.6
2001	62.7	55.9	m	59.3
2002	55.8	51.4	m	53.6
2003	55.0	54.0	49.9	53.0
2004	53.4	44.8	52.0	50.1

* Note that some parameter TSI values were missing for years 1979, 1981, 1989, 2001, and 2002. Means were calculated using available data.

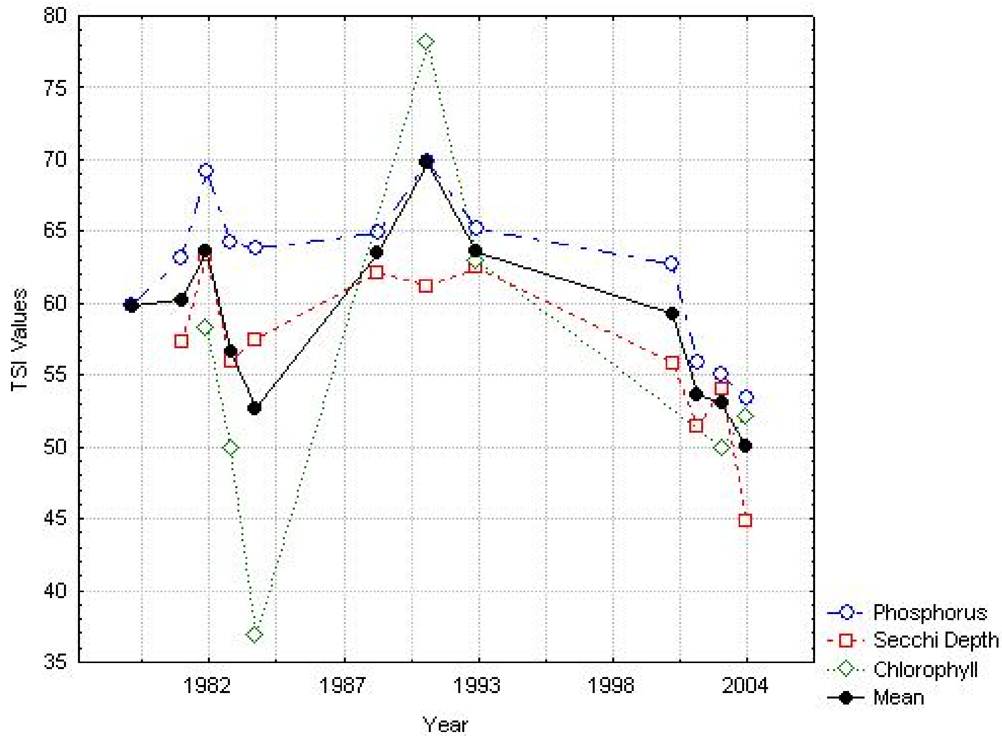

Figure 37. Historic Trophic State Index Values for Sylvan Lake (1979-2004).

Reduction Response Model

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

As anticipated, the predicted inlake concentrations of total nitrogen and phosphorus decreased as modeled stream loads decreased (Table 26). Individual parameter (i.e. phosphorus, chlorophyll, and Secchi) TSI values gradually decreased with the reduction of nitrogen and phosphorus load. Based on model results, a reduction in watershed nutrient loads of approximately 90-95% would be required for Sylvan Lake phosphorus and chlorophyll TSI values to be considered fully supporting the ecoregion-specific beneficial use criteria. Even with a 100% reduction of watershed nutrient load (i.e. no external nutrient loading), the Secchi depth and mean TSI would still not reach fully supporting status (Figure 38). These findings demonstrate that internal nutrient loading from lake sediment is a potential cause of water quality problems in Sylvan Lake.

Table 26. BATHTUB model-predicted concentrations of total phosphorus, total nitrogen, and TSI values for Sylvan Lake with successive 10-percent reductions in nitrogen and phosphorus inputs. TSI values are plotted on the following graph.

Percent Reduction	Total Phosphorus (ppb)	Total Nitrogen (ppb)	Predicted Phosphorus TSI value	Predicted Chlorophyll TSI value	Predicted Secchi Depth TSI value	Predicted Mean TSI value
0%	39.9	393.0	57.3	55.0	65.9	59.4
10%	38.0	386.6	56.6	54.5	65.7	59.0
20%	36.1	380.1	55.8	54.0	65.6	58.5
30%	34.0	373.6	55.0	53.5	65.4	58.0
40%	31.9	366.9	54.1	52.8	65.3	57.4
50%	29.6	360.1	53.0	52.1	65.1	56.7
60%	27.1	353.2	51.7	51.2	64.9	55.9
70%	24.4	346.2	50.2	50.1	64.6	55.0
80%	21.5	339.9	48.4	48.7	64.3	53.8
90%	18.1	331.8	45.9	46.8	64.0	52.3
100%	14.1	324.4	42.3	43.9	63.6	49.9

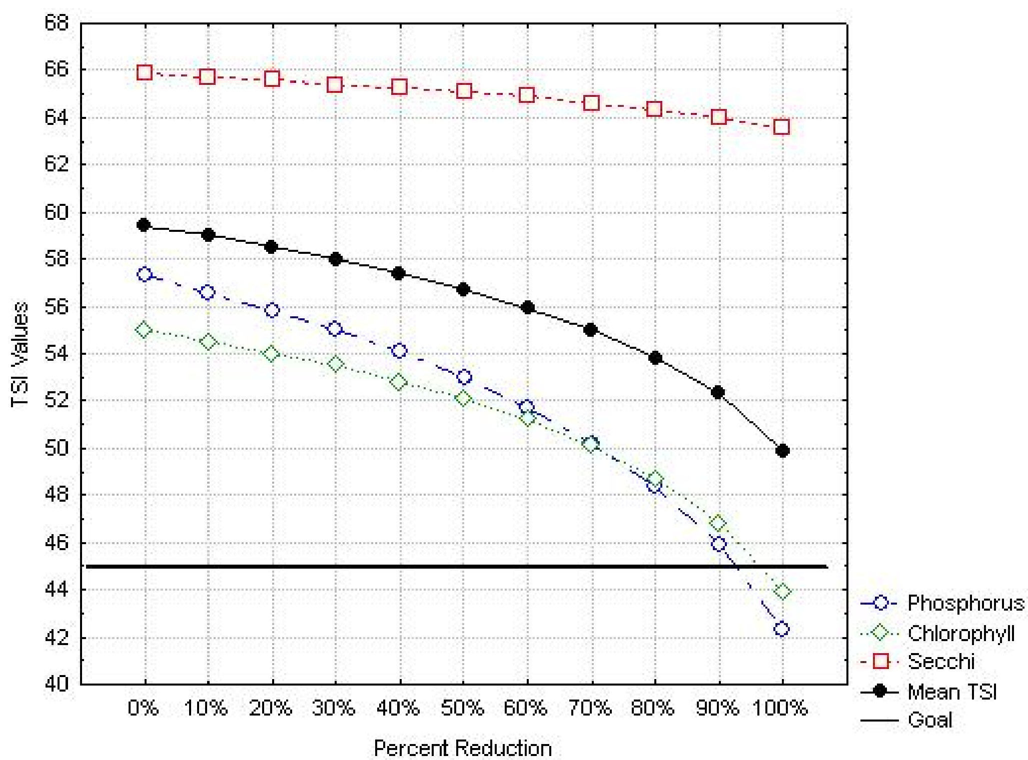

Figure 38. Model-predicted phosphorus, chlorophyll, and Secchi depth TSI values with successive 10-percent reductions in external nutrient loading. Line indicates TMDL goal (TSI = 45) and criterion for full support of beneficial use for the Middle Rockies Ecoregion using Carlson's TSI classifications.

Current watershed loads of total phosphorus to Sylvan Lake are approximately 12.4 kg/yr, representing approximately 63% of the overall phosphorus load to Sylvan Lake. According to model results and a lake total phosphorus mass balance, lake sediments contribute a significant amount of the total phosphorus load to Sylvan Lake. Approximately 7.3 kg/yr of total phosphorus (37% of the overall phosphorus load) originates from recycling of phosphorus in the lake's sediment. This load will also be targeted for reductions to meet the TMDL goal.

Bathtub model results show that Secchi depth TSI values are amplifying overall Mean TSI values, and may not accurately represent conditions of eutrophy in Sylvan Lake. Because Secchi depth measurements may be influenced by factors other than phosphorus concentrations and because measured chlorophyll concentrations were not available, it was decided that phosphorus TSI values alone should be used to determine support status.

Based on the phosphorus TSI criteria of 45 (i.e. TMDL numeric target), a phosphorus concentration can be back calculated that would represent a surrogate numeric target for the TMDL. Using this procedure, a lake total phosphorus concentration of 0.02 mg/L was established as a secondary TMDL target.

If only phosphorus loads originating from the watershed were managed, greater than 90% reduction would be required to meet the target. However, in-lake management (i.e. alum treatment) will provide a 50% reduction of the lake's internal phosphorus load. A combination of the 90% reduction from the watershed load (from 12.4 to 1.2 kg/year) and the 50% reduction from the internal load (from 7.3 to 3.7 kg/year) will provide approximately 75% reduction of the total load (from 19.7 to 4.9 kg/year). A total load of 4.9 kg/year will result in an in-lake concentration of approximately 0.019 mg/L.

Lake Biological Parameters

Fishery

The South Dakota Department of Game, Fish, and Parks (SDGF&P) last conducted a fishery survey in June of 1995. This survey consisted of using 4 ¾ inch mesh frame net sets, 2 quarter arc seine hauls with a 100 ft. x 6 ft. x ¼ inch mesh seine, and a baby frame net set with ½ inch mesh.

Golden shiners, fathead minnows, and rainbow trout were collected during this survey. Healthy populations of golden shiners and fathead minnows were sampled. A total of 106 fathead minnows and 130 golden shiners were collected.

Although Sylvan Lake is managed as a put and take rainbow trout fishery, only nine hatchery rainbow trout were captured by all sampling methods. Annual scheduled stocking of catchable rainbow trout and occasional supplemental stocking of adult rainbow trout maintains a viable trout fishery. On average, approximately 13,000 rainbow trout (catchable size) are stocked annually. It is expected that very little trout reproduction is occurring in the lake or inlet streams. The complete SD GF&P fish survey report can be found in Appendix B.

Fecal Coliform Bacteria

The beneficial use of immersion recreation is assigned to Sylvan Lake. Fecal coliform bacteria concentrations must be ≤ 400 CFU/100 ml in any single sample to support this use. Sylvan Lake samples did not show detectable fecal coliform bacteria concentrations.

Concentrations of *E. coli* bacteria in lake samples were also analyzed, and were not detected.

Quality Assurance/Quality Control

Proper laboratory and field sampling methods require that quality assurance and quality control (QA/QC) samples be collected. These samples should comprise 10% of the total samples taken. Nine QA/QC samples were collected during the project period, during which a total of 101 samples were collected. The QA/QC samples represent only 8.9% of the total samples collected, falling just short of the minimum requirement. Four replicate and five blank samples were collected on randomly chosen dates from Sylvan Lake or one of its tributaries. Standard chemical analysis was completed on each sample.

Values above the detection limit were observed in four of the blank samples, with three occurrences for each of three parameters (alkalinity, total phosphorous, and total dissolved phosphorous). These instances of slight contamination were possibly caused by use of different distilled water brands or field contamination during handling.

Replicate samples were compared to the routine samples using the industrial statistic (%I). The value given is the absolute difference between the routine and the replicate sample in percent, as follows:

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

%I = Industrial Statistic
ABS = Absolute Value
A = Parameter value for replicate sample
B = Parameter value for routine sample

The average percent differences for analyzed parameters ranged from 0.0% to 33.2%. The following three parameters had an average percent difference greater that 10%: total suspended solids, nitrate/nitrite, and total dissolved phosphorous. The difference between replicate and routine samples for these parameters may be due to contamination of the sample bottles/distilled water by the field sampler, natural variability, or a laboratory error. Overall, approximately 78% of all sample pair difference estimates were less than 10%. See Appendix for all QA/QC data.

Other Monitoring

Sediment Survey

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

A sediment survey was conducted for Sylvan Lake on December 24, 2003. Water depth and sediment depth was measured with a steel probe through holes drilled in the ice. Water depth and sediment depth was recorded at each site (134 sampling locations) with Global Positioning System (GPS) equipment.

Sediment depths in Sylvan Lake ranged from 0 to 6 feet (mean = 1.9). Using survey data, a sediment depth contour map was produced and total sediment volume was calculated (Figure 39). Sediment volume is approximately 49,400 cubic yards.

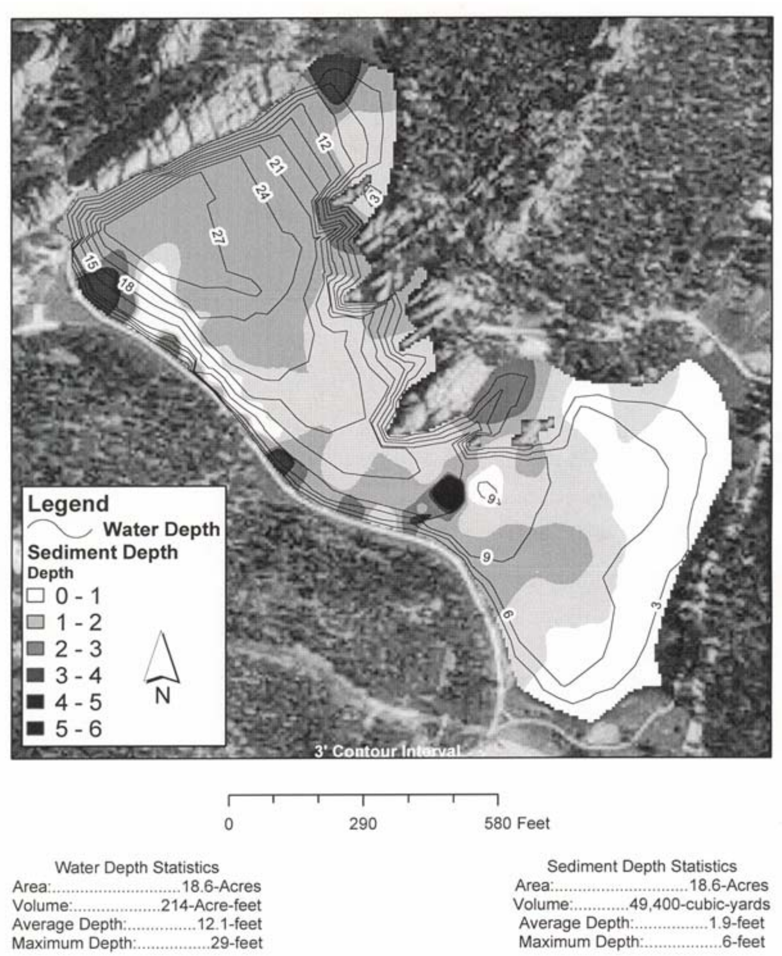

Figure 39. Estimated sediment depth and water depth contours for Sylvan Lake based on sediment survey data collected on December 24, 2003.

Sediment Phosphorus Concentration

Sediment samples assayed for total phosphorus were collected from 12 sites in Sylvan Lake. Samples were obtained using a Petite Ponar dredge and stored in 2-gallon HDPE containers until analyzed. Total phosphorus concentrations ranged from 610 to 5,100 mg/kg (mean = 1,706 mg/kg). Concentrations displayed a strong relationship to the water depth where the sample was collected; sediment phosphorus concentrations increase as water depth increase (Figure 40).

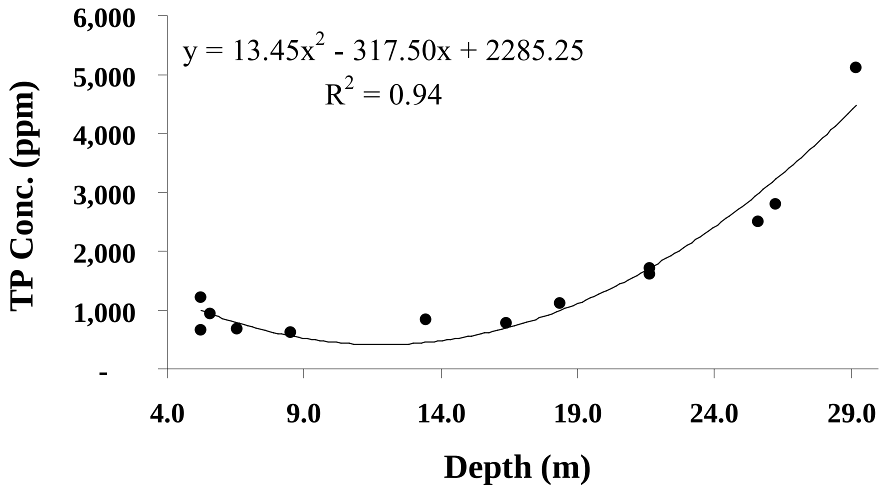

Figure 40. Sediment total phosphorus concentrations by water depth.

Sylvan Lake Restoration Project

In 1979, the South Dakota Department of Game, Fish, and Parks (SDGF&P) initiated a restoration project for Sylvan Lake. This project was instigated in response to increased visitation and resulting increase in usage of the Sylvan Lake watershed area. According to the restoration project report (Wierenga and Payne 1987), much of the surface area around the lake was being degraded by foot traffic and vehicle use. Graveled parking areas, roads, and footpaths along the lakeshore were resulting in increased erosion and sedimentation in the lake. Due to increased visitation, the SD GFP and SD DENR determined that a three-phase approach was needed to restore lake conditions and protect the adjacent areas from further erosion. The first phase involved a partial removal of sediments in the reservoir forebay. The second phase included paving of the existing parking areas and driving areas to reduce sedimentation. The third phase called for riparian vegetation improvements and construction of sediment controls in the inlet areas of the lake. The total cost for this restoration project was more than $450,000.

Sediment was removed from the east and southeast shoreline areas. The lake level was reduced by 2.7 meters (9 ft.) to allow the sediments to dry enough to allow removal using conventional construction equipment. Approximately 18,580 cubic meters (24,300 c.y.) of material was removed, which was 60% more material than originally projected for excavation. The contractor misidentified materials and depths of excavation cited in the original contract, resulting in the removal of native soils that existed prior to the reservoir's construction. It was determined that the additional removal of sediment was beneficial to the project, so the contractor was ultimately paid for the entire volume of material removed.

Graveled parking areas and roads were paved on the west side of the lake near the concession and on the east side of the lake in a parking area near a foot trail that leads to Harney Peak. Approximately 25,000 square feet of parking area was resurfaced along with associated roadway access.

Approximately five acres of disturbed surface were seeded and areas around the hiking trail system were graveled to reduce these sources of sedimentation. In addition, eight sediment control structures were placed in the watershed area.

As part of this restoration effort, several landuse management practices were established or changed. All lakeshore camping and horseback riding was eliminated, gasoline sales at the concession was closed, timber thinning was implemented to allow development of ground cover, and native trees and shrubs were planted to stabilize soils in areas experiencing heavy foot traffic.

According to the final project report, restoration activities did not greatly improve water quality. Sampling was conducted prior to (May-September 1979) and after (October 1981- April 1984) restoration activities. Total phosphorus concentrations before and after the project were approximately the same. During sediment removal, the trophic status of Sylvan Lake worsened, becoming hypereutriphic. Once the sediment removal operations ceased, the trophic status returned to eutrophic.

Lake Circulation

In an effort to control algae growth and improve oxygen levels in Sylvan Lake, a floating solar-powered circulator (Pump Systems, Inc.; SolarBee model SB2500) was installed on November 22, 2000 (Figure 41). In theory, the circulator draws water from below the machine and spreads it across the top of the reservoir with continuous surface renewal, resulting in higher DO concentrations from the depth of the intake hose to the water surface. Effects of this circulator on dissolved oxygen concentrations were monitored during this study.

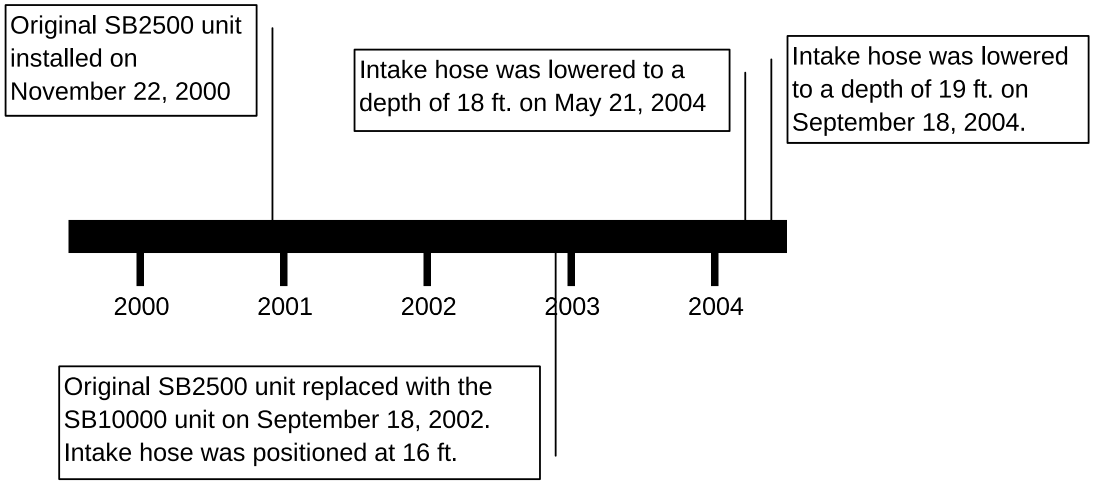

Figure 41. Timeline of service history and operational changes for the SolarBee circulator in Sylvan Lake.

Prior to the installation of SB2500 unit, the average depth at which the oxygen levels dropped below the state water quality criterion (6.0 mg/L) was 3.2 m. After the circulator was installed, this depth increased. DO profile data from 2001 to 2002 indicates DO levels dropped below the criterion at an average depth of 4.0 m.

The model SB2500 unit was replaced with a model SB10000 circulator on September 18, 2002. The new unit was positioned closer to the center of the deeper embayment at a water depth of approximately 20 feet. At this time, the circulator intake hose was positioned at 16 feet (4.9 m). After the installation of this new unit, DO profile date from 2003 indicates DO levels dropped below the criterion at an average depth of 4.5 m.

On May 21, 2004, the existing unit was moved to a location with a water depth of approximately 24 feet, and the suction hose was lowered to a depth of 18 feet (5.5 m). After the intake was lowered, DO profile data from 2004 indicates DO levels dropped below the criterion at an average depth of 5.0 m.

On September 18, 2004, the intake hose was replaced with one capable of extending to a depth 25 feet, but the intake depth was lowered to only 19 feet. During this service, the floats and motor brushes were replaced.

It appears that the circulator is increasing the oxygenated zone of the lake profile, as the depth at which DO levels are meeting the state criterion has been increased (see Appendix C for all temperature and DO profiles collected at site SL-1). SDDENR and SDGF&P are currently considering alternatives for future use of the circulator, including: 1) lowering the intake to its maximum depth (25 feet), 2) lowering the intake 2 feet each year until maximum depth is reached, 3) maintaining the current intake depth, or 4) removing the circulator from the reservoir.

If the entire lake was oxygenated, phosphorus releases from the lake sediment would likely abate. Aeration equipment, which injects forced air or pure oxygen to increase the dissolved oxygen content of the water, could be implemented to supplement the effect of the circulator. In the final report of the historic Sylvan Lake restoration project, aeration was recommended to maintain oxygen levels in the hypolimnion and to reduce total phosphorus concentrations in the lake.

Conclusions and Recommendations

Watershed and Lake Management

Five primary inlake treatment options were considered to reduce phosphorus concentrations in Sylvan Lake. These options included a chemical treatment (alum application), dredging, aeration in combination with circulation, and bioremediation. Of the four treatment alternatives evaluated, alum treatment is recommended to meet the TMDL goals. However, additional phosphorus load reductions could be achieved by implementing other lake management options described below.

Aluminum Sulfate (Alum) Treatment

Sediment-bound phosphorus loads from upland erosion accumulates at the lake bottom. Low oxygen concentrations allow this sediment-bound phosphorus to be released and available for algal growth. So even when external sources of phosphorus are eliminated, this nutrient remains in oversupply. For this reason, controlling phosphorus concentrations in lakes is a two-part process: keeping phosphorus out of the lake and reducing the availability of phosphorus from lake sediments.

Alum treatment involves the addition of aluminum sulfate slurry that produces an aluminum hydroxide precipitate. This precipitate removes phosphorus and suspended solids from the water column and settles to the bottom of the lake to form a phosphorus-binding blanket on the sediment surface. Alum has been used for centuries for clarification of drinking water, but only recently has it moved into the mainstream of lake management. It is a safe, effective, and economical means of controlling internal phosphorus loading. If external phosphorus loads are reduced, an alum treatment will control phosphorus levels and eliminate algae blooms for up to ten years (Conover 1988). The longevity of the treatment depends on the amount of alum applied and level of external phosphorus loading.

A phosphorus load reduction of approximately 50% is expected with the implementation of alum treatment (Welch and Cooke 1995). This reduction will lower the current internal phosphorus load from 7.3 to 3.7 kg/yr.

Lake Aeration and Circulation

The purpose of aeration and circulation techniques in lake management is to increase the dissolved oxygen content of the water. Various systems are available including aeration by air/oxygen injection or circulation by mechanical mixing.

Lake aeration can have multiple benefits to water quality and lake biota. Aeration can increase aquatic habitat for fish and other lake organisms. In some cases, nuisance algal blooms can be reduced or algae populations can be shifted to more desirable taxa.

The use of air injection (diffuser) systems is the most common destratification method. This system uses a compressor on shore to deliver air through lines connected to a perforated pipe(s) or other simple diffuser(s) placed near the bottom, typically in the deep area of the lake. The use of a diffuser system not only adds oxygen to the water, but also encourages mixing. The rising air bubbles cause water in the hypolimnion to rise, pulling this water into the epilimnion. When the colder, hypolimnetic water reaches the lake surface, it flows across the surface and eventually sinks, mixing with the warmer epilimnetic water.

The solar-powered circulator (SB10000) currently used in Sylvan lake to mix the oxygen-rich surface waters with oxygen-depleted waters in the lower depths could be supplemented with an air injection (diffuser) system. Additional oxygen delivered by an aeration system, in conjunction with the mixing action provided by the SB10000 circulator, may allow the lake to become completely aerated.

Dredging

Lake sediments contain much higher phosphorus concentrations than the water. Excavating the sediment in Sylvan Lake could reduce a significant source of phosphorus. Future dredging activities should be considered for the deeper embayment, because the shallow embayment has been recently dredged and the deeper embayment contains more sediment. Hydraulic dredging should be considered to remove phosphorus-laden sediments.

Hydraulic dredging typically involves a rotating cutter head and a suction pump to remove sediments. The cutter head cuts into sediment layers and churns them into a slurry. The pump vacuums the slurry through floating pipe to an on-shore dewatering facility. One disadvantage of this option is the amount of time and cost involved in dewatering the excavated sediments. The limited amount of level ground in the Sylvan Lake area restricts use of lower-cost alternatives.

The dry dredging option was not considered due to socio-economic reasons and cost. This option would require draining the lake and dewatering the removed sediment. While more sediment could be removed by dry dredging than hydraulic dredging, Custer

State Park may experience a greater loss of revenue if the dry dredging option is pursued. The amount of time required to drain, dredge, and refill the lake could be as much as four years. In addition, the quality and volume of drained water, as well as surface waters downstream of draining or dewatering activities, should be considered before water is discharged downstream.

Artificial Wetlands

Artificial wetlands are typically engineered systems that use natural processes involving wetland vegetation, soils, and their associated microbial assemblages to assist in treating an effluent or other source of water. Wetland plants assimilate nutrients, reducing concentrations in receiving waters.

Artificial wetlands are being constructed throughout the country to control the nutrient loadings to water bodies. Several communities in South Dakota, including Clear Lake, Huron, Lake Cochrane, Pickerel Lake, and Richmond Lake, have received Clean Water State Revolving Fund (CW-SRF) loans to construct artificial wetlands to improve their wastewater treatment facilities. In these cases, the wetlands follow a lagoon treatment system to further reduce pollutant levels in the wastewater prior to discharge.

Numerous studies have demonstrated the non-point source pollutant removal capabilities of artificial wetland systems. Total phosphorus concentrations have been reduced by up to 90%; the amount of phosphorus reduction dependent on wetland size, plant species composition, soil properties, maintenance, etc. (USEPA 2001).

It is recommended that artificial wetlands be constructed on the inlet streams to reduce phosphorus loads from the watershed. Current total phosphorus loads are 3.8 and 7.1 kg/yr for SLT-3 and SLT-4, respectively. The proposed wetland areas should reduce this total phosphorus load from 10.9 to 1.1 kg/year, approximately a 90% reduction (Fischer et al. 2004).

Bioremediation

One of the effects of alum treatment is increased water transparency. As algae become limited by the decrease in phosphorus concentration, the water will become more transparent. This increased water clarity may allow for natural establishment of emergent and submersed aquatic vegetation, which will further improve water quality. As algal density decreases and macrophyte colonization increases, water quality is predicted to improve.

The benefits of aquatic macrophytes are well documented. Heavy stands of emergent and submerged macrophytes have been linked to a distinct reduction of phytoplankton (Wetzel 2001). Macrophyte colonization also aids in stabilization of sediments in the littoral zone, provides habitat for fish and invertebrates, and maintains water clarity (Moss et al. 1997).

Currently, minimal aquatic vegetation exists. Cattails are scattered along the shoreline and a small amount of submergent vegetation can be found in the littoral zone of the shallow embayment. A large portion of the macrophytes were removed during the dredging activities of the previous restoration project. If macrophytes do not recolonize naturally, manual planting of desirable species should be considered.

Another biological technology, biofiltration, is being employed to reduce phosphorus concentrations in surface waters. Biofiltration is based on the controlled use of the ecological characteristics of common mollusk species. Freshwater mussels are natural filter feeders, which effectively and efficiently filter organic and inorganic matter from the water.

The biofiltration technology has very low costs. Most construction, including the preparation of the bedding, can be accomplished with minimal labor and materials costs. The filtration capacity is a characteristic feature of every mollusk species. On average, a single freshwater mussel (about 3 cm in diameter) can filter approximately 100 ml/hour. The volume of water filtered can be very large. Freshwater mussel populations in an area of 100 m^2 can filter a volume up to 28,000 m^3/day and absorb up to 5.5 g of phosphorus and 11.5 g of nitrogen (United Nations Environment Programme 2004).

It should be noted that this treatment method is considered experimental. Further research may be required before this technique is widely implemented. Consideration should also be given to the species of mollusk selected; non-native species should not be used.

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Appendix A

Total Maximum Daily Load (TMDL) Summary

TOTAL MAXIMUM DAILY LOAD EVALUATION

For

Sylvan Lake

(HUC 10120109)

Custer County, South Dakota

South Dakota Department of Environment and Natural Resources

November 05

Sylvan Lake Total Maximum Daily Load

Waterbody Type:	Lake (Impoundment)
303(d) Listing Parameter:	Trophic State Index (TSI)
Designated Uses:	Recreation, Coldwater Permanent Fish Life Propagation Water
Size of Impaired Waterbody:	18 acres
Size of Watershed:	565 acres
Water Quality Standards:	Narrative and Numeric
Indicators:	Trophic State Index and Total phosphorus concentrations
Analytical Approach:	Models including BATHTUB and FLUX
Location:	HUC Code: 10120109
Goal:	75% reduction of phosphorus load
Target:	Phosphorus TSI = 45 (lake total phosphorus concentration = 0.02 mg/L)

Objective

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

Introduction

Sylvan Lake is an 18-acre impoundment located in the Spring Creek Basin in northern Custer County, South Dakota (Figure 1). The lake reaches a maximum depth of 34 feet (10.5 m) and holds a total water volume of 214 acre-ft (at spillway elevation). Two unnamed inlets are located on the south and east sides of the lake. Portions of the lake exhibit thermal stratification during spring and summer months. The 2004 South Dakota 303(d) Waterbody List identified Sylvan Lake for TMDL development due to elevated trophic state index (TSI) values. Information supporting this listing was derived from statewide lake assessment data.

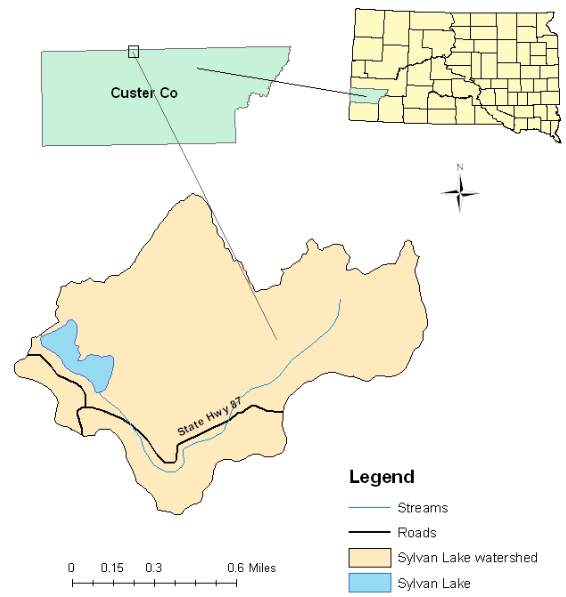

Figure 1. Location of Sylvan Lake and watershed in Custer County, South Dakota.

Problem Identification

The unnamed streams to Sylvan Lake Dam drain a watershed of 565 acres that predominantly consists of evergreen forest and state park camping areas (Figure 2). The streams carry sediment and nutrient loads, which degrade water quality in the lake and have caused increased eutrophication. An estimated 12.4 kg/year of phosphorus enter Sylvan Lake from watershed runoff.

The source of nonpoint source pollution loading from the Sylvan Lake watershed is likely a combination of recreational uses, forest management, as well as background sources (i.e. wildlife, natural weathering, etc.). However, degraded water quality in Sylvan Lake is primarily attributed to recreational activity within the watershed. According to Wierenga and Payne (1987), 5% of the total watershed area has been converted to commercial or developed recreational use. Approximately 90% of the watershed land area is managed by the SD Department of Game, Fish and Parks (Custer State Park), while the remaining 10% is managed by the US Forest Service. Although much of the watershed remains in its natural state, the intense usage of recreational facilities within Custer State Park has degraded the watershed condition.

Sylvan Lake also experiences considerable internal phosphorus loading from lake-bottom sediment. An estimated 7.3 kg/yr of total phosphorus is delivered from the lake sediment.

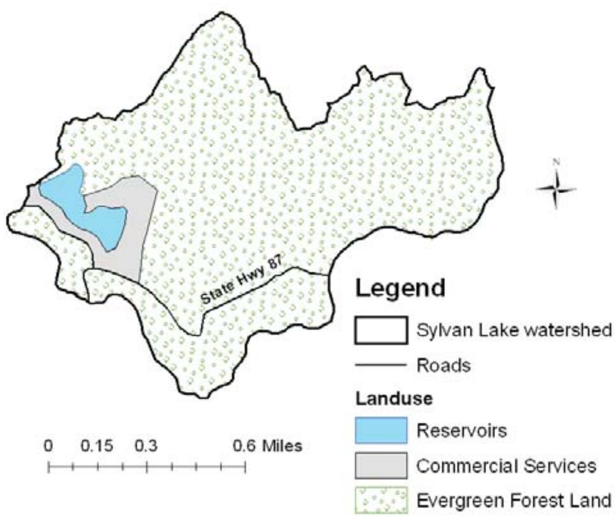

Figure 2. Sylvan Lake watershed landuse.

Description of Applicable Water Quality Standards & Numeric Water Quality Targets

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

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

Individual parameters, including the lake's TSI value, determine the support of these beneficial uses. Sylvan Lake experiences internal phosphorus loading from its sediments and external phosphorus loading from its watershed, which has caused increasing eutrophication. Sylvan Lake is identified in the 1998, 2002, and 2004 South Dakota Waterbody Lists as impaired due to its eutrophic state. The 2002 and 2004 lists identify Sylvan Lake as a high priority waterbody in terms of TMDL development.

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

If adequate numeric criteria are not available, the South Dakota Department of Environment and Natural Resources (SD DENR) uses surrogate measures to indicate impairment. To assess the trophic status of a lake, SD DENR uses the mean Trophic State Index or TSI (Carlson 1977). The mean TSI incorporates measures of Secchi depth, chlorophyll *a* concentrations, and phosphorus concentrations.

SD DENR has developed a protocol that establishes desired TSI levels for lakes based on an ecoregion approach (Stueven et al. 2000b). Sylvan Lake falls in the Middle Rockies Ecoregion. The mean TSI criterion established for this ecoregion is a mean TSI of 45.

Model results show that Secchi depth TSI values amplify overall Mean TSI values, and may not accurately represent conditions of eutrophy in Sylvan Lake. Because Secchi depth measurements may be influenced by factors other than phosphorus concentrations and because measured chlorophyll concentrations were not available, it was decided that phosphorus TSI values alone should be used to determine support status.

This protocol was used to assess impairment and determine a numeric target for Sylvan Lake. Sylvan Lake is currently considered partially supporting its beneficial uses with an average phosphorus TSI of 53. The numeric target established to improve the trophic state of Sylvan Lake is a phosphorus TSI value of 45, which equates to approximately 0.02 mg/L total phosphorus. A 75% reduction of total phosphorus load (a combination of external and internal load reductions) would be required to meet this goal. This reduction of phosphorus load will result in average lake phosphorus concentrations of approximately 0.02 mg/L and lower the TSI value by approximately 8 points and improve the trophic level of the lake from partially to fully supporting beneficial uses.

Pollutant Assessment

Point Sources

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

Nonpoint Sources

According to BATHTUB model results, greater than 90% reduction of watershed phosphorus loads is required meet the TMDL numeric target (i.e. phosphorus TSI = 45). Clearly, non-point sources of phosphorus from the watershed (external load) are only a portion of the total phosphorus load to Sylvan Lake. Still, external loads should be targeted for reductions using management practices recommended in the assessment report. Up to 90% of external load could be reduced with the implementation of constructed wetlands on inlet drainages.

Internal phosphorus loading from lake-bottom sediment is a significant source of phosphorus and should also be targeted for reductions. Alum treatment is recommended to remove phosphorus and suspended solids from the water column. Alum that settles to the bottom of the lake will also form a phosphorus-binding blanket on the sediment surface, thereby reducing the internal phosphorus loading potential of the lake sediment. Approximately 50% of the internal load could be reduced by applying alum to Sylvan Lake.

Excessive nutrient loading to Sylvan Lake has contributed to a higher oxygen demand and lower hypolimnetic DO levels. The proposed management practices to reduce phosphorus concentrations are expected to also improve the DO levels in Sylvan Lake.

Alum treatment, in conjunction with the construction of artificial wetlands, should result in a 75% reduction of the overall total phosphorus load to Sylvan Lake. The TMDL target can be achieved with the implementation of the above management practices.

Linkage Analysis

Water quality data was collected at two lake sites and three stream sites, including the lake's inlet and outlet. Lake samples were composited for analysis. 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 Energy Laboratories, Inc. in Rapid City, SD for analysis. Quality Assurance/Quality Control samples were collected on 10% of the samples according to South Dakota's EPA approved Non-point Source Quality Assurance/ Quality Control Plan. Details concerning water sampling techniques, analysis, and quality control are addressed in the assessment final report.

Phosphorus export coefficients were calculated for each subwatershed and were used to define critical non-point source (NPS) pollution areas within the watershed (those with higher sediment and phosphorus loads). The SLT-3 subwatershed displayed a higher phosphorus export coefficient than the SLT-4 subwatershed. When considering locations for implementation of BMPs to control erosion and nutrient runoff, the SLT-3 subwatershed should be given higher priority than the SLT-4 subwatershed. However, modeled management practices recommended in this report are intended to be implemented in both subwatersheds.

TMDL Allocations

Wasteload Allocation

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

Load Allocation (LA)

Current total phosphorus loads from the watershed are approximately 12.4 kg/yr. A 90% reduction of external phosphorus load to Sylvan Lake may be achieved through the implementation of constructed wetlands, resulting in an annual load of approximately 1.2 kg.

Current total phosphorus loads from the lake sediment (internal load) are approximately 7.3 kg/yr. A 50% reduction of internal phosphorus load in Sylvan Lake may be achieved through the addition of aluminum sulfate (i.e. alum treatment), resulting in an annual internal load or phosphorus recycling of approximately 3.7 kg (Table 1).

Table 1. Load allocation (kg/yr) summary for Sylvan Lake.

Load source	Current Load	BMP	Reduction	TMDL
External	12.4	Artificial wetlands	90%	1.2
Internal	7.3	Alum treatment	50%	3.7
Total	**19.7**		**75%**	**4.9**

Seasonal Variation

Different seasons of the year can yield differences in water quality due to changes in precipitation and landuse. To determine seasonal differences, Sylvan Lake sample data was graphed by month to facilitate viewing seasonal differences. Nearly all parameters assessed in this study displayed seasonal variation. For example, lake total phosphorus concentrations are highest in the early spring and late fall. Because much of the biologically available phosphorus is assimilated by algae, concentrations decrease during the early part of the growing season. Concentrations increase in the fall as algae assimilation decreases.

Seasonal hydrologic loadings from the Sylvan Lake watershed were also calculated. Seasonality in the hydrologic loads appeared to vary by location. Approximately one-third of the hydrologic load from subwatershed SLT-4 occurred during the fall months, while approximately one-third of the hydrologic load from SLT-3 subwatershed occurred during the spring (see page 13 of the assessment report for seasonal hydrologic budget).

Margin of Safety

The margin of safety is implicit based on conservative estimations of lake model coefficients and a conservative estimation of the percent reduction of total phosphorus achieved with the alum treatment.

Critical Conditions

The impairments to Sylvan Lake are most severe during late summer. This is the result of warm water temperatures and peak algal growth.

The TMDL load represents a measured load and may not represent the long term average load due to recent drought conditions.

Follow-Up Monitoring

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

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

Public Participation

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

1. Presentations to local groups on the findings of the Sylvan Lake assessment.
2. 30-day public notice period for public review and comment.

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

Implementation Plan

Funds to implement lake and watershed water quality improvements can be obtained through the SD DENR. SD DENR administers three major funding programs that provide low interest loans and grants for projects that protect and improve water quality in South Dakota. They include: Consolidated Water Facilities Construction program, Clean Water State Revolving Fund (SRF) program, and the Section 319 Nonpoint Source Grants program.

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Appendix B

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

SOUTH DAKOTA STATEWIDE FISHERIES SURVEY

2102 - F21-R-29

Name: Sylvan Lake County: Custer
Legal description: Sec. 30, R5E, T2S
Location from nearest town: 5 1/2 miles N and 1 1/2 miles E of Custer, SD.

Dates of present survey: 21-22 June 1995
Date last surveyed: 13-14-15 June 1990
Most recent lake management plan: F21-R-23 Date: 1989
Management classification: Coldwater Permanent
Contour mapped: Date 1987

Primary Species: (game and forage) Secondary and other species:
1. Hatchery rainbow trout 1. Golden shiner
2. ______________ 2. Fathead minnow

PHYSICAL CHARACTERISTICS

Surface Area: 17.3 acres; Watershed: 560 acres
Maximum depth: 34 feet; Mean depth: 12.8 feet
Lake elevation at survey (from known benchmark): full

1. Describe ownership of lake and adjacent lakeshore property:

Sylvan Lake is located within the boundary of Custer State Park and is owned by South Dakota Department of Game, Fish and Parks.

2. Describe watershed condition and percentages of land use:

The watershed for Sylvan Lake is located within Custer State Park and the Black Hills National Forest. Ponderosa pine and black hills spruce are the dominant trees within the watershed. Topography of watershed is mainly steep granite outcroppings; a part of the Black Hills commonly referred to as the "needles". Immediately adjacent to the lake is a parking lot, picnic area and store & paddle-boat concession. There is a campground in the drainage above the lake. A hotel/restaurant complex, several rental cabins and a dormitory for summer help are located to the west and south of the lake. Sewage from the dormitory, hotel/restaurant and cabins is treated in the Willow Creek drainage flowing to the southwest away from the lake. Roadways and parking lots were paved after the shallow, south portion of the lake was dredged to remove silt in 1982.

3. Describe aquatic vegetative condition:

There is minimal aquatic vegetation; some cattails are scattered along the shoreline and a small amount of submergent vegetation is located in the shallower portions of the lake.

4. Describe pollution problems:

No pollution problems were observed during the lake survey. Silt from roadways and parking lots have been addressed by paving.

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

All structures appeared to be in good condition.

CHEMICAL DATA

1. Describe general water quality characteristics.

One station (A) was established near the dam and sampled on 21 June 1995 to measure chemical parameters. (See Table 1). Field measurements included temperature profile, transparency, plus surface readings for dissolved oxygen, specific conductance, pH. Temperature and dissolved oxygen were taken with a YSI electric thermometer and dissolved oxygen meter. Conductivity was determined with a YSI #33 conductivity meter. Water transparency was estimated using a 20 cm Secchi disc. A phTestr 1 model 35624-00 by OAKTON was used to measure pH. A water sample was collected from the surface, processed and sent to the laboratory for total phosphorus and chlorophyll a analysis. Water was brownish in color.

Winter dissolved oxygen check on 10 January 1995 indicated 11.8 ppm at the surface and 4.2 ppm at 6.7 meters. Water temperature was 4.0^0C.

2. Thermocline: Yes X No __ Located between 2.0 and 4.0 meters.

3. Secchi disc reading: 1.4 m (2.58 ft.)

4. Station A for water chemistry is located on attached lake map (APPENDIX Figure 1).

Table 1. Water chemistry results from Sylvan Lake, Custer County, on 21 June 1995.

Station	Depth Meters	Temp ^{o}C	pH	DO ppm	Conductivity *u*mhos/cm^3	Chl a (mg/m^3)	Total (PO4)mg/l
A	S	19.0	8.6	8.0	54	3.69	0.256
A	2	14.0					
A	4	7.0					
A	6	6.0					
A	8	5.5					
A	10	5.0					

Trophic State Indices (TSI) for secchi disk transparency, chlorophyll a and total phosphorus were calculated according to criteria developed by Carlsen (1977). The TSI ranking is from 1-100. Lakes with low TSI values (<35) are considered oligotrophic, (35 to 50) as mesotrophic and with values (>50) indicating eutrophic conditions. Table 2 compares 1995 TSI values with data as reported by Koth (1981) and Stewart & Stueven (1994).

Table 2. Trophic State Indices (TSI) for Sylvan Lake 1979-1980-1989-1991-1993 and 1995. Indices include Secchi disk transparency (SD), chlorophyll a (Chl a) and Total Phosphorus (TP).

TSI Values	1979	1980	1989	1991	1993	1995	Mean
SD	63	64	52	60	62	55	59
Chl a	-	66	-	64	69	43	60
TP	61	-	73	80	70	84	74

Mean TSI values of 59, 60 and 74 SD,Chl a and TP respectively, indicate a eutrophic condition.

BIOLOGICAL DATA

1. Describe fish collection methods:

Gear used:

4 Frame net sets, 3/4 inch mesh with 75 foot leads.
1 Baby frame net set, 1/2 inch mesh with 25 foot lead.
2 Quarter arc seine hauls with 100 ft x 6 ft x 1/4 inch mesh seine.

Results:

Golden shiner (104) were the only species collected in four frame net sets (Table 3 and Appendix Table 1). Lengths and weights of fish were recorded.

Table 3. Total catch of four, 24 hour, 3/4 inch frame nets, at Sylvan Lake, Custer County, 21-22 June 1995.

Species	Total Number Caught	%	Total Weight (grams)	%	Mean Weight (grams)	Mean Length (mm)	Catch per Effort (CPUE)
Golden shiner	104	100.0	3,835	100.0	36.9	146.0	26.0

One baby frame net set on 21-22 June yielded fathead minnow (4) and golden shiner (4)(Table 4 and Appendix Table 2). All fish were measured for length and weight.

Table 4. Total catch of one, 24 hour, baby frame net, at Sylvan Lake, Custer County, 21-22 June 1995.

Species	Total Number Caught	%	Total Weight (grams)	%	Mean Weight (grams)	Mean Length (mm)	Catch per Effort (CPUE)
Fathead Minnow	4	50.0	20	9.2	5.0	72.3	4.0
Golden shiner	4	50.0	198	90.8	49.5	163.7	4.0
Totals	8	100.0	218	100.0			

Two quarter arc seining hauls were made to sample young of year (YOY) and forage species. Fish collected by seine were identified by species, measured and weighed (Table 5 and Appendix Table 3). No YOY were observed at the time of the survey.

Table 5. Total catch of two quarter arc seine hauls, 100 feet x 6 feet by 1/4 inch mesh at Sylvan Lake, Custer County, 21 June 1995.

Species	Total Number Caught	%	Total Weight (grams)	%	Mean Weight (grams)	Mean Length (mm)	Catch per Effort (CPUE)
Fathead minnow	106	43.3	474	9.8	4.5	74.3	53.0
Golden shiner	130	53.1	3,123	64.9	24.0	128.7	65.0
Hatchery rainbow	9	3.7	1,215	25.3	135.0	247.9	4.5
Totals	245	100.1	4,812	100.0			

Although Sylvan Lake is managed as a put and take rainbow trout fishery only 9 hatchery rainbow trout were captured by all sampling methods. Annual scheduled stocking of catchable rainbow trout and occasional supplemental stocking of adult rainbow (Appendix Table 4) maintain a viable trout fishery.

Length-frequency charts for species and gear type are shown in Appendix Figures 2 and 3.

RECOMMENDATIONS

1. Continue with six stockings of rainbow trout catchables annually totaling 13,560 fish. 1996 schedule is shown. Dates will change in following years.

01 May 1996	2,480
22 May 1996	2,480
12 June 1996	2,100
30 June 1996	2,100
24 July 1996	2,400
14 August 1996	2,000
Total	13,560

2. Conduct a lake survey on Sylvan Lake in mid to late June in the year 2000 or sooner if deemed necessary.

APPENDIX Table 1. Results of four individual frame net sets on Sylvan Lake, Custer County on 21-22 June 1995.

Frame Net #	1	2	3	4	Total
Species					
Golden shiner	0	100	2	2	104

APPENDIX Table 2. Results of one baby frame net set on Sylvan Lake, Custer County on 21-22 June 1995.

Frame Net #	1
Species	
Fathead minnow	4
Golden shiner	4
Total	8

APPENDIX Table 3. Results of two individual quarter arc seine hauls made on Sylvan Lake, Custer County on 21 June 1995.

Seine #	1	2	Total
Species			
Fathead minnow	6	100	106
Golden shiner	51	79	130
Hatchery rainbow trout	8	1	9
Totals	65	180	245

APPENDIX Table 4. Stocking record for Sylvan Lake, Custer County, for 1983 through 1995.

Species	Year	Number	Size
Rainbow trout	1983	12,285	Catchable
Rainbow trout	1984	12,285	Catchable
Rainbow trout	1986	13,560	Catchable
		81	Adult
Rainbow trout	1987	12,285	Catchable
		30	Adult
Rainbow trout	1988	13,560	Catchable
Rainbow trout	1989	13,560	Catchable
		200	Adult
Rainbow trout	1990	13,560	Catchable
		211	Adult
Rainbow trout	1991	13,560	Catchable
Rainbow trout	1992	13,560	Catchable
		248	Adult
Rainbow trout	1993	13,560	Catchable
Rainbow trout	1994	13,940	Catchable
Rainbow trout	1995	13,860	Catchable

Appendix C

Assessment Data

Chemical Data

Site	Date	Time	RelDepth	Personnel	Depth	Fecal	E Coli	Alka	Tot Sol	TDS	TSS	TVSS	Ammo	Nitrate	TKN	Tot P	TDP	NO3+NO4	S Type	S Depth	Tot N	Secchi	TSI Chl a	TSI Tot P	TSI Secchi	TSI N	TSI Mean
Comp	16-Jun-04	13:00	Surface	Larson/Mateo				44	77	73	4	<1	<.02	<0.10	0.44	0.031	0.01		GRAB	1.0		3.23	53.59	53.67	43.10		50.12
Comp	16-Jun-04	13:00	Bottom	Larson/Mateo				45	76	75	1	1	0.08	<0.10	0.64	0.029	0.01		GRAB					52.71			
Comp	22-Jul-04	11:00	Surface	Larson/Mateo				43	80	75	5	1	<.02	<0.10	0.39	0.030	0.01		GRAB	1.0		2.55	50.51	53.20	46.51		50.07
Comp	22-Jul-04	11:00	Bottom	Larson/Mateo				46	80	72	8	2	0.17	<0.10	0.73	0.045	0.01		GRAB					59.04			

Site	Date	Time	RelDepth	Personnel	Depth	Fecal	E Coli	Alka	Tot Sol	TDS	TSS	TVSS	Ammo	Nitrate	TKN	Tot P	TDP	NO3+NO4	S Type	S Depth	Tot N	Secchi	TSI Chl a	TSI Tot P	TSI Secchi	TSI N	TSI Mean
SL05	23-Aug-01	10:57		Scott Alan	0.5	2		36	74	58	16		<0.10		2.10	0.090	<0.01	<0.05	GRAB	0.2	2.10			69.04		65.16	
SL05	25-Sep-01	15:32		Scott Alan	0.6	<2		34	78	69	9		0.10		1.50	0.070	0.02	0.12	GRAB	0.3	1.62			65.41		61.41	
SL05	18-Apr-02	15:58		Scott Alan	0.5	<2	<2	44	68	42	26		0.30		1.00	0.090	0.02	0.15	GRAB	0.2	1.15			69.04		56.47	
SL05	24-Apr-02	12:00		Scott Alan	0.5	<2	<2	42	84	78	6		0.30		1.10	0.060	<0.01	0.07	GRAB	0.2	1.17			63.19		56.72	
SL05	2-May-02	11:17		Scott Alan	0.7	<2	<2	40	78	69	9		0.10		0.90	0.130	0.01	<0.05	GRAB	0.3	0.90			74.34		52.93	
SL05	26-Jun-02	13:41		Scott Alan	0.6	48	10	38	86	65	21		<0.10		0.70	0.080	0.02	<0.05	GRAB	0.3	0.70			67.34		49.30	
SL05	21-Jul-02	15:00		Scott Alan	0.5	250	<10	38	100	77	23		0.10		0.70	0.040	0.01	<0.05	GRAB	0.3	0.70			57.34		49.30	
SL05	12-Aug-02	17:03		Scott Alan	0.5	20	<10	40	70	63	7		0.10		1.00	0.050	<0.01	<0.05	GRAB	0.3	1.00			60.56		54.45	

Site	Date	Time	RelDepth	Personnel	Depth	Fecal	E Coli	Alka	Tot Sol	TDS	TSS	TVSS	Ammo	Nitrate	TKN	Tot P	TDP	NO3+NO4	S Type	S Depth	Tot N	Secchi	TSI Chl a	TSI Tot P	TSI Secchi	TSI N	TSI Mean
SL1	23-Aug-01	10:14	Surface	Scott Alan	26.2	<2		34	62	45	17		<0.10		2.10	0.060	<0.01	<0.05	GRAB	1.0	2.10	0.50		63.19	69.99	65.16	66.59
SL1	23-Aug-01	10:14	Bottom	Scott Alan	26.2	<2		38	54	48	6		0.10		1.20	0.050	<0.01	<0.05	GRAB	26.2	1.20			60.56		57.08	
SL1	25-Sep-01	13:45	Surface	Scott Alan	24.6	<2		38	58	55.5	<5		<0.10		1.50	0.050	0.02	<0.05	GRAB	1.0	1.50	1.50		60.56	54.16	60.30	57.36
SL1	25-Sep-01	13:45	Bottom	Scott Alan	24.6	<2		38	72	69.5	<5		0.20		1.20	0.050	0.01	<0.05	GRAB	24.6	1.20			60.56		57.08	
SL1	31-Oct-01	12:50	Surface	Scott Alan	24.6	<5	<2	42	80	77.5	<5		0.40		1.20	0.070	0.02	<0.05	GRAB	1.0	1.20	2.50		65.41	46.80	57.08	56.10
SL1	31-Oct-01	13:07	Bottom	Scott Alan	24.6	<2	<2	36	72	69.5	<5		0.40		1.20	0.060	0.02	<0.05	GRAB	24.6	1.20			63.19		57.08	
SL1	27-Dec-01	15:00	Surface	Scott Alan	24.6	<2	<2	42	70	67.5	<5		0.40		1.20	0.050	0.04	0.12	GRAB	1.0	1.32			60.56		58.46	
SL1	27-Dec-01	13:25	Bottom	Scott Alan	24.6	<2	<2	44	64	61.5	<5		0.40		1.20	0.050	0.03	0.09	GRAB	24.6	1.29			60.56		58.12	
SL1	30-Jan-02	15:40	Surface	Scott Alan	26.2	<2	<2	40	92	89.5	<5		0.30		1.20	0.070	0.02	0.15	GRAB	1.0	1.35			65.41		58.78	
SL1	30-Jan-02	16:00	Bottom	Scott Alan	26.2	<2	<2	40	70	67.5	<5		0.40		1.20	0.070	0.01	0.07	GRAB	26.2	1.27			65.41		57.90	
SL1	26-Feb-02	16:45	Surface	Scott Alan	23.0	<2	<2	30	50	47.5	<5		0.20		0.80	0.040	<0.01	0.11	GRAB	1.0	0.91			57.34		53.09	
SL1	26-Feb-02	16:27	Bottom	Scott Alan	23.0	<2	<2	34	67	64.5	<5		0.30		1.00	0.040	<0.01	0.11	GRAB	23.0	1.11			57.34		55.96	
SL1	13-May-02	15:27	Surface	Scott Alan	23.0	<2	<2	36	64	16	48		<0.10		0.80	0.040	0.01	<0.05	GRAB	1.0	0.80	1.50		57.34	54.16	51.23	55.75
SL1	13-May-02	15:27	Bottom	Scott Alan	23.0	<2	<2	36	62	22	40		<0.10		0.60	0.040	0.02	<0.05	GRAB	23.0	0.60			57.34		47.08	
SL1	6-Jun-02		Surface	Scott Alan	24.6	<2	<2	42	64	61.5	<5		<0.10		<0.50	0.020	<0.01	<0.05	GRAB	1.0		4.25		47.35	39.15		43.25
SL1	6-Jun-02	16:40	Bottom	Scott Alan	24.6	<2	<2	38	63	60.5	<5		0.10		0.80	0.040	<0.01	<0.05	GRAB	24.6	0.80			57.34		51.23	
SL1	1-Jul-02	9:50	Surface	Scott Alan	26.2	<2	<10	38	74	71.5	<5		<0.10		0.70	0.040	<0.01	<0.05	GRAB	1.0	0.70	2.00		57.34	50.01	49.30	53.68
SL1	1-Jul-02	9:50	Bottom	Scott Alan	26.2	<2	<10	44	74	66	8		0.40		1.10	0.060	0.01	<0.05	GRAB	26.2	1.10			63.19		55.83	
SL1	5-Aug-02	15:28	Surface	Scott Alan	24.6	<2	<10	38	66	61	5		<0.10		0.90	0.030	<0.01	<0.05	GRAB	1.0	0.90	1.50		53.20	54.16	52.93	53.68
SL1	5-Aug-02	15:28	Bottom	Scott Alan	24.6	<2	<10	44	64	58	6		0.20		1.20	0.020	0.08	<0.05	GRAB	24.6	1.20			47.35		57.08	
SL1	17-Apr-03	12:45	Surface	Larson/Goyer	24.0			41	76	68	8	3	<0.02	<0.10	0.39	0.058	0.03		GRAB	1.0		0.80		62.70	63.22		
SL1	17-Apr-03	12:45	Bottom	Larson/Goyer	24.0			52	88	76	12	4	0.52	<0.10	0.71	0.067	0.03		GRAB	24.0				64.78			
SL1	16-May-03	11:00	Bottom	Larson/Goyer	25.0			40	74	69	5	2	<0.02	<0.10	<0.11	0.065	0.03		GRAB	25.0				64.34			
SL1	16-May-03	11:00	Surface	Larson/Goyer	25.0			39	70	65	5	3	<0.02	<0.10	0.34	0.036	0.02		GRAB	1.0		1.00	50.00	55.82	60.00		55.27
SL1	12-Jun-03	11:05	Surface	Larson/Goyer	25.5			40	70	64	6	5	<0.02	<0.10	0.42	0.030	0.01		GRAB	1.0		2.40		53.20	47.38		
SL1	12-Jun-03	11:05	Bottom	Larson/Goyer	25.5			44	75	65	10	7	0.03	<0.10	0.31	0.047	0.02		GRAB	25.5				59.67			
SL1	2-Jul-03	11:00	Bottom	Larson/Goyer	25.7			45	86	74	12	7	0.06	<0.10	0.60	0.084	0.02		GRAB	25.0				68.04			
SL1	2-Jul-03	11:00	Surface	Larson/Goyer	25.7			40	75	71	4	3	<0.02	<0.10	0.48	0.027	0.02		GRAB	1.0		3.70	47.00	51.68	41.15		46.61
SL1	17-Jul-03	11:30	Bottom	Larson/Goyer	25.0			48	85	76	9	7	0.27	<0.10	0.87	0.074	0.03		GRAB	25.0				66.21			
SL1	17-Jul-03	11:30	Surface	Larson/Goyer	25.0			40	69	64	5	3	<0.02	<0.10	0.42	0.027	0.02		GRAB	1.0		2.20	48.00	51.68	48.64		49.44
SL1	19-Aug-03	12:30	Bottom	Larson/Goyer	23.4			62	105	99	6	4	1.04	<0.10	1.43	0.084	0.03		GRAB	23.0				68.04			
SL1	19-Aug-03	12:30	Surface	Larson/Goyer	23.4			40	81	75	6	6	<0.02	<0.10	0.67	0.036	0.02		GRAB	1.0		1.10	63.00	55.82	58.63		59.15

Site	Date	Time	RelDepth	Personnel	Depth	Fecal	E Coli	Alka	Tot Sol	TDS	TSS	TVSS	Ammo	Nitrate	TKN	Tot P	TDP	NO3+NO4	S Type	S Depth	Tot N	Secchi	TSI Chl a	TSI Tot P	TSI Secchi	TSI N	TSI Mean
SL2	23-Aug-01	9:50	Surface	Scott Alan	8.2	<2		34	70	61	9		<0.10		1.50	0.050	<0.01	<0.05	GRAB	1.0	1.50	1.00		60.56	60.00	60.30	60.28
SL2	23-Aug-01	9:50	Bottom	Scott Alan	8.2	<2		34	54	38	16		<0.10		1.50	0.060	<0.01	<0.05	GRAB	8.2	1.50			63.19		60.30	
SL2	25-Sep-01	12:05	Surface	Scott Alan	6.6	<2		38	60	52	8		0.10		1.20	0.050	0.02	<0.05	GRAB	1.0	1.20	1.50		60.56	54.16	57.08	57.36
SL2	25-Sep-01	12:05	Bottom	Scott Alan	7.4	<2		36	78	72	6		0.10		1.20	0.060	0.02	<0.05	GRAB	7.4	1.20			63.19		57.08	
SL2	31-Oct-01	13:27	Surface	Scott Alan	6.6	<2	<2	38	78	75.5	<5		0.40		1.20	0.080	0.03	<0.05	GRAB	1.0	1.20	2.00		67.34	50.01	57.08	58.68
SL2	31-Oct-01	13:43	Bottom	Scott Alan	7.4	<2	<2	38	70	67.5	<5		0.40		1.50	0.080	0.02	<0.05	GRAB	7.4	1.50			67.34		60.30	
SL2	27-Dec-01	16:01	Surface	Scott Alan	6.6	<2	<2	40	72	67	5		0.40		1.10	0.060	0.02	0.12	GRAB	1.0	1.22			63.19		57.32	
SL2	27-Dec-01	16:27	Bottom	Scott Alan	6.6	<2	<2	46	72	69.5	<5		0.40		1.20	0.060	0.02	0.12	GRAB	6.6	1.32			63.19		58.46	
SL2	30-Jan-02	16:27	Surface	Scott Alan	6.6	<2	<2	42	78	75.5	<5		0.20		0.90	0.050	<0.01	0.12	GRAB	1.0	1.02			60.56		54.74	
SL2	30-Jan-02	16:47	Bottom	Scott Alan	6.6	<2	<2	40	78	73	5		0.20		0.90	0.050	<0.01	0.11	GRAB	6.6	1.01			60.56		54.59	
SL2	26-Feb-02	16:55	Surface	Scott Alan	6.9	<2	<2	30	50	47.5	<5		<0.10		0.80	0.040	<0.01	0.09	GRAB	1.0	0.89			57.34		52.77	
SL2	26-Feb-02	17:17	Bottom	Scott Alan	6.6	<2	<2	32	62	59.5	<5		<0.10		1.20	0.060	<0.01	0.09	GRAB	6.6	1.29			63.19		58.12	
SL2	13-May-02	15:49	Surface	Scott Alan	8.2	<2	<2	38	70	24	46		<0.10		0.90	0.050	0.01	0.17	GRAB	1.0	1.07	1.00		60.56	60.00	55.43	60.28
SL2	13-May-02	15:49	Bottom	Scott Alan	8.2	<2	<2	34	70	8.0	62		<0.10		0.90	0.060	0.01	<0.05	GRAB	8.2	0.90			63.19		52.93	
SL2	6-Jun-02	17:10	Surface	Scott Alan	8.2	<2	<2	34	58	55.5	<5		<0.10		0.60	0.020	<0.01	<0.05	GRAB	1.0	0.60	2.50		47.35	46.80	47.08	47.07
SL2	6-Jun-02	17:49	Bottom	Scott Alan	8.2	<2	<2	36	69	66.5	<5		<0.10		0.60	0.020	0.01	<0.05	GRAB	8.2	0.60			47.35		47.08	
SL2	1-Jul-02	10:24	Surface	Scott Alan	8.2	<2	<10	36	74	71.5	<5		<0.10		0.60	0.030	0.01	<0.05	GRAB	1.0	0.60	2.00		53.20	50.01	47.08	51.60
SL2	1-Jul-02	10:24	Bottom	Scott Alan	8.2	2	<2	36	70	67.5	<5		<0.10		0.60	0.020	0.01	<0.05	GRAB	8.2	0.60			47.35		47.08	
SL2	5-Aug-02	15:49	Surface	Scott Alan	8.2	<2	<10	38	64	59	5		<0.10		0.90	0.030	<0.01	<0.05	GRAB	1.0	0.90	1.25		53.20	56.78	52.93	54.99
SL2	5-Aug-02	15:49	Bottom	Scott Alan	8.2	<2	<10	36	58	53	5		<0.10		0.80	0.030	<0.01	<0.05	GRAB	8.2	0.80			53.20		51.23	
SL2	17-Apr-03	14:30	Bottom	Larson/Goyer	10.0			42	86	64	22	4	<0.02	<0.10	0.18	0.065	0.02		GRAB	10.0				64.34			
SL2	17-Apr-03	14:30	Surface	Larson/Goyer	10.0			42	79	69	10	3	<0.02	<0.10	0.29	0.070	0.03		GRAB	1.0		0.90		65.41	61.52		
SL2	16-May-03	10:20	Bottom	Larson/Goyer	7.0			39	75	67	8	4	0.07	<0.10	0.49	0.042	0.02		GRAB	7.0				58.05			
SL2	16-May-03	10:20	Surface	Larson/Goyer	7.0			38	74	69	5	4	<0.02	<0.10	0.38	0.031	0.02		GRAB	1.0		0.90	49.00	53.67	61.52		54.73
SL2	12-Jun-03	10:10	Surface	Larson/Goyer	12.3			40	69	65	4	4	<0.02	<0.10	0.29	0.024	0.02		GRAB	1.0		2.60	31.00	49.98	46.23		42.40
SL2	12-Jun-03	10:10	Bottom	Larson/Goyer	12.3			40	72	67	5	4	<0.02	<0.10	0.34	0.047	0.01		GRAB	12.0				59.67			
SL2	2-Jul-03	10:30	Surface	Larson/Goyer	11.8			39	73	68	5	3	<0.02	<0.10	0.43	0.024	0.02		GRAB	1.0		3.60	46.00	49.98	41.54		45.84
SL2	2-Jul-03	10:30	Bottom	Larson/Goyer	11.8			39	74	67	7	6	<0.02	<0.10	0.45	0.033	0.02		GRAB	11.0				54.57			
SL2	17-Jul-03	10:30	Bottom	Larson/Goyer	15.0			41	75	68	7	4	<0.02	<0.10	0.48	0.038	0.02		GRAB	15.0				56.60			
SL2	17-Jul-03	10:30	Surface	Larson/Goyer	15.0			40	71	65	6	3	<0.02	<0.10	0.36	0.030	0.02		GRAB	1.0		2.20	53.00	53.20	48.64		51.61
SL2	19-Aug-03	12:00	Bottom	Larson/Goyer	13.1			41	86	80	6	5	<0.02	<0.10	0.63	0.047	0.02		GRAB	13.0				59.67			
SL2	19-Aug-03	12:00	Surface	Larson/Goyer	13.1			40	84	80	4	3	<0.02	<0.10	0.70	0.040	0.02		GRAB	1.0		1.00	64.00	57.34	60.00		60.45
Site	**Date**	**Time**	**RelDepth**	**Personnel**	**Depth**	**Fecal**	**E Coli**	**Alka**	**Tot Sol**	**TDS**	**TSS**	**TVSS**	**Ammo**	**Nitrate**	**TKN**	**Tot P**	**TDP**	**NO3+NO4**	**S Type**	**S Depth**	**Tot N**	**Secchi**	**TSI Chl a**	**TSI Tot P**	**TSI Secchi**	**TSI N**	**TSI Mean**
SLT3	23-Aug-01	11:35		Scott Alan	0.3	30		18	58	53	5		<0.10		<0.50	0.150	0.12	0.06	GRAB	0.2	0.06			76.40		13.85	
SLT3	25-Sep-01	15:06		Scott Alan	0.4	35		20	44	39	5		<0.10		<0.50	0.180	0.15	0.09	GRAB	0.2	0.09			79.03		19.70	
SLT3	10-Oct-01	11:29		Scott Alan	0.4	<4		18	52	49.5	<5		<0.10		0.60	0.190	0.14	0.09	GRAB	0.2	0.69			79.81		49.10	
SLT3	31-Oct-01	12:08		Scott Alan	0.4	<2	<2	20	72	69.5	<5		<0.10		<0.50	0.190	0.13	0.06	GRAB	0.2	0.06			79.81		13.85	
SLT3	18-Apr-02	15:20		Scott Alan	0.4	<2	<2	22	50	47.5	<5		<0.10		<0.50	0.080	0.07	0.06	GRAB	0.2	0.06			67.34		13.85	
SLT3	24-Apr-02	10:33		Scott Alan	0.3	4	2	24	86	83.5	<5		<0.10		<0.50	0.030	<0.01	0.05	GRAB	0.2	0.05			53.20		11.22	
SLT3	2-May-02	9:50		Scott Alan	0.3	2	<2	24	110	104	6		<0.10		<0.50	0.040	<0.01	0.07	GRAB	0.2	0.07			57.34		16.08	
SLT3	26-Jun-02	13:05		Scott Alan	0.3	6	6	22	74	67	7		<0.10		<0.50	0.060	0.04	<0.05	GRAB	0.2				63.19			
SLT3	21-Jul-02	14:31		Scott Alan	0.2	690	<10	36	80	74	6		<0.10		<0.50	0.080	0.04	<0.05	GRAB	0.2				67.34			
SLT3	12-Aug-02	16:32		Scott Alan	0.2	50	<2	26	62	59.5	<5		<0.10		<0.50	0.130	0.03	<0.05	GRAB	0.2				74.34			
Site	**Date**	**Time**	**RelDepth**	**Personnel**	**Depth**	**Fecal**	**E Coli**	**Alka**	**Tot Sol**	**TDS**	**TSS**	**TVSS**	**Ammo**	**Nitrate**	**TKN**	**Tot P**	**TDP**	**NO3+NO4**	**S Type**	**S Depth**	**Tot N**	**Secchi**	**TSI Chl a**	**TSI Tot P**	**TSI Secchi**	**TSI N**	**TSI Mean**
SLT4	23-Aug-01	11:55		Scott Alan	0.2	20		24	46	44	<5		<0.10		0.60	0.060	0.03	0.15	GRAB	0.3	0.75			63.19		50.30	
SLT4	25-Sep-01	15:24		Scott Alan	0.1	2		26	72	54	18		<0.10		<0.50	0.090	0.05	<0.05	GRAB	0.3				69.04			
SLT4	10-Oct-01	11:40		Scott Alan	0.2	5		24	38	36	<5		<0.10		<0.50	0.050	0.03	<0.05	GRAB	0.3				60.56			
SLT4	31-Oct-01	14:08		Scott Alan	0.1	<2	<2	24	74	72	<5		<0.10		<0.50	0.080	0.02	<0.05	GRAB	0.3				67.34			
SLT4	18-Apr-02	15:36		Scott Alan	0.1	<2	<2	16	58	52	6		<0.10		<0.50	0.180	0.15	0.13	GRAB	0.1	0.13			79.03		25.01	
SLT4	24-Apr-02	11:10		Scott Alan	0.1	<2	<2	42	80	69	11		<0.10		<0.50	0.150	0.10	0.11	GRAB	0.1	0.11			76.40		22.60	
SLT4	2-May-02	10:33		Scott Alan	0.1	<2	<2	16	76	65	11		<0.10		0.25	0.160	0.08	<0.05	GRAB	0.2	0.25			77.33		34.45	
SLT4	26-Jun-02	13:20		Scott Alan	0.2	56	12	14	65	63	<5		<0.10		<0.50	0.130	0.11	<0.05	GRAB	0.3				74.34			
SLT4	21-Jul-02	14:15		Scott Alan	0.2	780	<10	14	82	74	8		<0.10		0.60	0.160	0.11	0.06	GRAB	0.2	0.66			77.33		48.45	
SLT4	12-Aug-02	16:18		Scott Alan	0.2	30	<10	16	52	50	<5		<0.10		<0.50	0.130	0.12	0.08	GRAB	0.2	0.08			74.34		18.00	

Site	Date	Time	RelDepth	Personnel	Depth	Fecal	E Coli	Alka	Tot Sol	TDS	TSS	TVSS	Ammo	Nitrate	TKN	Tot P	TDP	NO3+NO4	S Type	S Depth	Tot N	Secchi	TSI Chl a	TSI Tot P	TSI Secchi	TSI N	TSI Mean
UnK	16-Nov-77	12:30	Surface	Nelson Gene		<3		30	77	62	15		0.03	<0.10	1.05	0.058	0.03		GRAB					62.70			
UnK	6-Feb-78	14:00	Surface	Nelson Gene		<3		39	82	77	5		0.30	<0.10	1.18	0.113	0.01		GRAB					72.32			
UnK	4-May-78	13:15	Surface	Nelson Gene		<3		27	98	85	13		<0.02	<0.10	1.27	0.057	0.01		GRAB					62.45			
UnK	9-Aug-78	10:30	Surface	Nelson Gene		3		20	80	71	9		0.02	<0.10	1.24	0.027	0.02		GRAB					51.68			
UnK	11-Sep-79	13:30	Surface	Nelson Gene				32	65	58	7		0.16	<0.05	0.74	0.100	<0.01		GRAB					70.56			
UnK	6-Oct-81	17:05	Bottom	Goebel Greg				52					1.10	0.18	2.10	0.270	0.21		GRAB	22.0				84.88			
UnK	6-Oct-81	17:10	Bottom	Goebel Greg	27.0			72					3.10	<0.10	8.30	2.450	1.32		GRAB	25.0				116.68			
UnK	6-Oct-81	16:55	Bottom	Goebel Greg				40	30	21	9		0.06	<0.10	0.86	0.070	0.04		GRAB	17.0				65.41			
UnK	6-Oct-81	16:45	Midwater	Goebel Greg				40	10	3	7		0.03	<0.10	0.88	0.054	0.02		GRAB	12.0				61.67			
UnK	6-Oct-81	16:20	Surface	Goebel Greg				39	49	39	10		0.06	<0.10	0.59	0.045	0.02		GRAB	2.0				59.04			
UnK	6-Oct-81	16:35	Surface	Goebel Greg				37	12	5	7		<0.03	<0.10	1.00	0.095	0.05		GRAB	7.0				69.82			
UnK	4-Nov-81	11:20	Bottom	Goebel Greg				45	96	85	11		0.09	0.12	0.70	0.077	0.03		GRAB	14.0				66.79			
UnK	4-Nov-81	10:30	Surface	Goebel Greg	17.0			44	96	83	13		0.05	0.10	0.65	0.082	0.04		GRAB	2.0		1.07		67.69	59.03		
UnK	4-Nov-81	11:00	Midwater	Goebel Greg				43	100	88	12		0.05	0.10	0.62	0.076	0.03		GRAB	8.0				66.60			
UnK	7-Dec-81	10:00	Surface	Goebel Greg	15.5			36	68	65	3		0.20	0.13	1.28	0.055	0.04		GRAB	2.0		1.37		61.94	55.46		
UnK	7-Dec-81	10:20	Midwater	Goebel Greg				38	76	71	5		0.20	0.14	1.50	0.060	0.04		GRAB	7.0				63.19			
UnK	7-Dec-81	10:30	Midwater	Goebel Greg				37	64	60	4		0.19	0.12	1.40	0.075	0.03			12.0				66.41			
UnK	14-Jan-82	10:00	Midwater	Goebel Greg				40	68	66	2		0.51	0.15	1.47	0.093	0.05		GRAB	8.0				69.51			
UnK	14-Jan-82	10:20	Bottom	Goebel Greg	16.0			40	68	65	3		0.51	0.17	1.37	0.097	0.06		GRAB	13.0				70.12			
UnK	14-Jan-82	9:30	Surface	Goebel Greg				40	61	59	2		0.46	0.20	1.42	0.087	0.04		GRAB	2.0		1.52		68.55	53.97		
UnK	3-Feb-82	10:15	Midwater	Goebel Greg					23	18	5		0.59	0.13	1.14	0.097	0.06		GRAB	8.0				70.12			
UnK	3-Feb-82	10:30	Bottom	Goebel Greg					28	24	4		0.60	0.12	0.76	0.089	0.08		GRAB	14.0				68.88			
UnK	3-Feb-82	10:00	Surface	Goebel Greg	17.0				42	40	2		0.59	0.13	1.28	0.090	0.04		GRAB	2.0		1.07		69.04	59.03		
UnK	3-Mar-82	10:00	Surface	Goebel Greg					58	50	8		0.29	0.13	1.37	0.093	0.04		GRAB	2.0		0.53		69.51	69.15		
UnK	3-Mar-82	10:20	Midwater	Goebel Greg					62	54	8		0.44	0.15	1.25	0.080	0.06		GRAB	8.0				67.34			
UnK	3-Mar-82	10:30	Bottom	Goebel Greg	17.0				56	47	9		0.64	0.13	1.36	0.140	0.12		GRAB	14.0				75.41			
UnK	31-Mar-82	11:00	Surface	Goebel Greg					42	39	3		0.19	0.16	0.84	0.077	0.07		GRAB	2.0		1.22		66.79	57.13		
UnK	31-Mar-82	11:20	Midwater	Goebel Greg					78	69	9		0.31	0.26	1.38	0.100	0.06		GRAB	8.0				70.56			
UnK	31-Mar-82	11:30	Bottom	Goebel Greg	17.5				130	104	26		0.59	0.39	1.68	0.196	0.13		GRAB	15.0				80.26			
UnK	28-Apr-82	10:40	Midwater	Goebel Greg	18.5				120	114	6		<0.03	0.17	1.85	0.068	0.03		GRAB	7.0				65.00			
UnK	28-Apr-82	11:00	Midwater	Goebel Greg	18.5				92	85	7		0.05	0.14	1.15	0.058	0.03		GRAB	12.0				62.70			
UnK	28-Apr-82	10:10	Surface	Goebel Greg	18.5				76	66	10		<0.03	0.15	2.05	0.066	0.03		GRAB	2.0		0.68		64.56	65.56		
UnK	28-Apr-82	11:05	Bottom	Goebel Greg	18.5				104	98	6		0.14	0.14	1.10	0.072	0.06		GRAB	16.0				65.82			
UnK	25-May-82	10:30	Surface	Goebel Greg	22.3				78	61	17		0.41	0.63	0.71	0.123	0.07		GRAB	2.0		0.30		73.54	77.35		
UnK	25-May-82	11:00	Surface	Goebel Greg					78	61	17		<0.03	0.17	1.03	0.092	0.06		GRAB	6.5				69.35			
UnK	25-May-82	11:20	Midwater	Goebel Greg					72	55	17		0.03	0.36	0.90	0.110	0.05		GRAB	11.0				71.93			
UnK	25-May-82	11:30	Midwater	Goebel Greg					70	56	14		<0.03	0.58	0.78	0.075	0.03		GRAB	15.5				66.41			
UnK	25-May-82	11:45	Bottom	Goebel Greg					66	51	15		<0.03	0.11	0.77	0.079	0.03		GRAB	20.0				67.16			
UnK	8-Jun-82	11:50	Bottom	Goebel Greg	25.3				66	58	8		0.14	0.13	0.71	0.084	0.05		GRAB	23.0				68.04			
UnK	8-Jun-82	11:40	Bottom	Goebel Greg	25.3				69	60	9		<0.03	0.15	0.52	0.067	0.04		GRAB	17.8				64.78			
UnK	8-Jun-82	10:50	Surface	Goebel Greg	25.3				70	64	6		0.03	0.12	0.74	0.075	0.03		GRAB	2.0		0.61		66.41	67.12		
UnK	8-Jun-82	11:10	Surface	Goebel Greg	25.3				45	40	5		<0.03	0.18	0.74	0.080	0.05		GRAB	7.3		0.61		67.34	67.12		
UnK	8-Jun-82	11:30	Midwater	Goebel Greg	25.3				58	48	10		<0.03	0.11	0.52	0.068	0.04		GRAB	12.5				65.00			
UnK	23-Jun-82	10:50	Bottom	Goebel Greg	26.0				18	18	<1		0.59	<0.10	1.19	0.200	0.15		GRAB	24.0				80.55			
UnK	23-Jun-82	9:40	Surface	Goebel Greg	26.0				38	30	8		<0.03	<0.10	0.53	0.082	0.03		GRAB	2.0		0.61		67.69	67.12		
UnK	23-Jun-82	10:05	Surface	Goebel Greg	26.0				45	36	9		<0.03	<0.10	0.62	0.105	0.04		GRAB	6.5				71.26			
UnK	23-Jun-82	10:15	Midwater	Goebel Greg	26.0				33	20	13		0.04	0.12	0.71	0.132	0.05		GRAB	11.0				74.56			
UnK	23-Jun-82	10:25	Midwater	Goebel Greg	26.0				29	24	5		<0.03	0.10	0.51	0.087	0.04		GRAB	15.5				68.55			
UnK	23-Jun-82	10:35	Bottom	Goebel Greg	26.0				29	22	7		0.16	0.12	0.65	0.115	0.06		GRAB	20.0				72.57			
UnK	7-Jul-82	9:10	Surface	Goebel Greg	27.0				77	66	11		0.06	<0.10	0.53	0.068	0.01		GRAB	7.5		0.91		65.00	61.36		
UnK	7-Jul-82	9:40	Bottom	Goebel Greg	27.0				78	58	20		1.12	<0.10	1.59	0.310	0.25		GRAB	25.0				86.87			
UnK	7-Jul-82	9:20	Midwater	Goebel Greg	27.0				63	52	11		0.05	0.10	0.53	0.092	0.04		GRAB	13.0				69.35			
UnK	7-Jul-82	8:45	Surface	Goebel Greg	27.0				57	52	5		0.06	0.10	0.47	0.072	0.03		GRAB	2.0		0.91		65.82	61.36		
UnK	7-Jul-82	9:30	Bottom	Goebel Greg	27.0				75	62	13		0.10	0.13	0.61	0.124	0.08		GRAB	18.5				73.66			
UnK	22-Jul-82	9:00	Surface	Goebel Greg	24.0				66	60	6		0.42	<0.10	1.82	0.084	0.03		GRAB	2.0		0.53		68.04	69.15		
UnK	22-Jul-82	9:20	Surface	Goebel Greg	24.0				69	60	9		0.10	0.30	1.57	0.070	0.02		GRAB	7.0		0.53		65.41	69.15		
UnK	22-Jul-82	9:30	Midwater	Goebel Greg	24.0				55	44	11		0.18	<0.10	0.70	0.111	0.06		GRAB	12.0				72.06			
UnK	22-Jul-82	9:40	Bottom	Goebel Greg	24.0				75	66	9		0.37	0.28	0.87	0.162	0.13		GRAB	17.0				77.51			
UnK	22-Jul-82	9:50	Bottom	Goebel Greg	24.0				72	58	14		1.30	<0.10	1.78	0.355	0.31		GRAB	22.0				88.83			
UnK	5-Aug-82	9:45	Bottom	Goebel Greg	24.5				72	10	62		1.68	0.13	2.13	0.418	0.39		GRAB	22.5				91.18			
UnK	5-Aug-82	9:40	Bottom	Goebel Greg	24.5				78	73	5		0.40	0.16	0.96	0.200	0.16		GRAB	17.0				80.55			

Site	Date	Time	RelDepth	Personnel	Depth	Fecal	E Coli	Alka	Tot Sol	TDS	TSS	TVSS	Ammo	Nitrate	TKN	Tot P	TDP	NO3+NO4	S Type	S Depth	Tot N	Secchi	TSI Chl a	TSI Tot P	TSI Secchi	TSI N	TSI Mean
UnK	5-Aug-82	9:00	Surface	Goebel Greg	24.5				68	62	6		0.04	0.12	0.70	0.063	0.03		GRAB	2.0		1.07		63.89	59.03		
UnK	5-Aug-82	9:15	Surface	Goebel Greg	24.5				86	83	3		0.04	0.10	0.84	0.071	0.03		GRAB	7.0		1.07		65.62	59.03		
UnK	5-Aug-82	9:30	Midwater	Goebel Greg	24.5				76	62	14		0.09	0.12	0.68	0.095	0.05		GRAB	12.0				69.82			
UnK	18-Aug-82	10:00	Bottom	Goebel Greg	24.0				80	56	24		1.50	<0.10	2.33	0.416	0.20		GRAB	22.0				91.11			
UnK	18-Aug-82	9:10	Surface	Goebel Greg	24.0				32	24	8		0.03	0.10	0.87	0.068	0.02		GRAB	2.0		0.84		65.00	62.51		
UnK	18-Aug-82	9:25	Surface	Goebel Greg	24.0				68	56	12		<0.03	<0.10	0.82	0.080	0.03		GRAB	7.0				67.34			
UnK	18-Aug-82	9:40	Midwater	Goebel Greg	24.0				76	59	17		0.25	<0.10	0.96	0.120	0.07		GRAB	12.0				73.19			
UnK	18-Aug-82	9:50	Bottom	Goebel Greg	24.0				79	55	24		0.65	0.11	1.10	0.250	0.20		GRAB	17.0				83.77			
UnK	9-Sep-82	10:10	Bottom	Goebel Greg	25.0				102	78	24		2.50	<0.10	3.52	0.535	0.52		GRAB	23.0				94.74			
UnK	9-Sep-82	10:00	Bottom	Goebel Greg	25.0				82	69	13		0.80	<0.10	1.52	0.245	0.22		GRAB	17.0				83.48			
UnK	9-Sep-82	9:45	Midwater	Goebel Greg	25.0				66	61	5		0.20	<0.10	1.02	0.071	0.03		GRAB	12.0				65.62			
UnK	9-Sep-82	9:00	Surface	Goebel Greg	25.0				58	53	5		0.06	<0.10	1.12	0.070	0.03		GRAB	2.0		0.91		65.41	61.36		
UnK	9-Sep-82	9:30	Surface	Goebel Greg	25.0				64	60	4		0.07	<0.10	0.72	0.056	0.02		GRAB	7.0				62.20			
UnK	7-Oct-82	10:55	Bottom	Goebel Greg					50	46	4		0.39	0.13	0.76	0.120	0.06		GRAB	23.0				73.19			
UnK	7-Oct-82	10:00	Surface	Goebel Greg	25.0				46	41	5		0.26	0.13	0.77	0.104	0.07		GRAB	2.0		0.99		71.12	60.14		
UnK	7-Oct-82	10:15	Surface	Goebel Greg					42	38	4		0.28	0.14	0.79	0.115	0.06		GRAB	7.0				72.57			
UnK	7-Oct-82	10:30	Midwater	Goebel Greg					40	33	7		0.28	0.14	0.80	0.115	0.07		GRAB	12.0				72.57			
UnK	7-Oct-82	10:40	Bottom	Goebel Greg					36	30	6		0.29	0.13	0.76	0.140	0.09		GRAB	17.0				75.41			
UnK	22-Nov-82	9:30	Surface	Goebel Greg	26.0				68	61	7		0.20	0.21	1.34	0.160	0.12		GRAB	2.0		1.22		77.33	57.13		
UnK	22-Nov-82	10:10	Surface	Goebel Greg					64	55	9		0.19	0.21	0.84	0.090	0.06		GRAB	7.5				69.04			
UnK	22-Nov-82	10:30	Midwater	Goebel Greg					72	64	8		0.17	0.16	1.13	0.095	0.06		GRAB	13.0				69.82			
UnK	22-Nov-82	10:40	Bottom	Goebel Greg					86	83	3		0.19	0.20	1.01	0.138	0.07		GRAB	18.5				75.20			
UnK	22-Nov-82	10:45	Bottom	Goebel Greg					86	83	3		0.18	0.20	0.88	0.142	0.07		GRAB	24.0				75.61			
UnK	15-Dec-82	10:05	Bottom	Goebel Greg					70	67	3		0.31	0.26	0.72	0.085	0.06		GRAB	18.5				68.21			
UnK	15-Dec-82	9:10	Surface	Goebel Greg	26.0				94	88	6		0.32	0.31	0.83	0.145	0.11		GRAB	2.0		1.22		75.91	57.13		
UnK	15-Dec-82	9:50	Midwater	Goebel Greg					60	58	2		0.32	0.26	0.70	0.080	0.05		GRAB	13.0				67.34			
UnK	15-Dec-82	10:20	Bottom	Goebel Greg					50	49	1		0.32	0.21	0.70	0.095	0.06		GRAB	24.0				69.82			
UnK	15-Dec-82	9:25	Surface	Goebel Greg					64	60	4		0.32	0.25	0.81	0.090	0.06		GRAB	7.5				69.04			
UnK	19-Jan-83	9:10	Surface	Goebel Greg	27.0				66	64	2		0.37	0.30	0.92	0.117	0.06		GRAB	2.0		1.52		72.82	53.97		
UnK	19-Jan-83	9:30	Midwater	Goebel Greg					8	6	2		0.45	0.25	0.96	0.115	0.07		GRAB	13.5				72.57			
UnK	19-Jan-83	9:45	Bottom	Goebel Greg					80	72	8		0.70	0.20	1.23	0.200	0.16		GRAB	25.0				80.55			
UnK	22-Feb-83	9:20	Surface	Goebel Greg					70	62	8		0.29	0.23	8.91	0.800	0.51		GRAB	8.0				100.54			
UnK	22-Feb-83	9:20	Midwater	Goebel Greg					24	20	4		0.73	0.19	1.06	0.110	0.09		GRAB	13.5				71.93			
UnK	22-Feb-83	10:00	Bottom	Goebel Greg					80	67	13		0.96	<0.10	1.56	0.310	0.29		GRAB	25.0				86.87			
UnK	22-Feb-83	9:10	Surface	Goebel Greg	27.0				68	65	3		0.35	0.21	0.97	0.105	0.06		GRAB	2.0		1.83		71.26	51.29		
UnK	24-Mar-83	9:25	Midwater	Goebel Greg					54	50	4		0.23	0.15	0.80	0.075	0.04		GRAB	14.0				66.41			
UnK	24-Mar-83	9:40	Bottom	Goebel Greg					82	66	16		1.75	<0.10	2.13	0.595	0.59		GRAB	26.0				96.27			
UnK	24-Mar-83	9:10	Surface	Goebel Greg	8.5				60	49	11		<0.03	0.19	1.15	0.208	0.14		GRAB	2.0		0.55		81.12	68.61		
UnK	19-Apr-83	9:15	Surface	Goebel Greg	28.0				48	47	1		0.04	0.13	0.64	0.053	0.01		GRAB	2.0		1.37		61.40	55.46		
UnK	19-Apr-83	9:50	Midwater	Goebel Greg					48	44	4		0.12	0.13	0.96	0.078	0.01		GRAB	14.0				66.97			
UnK	19-Apr-83	10:00	Bottom	Goebel Greg					72	60	12		1.60	0.10	2.18	0.548	0.24		GRAB	26.0				95.09			
UnK	9-May-83	10:00	Surface	Goebel Greg	27.0				78	72	6		<0.03	0.12	0.80	0.069	0.02		GRAB	2.0		1.07		65.21	59.03		
UnK	9-May-83	10:40	Midwater	Goebel Greg	27.0				54	48	6		<0.03	0.13	0.69	0.102	0.02		GRAB	13.5				70.84			
UnK	9-May-83	11:00	Bottom	Goebel Greg	27.0				96	82	14		0.77	0.18	1.38	0.250	0.11		GRAB	25.0				83.77			
UnK	23-May-83	9:40	Surface	Goebel Greg	28.0				56	50	6		<0.03	<0.10	0.64	0.070	0.06		GRAB	2.0		1.22		65.41	57.13		
UnK	23-May-83	10:30	Bottom	Goebel Greg	28.0				62	53	9		0.06	<0.10	0.92	0.220	0.08		GRAB	26.0				81.93			
UnK	23-May-83	10:10	Bottom	Goebel Greg	28.0				66	62	4		<0.03	<0.10	0.55	0.020	0.06		GRAB	20.0				47.35			
UnK	23-May-83	10:00	Midwater	Goebel Greg	28.0				62	56	6		<0.03	<0.10	0.68	0.165	0.06		GRAB	14.0				77.78			
UnK	8-Jun-83	9:40	Surface	Goebel Greg	28.0				52	47	5		<0.03	<0.10	0.40	0.020	0.01		GRAB	2.0		1.52		47.35	53.97		
UnK	8-Jun-83	10:15	Midwater	Goebel Greg					40	32	8		<0.03	<0.10	0.46	0.063	0.01		GRAB	14.0				63.89			
UnK	8-Jun-83	10:35	Bottom	Goebel Greg					70	55	15		0.82	<0.10	1.28	0.257	0.08		GRAB	26.0				84.17			
UnK	22-Jun-83	9:15	Surface	Goebel Greg	28.0				47	44	3		<0.03	<0.10	0.41	0.025	<0.01		GRAB	2.0		2.13		50.57	49.10		
UnK	22-Jun-83	9:40	Midwater	Goebel Greg					28	19	9		<0.03	<0.10	0.59	0.085	<0.01		GRAB	14.0				68.21			
UnK	22-Jun-83	10:00	Bottom	Goebel Greg	28.0				56	49	7		0.65	<0.10	1.13	0.289	0.09		GRAB	26.0				85.86			
UnK	6-Jul-83	10:30	Bottom	Goebel Greg	27.0				100	80	20		0.34	<0.10	0.89	0.230	0.20		GRAB	25.0				82.57			
UnK	6-Jul-83	9:55	Surface	Goebel Greg	27.0				58	55	3		<0.03	<0.10	0.42	0.025	0.01		GRAB	2.0				50.57			
UnK	6-Jul-83	10:15	Midwater	Goebel Greg					80	74	6		<0.03	<0.10	0.41	0.040	0.01		GRAB	13.5				57.34			
UnK	21-Jul-83	11:45	Bottom	Goebel Greg	27.5				76	62	14		1.20	0.13	1.94	0.516	0.51		GRAB	25.5				94.22			
UnK	21-Jul-83	10:55	Surface	Goebel Greg	27.5				52	47	5		<0.03	0.12	0.95	0.037	0.01		GRAB	2.0		1.37		56.22	55.46		
UnK	21-Jul-83	11:20	Midwater	Goebel Greg					58	48	10		0.05	0.14	0.98	0.090	0.01		GRAB	13.8				69.04			
UnK	4-Aug-83	11:00	Surface	Goebel Greg	28.0				42	39	3		<0.03	<0.10	0.83	0.040	<0.01		GRAB	2.0		1.22		57.34	57.13		

Site	Date	Time	RelDepth	Personnel	Depth	Fecal	E Coli	Alka	Tot Sol	TDS	TSS	TVSS	Ammo	Nitrate	TKN	Tot P	TDP	NO3+NO4	S Type	S Depth	Tot N	Secchi	TSI Chl a	TSI Tot P	TSI Secchi	TSI N	TSI Mean
UnK	4-Aug-83	11:20	Midwater	Goebel Greg					48	41	7		0.08	<0.10	0.84	0.088	0.01		GRAB	14.0				68.71			
UnK	4-Aug-83	11:40	Bottom	Goebel Greg	28.0				68	55	13		1.00	<0.10	1.62	0.390	0.27		GRAB	26.0				90.18			
UnK	17-Aug-83	10:20	Surface	Goebel Greg	28.0				72	61	11		0.03	<0.10	1.62	0.060	0.01		GRAB	2.0				63.19			
UnK	17-Aug-83	10:35	Midwater	Goebel Greg					52	44	8		0.10	<0.10	0.75	0.077	<0.01		GRAB	14.0				66.79			
UnK	17-Aug-83	10:55	Bottom	Goebel Greg	28.0				88	76	12		1.78	<0.10	2.37	0.520	0.50		GRAB	26				94.33			
UnK	31-Aug-83	10:35	Midwater	Goebel Greg					54	49	5		0.17	<0.10	0.79	0.060	0.01		GRAB	13.5				63.19			
UnK	31-Aug-83	10:20	Surface	Goebel Greg	27.5				70	63	7		0.03	<0.10	1.60	0.063	0.01		GRAB	2.0		0.68		63.89	65.56		
UnK	31-Aug-83	10:55	Bottom	Goebel Greg	27.5				84	74	10		1.54	<0.10	2.06	0.565	0.42		GRAB	25.0				95.53			
UnK	17-Oct-83	11:10	Surface	Goebel Greg	28.0				88	85	3		0.30	0.17	1.05	0.125	0.09		GRAB	2.0		1.75		73.77	51.94		
UnK	17-Oct-83	11:30	Midwater	Goebel Greg					70	67	3		0.31	0.18	1.03	0.136	0.08		GRAB	14.0				74.99			
UnK	17-Oct-83	11:50	Bottom	Goebel Greg					66	64	2		0.31	0.18	1.04	0.123	0.09		GRAB	26.0				73.54			
UnK	15-Nov-83	9:40	Surface	Goebel Greg	27.0				60	58	2		0.06	0.23	0.89	0.143	0.08		GRAB	2.0				75.71			
UnK	15-Nov-83	9:50	Midwater	Goebel Greg					64	56	8		0.06	0.21	0.84	0.136	0.08		GRAB	13.5				74.99			
UnK	15-Nov-83	10:20	Bottom	Goebel Greg					58	55	3		0.07	0.21	1.26	0.148	0.08		GRAB	25.0				76.21			
UnK	12-Dec-83	10:45	Bottom	Goebel Greg					48	46	2		0.46	0.24	1.16	0.163	0.10		GRAB	26.0				77.60			
UnK	12-Dec-83	10:00	Surface	Goebel Greg	28.0				64	61	3		0.12	0.35	1.02	0.133	0.08		GRAB	2.0		1.68		74.67	52.52		
UnK	12-Dec-83	10:35	Midwater	Goebel Greg					40	37	3		0.13	0.28	0.78	0.109	0.07		GRAB	14.0				71.80			
UnK	16-Jan-84	10:30	Bottom	Goebel Greg					52	50	2		0.44	0.18	0.98	0.207	0.13		GRAB	26.0				81.05			
UnK	16-Jan-84	9:10	Surface	Goebel Greg	28.0				50	48	2		0.15	0.3	0.78	0.120	0.08		GRAB	2.0		2.10		73.19	49.31		
UnK	16-Jan-84	10:05	Midwater	Goebel Greg					46	44	2		0.19	0.25	0.72	0.108	0.08		GRAB	14.0				71.67			
UnK	14-Feb-84	9:00	Surface	Goebel Greg	28.0				74	62	12		0.05	0.31	1.11	0.100	0.05		GRAB	2.0		0.60		70.56	67.36		
UnK	14-Feb-84	9:30	Midwater	Goebel Greg					70	68	2		0.10	0.28	0.91	0.090	0.06		GRAB	14.0				69.04			
UnK	14-Feb-84	10:00	Bottom	Goebel Greg					76	65	11		0.42	0.15	1.06	0.150	0.13		GRAB	26.0				76.40			
UnK	16-Apr-84	9:30	Surface	Goebel Greg	29.0				55	51	4		<0.03	0.11	0.64	0.042	0.02		GRAB	2.0		1.70		58.05	52.35		
UnK	16-Apr-84	9:50	Midwater	Goebel Greg					58	56	2		0.11	0.13	0.66	0.036	0.02		GRAB	14.5				55.82			
UnK	16-Apr-84	10:05	Bottom	Goebel Greg	29.0				106	91	15		1.14	<0.10	1.72	0.470	0.47		GRAB	27.0				92.87			
UnK	31-May-84	10:00	Surface	Goebel Greg	29.0				46	44	2		<0.03	<0.10	0.37	0.033	0.01		GRAB	2.0				54.57			
UnK	31-May-84	10:35	Midwater	Goebel Greg					40	36	4		<0.03	<0.10	0.43	0.045	0.01		GRAB	14.5				59.04			
UnK	31-May-84	10:55	Bottom	Goebel Greg					52	44	8		<0.03	<0.10	0.54	0.105	0.01		GRAB	27.0				71.26			
UnK	14-Jun-84	9:40	Surface	Goebel Greg	29.0				30	26	4		<0.03	<0.10	0.50	0.036	<0.01			2.0		1.50		55.82	54.16		
UnK	14-Jun-84	10:10	Midwater	Goebel Greg					36	34	2		<0.03	<0.10	0.57	0.025	0.01		GRAB	14.5				50.57			
UnK	14-Jun-84	10:30	Bottom	Goebel Greg					82	73	9		0.10	<0.10	0.58	0.110	0.05		GRAB	27.0				71.93			
UnK	27-Jun-84	10:00	Surface	Goebel Greg	29.5				76	66	10		0.05	<0.10	1.17	0.025	0.02		GRAB	2.0		0.91		50.57	61.36		
UnK	27-Jun-84	10:20	Midwater	Goebel Greg					74	70	4		0.06	<0.10	0.48	0.025	0.02			14.8				50.57			
UnK	27-Jun-84	10:40	Bottom	Goebel Greg					28	20	8		0.33	<0.10	0.90	0.220	0.14		GRAB	27.5				81.93			
UnK	11-Jul-84	9:45	Midwater	Goebel Greg					58	52	6		0.08	0.15	0.60	0.075	<0.01			14.8				66.41			
UnK	11-Jul-84	10:00	Bottom	Goebel Greg					70	64	6		0.49	0.11	0.92	0.310	0.24		GRAB	27.5				86.87			
UnK	11-Jul-84	9:20	Surface	Goebel Greg	29.5				68	60	8		0.09	0.16	0.70	0.060	<0.01		GRAB	2.0		1.45		63.19	54.65		
UnK	24-Jul-84	9:40	Midwater	Goebel Greg					52	48	4		0.06	<0.10	0.62	0.065	<0.01		GRAB	14.5				64.34			
UnK	24-Jul-84	9:45	Bottom	Goebel Greg	29.0				72	62	10		0.38	<0.10	0.93	0.284	0.22			27.0				85.61			
UnK	24-Jul-84	9:30	Surface	Goebel Greg	29.0				48	45	3		0.11	<0.10	0.62	0.052	<0.01		GRAB	2.0		1.60		61.13	53.23		
UnK	7-Aug-84	9:30	Surface	Goebel Greg	28.5				40	36	4		0.05	<0.10	1.00	0.070	0.02		GRAB	2.0		1.45		65.41	54.65		
UnK	7-Aug-84	10:00	Midwater	Goebel Greg					34	27	7		0.04	<0.10	0.82	0.072	<0.01		GRAB	14.3				65.82			
UnK	7-Aug-84	10:10	Bottom	Goebel Greg					52	39	13		0.39	0.14	1.30	0.245	0.09		GRAB	26.5				83.48			
UnK	22-Aug-84	9:15	Surface	Goebel Greg	29.0				46	42	4		0.04	0.13	1.40	0.065	<0.01		GRAB	2.0		0.76		64.34	63.92		
UnK	22-Aug-84	10:05	Midwater	Goebel Greg					52	46	6		0.04	0.18	1.20	0.071	0.01		GRAB	14.5				65.62			
UnK	22-Aug-84	10:30	Bottom	Goebel Greg					78	62	16		1.10	0.13	1.30	0.418	0.40		GRAB	27.0				91.18			
UnK	12-Sep-84	10:00	Bottom	Goebel Greg					820	815	5		1.30	0.33	2.20	0.490	0.48		GRAB	27.0				93.47			
UnK	12-Sep-84	9:40	Midwater	Goebel Greg					600	600	<1		<0.03	0.17	1.50	0.075	0.02		GRAB	14.5				66.41			

Sediment Total Phosphorus Concentrations

Sample Number	Total Phosphorus (mg/kg) (Dry)	Location W	Location N	Sample Depth (m)	Sample Depth (ft)
1	5,100	-103.5658000	43.8469000	8.9	29.2
2	2,800	-103.5652000	43.8467000	8	26.2
3	1,200	-103.5639000	43.8478000	1.6	5.2
4	1,100	-103.5644000	43.8473000	5.6	18.4
5	2,500	-103.5646100	43.8468000	7.8	25.6
6	1,600	-103.5646900	43.8461100	6.6	21.7
6E	1,700	-103.5646900	43.8461100	6.6	21.7
7	770	-103.5638960	43.8455300	5	16.4
8	830	-103.5631729	43.8452860	4.1	13.5
9	610	-103.5625880	43.8450702	2.6	8.5
10	660	-103.5619827	43.8442190	1.6	5.2
11	670	-103.5617690	43.8452780	2	6.6
12	930	-103.5613538	43.8457820	1.7	5.6

Sylvan Lake Field Data

Site	Date	Time	RelDepth	Personnel	Depth	DC	A Temp	Color	D Fish	Film	Odor	Precip	Wind	Cond	DO	F pH	W Temp	Secchi	Ice	Turb	Weather
Comp	16-Jun-04	13:00	Surface	Larson/Mateo			7.8	Clear	None	None	None	Mod	Mild	111.0	9.57	8.2	15.0	3.23		0.0	
Comp	16-Jun-04	13:00	Bottom	Larson/Mateo			7.8	Clear	None	None	None	Mod	Mild	145.7	4.78	8.1	11.4			15.1	
Comp	22-Jul-04	11:00	Surface	Larson/Mateo			13.9	Dk. Green	None	None	None	Mild	None	108.0	6.98	8.2	20.7	2.55		0.6	
Comp	22-Jul-04	11:00	Bottom	Larson/Mateo			13.9	Dk. Green	None	None	None	Mild	None	150.0	2.60	8.1	14.6			5.0	
Site	Date	Time	RelDepth	Personnel	Depth	DC	A Temp	Color	D Fish	Film	Odor	Precip	Wind	Cond	DO	F pH	W Temp	Secchi	Ice	Turb	Weather
SL05	23-Aug-01	10:57		Scott Alan	0.5	0.08	21.7							87.8	6.15	6.8	19.1				Sunny
SL05	25-Sep-01	15:32		Scott Alan	0.6	0.25	18.3							43.1	6.73	7.9	15.6				Sunny
SL05	18-Apr-02	15:58		Scott Alan	0.5	0.09	1.1							108.1	7.83	7.4	5.0				Sunny
SL05	24-Apr-02	12:00		Scott Alan	0.5	0.08	10.0							104.5	8.00	7.5	5.4				Sunny
SL05	2-May-02	11:17		Scott Alan	0.7	0.30	14.4							94.2	7.86	7.8	8.6				Sunny
SL05	26-Jun-02	13:41		Scott Alan	0.6	0.20	28.9							98.8	4.96	7.6	22.5				Sunny
SL05	21-Jul-02	15:00		Scott Alan	0.5	0.14	17.8							105.3	5.45	7.6	18.2				Rainy
SL05	12-Aug-02	17:03		Scott Alan	0.5	0.10	16.1							100.8	6.05	7.9	15.7				Sunny
Site	Date	Time	RelDepth	Personnel	Depth	DC	A Temp	Color	D Fish	Film	Odor	Precip	Wind	Cond	DO	F pH	W Temp	Secchi	Ice	Turb	Weather
SL1	23-Aug-01	10:14	Surface	Scott Alan	26.2		21.1		None	None	None	None	None	90.9	10.24	9.9	19.2	0.50	None		Sunny.
SL1	23-Aug-01	10:14	Bottom	Scott Alan	26.2		21.1		None	None	None	None	None	91.6	4.56	7.8	18.2		None		Sunny.
SL1	25-Sep-01	13:45	Surface	Scott Alan	24.6		20.6		None	None	None	None	None	89.4	7.80	8.8	15.6	1.50	None		Sunny.
SL1	25-Sep-01	13:45	Bottom	Scott Alan	24.6		20.6		None	None	None	None	None	89.3	4.71	8.1	13.9		None		Sunny.
SL1	31-Oct-01	12:50	Surface	Scott Alan	24.6		10.0		None	None	None	None	None	92.9	8.70	7.8	5.5	2.50	None		Sunny.
SL1	31-Oct-01	13:07	Bottom	Scott Alan	24.6		10.0		None	None	None	None	None	92.8	8.30	7.7	5.1		None		Sunny.
SL1	27-Dec-01	15:00	Surface	Scott Alan	24.6		0.6		None	None	None	None	None	96.2	6.59	8.1	3.3		Mild		O'cast. 12" ice cover.
SL1	27-Dec-01	13:25	Bottom	Scott Alan	24.6		0.6		None	None	None	None	None	99.0	4.06	7.9	3.8		Mild		O'cast. 12" ice cover.
SL1	30-Jan-02	15:40	Surface	Scott Alan	26.2		-6.7		None	None	None	None	None	102.1	6.22	7.9	2.5		Ext		O'cast. 18" ice cover.
SL1	30-Jan-02	16:00	Bottom	Scott Alan	26.2		-6.7		None	None	None	None	None	102.4	4.01	7.6	2.5		Ext		O'cast. 18" ice cover.
SL1	26-Feb-02	16:45	Surface	Scott Alan	23.0		-7.2		None	None	None	None	None	101.1	5.10	7.4	4.1		Mod		Sunny. 14" ice cover.
SL1	26-Feb-02	16:27	Bottom	Scott Alan	23.0				None	None	None	None	None	102.0	4.21	7.2	4.2		Mod		Sunny. 14" ice cover.
SL1	13-May-02	15:27	Surface	Scott Alan	23.0		8.9		None	None	None	None	None	90.2	9.85	8.6	9.2	1.50	None		Sunny.
SL1	13-May-02	15:27	Bottom	Scott Alan	23.0		8.9		None	None	None	None	None	90.4	8.02	8.0	7.1		None		Sunny.
SL1	6-Jun-02		Surface	Scott Alan	24.6		16.7		None	None	None	None	None	89.6	7.95	8.5	17.3	4.25	None		Sunny.
SL1	6-Jun-02	16:40	Bottom	Scott Alan	24.6		16.7		None	None	None	None	None	92.9	0.45	7.4	10.2		None		Sunny.
SL1	1-Jul-02	9:50	Surface	Scott Alan	26.2		21.1		None	None	None	None	None	93.1	6.54	9.0	21.7	2.00	None		Sunny.
SL1	1-Jul-02	9:50	Bottom	Scott Alan	26.2		21.1		None	None	None	None	None	107.1	0.42	7.6	10.2		None		Sunny.
SL1	5-Aug-02	15:28	Surface	Scott Alan	24.6		22.2		None	None	None	None	None	96.6	6.69	8.4	19.9	1.50	None		O'cast.
SL1	5-Aug-02	15:28	Bottom	Scott Alan	24.6		22.2		None	None	None	None	None	107.6	0.73	7.6	15.3		None		O'cast.
SL1	17-Apr-03	12:45	Surface	Larson/Goyer	24.0			Clear	None	None	None	None	Mild	97.0	11.14	8.2	7.6	0.80	None	4.1	PC
SL1	17-Apr-03	12:45	Bottom	Larson/Goyer	24.0			Clear	None	None	None	None	Mild	171.0	0.18	7.3	5.0		None	0.2	PC
SL1	16-May-03	11:00	Bottom	Larson/Goyer	25.0		14.0	Lt. Green	None	None	None	None	Mild	97.0	2.45	7.2	6.4		None	94.4	PC
SL1	16-May-03	11:00	Surface	Larson/Goyer	25.0		14.0	Lt. Green	None	None	None	None	Mild	96.0	9.70	8.3	12.3	1.00	None	3.7	PC
SL1	12-Jun-03	11:05	Surface	Larson/Goyer	25.5		18.3	Lt. Green	None	None	None	None	Mild	97.0	8.67	7.7	15.9	2.40	None	1.3	PC
SL1	12-Jun-03	11:05	Bottom	Larson/Goyer	25.5		18.3	Lt. Green	None	None	None	None	Mild	150.0	0.11	6.8	6.4		None	4.6	PC
SL1	2-Jul-03	11:00	Bottom	Larson/Goyer	25.7		25.6	Lt. Green	None	None	None	None	None	171.0	0.15	7.4	6.8		None	6.1	Sunny
SL1	2-Jul-03	11:00	Surface	Larson/Goyer	25.7		25.6	Lt. Green	None	None	None	None	None	108.0	9.00	7.4	19.0	3.70	None	0.4	Sunny
SL1	17-Jul-03	11:30	Bottom	Larson/Goyer	25.0		25.6	Lt. Green	None	None	None	None	Mild	234.0	0.27	6.6	7.4		None	1.6	Sunny
SL1	17-Jul-03	11:30	Surface	Larson/Goyer	25.0		25.6	Lt. Green	None	None	None	None	Mild	110.0	7.95	7.2	22.5	2.20	None	0.9	Sunny
SL1	19-Aug-03	12:30	Bottom	Larson/Goyer	23.4		23.9	Dk. Green	None	None	None	None	Mild	179.0	0.19	7.2	8.1		None	4.7	PC
SL1	19-Aug-03	12:30	Surface	Larson/Goyer	23.4		23.9	Dk. Green	None	None	None	None	Mild	101.0	9.71	8.4	21.8	1.10	None	5.0	PC
SL1	30-Aug-04		Surface	Larson/Mateo	28.1		22.2		None	None	None	None	None	112.0	8.19	8.6	17.7	1.90		2.5	
SL1	30-Aug-04		Bottom	Larson/Mateo	28.1		22.2		None	None	None	None	None	288.0	0.16	7.6	8.4			7.4	

Site	Date	Time	RelDepth	Personnel	Depth	DC	A Temp	Color	D Fish	Film	Odor	Precip	Wind	Cond	DO	F pH	W Temp	Secchi	Ice	Turb	Weather
SL2	23-Aug-01	9:50	Surface	Scott Alan	8.2		21.7		None	None	None	None	None	89.3	9.58	6.7	18.9	1.00	None		Sunny.
SL2	23-Aug-01	9:50	Bottom	Scott Alan	8.2		21.7		None	None	None	None	None	90.7	9.29	8.9	18.9		None		Sunny.
SL2	25-Sep-01	12:05	Surface	Scott Alan	6.6		21.1		None	None	None	None	None	88.6	7.74	8.8	14.7	1.50	None		Sunny.
SL2	25-Sep-01	12:05	Bottom	Scott Alan	7.4		21.1		None	None	None	None	None	89.6	4.28	8.4	13.5		None		Sunny.
SL2	31-Oct-01	13:27	Surface	Scott Alan	6.6		10.0		None	None	None	None	None	92.9	8.66	7.7	5.4	2.00	None		Sunny.
SL2	31-Oct-01	13:43	Bottom	Scott Alan	7.4		10.0		None	None	None	None	None	92.8	8.44	7.7	5.3		None		Sunny.
SL2	27-Dec-01	16:01	Surface	Scott Alan	6.6		4.4		None	None	None	None	None	57.8	7.75	8.0	1.4		Mild		O'cast. 12" ice cover.
SL2	27-Dec-01	16:27	Bottom	Scott Alan	6.6		4.4		None	None	None	None	None	99.4	6.68	7.8	3.3		Mild		O'cast. 12" ice cover.
SL2	30-Jan-02	16:27	Surface	Scott Alan	6.6		-6.7		None	None	None	None	None	103.3	6.40	7.9	4.0		Ext		O'cast. 18" ice cover.
SL2	30-Jan-02	16:47	Bottom	Scott Alan	6.6		-6.7		None	None	None	None	None	103.8	6.22	7.9	4.1		Ext		O'cast. 18" ice cover.
SL2	26-Feb-02	16:55	Surface	Scott Alan	6.9		-7.2		None	None	None	None	None	96.8	10.97	7.8	3.6		Mod		Sunny. 14" ice cover.
SL2	26-Feb-02	17:17	Bottom	Scott Alan	6.6		-7.2		None	None	None	None	None	100.0	8.13	7.6	4.2		Mod		Sunny. 14" ice cover.
SL2	13-May-02	15:49	Surface	Scott Alan	8.2		7.8		None	None	None	None	None	90.4	9.70	8.4	8.6	1.00	None		Sunny.
SL2	13-May-02	15:49	Bottom	Scott Alan	8.2		7.8		None	None	None	None	None	90.4	9.67	8.4	7.9		None		Sunny.
SL2	6-Jun-02	17:10	Surface	Scott Alan	8.2		21.1		None	None	None	None	None	90.3	8.10	8.7	17.1	2.50	None		Sunny.
SL2	6-Jun-02	17:49	Bottom	Scott Alan	8.2		21.1		None	None	None	None	None	90.1	8.04	8.7	15.5		None		Sunny.
SL2	1-Jul-02	10:24	Surface	Scott Alan	8.2		21.1		None	None	None	None	None	93.7	6.40	8.8	21.6	2.00	None		Sunny.
SL2	1-Jul-02	10:24	Bottom	Scott Alan	8.2		21.1		None	None	None	None	None	93.5	5.95	8.5	21.1		None		Sunny.
SL2	5-Aug-02	15:49	Surface	Scott Alan	8.2		22.2		None	None	None	None	None	96.8	6.19	8.1	19.7	1.25	None		O'cast.
SL2	5-Aug-02	15:49	Bottom	Scott Alan	8.2		22.2		None	None	None	None	None	96.6	5.48	7.9	19.2		None		O'cast.
SL2	17-Apr-03	14:30	Bottom	Larson/Goyer	10.0			Clear	None	None	None	None	Mild	99.0	8.63	7.6	6.4		None	3.6	PC
SL2	17-Apr-03	14:30	Surface	Larson/Goyer	10.0			Clear	None	None	None	None	Mild	98.0	10.07	7.5	7.4	0.90	None	4.0	PC
SL2	16-May-03	10:20	Bottom	Larson/Goyer	7.0		19.0	Lt. Green	None	None	None	None	Mild	93.0	9.53	8.2	10.4		None	4.3	PC
SL2	16-May-03	10:20	Surface	Larson/Goyer	7.0		19.0	Lt. Green	None	None	None	None	Mild	96.0	9.65	8.4	12.8	0.90	None	3.4	PC
SL2	12-Jun-03	10:10	Surface	Larson/Goyer	12.3		18.3	Lt. Green	None	None	None	None	Mild	97.0	9.19	8.0	16.0	2.60	None	1.0	PC
SL2	12-Jun-03	10:10	Bottom	Larson/Goyer	12.3		18.3	Lt. Green	None	None	None	None	Mild	97.0	2.35	7.4	11.3		None	17.8	PC
SL2	2-Jul-03	10:30	Surface	Larson/Goyer	11.8		25.6	Lt. Green	None	None	None	None	None	108.0	9.84	7.2	18.9	3.60	None	0.3	Sunny
SL2	2-Jul-03	10:30	Bottom	Larson/Goyer	11.8		25.6	Lt. Green	None	None	None	None	None	108.0	9.55	7.6	15.7		None	4.3	Sunny
SL2	17-Jul-03	10:30	Bottom	Larson/Goyer	15.0		24.4	Lt. Green	None	None	None	None	Mild	119.0	1.41	7.0	16.3		None	4.9	Sunny
SL2	17-Jul-03	10:30	Surface	Larson/Goyer	15.0		24.4	Lt. Green	None	None	None	None	Mild	111.0	8.25	7.8	22.4	2.20	None	1.0	Sunny
SL2	19-Aug-03	12:00	Bottom	Larson/Goyer	13.1		23.9	Dk. Green	None	None	None	None	Mild	110.0	1.08	8.1	20.0		None	5.2	PC
SL2	19-Aug-03	12:00	Surface	Larson/Goyer	13.1		23.9	Dk. Green	None	None	None	None	Mild	101.0	9.11	8.2	21.6	1.00	None	6.6	PC
SL2	30-Aug-04		Surface	Larson/Mateo	10.0		22.2		None	None	None	None	None	113.0	8.83	8.4	17.4			2.3	
SL-2	30-Aug-04		Bottom	Larson/Mateo	10.0		22.2		None	None	None	None	None	112.0	8.93	8.5	16.2			3.7	
Site	**Date**	**Time**	**RelDepth**	**Personnel**	**Depth**	**DC**	**A Temp**	**Color**	**D Fish**	**Film**	**Odor**	**Precip**	**Wind**	**Cond**	**DO**	**F pH**	**W Temp**	**Secchi**	**Ice**	**Turb**	**Weather**
SLT3	23-Aug-01	11:35		Scott Alan	0.3	0.01	23.3							38.5	8.64	6.9	11.4				Sunny
SLT3	25-Sep-01	15:06		Scott Alan	0.4	0.07	19.4							41.9	9.11	8.0	10.5				Sunny
SLT3	10-Oct-01	11:29		Scott Alan	0.4	0.07	12.8							43.8	9.54	7.7	6.2				Sunny
SLT3	31-Oct-01	12:08		Scott Alan	0.4	0.06	12.2							42.5	9.29	7.6	7.5				Sunny
SLT3	18-Apr-02	15:20		Scott Alan	0.4	0.06	1.1							98.7	8.08	7.4	3.2				Sunny
SLT3	24-Apr-02	10:33		Scott Alan	0.3	0.05	10.0							98.5	8.88	7.3	2.9				Sunny
SLT3	2-May-02	9:50		Scott Alan	0.3	0.04	14.4							44.5	9.15	7.6	1.5				Sunny
SLT3	26-Jun-02	13:05		Scott Alan	0.3	0.05	28.9							75.0	6.88	7.3	18.4				Sunny
SLT3	21-Jul-02	14:31		Scott Alan	0.2	0.03	15.6							86.3	5.49	8.0	14.6				Rainy
SLT3	12-Aug-02	16:32		Scott Alan	0.2	0.02	16.1							79.1	5.65	7.1	10.7				Sunny
Site	**Date**	**Time**	**RelDepth**	**Personnel**	**Depth**	**DC**	**A Temp**	**Color**	**D Fish**	**Film**	**Odor**	**Precip**	**Wind**	**Cond**	**DO**	**F pH**	**W Temp**	**Secchi**	**Ice**	**Turb**	**Weather**
SLT4	23-Aug-01	11:55		Scott Alan	0.2	0.14	23.3							61.5	7.51	6.9	14.1				Sunny
SLT4	25-Sep-01	15:24		Scott Alan	0.1	0.02	18.3							64.5	7.05	6.9	12.2				Sunny
SLT4	10-Oct-01	11:40		Scott Alan	0.2	0.07	12.8							69.0	10.02	6.8	4.0				Sunny
SLT4	31-Oct-01	14:08		Scott Alan	0.1	0.05	9.4							64.8	7.64	7.2	6.9				Sunny
SLT4	18-Apr-02	15:36		Scott Alan	0.1	0.01	1.1							47.8	8.95	7.2	5.4				Sunny
SLT4	24-Apr-02	11:10		Scott Alan	0.1	0.01	10.0							45.2	8.96	7.4	5.6				Sunny
SLT4	2-May-02	10:33		Scott Alan	0.1	0.01	14.4							44.5	9.15	7.6	5.1				Sunny
SLT4	26-Jun-02	13:20		Scott Alan	0.2	0.04	28.9							36.7	7.39	7.3	14.0				Sunny
SLT4	21-Jul-02	14:15		Scott Alan	0.2	0.03	16.7							39.1	7.29	8.4	11.7				Rainy
SLT4	12-Aug-02	16:18		Scott Alan	0.2	0.02	16.1							39.0	7.90	7.8	9.8				Sunny

Site	Date	Time	RelDepth	Personnel	Depth	DC	A Temp	Color	D Fish	Film	Odor	Precip	Wind	Cond	DO	F pH	W Temp	Secchi	Ice	Turb	Weather
UnK	16-Nov-77	12:30	Surface	Nelson Gene			-3.3	Clear							12.00	8.0	0.6				
UnK	6-Feb-78	14:00	Surface	Nelson Gene			0.0									6.5	0.0				No DO - chemicals froze?
UnK	4-May-78	13:15	Surface	Nelson Gene			3.9								10.60	7.2	8.9				
UnK	9-Aug-78	10:30	Surface	Nelson Gene			25.0	Olive							9.80	7.2	21.1				
UnK	11-Sep-79	13:30	Surface	Nelson Gene			16.7								8.60	7.6	18.9				
UnK	6-Oct-81	17:05	Bottom	Goebel Greg			11.1								3.90	6.8	10.0				
UnK	6-Oct-81	17:10	Bottom	Goebel Greg	27.0		10.6	Brown							0.00	7.0	9.4				Floc in DO test was gray instead of brown.
UnK	6-Oct-81	16:55	Bottom	Goebel Greg			11.1								6.50	7.2	10.6				
UnK	6-Oct-81	16:45	Midwater	Goebel Greg			11.1								7.00	7.5	11.1				
UnK	6-Oct-81	16:20	Surface	Goebel Greg			17.8		None	None	None	None	Mod		7.90	7.9	12.2				Lake level lowered 6-8" by siphons.
UnK	6-Oct-81	16:35	Surface	Goebel Greg			17.8								7.90	7.7	12.2				
UnK	4-Nov-81	11:20	Bottom	Goebel Greg			12.8								10.30	7.7	7.8				
UnK	4-Nov-81	10:30	Surface	Goebel Greg	17.0		12.8		None	None	None	None	Mod		10.80	8.3	7.8	1.07			Lake level 9' below spillway-sunny.
UnK	4-Nov-81	11:00	Midwater	Goebel Greg			12.8								10.40	8.0	7.8				
UnK	7-Dec-81	10:00	Surface	Goebel Greg	15.5		4.4		None	None	None	None	Mod		9.10	8.1	2.8	1.37			Sunny-5" ice cover.
UnK	7-Dec-81	10:20	Midwater	Goebel Greg			4.4								9.00	7.8	3.9				
UnK	7-Dec-81	10:30	Midwater	Goebel Greg			4.4								9.00	7.7	3.9				
UnK	14-Jan-82	10:00	Midwater	Goebel Greg			-1.1								3.40	7.5	0.6				11" ice cover.
UnK	14-Jan-82	10:20	Bottom	Goebel Greg	16.0		-1.1								2.40	8.0	0.6				11" ice cover.
UnK	14-Jan-82	9:30	Surface	Goebel Greg			-1.1		None	None	None	Mild	Ext		5.10	7.6	-0.6	1.52			4" snow cover-11" ice cover.
UnK	3-Feb-82	10:15	Midwater	Goebel Greg			-18.9		None	None	None	Mild	Mod		1.50	6.7	0.0				1' ice cover.
UnK	3-Feb-82	10:30	Bottom	Goebel Greg			-18.9		None	None	None	Mild	Mod		0.80	6.6	0.6				2" snow cover-cloudy-1' ice cover.
UnK	3-Feb-82	10:00	Surface	Goebel Greg	17.0		-18.9		None	None	None	None	Mod		3.60	6.7	-1.1	1.07			1' ice cover.
UnK	3-Mar-82	10:00	Surface	Goebel Greg			0.6		None	None	None	None	Mod		9.50	8.1	0.6	0.53			1" snow cover-15" ice cover.
UnK	3-Mar-82	10:20	Midwater	Goebel Greg			0.6		None	None	None	None	Mod		4.50	7.9	2.2				1" snow cover-15" ice cover.
UnK	3-Mar-82	10:30	Bottom	Goebel Greg	17.0		0.6		None	None	None	None	Mod		2.40	7.8	3.3				1" snow cover-15" ice cover.
UnK	31-Mar-82	11:00	Surface	Goebel Greg			3.9		None	None	None	None	Mod		7.90	8.0	3.9	1.22			Sunny-no snow cover-12" ice cover.
UnK	31-Mar-82	11:20	Midwater	Goebel Greg			3.9		None	None	None	None	None		6.60	8.0	4.4				12" ice cover.
UnK	31-Mar-82	11:30	Bottom	Goebel Greg	17.5		3.9		None	None	None	None	Mod		1.30	7.6	4.4				12" ice cover
UnK	28-Apr-82	10:40	Midwater	Goebel Greg	18.5		10.0		None		None	None	None		9.10	7.8	6.1				
UnK	28-Apr-82	11:00	Midwater	Goebel Greg	18.5		10.0		None	None	None	None	None		8.80	7.8	5.6				
UnK	28-Apr-82	10:10	Surface	Goebel Greg	18.5		10.0		None	None	None	None	None		9.60	7.8	5.6	0.68			Cloudy.
UnK	28-Apr-82	11:05	Bottom	Goebel Greg	18.5		10.0		None	None	None	None	None		8.70	7.8	5.6				
UnK	25-May-82	10:30	Surface	Goebel Greg	22.3		6.7	Brown	None	None	None	None	Mod		10.10	8.4	10.6	0.30			Partly cloudy.
UnK	25-May-82	11:00	Surface	Goebel Greg			7.8	Brown	None	None	None	Mild	None		9.00	7.6	10.6				
UnK	25-May-82	11:20	Midwater	Goebel Greg			12.2	Brown	None	None	None	Mild	None		7.30	7.5	10.0				Water level is 3' 3" below top of spillway.
UnK	25-May-82	11:30	Midwater	Goebel Greg			12.2	Brown	None	None	None	None	None		5.00	6.9	9.4				
UnK	25-May-82	11:45	Bottom	Goebel Greg			12.2	Brown	None	None	None	None	Mod		2.70	6.9	8.33				
UnK	8-Jun-82	11:50	Bottom	Goebel Greg	25.3		15.6	Brown							0.40	6.7	8.3				
UnK	8-Jun-82	11:40	Bottom	Goebel Greg	25.3		15.6	Brown							3.60	6.6	10.0				
UnK	8-Jun-82	10:50	Surface	Goebel Greg	25.3		12.2	Brown	None	None	None	None	Mod		9.00	7.5	13.3	0.61			Partly cloudy.
UnK	8-Jun-82	11:10	Surface	Goebel Greg	25.3		12.2	Brown							8.50	7.5	12.2	0.61			
UnK	8-Jun-82	11:30	Midwater	Goebel Greg	25.3		10.6	Brown					Mod		6.10	6.8	10.6				
UnK	23-Jun-82	10:50	Bottom	Goebel Greg	26.0		23.3		None	None	None	None	Mod		0.00	6.9	9.4				
UnK	23-Jun-82	9:40	Surface	Goebel Greg	26.0		23.3	Brown	None	None	None	None	Mod		9.10	8.9	17.2	0.61			Mostly sunny.
UnK	23-Jun-82	10:05	Surface	Goebel Greg	26.0		23.3		None	None	None	None	Mod		8.70	8.4	16.7				
UnK	23-Jun-82	10:15	Midwater	Goebel Greg	26.0		23.9		None	None	None	None	Mod		1.60	6.7	12.8				
UnK	23-Jun-82	10:25	Midwater	Goebel Greg	26.0		23.9		None	None	None	None	Mod		3.90	6.8	12.8				
UnK	23-Jun-82	10:35	Bottom	Goebel Greg	26.0		23.3		None	None	None	None	None		1.60	6.9	10.6				
UnK	7-Jul-82	9:10	Surface	Goebel Greg	27.0		18.3		None	None	None	None	Mod		7.30	7.6	16.7	0.91			Sunny.
UnK	7-Jul-82	9:40	Bottom	Goebel Greg	27.0		18.3		None	None	None	None	Mod		0.00	7.1	10.0				Sunny.
UnK	7-Jul-82	9:20	Midwater	Goebel Greg	27.0		18.3		None	None	None	None	Mod		3.20	6.9	13.9				Sunny.
UnK	7-Jul-82	8:45	Surface	Goebel Greg	27.0		18.3		None	None	None	None	Mod		7.70	7.8	17.2	0.91			Sunny-H2O 14" below top of spillway-siphan working
UnK	7-Jul-82	9:30	Bottom	Goebel Greg	27.0		18.3		None	None	None	None	Mod		1.00	7.0	10.6				Sunny.
UnK	22-Jul-82	9:00	Surface	Goebel Greg	24.0		26.1	Green	None	None	None	None	Mod		9.10	9.9	21.7	0.53			Sunny-lake level down 28" from top of spillway.
UnK	22-Jul-82	9:20	Surface	Goebel Greg	24.0		26.7	Green	None	None	None	None	Mod		7.20	7.9	20.6	0.53			Sunny.
UnK	22-Jul-82	9:30	Midwater	Goebel Greg	24.0		26.7	SL - Green	None	None	None	None	Mod		0.30	6.9	12.2				Sunny.
UnK	22-Jul-82	9:40	Bottom	Goebel Greg	24.0		26.7	SL - Green	None	None		None	Mod		0.90	7.0	11.7				Sunny.

Site	Date	Time	RelDepth	Personnel	Depth	DC	A Temp	Color	D Fish	Film	Odor	Precip	Wind	Cond	DO	F pH	W Temp	Secchi	Ice	Turb	Weather
UnK	22-Jul-82	9:50	Bottom	Goebel Greg	24.0		26.7	Green	None	None		None	Mod		0.00	7.0	10.0				Sunny.
UnK	5-Aug-82	9:45	Bottom	Goebel Greg	24.5				None	None		None	Mod		0.00	7.0	9.4				Clear & sunny-mild wind.
UnK	5-Aug-82	9:40	Bottom	Goebel Greg	24.5				None	None		None	Mod		0.00	7.0	10.6				Clear & sunny-mild wind.
UnK	5-Aug-82	9:00	Surface	Goebel Greg	24.5			Green	None	None	None	None	None		7.80	9.6	20.0	1.07			Clear skies-sunny.
UnK	5-Aug-82	9:15	Surface	Goebel Greg	24.5			Green	None	None	None	None	Mod		7.20	9.4	20.0	1.07			Clear & sunny-mild wind.
UnK	5-Aug-82	9:30	Midwater	Goebel Greg	24.5		21.1	Green	None	None		None	Mod		0.80	7.2	14.4				Clear & sunny-mild wind.
UnK	18-Aug-82	10:00	Bottom	Goebel Greg	24.0			Lt. Gray Blue	None	None		None	None		0.00	7.1	10.0				Partly cloudy-calm-hot.
UnK	18-Aug-82	9:10	Surface	Goebel Greg	24.0		25.0		None			None	None		8.00	9.5	21.7	0.84			Partly cloudy-calm-warm.
UnK	18-Aug-82	9:25	Surface	Goebel Greg	24.0				None		None	None	None		7.00	9.5	21.1				Partly cloudy-warm-calm.
UnK	18-Aug-82	9:40	Midwater	Goebel Greg	24.0			Lt. Gray Green	None	None		None	None		0.00	7.2	13.9				Partly cloudy-calm-warm-color & odor to sample.
UnK	18-Aug-82	9:50	Bottom	Goebel Greg	24.0			Lt. Gray Blue	None	None		None	Mod		0.00	7.1	10.6				Partly cloudy-mild wind-warm.
UnK	9-Sep-82	10:10	Bottom	Goebel Greg	25.0		21.1	Gray Blue	None	None	Extreme	None	None		0.00	7.0	10.0				
UnK	9-Sep-82	10:00	Bottom	Goebel Greg	25.0			Lt. Gray	None	None		None	None		0.00	7.0	10.6				
UnK	9-Sep-82	9:45	Midwater	Goebel Greg	25.0			Gray Green	None	None	None	None	None		0.70	7.1	15.6				
UnK	9-Sep-82	9:00	Surface	Goebel Greg	25.0		21.1	Lt. Green	None		None	None	None		7.80	8.1	18.3	0.91			Heavy surface algae-H2O 3' below top of spillway.
UnK	9-Sep-82	9:30	Surface	Goebel Greg	25.0			Lt. Green	None	None	None	None	None		6.20	7.9	18.3				
UnK	7-Oct-82	10:55	Bottom	Goebel Greg			12.2	Lt. Green			None				3.70	7.0	7.8				
UnK	7-Oct-82	10:00	Surface	Goebel Greg	25.0		11.1	Lt. Green	None	None	None	None	Mod		4.60	6.9	7.2	0.99			Lake level 27" below full.
UnK	7-Oct-82	10:15	Surface	Goebel Greg				Lt. Green	None	None	None				4.30	7.1	7.2				
UnK	7-Oct-82	10:30	Midwater	Goebel Greg				Lt. Green			None				4.10	7.0	7.2				
UnK	7-Oct-82	10:40	Bottom	Goebel Greg			12.2	Lt. Green							4.10	7.0	7.8				Sunny-Freezing temp 10/6/82 (night).
UnK	22-Nov-82	9:30	Surface	Goebel Greg	26.0		-11.1	Lt. Green				Mild			8.20	7.7	-0.6	1.22			Cloudy-no snow cover-4" ice cover.
UnK	22-Nov-82	10:10	Surface	Goebel Greg				Lt. Green							7.50	7.5	0.6				
UnK	22-Nov-82	10:30	Midwater	Goebel Greg				Lt. Green							7.70	7.5	1.7				
UnK	22-Nov-82	10:40	Bottom	Goebel Greg				Lt. Green							7.50	7.5	1.7				
UnK	22-Nov-82	10:45	Bottom	Goebel Greg				Lt. Green							7.60	7.5	1.7				
UnK	15-Dec-82	10:05	Bottom	Goebel Greg				Lt. Green	None	None	None	None	None		4.60	7.2	2.2				
UnK	15-Dec-82	9:10	Surface	Goebel Greg	26.0		-11.7	Lt. Green	None	None	None	None	None		6.30	7.2	-0.6	1.22			Sunny-3" snow cover-8" ice cover.
UnK	15-Dec-82	9:50	Midwater	Goebel Greg			-8.3	Lt. Green	None	None	None	None	None		4.60	7.3	2.2				
UnK	15-Dec-82	10:20	Bottom	Goebel Greg			-2.8	Lt. Green	None	None	None	None	None		4.60	7.3	2.2				
UnK	15-Dec-82	9:25	Surface	Goebel Greg				Lt. Green	None	None	None	None	None		4.90	7.3	1.7				
UnK	19-Jan-83	9:10	Surface	Goebel Greg	27.0		-5.0	Lt. Green	None	None		None	None		4.00	6.6	-0.6	1.52			Sunny. .5" scattered snow cover. 16" ice cover.
UnK	19-Jan-83	9:30	Midwater	Goebel Greg			-0.6		None	None	None	None	None		1.00	6.7	2.8				
UnK	19-Jan-83	9:45	Bottom	Goebel Greg			1.1		None	None	None	None	None		0.20	6.6	2.8				
UnK	22-Feb-83	9:20	Surface	Goebel Greg			2.8	Lt. Yellow			None				0.70	6.8	3.3				
UnK	22-Feb-83	9:20	Midwater	Goebel Greg			1.1	Lt. Yellow	None	None	None	None	None		0.30	6.7	2.8				Sunny-No snow cover except scattered around shore.
UnK	22-Feb-83	10:00	Bottom	Goebel Greg			2.8	Lt. Yellow							0.00	7.0	3.3				
UnK	22-Feb-83	9:10	Surface	Goebel Greg	27.0		1.1		None			None	None		2.10	6.7	-0.6	1.83			Ice depth 18"-Kemmerer sample just below ice.
UnK	24-Mar-83	9:25	Midwater	Goebel Greg			1.1	Green			None				1.40	6.8	2.2				Partly cloudy.
UnK	24-Mar-83	9:40	Bottom	Goebel Greg			1.1	Lt. Gray							0.00	6.9	2.8				
UnK	24-Mar-83	9:10	Surface	Goebel Greg	8.5		1.1	Green	None	None	None	None	Mod		11.60	7.1	0.0	0.55			2" snow cover. Algae visible. 11" ice cover.
UnK	19-Apr-83	9:15	Surface	Goebel Greg	28.0		10.0		None	None	None		Mod		11.50	7.4	1.7	1.37			5" clear ice under 6" icy snow.
UnK	19-Apr-83	9:50	Midwater	Goebel Greg			10.0	Lt. Yellowish							4.10	7.3	2.8				Slope runoff - slight. Creek bed under snow.
UnK	19-Apr-83	10:00	Bottom	Goebel Greg			11.1	Lt. Grayish							0.00	7.1	4.4				Sunny.
UnK	9-May-83	10:00	Surface	Goebel Greg	27.0		16.7		None			None	Mod		10.30	7.3	5.6	1.07			Sunny-Wind NW 15.
UnK	9-May-83	10:40	Midwater	Goebel Greg	27.0		16.7	Lt. Green	None		None	None	Mod		9.10	6.9	6.7				Sunny.
UnK	9-May-83	11:00	Bottom	Goebel Greg	27.0		16.7	Lt. Green	None		None	None	Mod		2.30	6.7	4.4				Sunny-Wind NW 15.
UnK	23-May-83	9:40	Surface	Goebel Greg	28		17.8		None	None	None	None	Mod		10.20	7.4	8.9	1.22			Partly cloudy.
UnK	23-May-83	10:30	Bottom	Goebel Greg	28.0		16.1		None	None		None	Mod		0.50	6.5					
UnK	23-May-83	10:10	Bottom	Goebel Greg	28.0		15.0	Lt. Yellowish	None	None	None	None	Mod		5.30	6.8	6.1				
UnK	23-May-83	10:00	Midwater	Goebel Greg	28.0		15.0	Lt. Yellowish	None	None	None	None	Mod		8.10	7.0	7.2				
UnK	8-Jun-83	9:40	Surface	Goebel Greg	28.0		17.2	Lt. Yellowish Green	None	None	None	None	Mod		9.50	8.1	14.4	1.52			Partly cloudy.
UnK	8-Jun-83	10:15	Midwater	Goebel Greg			15.6	Lt. Green			None				5.50	6.8	9.4				Mostly cloudy.
UnK	8-Jun-83	10:35	Bottom	Goebel Greg			11.7	Lt. Grayish Green							0.00	6.7	5.6				
UnK	22-Jun-83	9:15	Surface	Goebel Greg	28.0		20.6	Lt. Green	None	None	None	None	Mod		7.90	7.7	18.3	2.13			Mostly sunny.
UnK	22-Jun-83	9:40	Midwater	Goebel Greg			17.8	Lt. Green			None				6.00	6.9	11.7				
UnK	22-Jun-83	10:00	Bottom	Goebel Greg	28.0		17.8	Lt. Yellowish Green							0.00	6.8	7.8				
UnK	6-Jul-83	10:30	Bottom	Goebel Greg	27.0		34.4								0.00	6.7	7.8				Fewer algae visible-Lake is full.
UnK	6-Jul-83	9:55	Surface	Goebel Greg	27.0		31.7	Lt. Green	None	None	None	None	None		8.00	7.9	19.4				Sunny-Water appears the same as SY-11-2

Site	Date	Time	RelDepth	Personnel	Depth	DC	A Temp	Color	D Fish	Film	Odor	Precip	Wind	Cond	DO	F pH	W Temp	Secchi	Ice	Turb	Weather
UnK	6-Jul-83	10:15	Midwater	Goebel Greg			32.2	Lt. Green			None				8.20	7.4	16.1				
UnK	21-Jul-83	11:45	Bottom	Goebel Greg	27.5		20.0	Lt. Gray Green			Extreme				0.00	6.5	7.8				
UnK	21-Jul-83	10:55	Surface	Goebel Greg	27.5		22.2	Lt. Green	None	None	None	None	Mod		9.50	9.5	21.7	1.37			Partly cloudy.
UnK	21-Jul-83	11:20	Midwater	Goebel Greg			22.2	Lt. Green			None				4.20	6.8	16.7				
UnK	4-Aug-83	11:00	Surface	Goebel Greg	28.0		23.3	Lt. Green	Mild	None	None	None	Mod		9.20	9.5	21.7	1.22			Partly cloudy.
UnK	4-Aug-83	11:20	Midwater	Goebel Greg			23.3	Lt. Green			None				4.20	6.8	16.7				
UnK	4-Aug-83	11:40	Bottom	Goebel Greg	28.0			Lt. Grayish Green			Extreme				0.00	6.7					
UnK	17-Aug-83	10:20	Surface	Goebel Greg	28.0		22.8	Green	None	None	None	None	Mod		10.40	10.1	21.1				Small amt film along shore-lt brown,slimy-as SY11.
UnK	17-Aug-83	10:35	Midwater	Goebel Greg			22.8	Lt. Green			None				2.10	7.4	18.3				Water level approx. 3" below overtopping spillway.
UnK	17-Aug-83	10:55	Bottom	Goebel Greg	28.0		23.3	Lt. Gray Green			Extreme				0.00	6.8	6.1				
UnK	31-Aug-83	10:35	Midwater	Goebel Greg			24.4	Lt. Green			None				3.60	8.6	19.4				Water running through crack in rock near dam.
UnK	31-Aug-83	10:30	Surface	Goebel Greg	27.5		22.8	Green			None				8.50	10.0	19.4				
UnK	31-Aug-83	10:20	Surface	Goebel Greg	27.5		22.2	Green	None	None	None	None	Mod		8.70	10.0	19.4	0.68			Sunny.
UnK	31-Aug-83	10:55	Bottom	Goebel Greg	27.5		24.4	Lt. Gray Green			Extreme				0.00	6.8	9.4				
UnK	17-Oct-83	11:10	Surface	Goebel Greg	28.0		12.8	Lt. Yellow/Green				None	None		5.60	7.0	5.6				
UnK	17-Oct-83	11:30	Midwater	Goebel Greg				Lt. Yellow/Green	None	None	None	None	None		5.50	7.0	5.6				
UnK	17-Oct-83	11:50	Bottom	Goebel Greg			11.7	Lt. Yellow/Green	None	None	None	None	None		5.50	7.0	6.1				H2O not going over spillway-occasional decay odor.
UnK	15-Nov-83	9:40	Surface	Goebel Greg	27.0		3.9	Lt. Green	None	None	None	None	None		10.00	7.4	1.1	1.60			Sunny-thin ice on west side-new rope on kiemmerer.
UnK	15-Nov-83	9:50	Midwater	Goebel Greg			3.9	Lt. Green	None	None	None	None	None		9.70	7.3	2.8				
UnK	15-Nov-83	10:20	Bottom	Goebel Greg			4.4	Lt. Green	None		None	None	Mod		9.20	7.3	2.8				
UnK	12-Dec-83	10:45	Bottom	Goebel Greg			2.2	Lt. Yellow/Green			None				1.30	7.1	2.8				
UnK	12-Dec-83	10:00	Surface	Goebel Greg	28.0		2.2	Lt. Yellow/Green	None		None	None	Mod		12.10	7.5	0.0	1.68			Partly cloudy-8" Ice cover.
UnK	12-Dec-83	10:35	Midwater	Goebel Greg				Lt. Yellow/Green			None				8.40	7.5	1.7				
UnK	16-Jan-84	10:30	Bottom	Goebel Greg			-11.7	Lt. Green			None				0.40	6.9	2.8				
UnK	16-Jan-84	9:10	Surface	Goebel Greg	28.0		-12.8	Lt. Green			None	None	Mod		7.70	6.8	0.0	2.10			Mostly cloudy-1" snow cover, 13" ice cover on lake
UnK	16-Jan-84	10:05	Midwater	Goebel Greg			-12.8	Lt. Green			None				4.50	6.9	1.7				
UnK	14-Feb-84	9:00	Surface	Goebel Greg	28.0		5.6	Med-Lt Green	None		None	None	None		8.50	6.9	0.0	0.60			Cloudy-16.5" ice-snow cover melted-recent warm wea
UnK	14-Feb-84	9:30	Midwater	Goebel Greg			6.1	Very Light Green			None				5.50	6.9	2.2				Deeper samples not as turbid or green as shallow
UnK	14-Feb-84	10:00	Bottom	Goebel Greg			7.8	Slight Green			Mild				1.60	6.6	3.3				
UnK	16-Apr-84	9:30	Surface	Goebel Greg	29.0		10.6	Lt. Green			None	None	None		9.50		2.8	1.70			Sunny-Ice melt arnd edges-Samples just below ice.
UnK	16-Apr-84	9:50	Midwater	Goebel Greg			11.1	Lt. Green			None				8.00		3.9				
UnK	16-Apr-84	10:05	Bottom	Goebel Greg	29.0		12.2	Lt. Green			Mild				0.20		3.9				
UnK	31-May-84	10:00	Surface	Goebel Greg	29.0		18.9	Lt. Green	None	None	None	None	Mod		9.20	7.6	13.3				Partly cloudy.
UnK	31-May-84	10:35	Midwater	Goebel Greg			19.4	Lt. Green			None	None			8.40	7.2	9.4				
UnK	31-May-84	10:55	Bottom	Goebel Greg			20.6	Lt. Green			None	None			4.40	6.9	6.7				
UnK	14-Jun-84	9:40	Surface	Goebel Greg	29.0		19.4	Lt. Green	None	None	None	None	None		8.90	7.6	13.3	1.50			Partly cloudy.
UnK	14-Jun-84	10:10	Midwater	Goebel Greg			22.2	Lt. Green			None				7.40	7.2	11.7				
UnK	14-Jun-84	10:30	Bottom	Goebel Greg			22.2	Lt. Green							0.00	6.9	7.2				
UnK	27-Jun-84	10:00	Surface	Goebel Greg	29.5		22.8	Green			None	None	Mod		12.60	10.0	19.4	0.91			Sunny-4 to 5 dead minnows-Algae small, no clumping
UnK	27-Jun-84	10:20	Midwater	Goebel Greg			22.8	Lt. Green			None				4.70	6.7	11.7				
UnK	27-Jun-84	10:40	Bottom	Goebel Greg			22.8	Lt. Yellow Green							0.00	6.8	6.7				
UnK	11-Jul-84	9:45	Midwater	Goebel Greg			18.9	Lt. Yellow Green			None				2.00	6.7	12.2				
UnK	11-Jul-84	10:00	Bottom	Goebel Greg			18.9	Lt. Gray Green							0.00	6.9	7.2				
UnK	11-Jul-84	9:20	Surface	Goebel Greg	29.5		18.9	Lt. Green	None	None	None	None	Mod		9.00	9.7	19.4	1.45			Sunny.
UnK	24-Jul-84	9:40	Midwater	Goebel Greg			15.0	Lt. Green			None				0.30	6.5	12.2				
UnK	24-Jul-84	9:45	Bottom	Goebel Greg	29.0		15.0	Gray Green							0.00	6.7	7.2				
UnK	24-Jul-84	9:30	Surface	Goebel Greg	29.0		15.0	Lt. Green	None	None	None	Mild	Mod		7.90	9.1	20.6	1.60			Cloudy - Foggy.
UnK	7-Aug-84	9:30	Surface	Goebel Greg	28.5		22.8	Green			None	None	None		9.50	9.6	21.1	1.45			Sunny. Algae is small (1/32") and evenly mixed.
UnK	7-Aug-84	10:00	Midwater	Goebel Greg			22.8	Lt. Green			None				1.70	6.5	15.6				
UnK	7-Aug-84	10:10	Bottom	Goebel Greg			22.8	Gray Green							0.00	6.8	8.3				
UnK	22-Aug-84	9:15	Surface	Goebel Greg	29.0		17.2	Green	None	None	None	None	Mod		8.20	10.0	19.4	0.76			
UnK	22-Aug-84	10:05	Midwater	Goebel Greg			17.2	Green			Mild				6.70	7.8	16.7				
UnK	22-Aug-84	10:30	Bottom	Goebel Greg			17.2	Gray Green							0.00	6.9	8.9				
UnK	12-Sep-84	10:00	Bottom	Goebel Greg			18.9	Gray Green							0.00	6.8	7.8				
UnK	12-Sep-84	9:40	Midwater	Goebel Greg			18.9	Green			None				6.30	7.4	13.9				

DO and Temperature Data

Date	Depth (m)	W Temp	DO
11-Jul-89	0.3	19.0	7.0
	0.9	19.0	6.8
	1.8	18.0	6.0
	2.7	17.0	5.0
	3.6	15.5	1.5
	4.5	15.0	1.2
	5.5	16.0	2.0
16-Aug-89	0.3	18.2	7.7
	0.9	18.1	7.8
	1.8	18.0	7.6
	2.7	18.0	7.0
	3.6	18.0	7.0
	4.5	15.0	0.2
	5.5	13.0	0.3
19-Jun-91	0.0	18.2	11.2
	0.6	17.9	11.4
	1.2	18.1	11.3
	1.8	18.0	11.1
	2.4	12.7	4.2
	3.0	10.9	0.3
	3.6	9.6	0.2
	4.2	9.0	0.1
	4.8	7.9	0.2
	5.5	7.0	0.1
	6.1	7.0	0.1
	6.7	6.4	0.1
	7.0	6.0	0.0
2-Oct-91	0.0	11.5	8.9
	0.6	11.5	8.8
	1.2	11.5	9.0
	1.8	11.5	8.3
	2.4	11.0	6.2
	3.0	10.0	3.6
	3.6	9.5	2.2
	4.2	9.3	1.4
	4.8	9.0	0.8
	5.5	8.2	0.1
	6.1	8.0	0.0
	6.7	7.0	0.0
	7.3	6.1	0.0

Date	Depth (m)	W Temp	DO
15-Jun-93	0.0	14.5	8.8
	0.9	14.0	8.7
	1.8	13.5	8.2
	2.7	10.0	6.3
	3.6	8.6	4.8
	4.5	7.0	1.0
	5.5	6.0	0.8
	6.4	5.0	0.9
	7.3	4.5	0.8
3-Aug-93	0.0	16.0	8.2
	0.9	16.0	8.0
	1.8	16.0	6.5
	2.7	14.0	1.5
	3.6	12.0	0.2
	4.5	9.0	0.1
	5.5	9.0	0.1
	6.4	7.0	0.1
23-Aug-01	1.0	19.2	10.2
	2.0	19.1	10.1
	3.0	18.8	9.1
	4.0	18.8	7.1
	5.0	18.6	5.0
	6.0	18.3	4.8
	7.0	18.2	4.6
25-Sep-01	1.0	15.6	7.8
	2.0	15.3	7.2
	3.0	14.0	5.4
	4.0	13.7	4.4
	5.0	14.2	5.9
	6.0	13.9	5.1
	7.0	14.1	4.8
31-Oct-01	1.0	5.5	8.7
	2.0	5.1	8.3
	3.0	5.0	8.0
	4.0	5.2	8.3
	5.0	5.1	8.3
	6.0	5.1	8.5
	7.0	5.1	8.3

Date	Depth (m)	W Temp	DO
27-Dec-01	1.0	3.3	6.6
	2.0	3.6	6.0
	3.0	3.7	5.7
	4.0	3.7	5.5
	5.0	3.7	5.0
	6.0	3.8	4.8
	7.0	3.8	4.1
31-Jan-02	1.0	2.5	6.2
	2.0	2.5	6.0
	3.0	2.5	5.9
	4.0	2.5	5.2
	5.0	2.6	4.5
	6.0	2.6	4.4
	7.0	2.6	4.0
26-Feb-02	1.0	4.1	5.1
	2.0	4.0	4.8
	3.0	4.0	4.6
	4.0	4.1	4.6
	5.0	4.0	4.2
	6.0	4.1	4.3
	7.0	4.2	4.2
13-May-02	1.0	9.2	9.9
	2.0	9.0	9.8
	3.0	8.3	9.5
	4.0	7.6	9.2
	5.0	7.0	8.2
	6.0	7.1	8.0
	7.0	7.0	7.8
6-Jun-02	1.0	17.3	8.0
	2.0	16.3	7.9
	3.0	13.9	7.5
	4.0	12.5	6.2
	5.0	11.1	4.1
	6.0	10.2	2.6
	7.0	9.3	0.5

Date	Depth (m)	W Temp	DO
2-Jul-02	1.0	21.7	6.5
	2.0	18.1	6.0
	3.0	17.4	5.9
	4.0	15.1	4.2
	5.0	14.0	3.3
	6.0	12.3	1.9
	7.0	10.2	0.4
5-Aug-02	1.0	19.9	6.7
	2.0	19.8	6.3
	3.0	19.3	5.2
	4.0	19.1	4.3
	5.0	18.7	2.0
	6.0	15.3	0.7
	7.0	14.7	0.5
18-Apr-03	0.3	7.6	11.1
	0.6	7.6	11.0
	0.9	7.6	11.0
	1.2	7.6	11.1
	1.5	7.5	11.0
	1.8	7.6	11.0
	2.2	7.6	11.0
	2.5	7.5	10.9
	2.8	7.5	10.9
	3.1	7.5	10.9
	3.4	7.3	10.9
	3.7	6.9	10.3
	4.0	6.6	9.1
	4.3	6.3	8.7
	4.6	6.1	7.9
	4.9	5.8	7.6
	5.2	5.7	7.5
	5.5	5.6	7.4
	5.8	5.5	7.1
	6.1	5.2	5.6
	6.4	4.8	2.9
	6.7	4.8	0.4
	7.0	4.9	0.3
	7.3	4.9	0.2

Date	Depth (m)	W Temp	DO
16-May-03	0.0	12.3	9.7
	0.3	12.1	9.8
	0.7	11.5	9.9
	0.9	11.4	9.8
	1.2	11.4	9.7
	1.5	11.1	9.8
	1.9	10.9	9.7
	2.2	10.1	9.8
	2.5	9.4	9.4
	2.8	9.1	9.2
	3.1	8.3	9.0
	3.4	7.8	8.5
	3.7	7.6	8.3
	4.0	7.5	8.1
	4.3	7.4	7.7
	4.6	7.0	7.0
	5.0	6.8	6.1
	5.2	6.7	6.1
	5.5	6.7	6.2
	5.8	6.6	6.0
	6.1	6.6	5.8
	6.4	6.5	5.7
	6.7	6.5	5.8
	7.0	6.5	5.8
	7.3	6.5	4.2
	7.6	6.4	2.4

Date	Depth (m)	W Temp	DO
12-Jun-03	0.1	15.9	8.7
	0.3	15.7	8.6
	0.6	15.5	8.6
	0.9	15.3	8.5
	1.2	15.1	8.4
	1.5	14.7	7.9
	1.8	14.4	8.0
	2.2	13.9	8.3
	2.5	13.5	8.0
	2.8	13.0	7.8
	3.1	12.2	7.1
	3.3	11.8	6.7
	3.7	11.7	6.3
	4.0	11.5	6.0
	4.3	11.3	5.5
	4.6	10.7	3.9
	4.9	9.5	0.4
	5.2	8.5	0.2
	5.5	7.6	0.2
	5.8	7.2	0.1
	6.1	6.9	0.1
	6.4	6.7	0.1
	6.7	6.7	0.1
	7.1	6.6	0.1
	7.3	6.5	0.1
	7.6	6.4	0.1
	7.9	6.3	0.1
	8.2	6.3	0.1

Date	Depth (m)	W Temp	DO
2-Jul-03	0.1	19.0	9.0
	0.3	18.7	8.7
	0.6	18.5	9.1
	0.9	18.3	8.9
	1.3	17.8	8.6
	1.6	17.5	9.0
	1.9	17.3	8.8
	2.1	17.0	8.6
	2.5	16.3	8.4
	2.7	16.1	8.3
	3.2	15.8	8.4
	3.5	15.8	7.7
	3.7	15.1	7.5
	4.1	14.8	7.2
	4.3	14.4	6.8
	4.6	13.6	5.3
	4.8	13.2	4.5
	5.2	11.9	1.8
	5.5	10.3	0.8
	5.8	8.8	0.2
	6.1	8.3	0.2
	6.4	7.7	0.2
	6.7	7.3	0.2
	7.0	7.1	0.1
	7.3	7.0	0.1
	7.7	6.8	0.2

Date	Depth (m)	W Temp	DO
17-Jul-03	0.1	22.5	8.0
	0.3	22.5	8.0
	0.7	22.4	8.0
	0.9	22.4	8.1
	1.2	22.1	8.1
	1.5	22.0	8.1
	1.8	21.8	8.0
	2.1	21.5	8.0
	2.5	21.1	7.5
	2.7	20.9	7.5
	3.0	20.6	7.4
	3.3	20.0	6.7
	3.6	19.5	6.4
	3.9	18.3	5.5
	4.2	17.3	4.8
	4.5	15.8	3.2
	4.8	14.6	1.6
	5.1	13.1	0.6
	5.4	11.1	0.4
	5.7	10.1	0.3
	6.0	9.3	0.3
	6.4	8.4	0.2
	6.7	7.9	0.2
	6.9	7.5	0.3
	7.3	7.3	0.2

Date	Depth (m)	W Temp	DO
19-Aug-03	0.0	21.8	9.6
	0.3	21.5	9.8
	0.6	21.0	9.5
	0.9	20.9	9.0
	1.2	20.8	8.2
	1.5	20.7	7.8
	1.8	20.6	6.3
	2.2	20.5	5.7
	2.4	20.5	5.9
	2.7	20.5	5.8
	3.0	20.4	5.2
	3.3	20.3	4.8
	3.7	20.2	4.1
	4.0	20.1	3.2
	4.3	19.7	1.0
	4.6	19.3	0.5
	4.9	17.9	0.3
	5.1	16.1	0.2
	5.5	13.4	0.1
	5.7	12.0	0.1
	6.0	10.4	0.2
	6.3	9.6	0.2
	6.7	8.5	0.1
	6.9	8.1	0.2

Date	Depth (m)	W Temp	DO
16-Jun-04	0.5	15.0	8.8
	1.1	15.0	10.1
	1.6	14.9	10.0
	2.0	14.9	9.9
	2.6	14.9	10.0
	3.1	14.6	9.9
	3.9	14.0	9.4
	4.5	12.7	7.7
	5.1	11.9	6.8
	5.6	11.1	4.0
	6.1	9.4	2.4
	6.5	8.5	1.6
	7.0	7.8	1.1
	7.5	6.8	0.4
22-Jul-04	0.5	20.8	6.8
	1.0	20.8	6.9
	1.5	20.8	6.9
	2.0	20.8	6.9
	2.5	20.7	6.8
	3.0	20.4	6.7
	3.5	18.5	6.4
	4.0	17.1	5.3
	4.5	16.3	3.6
	5.0	15.1	1.4
	5.5	13.9	0.6
	6.0	11.9	0.4
	6.5	10.5	0.3
	7.0	9.0	0.3
	7.5	8.1	0.3

Date	Depth (m)	W Temp	DO
30-Aug-04	0.5	17.7	8.2
	1.0	16.8	8.2
	1.5	16.4	8.3
	2.0	16.3	8.3
	2.5	16.2	8.2
	3.0	16.2	8.2
	3.5	16.2	8.1
	4.0	16.2	7.8
	4.5	16.1	7.6
	5.0	16.1	7.1
	5.5	15.8	5.2
	6.0	13.4	0.3
	6.5	11.8	0.2
	7.0	9.6	0.2
	7.5	8.8	0.2
	8.0	8.4	0.2

Table of Abbreviations and Units

Abbreviation	Parameter	Units
A Temp	Air Temperature	°C
Alka	Alkalinity	mg/L
Ammo	Ammonia	mg/L
Chlorophyll a	Chlorophyll a - corrected for Phaeophytin	mg/m^3
Comp	Composite	
Cond	Conductivity	µmhos/cm
D Fish	Dead Fish	
DC	Discharge	cfs
Depth	Total Water Depth	ft
DO	Dissolved Oxygen	mg/L
E Coli	E Coli Coliform	Colony Forming Units (CFU)/100 mL
Ext	Extreme	
F pH	Field pH	su
Fecal	Fecal Coliform	Colony Forming Units (CFU)/100 mL
Ice	Ice Cover	
Mod	Moderate	
NO3+NO4	Nitrate + Nitrite	mg/L
Precip	Precipitation	
RelDepth	Relative Depth	
Rep	Replicate Sample	
S Depth	Sample Depth	ft
S Type	Sample Type	
Secchi	Secchi Depth	m
TDP	Total Dissolved Phosphorous	mg/L
TDS	Total Dissolved Solids	mg/L
TKN	Total Kjeldahl Nitrogen	mg/L
Tot N	Total Nitrogen	mg/L
Tot P	Total Phosphorous	mg/L
Tot Sol	Total Solids	mg/L
TSI Chl a	Trophic State Index - Chlorophyll a	Chl a in mg/m^3
TSI Mean	Trophic State Index Mean	
TSI N	Trophic State Index - Nitrogen	N in mg/L
TSI Secchi	Trophic State Index - Secchi Depth	Secchi Depth in m
TSI Tot P	Trophic State Index - Total Phosphorous	Tot P in mg/L
TSS	Total Suspended Solids	mg/L
Turb	Turbidity	Nephelometric Turbidity Units (NTU)
TVSS	Total Volatile Suspended Solids	mg/L
UnK	Unknown	
W Temp	Water Temperature	°C
Weather	Weather Conditions and/or Field Comments	
	Nitrate	mg/L

Appendix D

Benthic Macroinvertebrate Data

Client: **Scott Environmental**, Custer, SD Phone: 605-673-3353

Project: Benthic Macroinvertebrate Samples collected from Center, Legion and Sylvan Lake Tributaries within Custer State Park, SD. Samples collected November 9, 2001.

Data collected and compiled by: ***Natural Resource Solutions***

Contact Information:
Natural Resource Solutions
Attn: Rebecca Spawn-Stroup
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Phone/Fax: 605-693-6767
Email: stroup@itctel.com

Benthic Macroinvertebrate Data - Custer State Park, SD

(Complete Data Set, 21 samples)

		Site:	CLT	CLT	CLT	CLT	CLT	CLT	CLT	LLT	LLT	LLT	LLT	LLT	LLT	SLT	SLT	SLT	SLT	SLT	SLT	SLT	SLT
CLASS/ORDER	FAMILY	FINAL DETERMINATION	Life Stage	3-A	3-A (dup)	3-B	3-C	5-A	5-B	5-C	3-A	3-B	3-C	5-A	5-B	5-C	4-A	4-A (dup)	4-B	4-C	5-A	5-A (dup)	5-B	5-C
Amphipoda	Crangonyctidae	*Crangonyx* sp.	NA	0	0	0	0	0	0	0	34	6	29	6	6	2	0	0	0	0	0	0	0	0
Amphipoda	Gammaridae	*Gammarus* sp.	NA	0	0	0	0	3	0	0	59	37	78	17	34	4	0	0	0	0	0	0	0	0
Coleoptera	Dytiscidae	*Hydaticus* sp.	A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Coleoptera	Dytiscidae	*Hydaticus* sp.	L	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Coleoptera	Dytiscidae	*Laccophilus* sp.	A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Coleoptera	Dytiscidae	*Uvarus* sp.	A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Coleoptera	Elmidae	*Dubiraphia* sp.	L	0	0	0	0	1	2	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Coleoptera	Elmidae	*Heterlimnius corpulentus*	L	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Coleoptera	Elmidae	*Optioservus* sp.	L	0	2	41	22	16	34	9	0	0	0	65	77	59	1	0	0	0	0	0	0	0
Coleoptera	Elmidae	*Optioservus* sp.	A	0	0	1	4	0	3	0	0	1	0	0	9	0	0	0	0	0	0	0	0	0
Coleoptera	Elmidae	*Stenelmis* sp.	A	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Coleoptera	Elmidae	*Zaitzevia parvula*	L	2	1	5	5	13	59	3	0	0	5	1	9	7	1	0	0	0	0	0	0	0
Coleoptera	Elmidae	*Zaitzevia parvula*	A	0	0	0	0	0	1	0	0	1	0	0	3	0	0	0	0	0	0	0	0	0
Coleoptera	Hydraenidae	*Hydraena* sp.	A	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0
Coleoptera	Hydrophilidae	*Anacaena* sp.	A	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0
Diptera	Ceratopogonidae	Ceratopogoninae	L	4	3	4	0	22	1	4	20	12	36	5	2	10	36	48	58	29	8	3	26	4
Diptera	Chironomidae	*Ablabesmyia* sp.	L	0	0	0	0	0	1	14	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Diptera	Chironomidae	*Brillia* sp.	L	0	0	0	0	0	0	0	0	1	0	0	0	0	3	1	2	1	0	0	0	1
Diptera	Chironomidae	*Chaetocladius* sp.	L	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diptera	Chironomidae	Chironominae (imm.)	L	0	0	0	0	0	0	0	0	0	0	0	0	22	0	0	0	0	0	0	0	0
Diptera	Chironomidae	*Corynoneura* sp.	L	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	1
Diptera	Chironomidae	*Cricotopus/Orthocladius* sp.	L	0	0	1	0	1	3	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Diptera	Chironomidae	*Cryptochironomus* sp.	L	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diptera	Chironomidae	*Eukiefferiella* sp.	L	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	0	0	1	0
Diptera	Chironomidae	*Harnischia* complex	L	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Diptera	Chironomidae	*Heleniella* sp.	L	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diptera	Chironomidae	*Heterotrissocladius* sp.	L	0	0	0	0	1	0	1	0	0	0	0	0	0	14	5	0	0	8	6	2	0
Diptera	Chironomidae	*Krenopelopia* sp.	L	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diptera	Chironomidae	*Larsia* sp.	L	110	79	85	0	0	0	0	0	0	1	1	0	2	0	0	0	5	0	0	10	17
Diptera	Chironomidae	*Limnophyes* sp.	L	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
Diptera	Chironomidae	*Metriocnemus* sp.	L	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Diptera	Chironomidae	*Micropsectra* sp.	L	25	20	1	4	42	0	36	6	0	0	2	1	26	5	2	0	4	0	3	0	0
Diptera	Chironomidae	*Microtendipes pedellus* gp.	L	43	57	1	0	52	2	13	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Diptera	Chironomidae	*Odontomesa* sp.	L	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Diptera	Chironomidae	Orthocladiinae (imm.)	L	0	0	0	1	13	0	0	0	0	0	0	0	1	0	3	14	0	0	0	0	0
Diptera	Chironomidae	*Pagastia* sp.	L	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	1	0	2	0
Diptera	Chironomidae	*Parachaetocladius* sp.	L	0	0	0	0	0	0	0	36	39	27	2	2	0	0	0	0	0	0	0	0	0
Diptera	Chironomidae	*Parakiefferiella* sp.	L	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0
Diptera	Chironomidae	*Parametriocnemus* sp.	L	0	0	0	1	2	2	1	0	1	0	0	0	2	0	0	0	0	0	0	0	0
Diptera	Chironomidae	*Pentaneura* sp.	L	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diptera	Chironomidae	*Polypedilum* sp.	L	23	30	23	1	18	28	64	25	20	26	1	0	16	89	110	43	53	149	182	77	120
Diptera	Chironomidae	*Procladius* sp.	L	6	6	1	0	1	0	18	0	0	0	0	4	3	0	0	0	0	0	0	0	0
Diptera	Chironomidae	*Prodiamesa* sp.	L	0	0	0	0	0	0	0	7	4	1	0	0	0	3	4	1	3	2	0	0	4
Diptera	Chironomidae	*Radotanypus* sp.	L	0	0	0	0	0	0	2	9	3	1	21	1	18	37	38	15	12	15	11	13	29
Diptera	Chironomidae	*Rheocricotopus* sp.	L	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0
Diptera	Chironomidae	Tanypodinae (imm.)	L	0	0	0	14	4	0	3	0	0	2	0	0	0	12	0	0	0	0	0	0	0
Diptera	Chironomidae	*Tanytarsus* sp.	L	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Diptera	Chironomidae	*Thienemanniella* sp.	L	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Diptera	Chironomidae	*Thienemannimyia* gp.	L	56	51	27	50	19	2	6	8	1	3	18	11	2	0	0	6	1	0	2	2	0
Diptera	Chironomidae	*Tvetenia* sp.	L	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
Diptera	Psychodidae	*Pericoma/Telmatoscopus* sp.	L	0	0	0	0	0	0	0	0	9	7	0	0	0	0	0	0	0	0	0	0	0
Diptera	Ptychopteridae	*Ptychoptera* sp.	L	0	0	0	0	0	0	0	12	3	1	0	0	5	2	1	0	0	0	0	0	0
Diptera	Simuliidae	*Simulium* sp.	L	0	0	0	1	0	1	0	0	0	0	14	21	4	0	1	0	0	0	0	0	1
Diptera	Tabanidae	*Chrysops* sp.	L	2	1	0	0	0	0	2	4	0	0	1	0	0	0	0	0	0	0	0	0	0

			Site:	CLT	CLT	CLT	CLT	CLT	CLT	CLT	LLT	LLT	LLT	LLT	LLT	LLT	SLT	SLT	SLT	SLT	SLT	SLT	SLT	SLT
CLASS/ORDER	FAMILY	FINAL DETERMINATION	Life Stage	3-A	3-A (dup)	3-B	3-C	5-A	5-B	5-C	3-A	3-B	3-C	5-A	5-B	5-C	4-A	4-A (dup)	4-B	4-C	5-A	5-A (dup)	5-B	5-C
Diptera	Tipulidae	*Antocha* sp.	L	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diptera	Tipulidae	*Dicranota* sp.	L	0	0	0	0	0	0	0	1	2	2	0	0	0	5	0	14	4	0	0	0	1
Diptera	Tipulidae	*Hexatoma* sp.	L	1	2	4	2	1	1	1	0	0	0	2	1	2	0	0	0	0	0	0	0	0
Diptera	Tipulidae	*Tipula* sp.	L	0	0	0	5	3	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diptera	Tipulidae	Tipulidae (imm.)	L	0	0	0	0	0	0	0	6	7	4	4	2	4	0	0	0	0	0	0	0	0
Ephemeroptera	Baetidae	Baetidae (imm./damaged)	L	2	2	23	17	3	14	4	0	0	0	7	0	5	6	4	2	1	1	0	63	58
Ephemeroptera	Baetidae	*Baetis* sp.	L	0	0	0	0	0	8	0	0	0	0	5	0	5	5	13	8	0	0	0	0	0
Ephemeroptera	Baetidae	*Paracloeodes minutus*	L	0	0	0	4	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	4	0
Ephemeroptera	Ephemerellidae	Ephemerellidae (imm.)	L	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ephemeroptera	Leptohyphidae	*Tricorythodes* sp.	L	0	0	0	0	2	0	11	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Ephemeroptera	Leptophlebiidae	*Paraleptophlebia* sp.	L	4	2	20	50	11	11	8	0	0	0	4	38	0	0	0	0	0	0	0	0	0
Gastropoda	Ancylidae	*Ferrissia* sp.	NA	0	0	0	0	3	3	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Gastropoda	Planorbidae	*Gyraulus* sp.	NA	0	0	0	4	10	0	8	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Gastropoda	Physellidae	*Physella* sp.	NA	2	4	2	18	2	2	0	3	1	0	0	9	4	0	0	0	0	1	0	2	1
Hirudinea	Glossiphoniidae	*Glossiphonia complanata*	NA	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
Hirudinea	Glossiphoniidae	*Helobdella stagnalis*	NA	7	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Megaloptera	Sialidae	*Sialis* sp.	L	4	7	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Odonata	Aeshnidae	*Anax* sp.	L	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Odonata	Corduliidae	*Epitheca (Tetragoneuria)* sp.	L	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Odonata	Gomphidae	Gomphidae (imm.)	L	0	0	0	0	1	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Odonata	Gomphidae	*Gomphus* sp.	L	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Odonata	Gomphidae	*Ophiogomphus* sp.	L	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oligochaeta	Oligochaeta	Oligochaeta	NA	0	0	0	0	0	0	0	0	0	0	2	3	1	0	0	0	0	0	0	8	20
Oligochaeta	Naididae	*Slavina appendiculata*	NA	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oligochaeta	Tubificidae	Tubificidae (imm. w/o cc)	NA	1	1	3	0	4	10	20	0	0	0	0	0	0	49	13	8	0	2	48	7	0
Oligochaeta	Tubificidae	Tubificidae (imm. w/ cc)	NA	1	0	0	0	0	0	0	0	0	0	0	0	0	23	12	2	0	1	2	1	0
Pelecypoda	Sphaeriidae	*Pisidium* sp.	NA	0	0	0	0	0	0	4	1	0	0	2	3	6	0	0	2	0	3	0	0	0
Pelecypoda	Sphaeriidae	Sphaeriidae (imm.)	NA	43	25	6	11	8	67	49	2	6	11	35	3	96	19	5	30	0	44	28	16	22
Pelecypoda	Sphaeriidae	Sphaerium sp.	NA	0	0	0	0	0	0	0	0	0	1	0	0	0	0	31	8	3	17	0	0	0
Plecoptera	NA	Plecoptera (imm./damaged)	L	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	74
Plecoptera	Capniidae	*Paracapnia* sp.	L	2	2	4	27	0	3	0	1	0	0	4	0	0	0	0	8	4	0	0	0	0
Plecoptera	Chloroperlidae	Chloroperlidae (imm.)	L	4	6	4	7	10	6	4	9	2	5	23	12	17	5	6	1	3	21	6	29	12
Plecoptera	Chloroperlidae	*Sweltsa* sp.	L	3	5	4	29	2	5	4	1	0	12	4	0	0	0	0	0	1	0	0	0	0
Plecoptera	Nemouridae	Nemouridae (imm.)	L	0	0	0	0	0	0	0	23	13	0	1	0	0	1	0	1	2	7	4	2	3
Plecoptera	Nemouridae	*Zapada cinctipes*	L	0	0	12	6	0	5	0	0	0	0	5	8	4	0	1	0	0	0	0	0	0
Plecoptera	Perlodidae	*Skwala* sp.	L	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trichoptera	NA	Trichoptera (imm.)	L	1	0	0	0	0	0	1	0	0	0	3	0	0	0	0	0	0	0	0	0	0
Trichoptera	Apataniidae	*Allomyia* sp.	L	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
Trichoptera	Brachycentridae	*Brachycentrus* sp.	L	0	0	1	0	0	2	1	0	0	0	0	1	2	0	0	0	0	0	0	0	0
Trichoptera	Brachycentridae	*Micrasema* sp.	L	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trichoptera	Glossosomatidae	*Glossosoma* sp.	L	0	0	0	1	0	1	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0
Trichoptera	Hydropsychidae	*Ceratopsyche morosa* gp. (imm.)	L	0	0	0	0	0	6	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trichoptera	Hydropsychidae	*Ceratopsyche slossonae*	L	0	0	11	1	0	3	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0
Trichoptera	Hydropsychidae	*Cheumatopsyche* sp.	L	0	0	9	2	0	28	0	0	0	0	16	28	0	0	0	0	0	0	0	0	0
Trichoptera	Hydropsychidae	*Hydropsyche* sp.	L	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trichoptera	Hydroptilidae	Hydroptilidae (damaged)	P	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trichoptera	Leptoceridae	Leptoceridae (imm.)	L	0	0	0	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trichoptera	Leptoceridae	*Mystacides* sp.	L	0	0	0	0	4	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trichoptera	Leptoceridae	*Oecetis* sp.	L	2	4	1	0	6	0	0	1	1	1	7	6	6	2	0	0	0	0	0	0	0
Trichoptera	Lepidostomatidae	*Lepidostoma* sp.	L	1	3	1	18	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trichoptera	Limnephilidae	Limnephilidae (imm.)	L	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	3	0	0
Trichoptera	Limnephilidae	*Limnephilus* sp.	L	2	1	0	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Trichoptera	Limnephilidae	*Hesperophylax* sp.	L	0	0	0	0	0	0	0	18	20	28	7	5	6	33	35	38	31	6	4	19	4
Trichoptera	Phryganeidae	*Ptilostomis* sp.	L	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0
Trichoptera	Polycentropodidae	*Polycentropus* sp.	L	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Acari	NA	0	0	0	2	10	2	0	5	5	10	2	8	1	3	0	0	0	2	0	0	6
		Ostracoda	NA	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2	0	0	0	0	0
		Turbellaria	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	13	10	1	0	0	0	0	0
			ttl:	**352**	**319**	**300**	**311**	**311**	**328**	**301**	**295**	**195**	**304**	**296**	**323**	**344**	**371**	**347**	**267**	**157**	**297**	**304**	**311**	**379**

Metrics Analysis Results for Legion, Center and Sylvan Lake Tributary samples,
Custer State Park, SD

Metrics compiled analyzed by:
Natural Resource Solutions
Phone: 605-693-6767
Email: stroup@itctel.com

Metric 1		Metric 2		Metric 3		Metric 4		Metric 5	
StationID	**Taxa Richness**	StationID	**EPT Taxa**	StationID	**Ephemeroptera Taxa**	StationID	**Trichoptera Taxa**	StationID	**Plecoptera Taxa**
CLT 3-A	25	CLT 3-A	9	CLT 3-A	2	CLT 3-A	4	CLT 3-A	3
CLT 3-A (dup)	27	CLT 3-A (dup)	8	CLT 3-A (dup)	2	CLT 3-A (dup)	3	CLT 3-A (dup)	3
CLT 3-B	28	CLT 3-B	12	CLT 3-B	3	CLT 3-B	5	CLT 3-B	4
CLT 3-C	28	CLT 3-C	13	CLT 3-C	3	CLT 3-C	6	CLT 3-C	4
CLT 5-A	39	CLT 5-A	11	CLT 5-A	3	CLT 5-A	5	CLT 5-A	3
CLT 5-B	37	CLT 5-B	15	CLT 5-B	4	CLT 5-B	6	CLT 5-B	5
CLT 5-C	34	CLT 5-C	9	CLT 5-C	3	CLT 5-C	4	CLT 5-C	2
LLT 3-A	25	LLT 3-A	6	LLT 3-A	0	LLT 3-A	2	LLT 3-A	4
LLT 3-B	23	LLT 3-B	4	LLT 3-B	0	LLT 3-B	2	LLT 3-B	2
LLT 3-C	26	LLT 3-C	4	LLT 3-C	0	LLT 3-C	2	LLT 3-C	2
LLT 5-A	37	LLT 5-A	14	LLT 5-A	4	LLT 5-A	5	LLT 5-A	5
LLT 5-B	33	LLT 5-B	11	LLT 5-B	2	LLT 5-B	7	LLT 5-B	2
LLT 5-C	32	LLT 5-C	7	LLT 5-C	2	LLT 5-C	3	LLT 5-C	2
SLT 4-A	26	SLT 4-A	6	SLT 4-A	2	SLT 4-A	2	SLT 4-A	2
SLT 4-A (dup)	21	SLT 4-A (dup)	6	SLT 4-A (dup)	2	SLT 4-A (dup)	2	SLT 4-A (dup)	2
SLT 4-B	21	SLT 4-B	6	SLT 4-B	2	SLT 4-B	1	SLT 4-B	3
SLT 4-C	16	SLT 4-C	6	SLT 4-C	1	SLT 4-C	1	SLT 4-C	4
SLT 5-A	22	SLT 5-A	6	SLT 5-A	1	SLT 5-A	3	SLT 5-A	2
SLT 5-A (dup)	13	SLT 5-A (dup)	4	SLT 5-A (dup)	0	SLT 5-A (dup)	2	SLT 5-A (dup)	2
SLT 5-B	25	SLT 5-B	6	SLT 5-B	2	SLT 5-B	1	SLT 5-B	3
SLT 5-C	19	SLT 5-C	5	SLT 5-C	1	SLT 5-C	1	SLT 5-C	3

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Metric 6	
StationID	Diptera Taxa
CLT 3-A	9
CLT 3-A (dup)	10
CLT 3-B	9
CLT 3-C	9
CLT 5-A	16
CLT 5-B	12
CLT 5-C	16
LLT 3-A	12
LLT 3-B	12
LLT 3-C	12
LLT 5-A	12
LLT 5-B	12
LLT 5-C	15
SLT 4-A	14
SLT 4-A (dup)	11
SLT 4-B	9
SLT 4-C	9
SLT 5-A	9
SLT 5-A (dup)	7
SLT 5-B	11
SLT 5-C	9

Metric 7	
StationID	Chironomidae Taxa
CLT 3-A	6
CLT 3-A (dup)	7
CLT 3-B	7
CLT 3-C	6
CLT 5-A	13
CLT 5-B	8
CLT 5-C	12
LLT 3-A	7
LLT 3-B	7
LLT 3-C	7
LLT 5-A	7
LLT 5-B	8
LLT 5-C	10
SLT 4-A	11
SLT 4-A (dup)	8
SLT 4-B	7
SLT 4-C	7
SLT 5-A	8
SLT 5-A (dup)	6
SLT 5-B	10
SLT 5-C	6

Metric 8			
StationID	EPT Abund	Chiro Abund	EPT/Chiro Abundance
CLT 3-A	21	263	0.08
CLT 3-A (dup)	25	244	0.10
CLT 3-B	91	139	0.65
CLT 3-C	166	71	2.34
CLT 5-A	57	156	0.37
CLT 5-B	97	41	2.37
CLT 5-C	36	160	0.23
LLT 3-A	53	93	0.57
LLT 3-B	36	69	0.52
LLT 3-C	46	61	0.75
LLT 5-A	90	46	1.96
LLT 5-B	109	23	4.74
LLT 5-C	184	93	1.98
SLT 4-A	52	167	0.31
SLT 4-A (dup)	61	165	0.37
SLT 4-B	58	84	0.69
SLT 4-C	42	79	0.53
SLT 5-A	40	178	0.22
SLT 5-A (dup)	17	206	0.08
SLT 5-B	137	111	1.23
SLT 5-C	151	172	0.88

Metric 9	
StationID	% EPT
CLT 3-A	5.97
CLT 3-A (dup)	7.84
CLT 3-B	30.33
CLT 3-C	53.38
CLT 5-A	18.33
CLT 5-B	29.57
CLT 5-C	11.96
LLT 3-A	17.97
LLT 3-B	18.46
LLT 3-C	15.13
LLT 5-A	30.41
LLT 5-B	33.75
LLT 5-C	13.08
SLT 4-A	14.02
SLT 4-A (dup)	17.58
SLT 4-B	21.72
SLT 4-C	26.75
SLT 5-A	13.47
SLT 5-A (dup)	5.59
SLT 5-B	44.05
SLT 5-C	39.84

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Metric 10		Metric 11		Metric 12		Metric 13		Metric 14	
StationID	**% Ephemeroptera**	StationID	**% Plecoptera**	StationID	**% Trichoptera**	StationID	**% Chironomidae**	StationID	**% Tanytarsini**
CLT 3-A	1.70	CLT 3-A	2.56	CLT 3-A	1.70	CLT 3-A	74.72	CLT 3-A	0.00
CLT 3-A (dup)	1.25	CLT 3-A (dup)	4.08	CLT 3-A (dup)	2.51	CLT 3-A (dup)	76.49	CLT 3-A (dup)	0.00
CLT 3-B	14.67	CLT 3-B	8.00	CLT 3-B	7.67	CLT 3-B	46.33	CLT 3-B	0.00
CLT 3-C	22.83	CLT 3-C	22.19	CLT 3-C	8.36	CLT 3-C	22.83	CLT 3-C	0.00
CLT 5-A	5.14	CLT 5-A	4.18	CLT 5-A	9.00	CLT 5-A	50.16	CLT 5-A	0.00
CLT 5-B	10.37	CLT 5-B	6.10	CLT 5-B	13.11	CLT 5-B	12.50	CLT 5-B	0.00
CLT 5-C	7.64	CLT 5-C	2.66	CLT 5-C	1.66	CLT 5-C	53.16	CLT 5-C	0.00
LLT 3-A	0.00	LLT 3-A	11.53	LLT 3-A	6.44	LLT 3-A	31.53	LLT 3-A	0.00
LLT 3-B	0.00	LLT 3-B	7.69	LLT 3-B	10.77	LLT 3-B	35.38	LLT 3-B	0.00
LLT 3-C	0.00	LLT 3-C	5.59	LLT 3-C	9.54	LLT 3-C	20.07	LLT 3-C	0.00
LLT 5-A	5.74	LLT 5-A	12.50	LLT 5-A	12.16	LLT 5-A	15.54	LLT 5-A	0.00
LLT 5-B	13.00	LLT 5-B	6.19	LLT 5-B	14.55	LLT 5-B	7.12	LLT 5-B	0.00
LLT 5-C	2.91	LLT 5-C	6.10	LLT 5-C	4.07	LLT 5-C	27.03	LLT 5-C	0.00
SLT 4-A	2.96	SLT 4-A	1.62	SLT 4-A	9.43	SLT 4-A	45.01	SLT 4-A	0.00
SLT 4-A (dup)	4.90	SLT 4-A (dup)	2.02	SLT 4-A (dup)	10.66	SLT 4-A (dup)	47.55	SLT 4-A (dup)	0.00
SLT 4-B	3.75	SLT 4-B	3.75	SLT 4-B	14.23	SLT 4-B	31.46	SLT 4-B	0.00
SLT 4-C	0.64	SLT 4-C	6.37	SLT 4-C	19.75	SLT 4-C	50.32	SLT 4-C	0.00
SLT 5-A	0.34	SLT 5-A	9.43	SLT 5-A	3.70	SLT 5-A	59.93	SLT 5-A	0.00
SLT 5-A (dup)	0.00	SLT 5-A (dup)	3.29	SLT 5-A (dup)	2.30	SLT 5-A (dup)	67.76	SLT 5-A (dup)	0.00
SLT 5-B	21.54	SLT 5-B	16.40	SLT 5-B	6.11	SLT 5-B	35.69	SLT 5-B	0.00
SLT 5-C	15.30	SLT 5-C	23.48	SLT 5-C	1.06	SLT 5-C	45.38	SLT 5-C	0.00

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Metric 15	
StationID	% Diptera
CLT 3-A	76.70
CLT 3-A (dup)	78.37
CLT 3-B	49.00
CLT 3-C	25.40
CLT 5-A	58.52
CLT 5-B	14.02
CLT 5-C	55.81
LLT 3-A	46.10
LLT 3-B	52.31
LLT 3-C	36.51
LLT 5-A	24.32
LLT 5-B	15.17
LLT 5-C	34.30
SLT 4-A	56.60
SLT 4-A (dup)	61.96
SLT 4-B	58.43
SLT 4-C	71.34
SLT 5-A	62.63
SLT 5-A (dup)	68.75
SLT 5-B	44.05
SLT 5-C	46.97

Metric -- extra, not required	
StationID	% Hydropsychidae/EPT
CLT 3-A	0.00
CLT 3-A (dup)	0.00
CLT 3-B	21.98
CLT 3-C	1.81
CLT 5-A	8.77
CLT 5-B	38.14
CLT 5-C	2.78
LLT 3-A	0.00
LLT 3-B	0.00
LLT 3-C	0.00
LLT 5-A	21.11
LLT 5-B	25.69
LLT 5-C	0.00
SLT 4-A	0.00
SLT 4-A (dup)	0.00
SLT 4-B	0.00
SLT 4-C	0.00
SLT 5-A	0.00
SLT 5-A (dup)	0.00
SLT 5-B	0.00
SLT 5-C	0.00

Metric 16	
StationID	% Non-Insects
CLT 3-A	15.34
CLT 3-A (dup)	10.34
CLT 3-B	4.33
CLT 3-C	11.25
CLT 5-A	12.86
CLT 5-B	25.91
CLT 5-C	26.91
LLT 3-A	35.25
LLT 3-B	28.21
LLT 3-C	42.76
LLT 5-A	22.64
LLT 5-B	20.74
LLT 5-C	33.14
SLT 4-A	28.84
SLT 4-A (dup)	20.46
SLT 4-B	19.85
SLT 4-C	1.91
SLT 5-A	23.91
SLT 5-A (dup)	25.66
SLT 5-B	10.93
SLT 5-C	12.93

Metric 17	
StationID	% Oligochaeta
CLT 3-A	0.57
CLT 3-A (dup)	0.63
CLT 3-B	1.00
CLT 3-C	0.00
CLT 5-A	1.29
CLT 5-B	3.35
CLT 5-C	6.64
LLT 3-A	0.00
LLT 3-B	0.00
LLT 3-C	0.00
LLT 5-A	0.96
LLT 5-B	1.01
LLT 5-C	4.87
SLT 4-A	19.41
SLT 4-A (dup)	7.20
SLT 4-B	3.75
SLT 4-C	0.00
SLT 5-A	1.01
SLT 5-A (dup)	16.45
SLT 5-B	5.14
SLT 5-C	5.28

Metric 18	
StationID	Pinkham-Pearson*
CLT 3-A	
CLT 3-A (dup)	Reference Conditions
CLT 3-B	Required.
CLT 3-C	See Note* on
CLT 5-A	last page.
CLT 5-B	
CLT 5-C	
LLT 3-A	
LLT 3-B	
LLT 3-C	
LLT 5-A	
LLT 5-B	
LLT 5-C	
SLT 4-A	
SLT 4-A (dup)	
SLT 4-B	
SLT 4-C	
SLT 5-A	
SLT 5-A (dup)	
SLT 5-B	
SLT 5-C	

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Metric 19

Jaccard Similarity Index**	C_{ij}	U_i	U_j	S_{ij}

Note**:

Due to the complexity of this metric and the amount of time it would take to compute this metric for all samples, it cannot be run at this time. I have provided information below on how to compute this metric so you may compute combinations of interest yourselves, or, if you have certain comparison combinations you would like computed, let me know which specific ones and I would be happy to compute them for you.

Formula: $S_{ij} = C_{ij} / (C_{ij} + U_i + U_j)$

C_{ij} = Number of organisms common to both i & j.
U_i = Number of organisms unique to i.
U_j = Number of organisms unique to j.

Metric 20

StationID	ShanWeaver (log e)	ShanWeaver (log 2)	ShanWeaver (log 10)
CLT 3-A			
CLT 3-A (dup)	The EDAS program would not run this metric.		
CLT 3-B	If needed, this metric can be calculated by hand		
CLT 3-C	at a later time.		
CLT 5-A			
CLT 5-B			
CLT 5-C			
LLT 3-A			
LLT 3-B			
LLT 3-C			
LLT 5-A			
LLT 5-B			
LLT 5-C			
SLT 4-A			
SLT 4-A (dup)			
SLT 4-B			
SLT 4-C			
SLT 5-A			
SLT 5-A (dup)			
SLT 5-B			
SLT 5-C			

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Metric 21	
StationID	Invert. Community Index***
CLT 3-A	See Note***
CLT 3-A (dup)	on last page
CLT 3-B	
CLT 3-C	
CLT 5-A	
CLT 5-B	
CLT 5-C	
LLT 3-A	
LLT 3-B	
LLT 3-C	
LLT 5-A	
LLT 5-B	
LLT 5-C	
SLT 4-A	
SLT 4-A (dup)	
SLT 4-B	
SLT 4-C	
SLT 5-A	
SLT 5-A (dup)	
SLT 5-B	
SLT 5-C	

Metric 22	
StationID	% Similarity[+]
CLT 3-A	See Note[+]
CLT 3-A (dup)	on last page
CLT 3-B	
CLT 3-C	
CLT 5-A	
CLT 5-B	
CLT 5-C	
LLT 3-A	
LLT 3-B	
LLT 3-C	
LLT 5-A	
LLT 5-B	
LLT 5-C	
SLT 4-A	
SLT 4-A (dup)	
SLT 4-B	
SLT 4-C	
SLT 5-A	
SLT 5-A (dup)	
SLT 5-B	
SLT 5-C	

Metric 23	
StationID	No. Intolerant Taxa
CLT 3-A	6
CLT 3-A (dup)	6
CLT 3-B	8
CLT 3-C	9
CLT 5-A	7
CLT 5-B	13
CLT 5-C	9
LLT 3-A	8
LLT 3-B	6
LLT 3-C	5
LLT 5-A	7
LLT 5-B	7
LLT 5-C	5
SLT 4-A	4
SLT 4-A (dup)	4
SLT 4-B	5
SLT 4-C	6
SLT 5-A	4
SLT 5-A (dup)	3
SLT 5-B	3
SLT 5-C	4

Metric -- extra, not required			
StationID	Intolerant Individuals	Total Ind.	% Intolerant
CLT 3-A	16	352	4.55
CLT 3-A (dup)	19	319	5.96
CLT 3-B	47	300	15.67
CLT 3-C	141	311	45.34
CLT 5-A	28	311	9.00
CLT 5-B	47	328	14.33
CLT 5-C	23	301	7.64
LLT 3-A	80	295	27.12
LLT 3-B	61	195	31.28
LLT 3-C	47	304	15.46
LLT 5-A	43	296	14.53
LLT 5-B	66	323	20.43
LLT 5-C	26	344	7.56
SLT 4-A	14	371	3.77
SLT 4-A (dup)	13	347	3.75
SLT 4-B	25	267	9.36
SLT 4-C	17	157	10.83
SLT 5-A	31	297	10.44
SLT 5-A (dup)	12	304	3.95
SLT 5-B	33	311	10.61
SLT 5-C	20	379	5.28

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Metric 24	
StationID	Sediment Intolerant Taxa[++]
CLT 3-A	See Note[++]
CLT 3-A (dup)	on last page
CLT 3-B	
CLT 3-C	
CLT 5-A	
CLT 5-B	
CLT 5-C	
LLT 3-A	
LLT 3-B	
LLT 3-C	
LLT 5-A	
LLT 5-B	
LLT 5-C	
SLT 4-A	
SLT 4-A (dup)	
SLT 4-B	
SLT 4-C	
SLT 5-A	
SLT 5-A (dup)	
SLT 5-B	
SLT 5-C	

Metric 25			
StationID	Tolerant Individuals	Total Ind.	% Tolerant Organisms
CLT 3-A	100	352	28.41
CLT 3-A (dup)	99	319	31.03
CLT 3-B	15	300	5.00
CLT 3-C	57	311	18.33
CLT 5-A	94	311	30.23
CLT 5-B	90	328	27.44
CLT 5-C	133	301	44.19
LLT 3-A	23	295	7.80
LLT 3-B	11	195	5.64
LLT 3-C	17	304	5.59
LLT 5-A	63	296	21.28
LLT 5-B	54	323	16.72
LLT 5-C	124	344	36.05
SLT 4-A	108	371	29.11
SLT 4-A (dup)	65	347	18.73
SLT 4-B	52	267	19.48
SLT 4-C	3	157	1.91
SLT 5-A	70	297	23.57
SLT 5-A (dup)	78	304	25.66
SLT 5-B	34	311	10.93
SLT 5-C	25	379	6.60

Metric 26						
StationID	Orth/Chi	Gastr	Nonin	Oligo	Burrwr	% Sediment Tolerant
CLT 3-A	0.0	0.6	15.3	0.6	1.4	17.90
CLT 3-A (dup)	0.0	1.3	10.3	0.6	2.8	15.05
CLT 3-B	0.0	0.7	4.3	1.0	1.3	7.33
CLT 3-C	1.4	7.1	11.3	0.0	1.0	20.70
CLT 5-A	8.3	4.8	12.9	1.3	4.8	32.13
CLT 5-B	0.0	1.5	25.9	3.4	0.6	31.40
CLT 5-C	0.0	2.7	26.9	6.6	1.0	37.21
LLT 3-A	0.0	1.0	35.3	0.0	0.0	36.27
LLT 3-B	0.0	0.5	28.2	0.0	0.0	28.72
LLT 3-C	0.0	0.3	42.8	0.0	0.0	43.09
LLT 5-A	0.0	0.0	22.6	1.0	0.7	24.28
LLT 5-B	0.0	2.8	20.7	1.0	0.3	24.85
LLT 5-C	1.1	1.2	33.1	4.9	1.2	41.41
SLT 4-A	0.0	0.0	28.8	19.4	0.0	48.25
SLT 4-A (dup)	1.8	0.0	20.5	7.2	0.9	30.35
SLT 4-B	16.7	0.0	19.9	3.7	5.2	45.51
SLT 4-C	0.0	0.0	1.9	0.0	0.0	1.91
SLT 5-A	0.0	0.7	23.9	1.0	0.0	25.59
SLT 5-A (dup)	0.0	0.0	25.7	16.4	0.0	42.11
SLT 5-B	0.0	0.6	10.9	5.1	0.0	16.72
SLT 5-C	0.0	0.3	12.9	5.3	0.0	18.47

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Metric 27		Metric 28		Metric 29		Metric 30	
StationID	% 1st Dominant Taxon	StationID	Hilsenhoff Biotic Index	StationID	Biotic Index	StationID	Biotic Condition Index[+++]
CLT 3-A	31.25	CLT 3-A	6.07	CLT 3-A	16	CLT 3-A	See Note[+++]
CLT 3-A (dup)	24.76	CLT 3-A (dup)	5.97	CLT 3-A (dup)	16	CLT 3-A (dup)	on last page
CLT 3-B	28.33	CLT 3-B	4.84	CLT 3-B	19	CLT 3-B	
CLT 3-C	16.08	CLT 3-C	3.99	CLT 3-C	19	CLT 3-C	
CLT 5-A	16.72	CLT 5-A	5.37	CLT 5-A	22	CLT 5-A	
CLT 5-B	20.43	CLT 5-B	5.12	CLT 5-B	25	CLT 5-B	
CLT 5-C	21.26	CLT 5-C	6.24	CLT 5-C	22	CLT 5-C	
LLT 3-A	20.00	LLT 3-A	4.20	LLT 3-A	17	LLT 3-A	
LLT 3-B	20.00	LLT 3-B	4.21	LLT 3-B	12	LLT 3-B	
LLT 3-C	25.66	LLT 3-C	4.51	LLT 3-C	11	LLT 3-C	
LLT 5-A	21.96	LLT 5-A	4.83	LLT 5-A	21	LLT 5-A	
LLT 5-B	26.63	LLT 5-B	4.39	LLT 5-B	17	LLT 5-B	
LLT 5-C	27.91	LLT 5-C	5.67	LLT 5-C	16	LLT 5-C	
SLT 4-A	23.99	SLT 4-A	6.45	SLT 4-A	12	SLT 4-A	
SLT 4-A (dup)	31.70	SLT 4-A (dup)	6.08	SLT 4-A (dup)	10	SLT 4-A (dup)	
SLT 4-B	21.72	SLT 4-B	5.91	SLT 4-B	9	SLT 4-B	
SLT 4-C	33.76	SLT 4-C	5.33	SLT 4-C	11	SLT 4-C	
SLT 5-A	50.17	SLT 5-A	5.87	SLT 5-A	11	SLT 5-A	
SLT 5-A (dup)	59.87	SLT 5-A (dup)	6.58	SLT 5-A (dup)	7	SLT 5-A (dup)	
SLT 5-B	24.76	SLT 5-B	5.18	SLT 5-B	7	SLT 5-B	
SLT 5-C	31.66	SLT 5-C	5.39	SLT 5-C	6	SLT 5-C	

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Metric 31	
StationID	% Hydropsychidae/Trichoptera
CLT 3-A	0.00
CLT 3-A (dup)	0.00
CLT 3-B	86.96
CLT 3-C	11.54
CLT 5-A	17.86
CLT 5-B	86.05
CLT 5-C	20.00
LLT 3-A	0.00
LLT 3-B	0.00
LLT 3-C	0.00
LLT 5-A	52.78
LLT 5-B	59.57
LLT 5-C	0.00
SLT 4-A	0.00
SLT 4-A (dup)	0.00
SLT 4-B	0.00
SLT 4-C	0.00
SLT 5-A	0.00
SLT 5-A (dup)	0.00
SLT 5-B	0.00
SLT 5-C	0.00

Metric 32	
StationID	Total Abundance
CLT 3-A	352
CLT 3-A (dup)	319
CLT 3-B	300
CLT 3-C	311
CLT 5-A	311
CLT 5-B	328
CLT 5-C	301
LLT 3-A	295
LLT 3-B	195
LLT 3-C	304
LLT 5-A	296
LLT 5-B	323
LLT 5-C	344
SLT 4-A	371
SLT 4-A (dup)	347
SLT 4-B	267
SLT 4-C	157
SLT 5-A	297
SLT 5-A (dup)	304
SLT 5-B	311
SLT 5-C	379

Metric 33	
StationID	No. Predator Taxa
CLT 3-A	11
CLT 3-A (dup)	11
CLT 3-B	10
CLT 3-C	7
CLT 5-A	14
CLT 5-B	8
CLT 5-C	10
LLT 3-A	7
LLT 3-B	6
LLT 3-C	11
LLT 5-A	9
LLT 5-B	8
LLT 5-C	9
SLT 4-A	7
SLT 4-A (dup)	3
SLT 4-B	5
SLT 4-C	6
SLT 5-A	3
SLT 5-A (dup)	3
SLT 5-B	9
SLT 5-C	7

Metric 34	
StationID	% Omnivores+Scavengers
CLT 3-A	43.75
CLT 3-A (dup)	47.96
CLT 3-B	55.33
CLT 3-C	65.92
CLT 5-A	73.31
CLT 5-B	94.21
CLT 5-C	85.71
LLT 3-A	64.75
LLT 3-B	69.23
LLT 3-C	47.04
LLT 5-A	72.97
LLT 5-B	75.54
LLT 5-C	86.05
SLT 4-A	79.51
SLT 4-A (dup)	81.56
SLT 4-B	70.04
SLT 4-C	72.61
SLT 5-A	89.56
SLT 5-A (dup)	96.38
SLT 5-B	71.06
SLT 5-C	69.66

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Metric 35				
StationID	Ind.Gather	Ind.Filter	Total Abund	% Ind. Gatherers+Filterers
CLT 3-A	37	86	352	34.94
CLT 3-A (dup)	29	82	319	34.80
CLT 3-B	53	28	300	27.00
CLT 3-C	78	15	311	29.90
CLT 5-A	109	65	311	55.95
CLT 5-B	116	109	328	68.60
CLT 5-C	104	68	301	57.14
LLT 3-A	112	3	295	38.98
LLT 3-B	66	6	195	36.92
LLT 3-C	72	11	304	27.30
LLT 5-A	55	70	296	42.23
LLT 5-B	66	57	323	38.08
LLT 5-C	95	108	344	59.01
SLT 4-A	148	20	371	45.28
SLT 4-A (dup)	128	6	347	38.62
SLT 4-B	63	32	267	35.58
SLT 4-C	23	0	157	14.65
SLT 5-A	50	47	297	32.66
SLT 5-A (dup)	72	28	304	32.89
SLT 5-B	101	16	311	37.62
SLT 5-C	112	23	379	35.62

Metric 36	
StationID	% Gatherers
CLT 3-A	10.51
CLT 3-A (dup)	9.09
CLT 3-B	17.67
CLT 3-C	25.08
CLT 5-A	35.05
CLT 5-B	35.37
CLT 5-C	34.55
LLT 3-A	37.97
LLT 3-B	33.85
LLT 3-C	23.68
LLT 5-A	18.58
LLT 5-B	20.43
LLT 5-C	27.62
SLT 4-A	39.89
SLT 4-A (dup)	36.89
SLT 4-B	23.60
SLT 4-C	14.65
SLT 5-A	16.84
SLT 5-A (dup)	23.68
SLT 5-B	32.48
SLT 5-C	29.55

Metric 37	
StationID	% Filterers
CLT 3-A	24.43
CLT 3-A (dup)	25.71
CLT 3-B	9.33
CLT 3-C	4.82
CLT 5-A	20.90
CLT 5-B	33.23
CLT 5-C	22.59
LLT 3-A	1.02
LLT 3-B	3.08
LLT 3-C	3.62
LLT 5-A	23.65
LLT 5-B	17.65
LLT 5-C	31.40
SLT 4-A	5.39
SLT 4-A (dup)	1.73
SLT 4-B	11.99
SLT 4-C	0.00
SLT 5-A	15.82
SLT 5-A (dup)	9.21
SLT 5-B	5.14
SLT 5-C	6.07

Metric 38	
StationID	% Grazers+Scrapers
CLT 3-A	0.57
CLT 3-A (dup)	1.88
CLT 3-B	14.67
CLT 3-C	17.04
CLT 5-A	10.29
CLT 5-B	13.11
CLT 5-C	5.65
LLT 3-A	1.02
LLT 3-B	1.03
LLT 3-C	0.66
LLT 5-A	21.96
LLT 5-B	31.89
LLT 5-C	18.31
SLT 4-A	0.27
SLT 4-A (dup)	0.58
SLT 4-B	0.00
SLT 4-C	0.00
SLT 5-A	0.67
SLT 5-A (dup)	0.00
SLT 5-B	1.93
SLT 5-C	0.26

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Metric 39	
StationID	Scrapers / Filterers
CLT 3-A	0
CLT 3-A (dup)	0
CLT 3-B	2
CLT 3-C	4
CLT 5-A	0
CLT 5-B	0
CLT 5-C	0
LLT 3-A	1
LLT 3-B	0
LLT 3-C	0
LLT 5-A	1
LLT 5-B	2
LLT 5-C	1
SLT 4-A	0
SLT 4-A (dup)	0
SLT 4-B	0
SLT 4-C	0
SLT 5-A	0
SLT 5-A (dup)	0
SLT 5-B	0
SLT 5-C	0

Metric 40	
StationID	% Scrapers / (Scrapers+Filterers)
CLT 3-A	2.27
CLT 3-A (dup)	6.82
CLT 3-B	61.11
CLT 3-C	77.94
CLT 5-A	32.99
CLT 5-B	28.29
CLT 5-C	20.00
LLT 3-A	50.00
LLT 3-B	25.00
LLT 3-C	15.38
LLT 5-A	48.15
LLT 5-B	64.38
LLT 5-C	36.84
SLT 4-A	4.76
SLT 4-A (dup)	25.00
SLT 4-B	0.00
SLT 4-C	0.00
SLT 5-A	4.08
SLT 5-A (dup)	0.00
SLT 5-B	27.27
SLT 5-C	4.17

Metric 41	
StationID	% Predators
CLT 3-A	56.25
CLT 3-A (dup)	52.04
CLT 3-B	44.67
CLT 3-C	34.08
CLT 5-A	25.72
CLT 5-B	5.79
CLT 5-C	14.29
LLT 3-A	15.25
LLT 3-B	11.79
LLT 3-C	27.30
LLT 5-A	21.28
LLT 5-B	13.93
LLT 5-C	12.79
SLT 4-A	20.49
SLT 4-A (dup)	18.44
SLT 4-B	29.96
SLT 4-C	27.39
SLT 5-A	10.44
SLT 5-A (dup)	3.62
SLT 5-B	28.94
SLT 5-C	30.34

Metric 42	
StationID	% Shredders
CLT 3-A	8.24
CLT 3-A (dup)	11.29
CLT 3-B	13.67
CLT 3-C	18.97
CLT 5-A	7.07
CLT 5-B	12.50
CLT 5-C	22.92
LLT 3-A	24.75
LLT 3-B	31.28
LLT 3-C	19.08
LLT 5-A	8.78
LLT 5-B	5.57
LLT 5-C	8.72
SLT 4-A	33.96
SLT 4-A (dup)	42.36
SLT 4-B	34.46
SLT 4-C	57.96
SLT 5-A	56.23
SLT 5-A (dup)	63.49
SLT 5-B	31.51
SLT 5-C	33.77

Metrics compiled analyzed by:
Natural Resource Solutions
Phone: 605-693-6767
Email: stroup@itctel.com

NOTES:

Pinkham-Pearson* : This metric is a measure of functional feeding group similarity to a reference stream, or reference conditions for a given stream type based on a model. You must first have a reference stream/model before this metric can be computed.

Jaccard Similarity Index** : See note below the metric (# 19), on page 5.

Invertebrate Community Index (ICI)*** : This is not one metric. The ICI is a multimetric macroinvertebrate index, patterned after the IBI for Fish (Karr 1981). To perform this multimetric analysis would be a whole separate project/contract in itself.

% Similarity[+] : The information you want from this metric is not clear. Do you want a comparison between sites, averaging the replicates, or are you interested in the % Similarity between the replicates? The Jaccard Similarity Index will give you similar information.

No. Sediment-Intolerant Taxa[++] : Sediment intolerance information was not available for all taxa, therefore an accurate total number of sediment-intolerant taxa was not able to be provided.

Biotic Condition Index[+++] : A difference between the formulas for the Biotic Condition Index and the Biotic Index (See Metric # 29) was unable to be determined. If you can provide a Specific formula for this metric, I may be able to compute it for you.

Contact Information:
Natural Resource Solutions
Attn: Rebecca Spawn-Stroup
511 East Wye Mesa
Brookings, SD 57006-4534

Phone/Fax: 605-693-6767
Cell: 605-690-2105 or 5549
Email: ***stroup@itctel.com***

Client: Allen Scott, Scott Environmental, Custer, SD
Methods, Equipment and Keys used for Benthic Macroinvertebrate samples collected in November, 2001 from Custer State Park, SD
Data collected and compiled by: ***Natural Resource Solutions***, *511 E. Wye Mesa, Brookings, SD 57006, Ph: 605-693-6767*

Sample Processing & Identification Methods:

For all laboratory sample processing and identification, the methods detailed in the SD-DENR's SOP, (attached to the contract under the heading, "Attachment A") were employed.

Processing/Sorting Equipment:

Olympus SZ60 Scientific Stereo Dissecting Microscope with Zoom, 10x-1200x
Various sizes of gridded sample trays, splitters and seives
Misc. forceps, petri dishes, etc.
Ethanol for preservation, Magnesium Sulfate (Epsom Salt, $MgSO_4$) for sample flotation, when needed.

Identification Equipment:

Olympus SZ60 Scientific Stereo Dissecting Microscope with Zoom, 10x-1200x
Misc. forceps, dissection utensils, petri dishes, etc.

Taxonomic Keys Used:

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5. Gordon, R.D., R.L. Post. 1965. North Dakota Water Beetles. North Dakota Insects, Pub. No. 5, 52pp.
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7. Hilsenhoff, William L., 1995. Aquatic Insects of Wisconsin. Natural History Museums Council, Dept. of Entomology, University of Wisconsin-Madison, Pub. No. 3, 79pp.
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14. McCafferty, W.P., R.D. Waltz 1995. Labiobaetis (Ephemeroptera:Baetidae): New status, new North American species and related new genus. Entomological News. 106: 19-28.
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20. Simpson, K. W., R. W. Bode and P. Albu. 1983. Keys for the genus *Cricotopus* adapted from "Revision der Gattung *Cricotopus* van der Wulp und ihrer Verwandten (Diptera, Chironomidae)" by M. Hirvenoja. Bull. N. Y. St. Mus. 450:1-13
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28. Wold, J.L. 1974. Systematics of the genus *Rhyacophila* (Trichoptera: Rhyacophilidae) in Western North America with special reference to the immature stages. Master's Thesis, Oregon State Univ., Corvallis. 220pp.

Appendix E

Quality Assurance/Quality Control (QA/QC) Data

QA/QC data for replicate and routine sample pairs

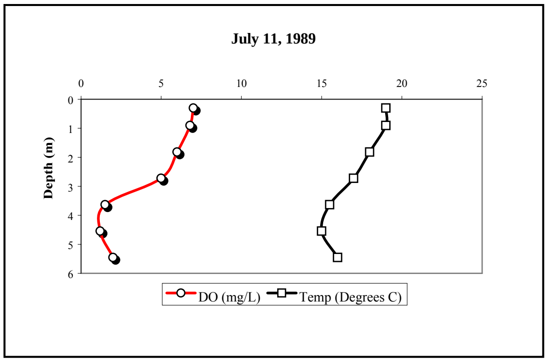
Site	Depth	Type	Date	E-Coli	Fecal C	Alka	Tot S	TSS	Ammo	Nit	TKN	Tot P	TDP
SLT3			23-Aug-01		30	18	58	5	0.05	0.06	0.25	0.15	0.12
SLT3		Dup	23-Aug-01		34	16	66	19	0.05	0.025	0.25	0.15	0.13
					6.3%	**5.9%**	**6.5%**	**58.3%**	**0.0%**	**41.2%**	**0.0%**	**0.0%**	**4.0%**
SL1	Surface		30-Jan-02	1	1	40	92	2.5	0.3	0.15	1.2	0.07	0.02
SL1	Surface	Dup	30-Jan-02	1	1	42	76	2.5	0.3	0.15	0.6	0.05	0.005
				0.0%	**0.0%**	**2.4%**	**9.5%**	**0.0%**	**0.0%**	**0.0%**	**33.3%**	**16.7%**	**60.0%**
SLT3			12-Aug-02	1	50	26	62	2.5	0.05	0.025	0.25	0.13	0.03
SLT3		Dup	12-Aug-02	1	36	26	84	17	0.05	0.025	0.25	0.13	0.03
				0.0%	**16.3%**	**0.0%**	**15.1%**	**74.4%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**
SL1	Surface		12-Jun-03			40	70	6	0.01	0.05	0.42	0.03	0.013
SL1	Surface	Dup	12-Jun-03			40	69	6	0.01	0.05	0.39	0.026	0.013
						0.0%	**0.7%**	**0.0%**	**0.0%**	**0.0%**	**3.7%**	**7.1%**	**0.0%**
			Average Percent Difference	**0.0%**	**7.5%**	**2.1%**	**7.9%**	**33.2%**	**0.0%**	**10.3%**	**9.3%**	**6.0%**	**16.0%**

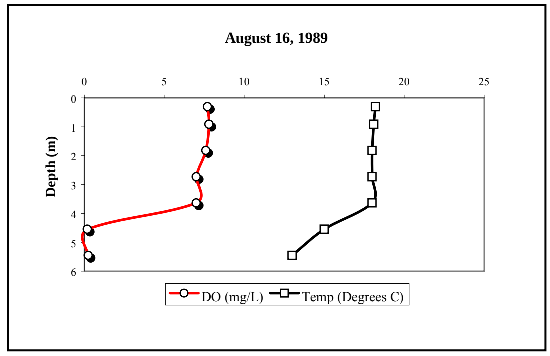
QA/QC data for blank samples

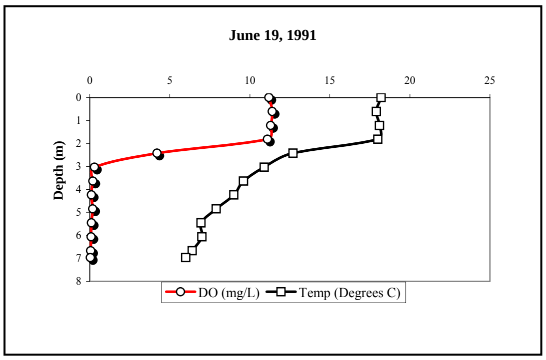
Date	E Coli	Fecal	Alka	Tot Sol	TSS	Ammo	NO3+NO4	TKN	Tot P	TDP
12-Dec-02	ND	ND	10	ND	ND	ND	ND	ND	ND	ND
12-Dec-02	ND	ND	6	ND	ND	ND	ND	ND	0.01	0.01
12-Dec-02	ND	ND	6	ND	ND	ND	ND	ND	0.01	0.02
12-Dec-02	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
12-Jun-03			ND	ND	ND	ND	ND	ND	0.002	0.006

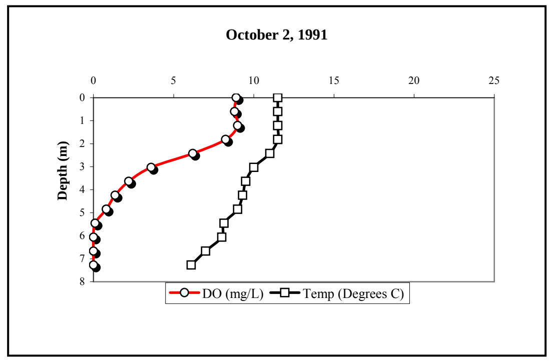
Appendix F

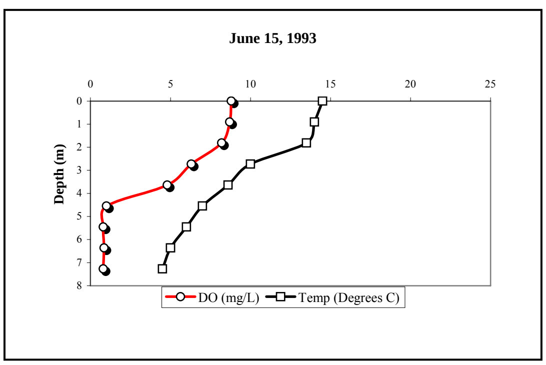
Water Temperature and Dissolved Oxygen Profiles

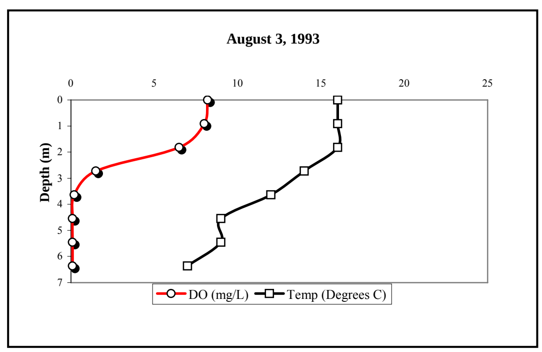

July 11, 1989
Depth (m)
DO (mg/L)
Temp (Degrees C)

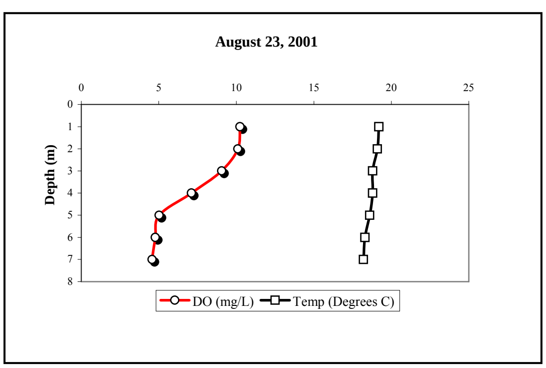

August 16, 1989
Depth (m)
DO (mg/L)
Temp (Degrees C)

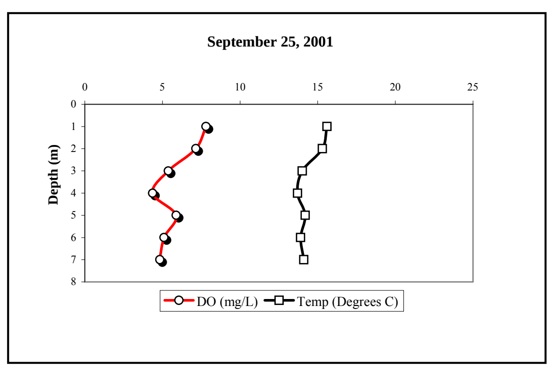

June 19, 1991
Depth (m)
DO (mg/L)
Temp (Degrees C)

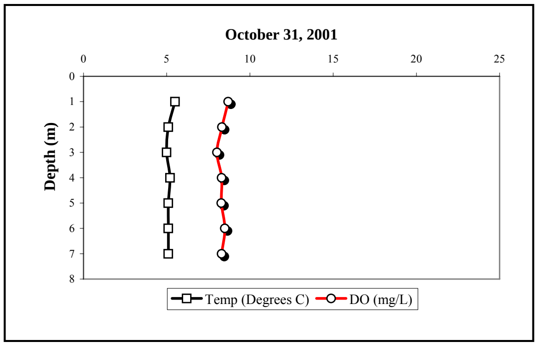

October 2, 1991
Depth (m)
DO (mg/L)
Temp (Degrees C)

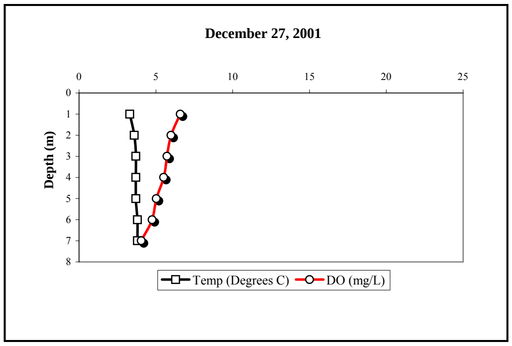

June 15, 1993
Depth (m)
DO (mg/L)
Temp (Degrees C)

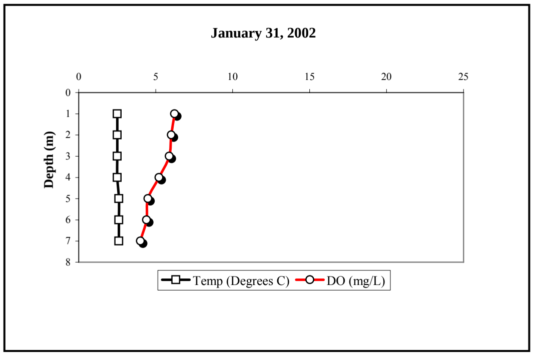

August 3, 1993
Depth (m)
DO (mg/L)
Temp (Degrees C)

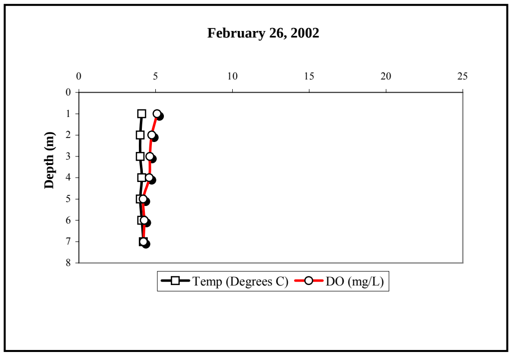

August 23, 2001
Depth (m)
DO (mg/L)
Temp (Degrees C)


September 25, 2001
Depth (m)
DO (mg/L)
Temp (Degrees C)


October 31, 2001
0 5 10 15 20 25
Depth (m)
0 1 2 3 4 5 6 7 8
Temp (Degrees C)
DO (mg/L)


December 27, 2001
0 5 10 15 20 25
Depth (m)
0 1 2 3 4 5 6 7 8
Temp (Degrees C)
DO (mg/L)


January 31, 2002
0 5 10 15 20 25
Depth (m)
0 1 2 3 4 5 6 7 8
Temp (Degrees C)
DO (mg/L)


February 26, 2002
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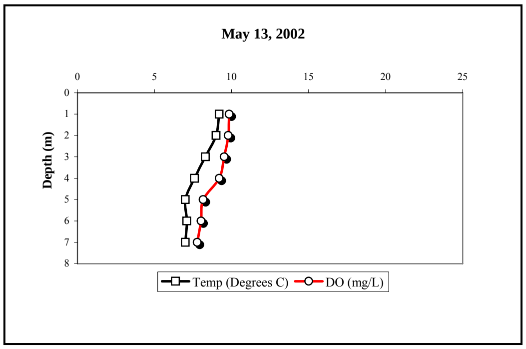
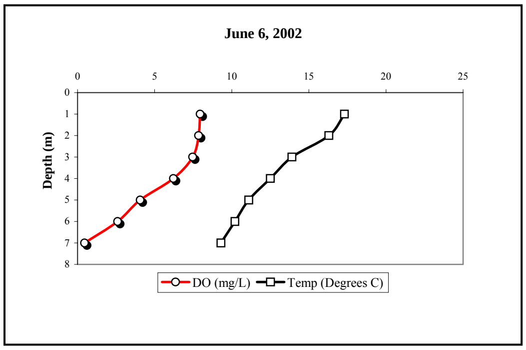
Depth (m)
0 1 2 3 4 5 6 7 8
Temp (Degrees C)
DO (mg/L)


May 13, 2002
0 5 10 15 20 25
Depth (m)
0 1 2 3 4 5 6 7 8
Temp (Degrees C)
DO (mg/L)


June 6, 2002
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Depth (m)
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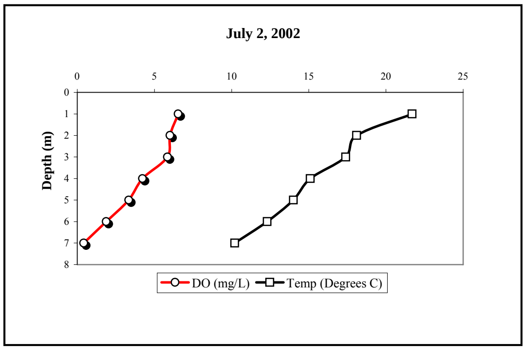
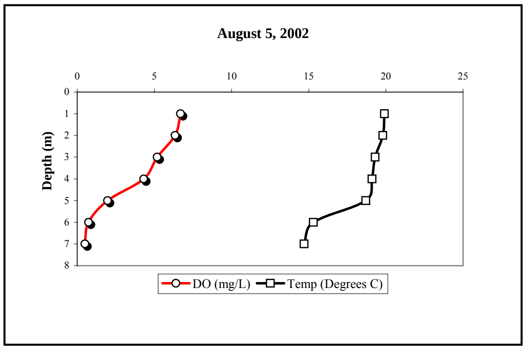
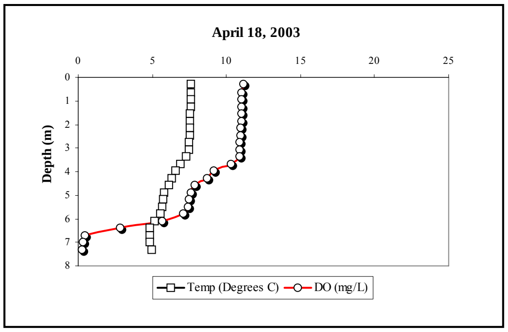
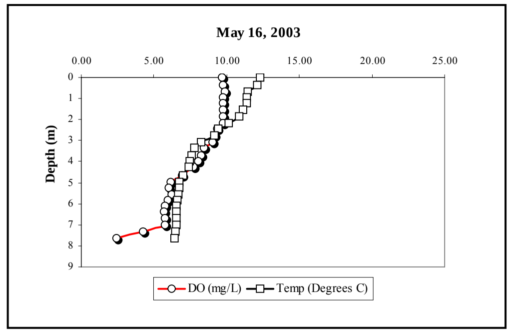
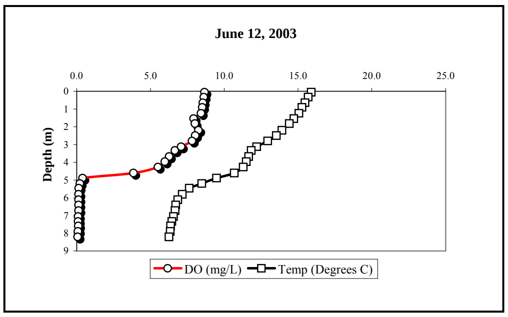
DO (mg/L)
Temp (Degrees C)

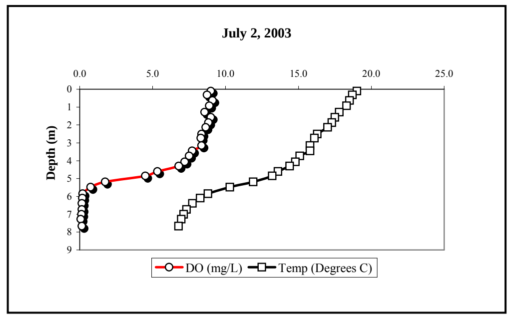

July 2, 2002
0 5 10 15 20 25
Depth (m)
0 1 2 3 4 5 6 7 8
DO (mg/L)
Temp (Degrees C)


August 5, 2002
0 5 10 15 20 25
Depth (m)
0 1 2 3 4 5 6 7 8
DO (mg/L)
Temp (Degrees C)


April 18, 2003
0 5 10 15 20 25
Depth (m)
Temp (Degrees C)
DO (mg/L)


May 16, 2003
0.00 5.00 10.00 15.00 20.00 25.00
Depth (m)
DO (mg/L)
Temp (Degrees C)


June 12, 2003
0.0 5.0 10.0 15.0 20.0 25.0
Depth (m)
DO (mg/L)
Temp (Degrees C)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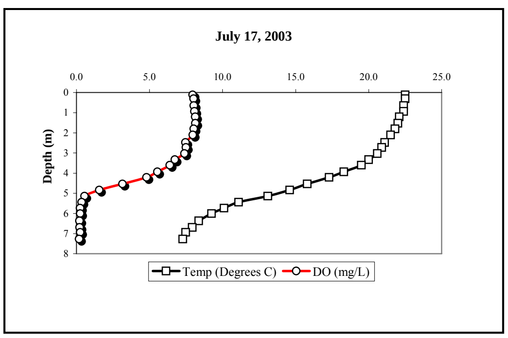
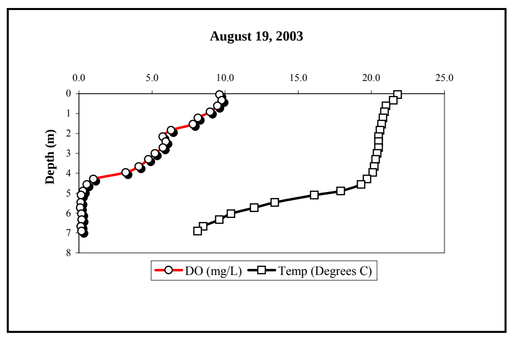
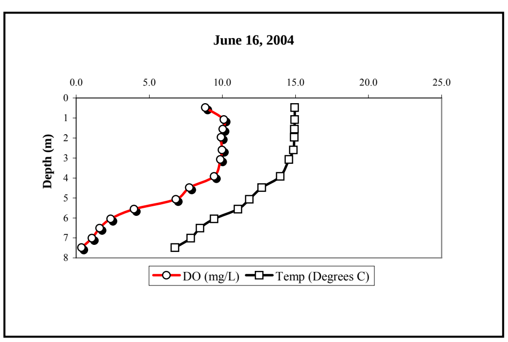
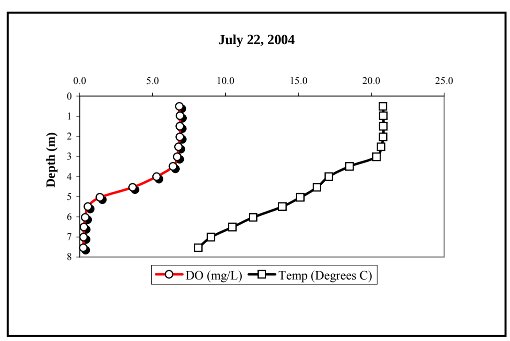
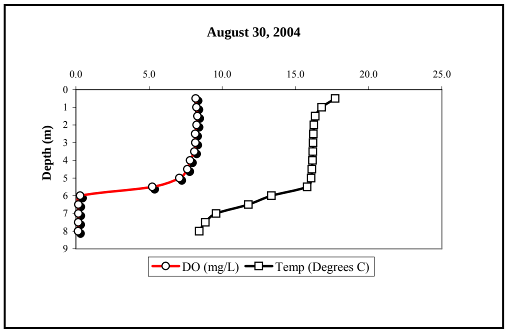
Depth (m)
DO (mg/L)
Temp (Degrees C)


July 17, 2003
0.0 5.0 10.0 15.0 20.0 25.0
Depth (m)
Temp (Degrees C)
DO (mg/L)


August 19, 2003
0.0 5.0 10.0 15.0 20.0 25.0
Depth (m)
DO (mg/L)
Temp (Degrees C)


June 16, 2004
0.0 5.0 10.0 15.0 20.0 25.0
Depth (m)
DO (mg/L)
Temp (Degrees C)


July 22, 2004
0.0 5.0 10.0 15.0 20.0 25.0
Depth (m)
DO (mg/L)
Temp (Degrees C)



August 30, 2004
0.0
5.0
10.0
15.0
20.0
25.0
0
1
2
3
4
5
6
7
8
9
Depth (m)
DO (mg/L)
Temp (Degrees C)

Appendix G

Public Comments and TMDL Approval Letter

Response to Public Notice Comments

Only one TMDL review criterion was not satisfied. The following lists this criterion and EPA's comments. The comments are addressed below. No other public comments were received.

1. Water Quality Impairment Status

☒ Partially satisfies criterion. Questions or comments provided below need to be addressed.

EPA's COMMENTS - The assessment report (pp 35-36) indicates that the dissolved oxygen (DO) standard is not being met in the lake. The report (p 37) says that despite the numerous DO readings below the standard in the hypolimnion, the cold water permanent fish life propagation beneficial use is being met. This argument for not listing DO as an impairment in the lake would be supportable if: 1) there were fisheries data that supported the conclusion that the designated use is being met; and 2) the DO standard specified that the numeric DO values, when applied to stratified lakes, applied only to the epilimnion.

The 1995 fisheries data (9 surviving rainbow trout) alone do not appear to support the claim that the designated use is supported by the current conditions. Is there more recent fisheries data for the lake? Additional data or additional explanation (e.g., evidence that it is not unusual to have all of the stocked fish caught and removed during one fishing season) are needed to support the "use protected" claim.

The recorded high temperatures in the epilimnion are likely to occur concurrent with the low DO values in the hypolimnion. Therefore, it is possible to have conditions, at least for part of the summer, when the lake is unsuitable for rainbow trout (i.e., no suitable refuge - too warm in the epilimnion and insufficient DO in the hypolimnion).

Other states have addressed the stratified lake issue by specifying in the WQS that the DO standard applied only to the epilimnion of stratified lakes where the temperature of the epilimnion was suitable. Without such specificity, it is reasonable to assume the standard applies throughout the water column.

It is likely that the identified phosphorus problem is the root cause of the hypolimneic DO problem, and therefore, it might be expected that the phosphorous TMDL will address the DO issue as well. As such, it would seem that adding DO as a cause of impairment (if it can't be demonstrated that the use is unimpaired) would not have a significant effect on the proposed corrective action.

We recommend that either: 1) the TMDL be revised to include a DO target (e.g., > 6.0 mg/L) as well as an explanation in the technical analysis of how the proposed controls can be expected to result in the DO standard being met; 2) a statement that the proposed controls for phosphorous are expected to also improve the DO; 3) a statement that the DO impairment will be addressed by a separate TMDL; or 4) revisions to the DO standard. For options 2 and 3 the lake will need to be evaluated during the 2006 listing cycle and included on the list unless new data show that the standard is being met or a separate TMDL is completed and approved.

RESPONSE TO COMMENTS - Author agrees with EPA's comments, and suggested change #2 above was incorporated. The following statement was added to the Pollutant Assessment section (page 73) of the TMDL summary and the Dissolved Oxygen section (page 37) of the final report.

"Excessive nutrient loading to Sylvan Lake has contributed to a higher oxygen demand and thus lower hypolimnetic DO levels. The proposed management practices to reduce phosphorus concentrations are expected to also improve the DO levels in Sylvan Lake."

A DO TMDL for Sylvan Lake has not been developed due to the expected change of a water quality standards and/or 303(d) listing criteria. If the standards and/or listing criteria are not revised, the lake will be listed as an impaired waterbody in the 2006 Integrated Report.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 8
999 18TH STREET- SUITE 300
DENVER, CO 80202-2466
Phone 800-227-8917
http://www.epa.gov/region08

September 1, 2005

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
Sylvan Lake

Dear Mr. Pirner:

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

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

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

In the course of developing TMDLs for impaired waters, EPA has recognized that not all impairments are linked to water chemistry alone. Rather, EPA recognizes that *"Section 303(d) requires the States to identify all impaired waters regardless of whether the impairment is due to toxic pollutants, other chemical, heat, habitat, or other problems."* (see 57 FR 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 one 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,

Max H Dodson

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

Enclosures

ENCLOSURE 1

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)
Sylvan Lake*	phosphorus	Phosphorous TSI = 45.0 Total Phosphorous = 0.02 mg/L	4.9 kg/yr total phosphorous load to the lake (75% reduction in average annual total phosphorus load)	Section 303(d)(1)	■ Section 319 Nonpoint Source Pollution Control Assessment/Planning Project Final Report, Sylvan Lake, Custer County, South Dakota (SD DENR, June 2005)

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

EPA REGION VIII TMDL REVIEW FORM

Document Name:	**Sylvan Lake**
Submitted by:	**Gene Stueven, SD DENR**
Date Received:	**August 22, 2005**
Review Date:	**August 24, 2005**
Reviewer:	**Vern Berry, EPA**
Formal or Informal Review?	**Formal – Final Approval**

This document provides a standard format for EPA Region 8 to provide comments to the South Dakota Department of Environment and Natural Resources on TMDL documents provided to the EPA for either official formal or informal review. All TMDL documents are measured against the following 12 review criteria:

1. Water Quality Impairment Status
2. Water Quality Standards
3. Water Quality Targets
4. Significant Sources
5. Technical Analysis
6. Margin of Safety and Seasonality
7. Total Maximum Daily Load
8. Allocation
9. Public Participation
10. Monitoring Strategy
11. Restoration Strategy
12. Endangered Species Act Compliance

Each of the 12 review criteria are described below to provide the rational for the review, followed by EPA's comments. This review is intended to ensure compliance with the Clean Water Act and also to ensure that the reviewed documents are technically sound and the conclusions are technically defensible.

1. Water Quality Impairment Status

Criterion Description – Water Quality Impairment Status
TMDL documents must include a description of the listed water quality impairments. While the 303(d) list identifies probable causes and sources of water quality impairments, the information contained in the 303(d) list is generally not sufficiently detailed to provide the reader with an adequate understanding of the impairments. TMDL documents should include a thorough description/summary of all available water quality data such that the water quality impairments are clearly defined and linked to the impaired beneficial uses and/or appropriate water quality standards.

- ☒ Satisfies Criterion
- ☐ Satisfies Criterion. Questions or comments provided below should be considered.
- ☐ Partially satisfies criterion. Questions or comments provided below need to be addressed.
- ☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
- ☐ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – Sylvan Lake is located in the Middle Cheyenne-Spring Basin, Custer County, South Dakota. It is listed on SD's 2004 303(d) list as impaired for trophic state index (TSI) due to nonpoint sources and is ranked as priority 1 (i.e., high priority) for TMDL development. The watershed is approximately 565 acres and drains predominantly evergreen forest land. The mean TSI during the period of the project assessment was 53, and is not currently meeting its designated beneficial use for coldwater permanent fish life propagation. Assessment data indicates that dissolved oxygen levels are occasionally below the applicable water quality standard at the surface and near the bottom of the lake. The proposed management practices to reduce phosphorous concentrations are expected to also improve dissolved oxygen concentrations. This data will be evaluated during the 2006 303(d) listing process for possible inclusion in category 5 as impaired for dissolved oxygen.

2. Water Quality Standards

Criterion Description – Water Quality Standards
The TMDL document must include a description of all applicable water quality standards for all affected jurisdictions. TMDLs result in maintaining and attaining water quality standards. Water quality standards are the basis from which TMDLs are established and the TMDL targets are derived, including the numeric, narrative, use classification, and antidegradation components of the standards.

- ☒ Satisfies Criterion
- ☐ Satisfies Criterion. Questions or comments provided below should be considered.
- ☐ Partially satisfies criterion. Questions or comments provided below need to be addressed.
- ☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
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SUMMARY – Sylvan Lake is impaired for TSI which is a surrogate measure used to determine whether the narrative standards are being met. South Dakota has applicable narrative standards that may be applied to the undesirable eutrophication of lakes. Data from Sylvan Lake indicates problems with nutrient enrichment and nuisance algal blooms, which are typical signs of the eutrophication process. The narrative standards being implemented in this TMDL are:

> "*Materials which produce nuisance aquatic life may not be discharged or caused to be discharged into surface waters of the state in concentrations that impair a beneficial use or create a human health problem.*" (See ARSD §74:51:01:09)

> "*All waters of the state must be free from substances, whether attributable to human-induced point source discharges or nonpoint source activities, in concentration or combinations which will adversely impact the structure and function of indigenous or intentionally introduced aquatic communities.*" (See ARSD §74:51:01:12)

Other applicable water quality standards are included on pages 5 and 6 of the assessment report.

3. Water Quality Targets

Criterion Description – Water Quality Targets

Quantified targets or endpoints must be provided to address each listed pollutant/water body combination. Target values must represent achievement of applicable water quality standards and support of associated beneficial uses. For pollutants with numeric water quality standards, the numeric criteria are generally used as the TMDL target. For pollutants with narrative standards, the narrative standard must be translated into a measurable value. At a minimum, one target is required for each pollutant/water body combination. It is generally desirable, however, to include several targets that represent achievement of the standard and support of beneficial uses (e.g., for a sediment impairment issue it may be appropriate to include targets representing water column sediment such as TSS, embeddeness, stream morphology, up-slope conditions and a measure of biota).

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SUMMARY – Water quality targets for this TMDL are based on interpretation of narrative provisions found in State water quality standards. In May 2000, SD DENR published *Ecoregion Targeting for Impaired Lakes in South Dakota*. This document proposed ecoregion-specific targeted Trophic State Index (TSI) values based on beneficial uses. EPA approved the use of these ecoregion-specific targets to evaluate lakes using beneficial use categories. In South Dakota algal blooms can limit contact and immersion recreation beneficial uses. Also algal blooms can deplete oxygen levels which can affect aquatic life uses. SD DENR considers several algal species to be nuisance aquatic species. TSI measurements can be used to estimate how much algal production may occur in lakes. Therefore, TSI is used as a measure of the narrative standard in order to determine whether beneficial uses are being met.

The mean phosphorous TSI for Sylvan Lake during the period of the assessment (2001-2003) was 57. The average phosphorous TSI for the most current year (2004) is 53. Nutrient reduction response modeling was conducted with BATHTUB, an Army Corps of Engineers eutrophication response model. The results of the modeling show that 90% or more reduction in the total phosphorous loading from the watershed would is necessary to meet the ecoregion-based beneficial use TSI target of 45 or less.

The water quality target used in this TMDL is: **maintain a mean annual phosphorous TSI at or below 45**. A secondary target is specified as an in-lake target for total phosphorous equal to 0.02 mg/L.

4. Significant Sources

Criterion Description – Significant Sources
TMDLs must consider all significant sources of the stressor of concern. All sources or causes of the stressor must be identified or accounted for in some manner. The detail provided in the source assessment step drives the rigor of the allocation step. In other words, it is only possible to specifically allocate quantifiable loads or load reductions to each significant source when the relative load contribution from each source has been estimated. Ideally, therefore, the pollutant load from each significant source should be quantified. This can be accomplished using site-specific monitoring data, modeling, or application of other assessment techniques. If insufficient time or resources are available to accomplish this step, a phased/adaptive management approach can be employed so long as the approach is clearly defined in the document.

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SUMMARY – The TMDL identifies the major sources of phosphorous as coming from nonpoint sources within the watershed. In particular, a loading analysis was done for nutrients and sediment considering various land use and land management factors. The results from modeling indicate that internal phosphorus loading from lake-bottom sediment contributes approximately 37% of the overall load. The remaining 63% originates from recreational uses, forest management and other sources such as wildlife and natural weathering. However, recreational activity is thought to be primary source of phosphorous loading from the watershed.

5. Technical Analysis

Criterion Description – Technical Analysis
*TMDLs must be supported by an appropriate level of technical analysis. It applies to **all** of the components of a TMDL document. It is vitally important that the technical basis for **all** conclusions be articulated in a manner that is easily understandable and readily apparent to the reader. Of particular importance, the cause and effect relationship between the pollutant and impairment and between the selected targets, sources, TMDLs, and allocations needs to be supported by an appropriate level of technical analysis.*

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SUMMARY – The technical analysis addresses the needed phosphorous reduction to achieve the desired water quality. The TMDL recommends a combination of 90% reduction in phosphorous loading from the watershed plus 50% reduction in internal phosphorous loading. It is estimated that this combination of load reductions will achieve an overall reduction of 75% of the total annual average phosphorous load to Sylvan Lake. Based on the loads measured during the period of the assessment the total phosphorous load should be 4.9 kg/yr to achieve the desired TSI target. This reduction is based in large part on the BATHTUB mathematical modeling of the Lake and its predicted response to nutrient load reductions.

The FLUX model was used to develop nutrient and sediment loadings for the Sylvan Lake inlet and outlet sites. This information was used to derive export coefficients for nutrients and sediment to target areas within the watershed with excessive loads of these pollutants.

6. Margin of Safety and Seasonality

Criterion Description – Margin of Safety and Seasonality

A margin of safety (MOS) is a required component of the TMDL that accounts for the uncertainty about the relationship between the pollutant loads and the quality of the receiving water body (303(d)(1)(c)). The MOS can be implicitly expressed by incorporating a margin of safety into conservative assumptions used to develop the TMDL. In other cases, the MOS can be built in as a separate component of the TMDL (in this case, quantitatively, a TMDL = WLA + LA + MOS). In all cases, specific documentation describing the rational for the MOS is required.

Seasonal considerations, such as critical flow periods (high flow, low flow), also need to be considered when establishing TMDLs, targets, and allocations.

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SUMMARY – An appropriate margin of safety is included through conservative assumptions in the derivation of the target and in the modeling. Additionally, ongoing monitoring has been proposed to assure water quality goals are achieved. Seasonality was adequately considered by evaluating the cumulative impacts of the various seasons on water quality and by proposing BMPs that can be tailored to seasonal needs.

7. TMDL

Criterion Description – Total Maximum Daily Load

TMDLs include a quantified pollutant reduction target. According to EPA regulations (see 40 CFR 130.2(i)). TMDLs can be expressed as mass per unit of time, toxicity, % load reduction, or other measure. TMDLs must address, either singly or in combination, each listed pollutant/water body combination.

☒ Satisfies Criterion
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☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
☐ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – The TMDL established for Sylvan Lake is a 4.9 kg/yr total phosphorus load to the lake (75% reduction in annual total phosphorus load). This is the "measured load" which is based on the flow and concentration data collected during the period of the assessment. Since the annual loading varies from year-to-year, this TMDL is considered a long term average percent reduction in total phosphorous loading.

8. Allocation

Criterion Description – Allocation

TMDLs apportion responsibility for taking actions or allocate the available assimilative capacity among the various point, nonpoint, and natural pollutant sources. Allocations may be expressed in a variety of ways such as by individual discharger, by tributary watershed, by source or land use category, by land parcel, or other appropriate scale or dividing of responsibility. A performance based allocation approach, where a detailed strategy is articulated for the application of BMPs, may also be appropriate for nonpoint sources. Every effort should be made to be as detailed as possible and also, to base all conclusions on the best available scientific principles.

In cases where there is substantial uncertainty regarding the linkage between the proposed allocations and achievement of water quality standards, it may be necessary to employ a phased or adaptive management approach (e.g., establish a monitoring plan to determine if the proposed allocations are, in fact, leading to the desired water quality improvements).

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SUMMARY – This TMDL addresses the need to achieve further reductions in nutrients to attain water quality goals in Sylvan Lake. The allocation for the TMDL is a "load allocation" attributed to nonpoint sources. There are no significant point source contributions in this watershed. The source allocations for phosphorous are assigned to nonpoint source runoff from the watershed, and internal loading from lake-bottom sediment.

9. Public Participation

> ***Criterion Description – Public Participation***
>
> *The fundamental requirement for public participation is that all stakeholders have an opportunity to be part of the process. Notifications or solicitations for comments regarding the TMDL should clearly identify the product as a TMDL and the fact that it will be submitted to EPA for review. When the final TMDL is submitted to EPA for review, a copy of the comments received by the state should be also submitted to EPA..*

☒ Satisfies Criterion
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☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
☐ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – The State's submittal includes a summary of the public participation process that has occurred which describes the ways the public has been given an opportunity to be involved in the TMDL development process. In particular, the State has encouraged participation through public meetings in the watershed, individual contact with residents in the watershed, and widespread solicitation of comments on the draft TMDL. Also, the draft TMDL was posted on the State's internet site to solicit comments during the public notice period. The level of public participation is found to be adequate.

10. Monitoring Strategy

> ***Criterion Description – Monitoring Strategy***
>
> *TMDLs may have significant uncertainty associated with selection of appropriate numeric targets and estimates of source loadings and assimilative capacity. In these cases, a phased TMDL approach may be necessary. For Phased TMDLs, it is EPA's expectation that a monitoring plan will be included as a component of the TMDL documents to articulate the means by which the TMDL will be evaluated in the field, and to provide supplemental data in the future to address any uncertainties that may exist when the document is prepared.*

☐ Satisfies Criterion
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☐ Partially satisfies criterion. Questions or comments provided below need to be addressed.
☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
☒ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – Sylvan Lake will continue to be monitored through the statewide lake assessment project. Post-implementation monitoring will be necessary to assure the TMDL has been reached and maintenance of the beneficial use occurs.

11. Restoration Strategy

Criterion Description – Restoration Strategy
At a minimum, sufficient information should be provided in the TMDL document to demonstrate that if the TMDL were implemented, water quality standards would be attained or maintained. Adding additional detail regarding the proposed approach for the restoration of water quality ***is not*** *currently a regulatory requirement, but is considered a value added component of a TMDL document.*

☐ Satisfies Criterion
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☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
☒ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – The South Dakota DENR will work with the local interested parties in the watershed to develop a plan for an implementation project for Sylvan Lake. Implementation of various best management practices is expected to meet or exceed the WQ and TMDL targets/goals. This includes in-lake treatment with aluminum sulfate to reduce in-lake loading, and construction of artificial wetlands on the inlet streams to reduce phosphorous loading from the watershed. Additional BMPs that could be implemented if necessary include lake aeration, dredging and in-lake bioremediation.

12. Endangered Species Act Compliance

Criterion Description – Endangered Species Act Compliance
EPA's approval of a TMDL may constitute an action subject to the provisions of Section 7 of the Endangered Species Act (ESA). EPA will consult, as appropriate, with the US Fish and Wildlife Service (USFWS) to determine if there is an effect on listed endangered and threatened species pertaining to EPA's approval of the TMDL. The responsibility to consult with the USFWS lies with EPA and is not a requirement under the Clean Water Act for approving TMDLs. States are encouraged, however, to participate with USFWS and EPA in the consultation process and, most importantly, to document in its TMDLs the potential effects (adverse or beneficial) the TMDL may have on listed as well as candidate and proposed species under the ESA.

☐ Satisfies Criterion
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☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
☒ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – EPA has received ESA Section 7 concurrence from the FWS for this TMDL.

13. Miscellaneous Comments/Questions

NOTICE OF
TOTAL MAXIMUM DAILY LOADS

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

Sylvan Lake, Custer County

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

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

Any person interested in reviewing this TMDL document may request a copy by telephone or by mail. Also, each document has been uploaded to DENR's website at the Internet address

http://www.state.sd.us/denr/What'sNew.htm

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

Persons are encouraged to comment electronically by sending the comments to Gene Stueven at the email address in the above paragraph. The department must receive the comments by June 6, 2005.

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

Steven M. Pirner
Secretary
Department of Environment and Natural Resources