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

Loyalton Dam
Edmunds County, SD

By

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Sponsor

Dakota Central Conservation Association, Inc.

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

Grant # C9998185-00

Executive Summary

PROJECT TITLE: Dakota Central Watershed Assessment

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

FUNDING: TOTAL BUDGET: $87,200.00

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

FUNDING SUMMARY:

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

SUMMARY OF ACCOMPLISHMENTS:

The primary objectives of this effort were to (1) assess current physical, chemical, and biological integrity of Loyalton Dam and Dry Run Creek, (2) determine non-point source critical areas within the watershed, and (3) define management prescriptions for identified non-point source critical areas.

Two lake sites and two tributary sites (inlet and outlet) were sampled monthly and immediately following major rain events from June 2000 to June 2001. Continuous discharge data was collected from the inlet and outlet sites throughout the project period in order to determine sediment and nutrient loading.

Loyalton Dam was included in the 1998 South Dakota 303(d) list as an impairment-related TMDL waterbody (SDDENR, 1998). Information supporting this listing was derived from statewide lake assessment data (Stueven and Stewart, 1996) and the 1996 305(b) report (SDDENR, 1996). According to the 1996 305(b) report, causes for impaired uses include two agricultural nonpoint source pollutants - nutrients and silt. The 2000 305(b) report lists the same sources of impairment, however, the magnitude of theses sources are considered "very slight" (SDDENR, 2000). No additional impairment sources were documented. Loyalton Dam is also listed in "Ecoregion Targeting for Impaired Lakes in South Dakota" (Stueven et al., 2000b) as partially supporting its beneficial uses. In this document, Loyalton Dam ranks highest in water quality of the assessed lakes in the Northern Glaciated Plains ecoregion in terms of trophic state (lowest mean TSI values).

Most of the assessed parameters fell within state water quality standards. However, high concentrations of nutrients and sediment were observed in both lake and tributary samples. Average inlake total nitrogen concentration was 2.12 mg/L and average total phosphorus concentration was 0.176 mg/L. One lake sample exceeded the total suspended solids standard with a concentration of 164 mg/L. Fecal coliform bacteria were also present in elevated concentrations in several samples. Approximately nine percent of inlake fecal bacteria samples exceeded the single-sample standard.

Non-point source critical areas within the study watershed were identified using the AGNPS loading model. AGNPS nutrient output indicates that the study watershed has a total nitrogen (soluble + sediment bound) delivery rate of 0.94 lbs/acre/year (3.6 tons/year) and a total phosphorus (soluble + sediment bound) delivery rate of 0.29 lbs/acre/year (1.1 tons/year). The model indicates that a large portion of the nutrients delivered from the watershed were sediment bound, indicating erosion from cropland may be the major contributor of nutrients to Loyalton Dam. AGNPS estimated sediment delivery rate was 0.06 tons/acre/year (456 tons/year). Most of the high erosion areas are on slopes of greater than 3% and where conventional tillage is practiced.

A variety of BMPs were modeled using AGNPS to estimate percent reductions in nutrient and sediment load. By practicing conservation tillage and installing grassed waterways, a 6.4% reduction in nitrogen, 10.3% reduction in phosphorus, and 16.7% reduction in sediment load could be achieved.

A significant amount of phosphorus loading could be reduced within the lake itself. Highest inlake total dissolved phosphorus and total phosphorus concentrations were observed in samples collected in December. These elevated concentrations are most likely the result of internal phosphorus loading. While watershed management activities are necessary to maintain relatively low nutrient and sediment loadings from the watershed, internal phosphorus loads must also be reduced. A 50% reduction of inlake phosphorus is possible with the addition of aluminum sulfate (alum treatment).

The inlake and watershed management projects that are recommended in this report will improve the water quality of Loyalton Dam. Long-term monitoring is recommended following implementation to evaluate the effects of management activities.

Acknowledgements

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

Edmunds County Conservation District

Natural Resource Conservation Service – Edmunds County

South Dakota Department of Health

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

South Dakota Department of Environment and Natural Resources – Water Rights

United States Environmental Protection Agency – Non-Point Source Program

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Introduction

The purpose of the Dakota Central Watershed Assessment was to determine sources of impairment for two waterbodies, Cresbard Lake and Loyalton Dam. This report discusses the current condition, possible restoration alternatives, and a TMDL summary for the Loyalton Dam watershed only.

Watershed Description

Loyalton Dam is located in southeast Edmunds County, three miles southeast of Loyalton, SD (Figure 1). Construction of this 36-acre man-made dam began in 1933 and was completed in 1938. A federal relief program, intended to assist drought-stricken producers, funded the construction of the dam (Allbee, 1983).

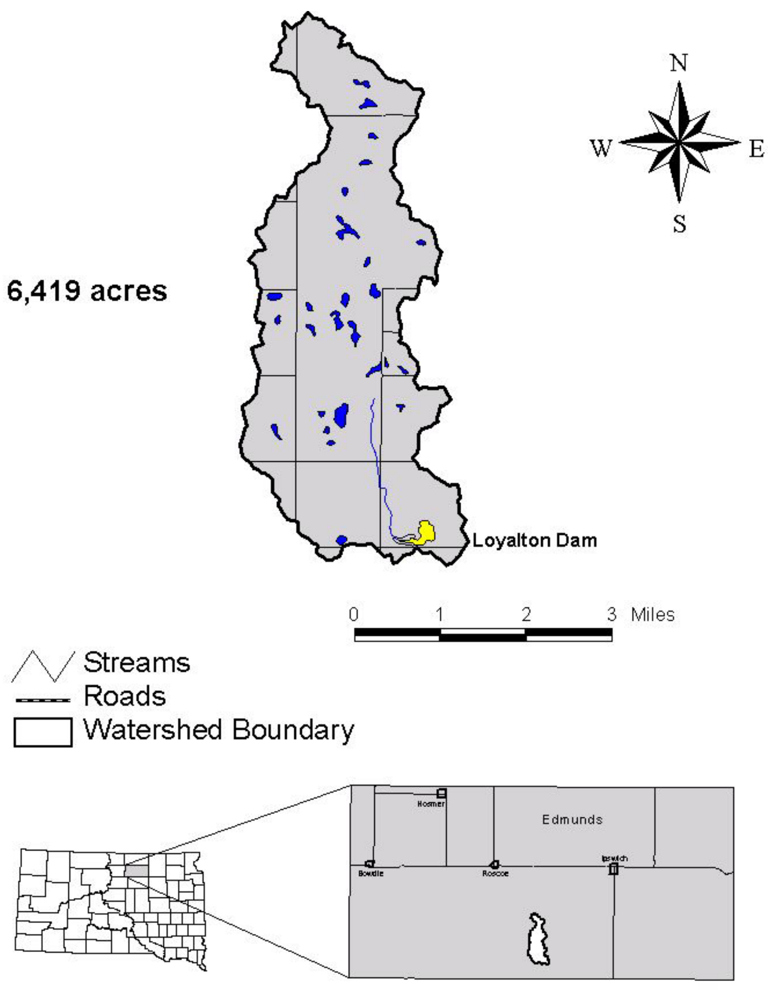

Figure 1. Location of the Dry Run Creek watershed and Loyalton Dam, Edmunds County, SD.

Dry Run Creek serves as both the inlet and outlet for Loyalton Dam and drains 6,419 acres above the impoundment (Figure 1). The creek receives runoff from croplands, which has resulted in declining water quality. Land use within the watershed is predominately agricultural, including cropland and pasture. Approximately 42% of the watershed area is cropland and 58% is grasslands (native and non-native).

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.

Loyalton Dam has been assigned the following beneficial uses: (1) warmwater semipermanent fish propagation, (2) immersion recreation, (3) limited contact recreation, and (4) wildlife propagation, recreation, and stock watering. Table 1 lists the criteria that must be met to maintain the above beneficial uses. When multiple standards exist for a particular parameter, the most stringent standard is used.

Table 1. State surface water quality standards for Loyalton Dam.

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

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

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

Table 2. State surface water quality standards for Dry Run Creek.

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

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

Threatened and Endangered Species

No threatened or endangered species have been documented in the Dry Run Creek Watershed. The U.S. Fish and Wildlife Service lists the whooping crane, bald eagle, and western prairie fringed orchid as species that could potentially be found in the area. None of these species were encountered during this study. However, care should be taken when considering management activities in this watershed.

Project Goals, Objectives, and Activities

Project Goals

The goal of this assessment project was to determine and document sources of impairments to the Loyalton Dam watershed and to develop feasible alternatives for restoration.

Project Objectives and Tasks

Objective 1: Lake Sampling

The first objective was to determine current conditions of Loyalton Dam and calculate the trophic state. This information was used to determine the extent of nutrient-trapping occurring in the lake and the required reduction of nutrients to improve the trophic condition of Loyalton Dam.

To accomplish this objective, two in-lake sites were sampled on a monthly basis (excluding periods of unsafe ice cover). Samples were collected to assess physical, chemical, and biological characteristics of Loyalton Dam. Water column dissolved oxygen and temperature profiles were also collected on a monthly basis using a YSI meter.

Project sponsor staff collected all samples. Staff from the Water Resource Assistance Program, Pierre, SD, analyzed biological samples in the Matthew Training Center Laboratory, excluding fecal coliform bacteria. South Dakota State Health Laboratory analyzed fecal coliform samples, as well as the chemical parameters.

Objective 2: Tributary Sampling

Sediment and nutrient loads from the Loyalton Dam watershed were estimated through hydrologic and chemical analysis. Water level recorders were installed on two tributary sites (inlet and outlet) to maintain a continuous stage record for the project period. Discrete discharge measurements were taken on a regular schedule and during storm events. Discharge and stage data were used to calculate a hydrologic budget for the drainage system. Discharge measurements and concentrations of sediment and nutrients were used to calculate watershed loads. Water samples were collected from tributary sites. Samples were collected during spring runoff, storm events, and base flows.

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

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

Agricultural impacts on water quality in the watershed were assessed using the Agricultural Nonpoint Source (AGNPS) model. AGNPS is a comprehensive land use model that estimates soil loss and delivery and evaluates the impact of livestock feeding areas. The watershed was divided into 40-acre cells. Each cell was analyzed using 21 parameters with additional information collected for animal feeding operations. This model was used to identify critical areas of nonpoint source pollution to the surface waters in the watershed. Contributions of nutrients and sediment to surface water in the Loyalton Dam watershed were identified.

Objective 5: Public Participation

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

Objective 6: Development of Restoration Alternatives

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

Methods

Tributary Assessment Methods

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

Table 3. Parameters measured at stream sites.

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

Water level recorders were installed at these sites to maintain a continuous stage record for the project period. An ISCO model 4230 bubbler stage recorder was installed at the inlet site (stream stage), a Stevens Type F stage recorder was installed at the outlet site (lake stage). Daily stage averages were calculated for both sites. Instantaneous discharge measurements were taken with a hand-held current velocity meter. A regression equation was developed from the relationship between discharge and stage data to estimate a hydrologic budget for the drainage system. Watershed loads were calculated from discharge measurements and sample concentrations of sediment and nutrients. FLUX, a eutrophication model developed by the Army Corps of Engineers (US ACOE, 1999) was used to estimate nutrient and sediment loading. These estimates were then used to determine nutrient balances in Loyalton Dam.

Lake Assessment Methods

Physical, chemical, and biological parameters were examined for Loyalton Dam on a monthly basis and during rain events, excluding the months November and February. Samples were collected from surface and bottom depths at two sites (Figure 2). Air and water temperature, dissolved oxygen, conductivity, field pH, and water depth were measured using a YSI meter. As with tributary sampling, all samples and measurements were collected using methods described in *Standard Operating Procedures for Field Samplers* for the South Dakota Water Resources Assistance Program (Stueven et al., 2000a). Table 4 lists all parameters measured for Loyalton Dam.

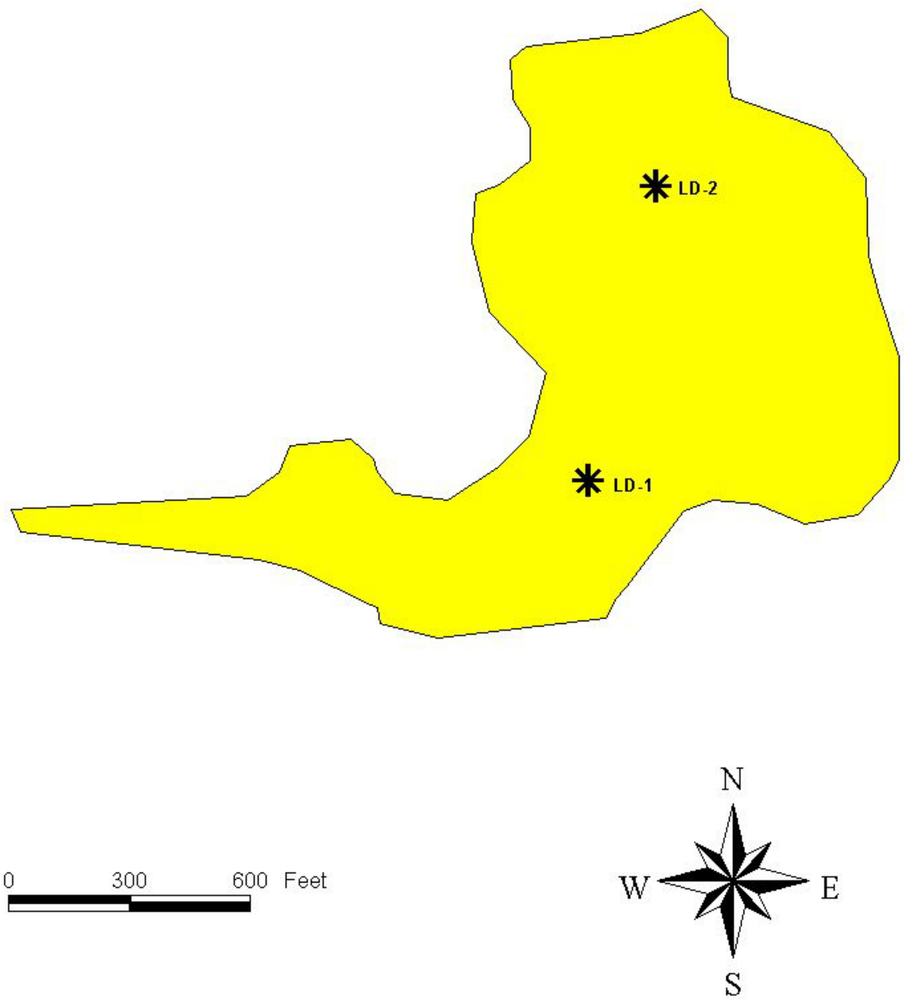

Figure 2. Location of inlake sampling sites for Loyalton Dam, Edmunds County, SD.

Table 4. Parameters measured at lake sites.

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

Results

Tributary Physical and Chemical Parameters

Annual Loading

Sample data and instantaneous flow measurements were used to estimate loads using the FLUX model. Data from three outlet samples was omitted before executing the model because the samples were collected on dates (18-Jul-00, 10-Apr-00, and 31-May-01) when predicted flows were at or below zero.

Hydrologic load was calculated using FLUX in order to develop a water budget for Loyalton Dam. Approximately 3,110,000,000 liters (2,520 acre-ft) of water flowed into Loyalton Dam from the Dry Run Creek inlet during the project period. The amount of water delivered per acre for the gauged portion of the watershed was 484,500 liters.

Seasonal and annual loads for each measured parameter (nutrients and solids) were also calculated using FLUX (Table 5). Highest hydrologic loads occurred during the spring (84%) due to spring snowmelt runoff and rain events. The summer months also contributed a significant amount of load (16%), mostly due to one large storm event occurring in August 2000. Fall and winter months contributed no loading as measured by the gauging stations.

Table 5. Seasonal and annual loads (kg) delivered from the Loyalton Dam watershed.

Parameter	Spring (kg)	Summer (kg)	Annual (kg)
Alkalinity	307,522	57,950	365,472
Ammonia	1,256	237	1,493
Nitrate	5,906	1,113	7,019
Organic Nitrogen	5,310	1,001	6,310
Total Kjehldahl Nitrogen	6,566	1,237	7,803
Total Nitrogen	12,472	2,350	14,822
Total Dissolved Phosphorus	2,180	411	2,591
Total Phosphorus	2,774	523	3,297
Total Dissolved Solids	1,125,178	212,030	1,337,207
Total Suspended Solids	50,367	9,491	59,858
Total Solids	1,175,545	221,521	1,397,066

Water Temperature

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

As expected in lotic (flowing water) systems, temperatures were extremely variable at both sites. Average temperature at the inlet site was 10.48 degrees Celsius, while average temperature at the outlet site was 14.87 degrees Celsius (Table 6). Lower average inlet water temperatures could be attributed to the colder water coming from spring runoff. Spring snow melt-water can keep stream water temperatures below air temperatures for long periods (Hynes, 1970). Due to large variability in the temperature measurements (Figure 3) no significant difference was observed between the sites. Seasonal or monthly temperatures are not reported due to limited data.

Table 6. Descriptive statistics of water temperature (degrees Celsius) for Dry Run Creek sites.

	Number of Measurements	Mean	Minimum	Maximum	Standard Deviation
Inlet	6	10.48	2.79	19.76	7.04
Outlet	5	14.87	3.02	27.00	11.17

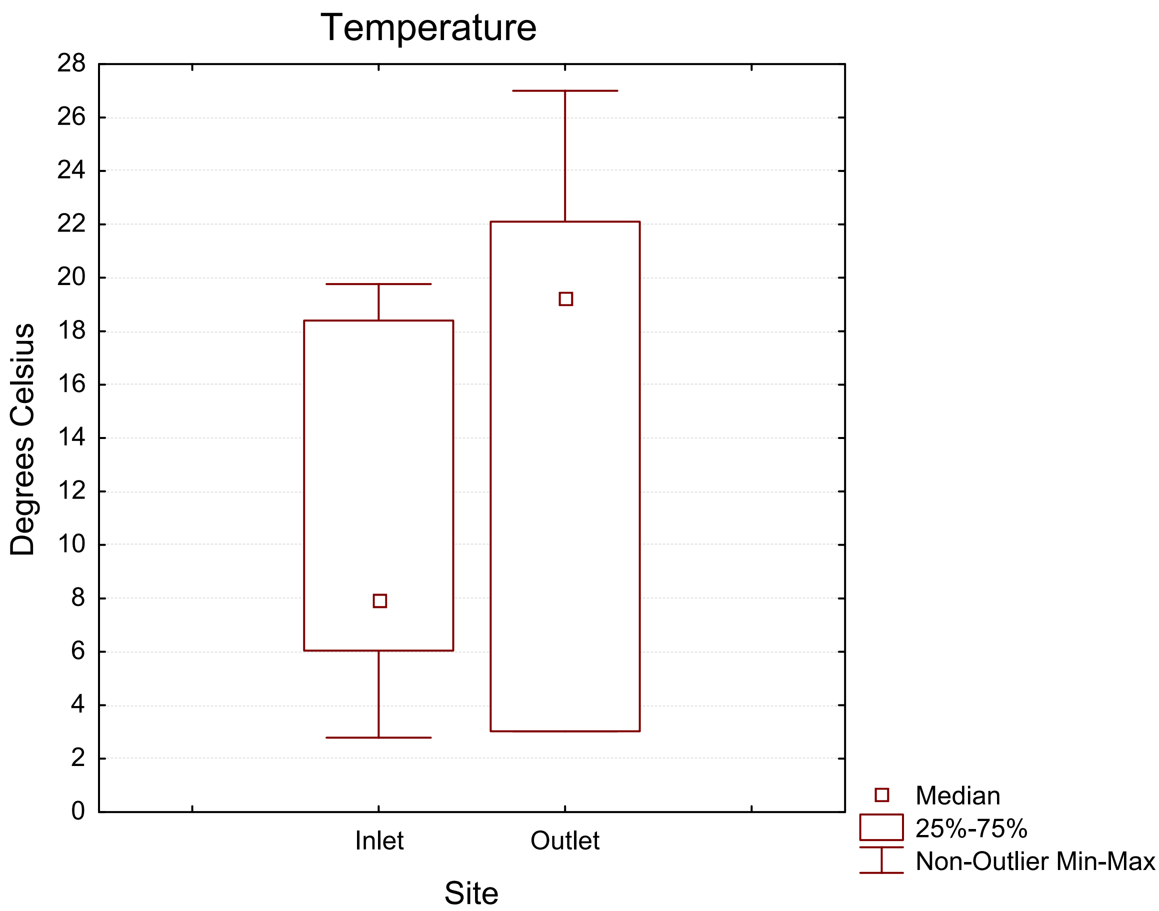

Figure 3. Box plot of temperature by site for Dry Run Creek. This box plot demonstrates medians, quartiles (25th and 75th percentiles), and non-outlier minima and maxima (see legend).

Dissolved Oxygen

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

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

Average DO concentration at the inlet site was 10.2 mg/L, while average DO concentration was 8.09 mg/L at the outlet (Table 7). Lower DO concentrations at the outlet are probably due to warmer temperatures at the outlet site and respiration occurring in the lake. Similar to temperature data, large variability in the DO measurements (Figure 4) suggests no significant difference between the sites. Minimum values observed at the inlet and outlet are inexplicably low values that are possibly due to sampler error or a faulty meter. As stated before, seasonal or monthly concentrations are not reported due to limited data.

Table 7. Descriptive statistics of dissolved oxygen (mg/L) for Dry Run Creek sites.

	Number of Measurements	Mean	Minimum	Maximum	Standard Deviation
Inlet	6	10.12	2.80	19.87	5.98
Outlet	5	8.09	1.10	14.28	6.43

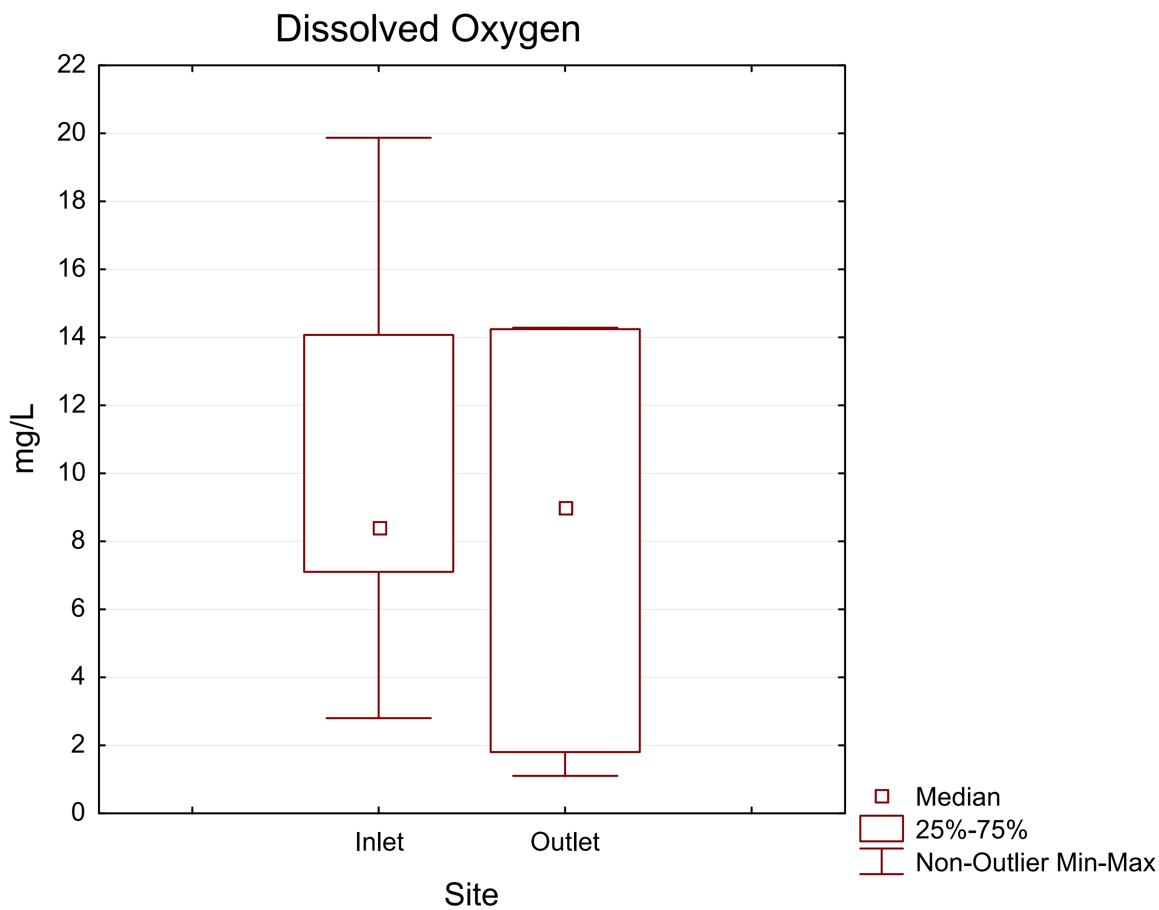

Figure 4. Box plot of dissolved oxygen by site for Dry Run Creek.

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.

Average field pH at the inlet site was 7.84, while average pH at the outlet site was 6.34 (Table 8). Small impoundments often increase the carbon dioxide content of the water as it passes through them. Relatively high content of carbonic acid can drastically lower pH (Hynes, 1970). Field pH measurements at the outlet were also more variable than inlet measurements (Figure 5). The minimum value observed at the outlet is an inexplicably low value that is possibly due to sampler error or a faulty meter

Table 8. Descriptive statistics of field pH (standard units) for Dry Run Creek sites.

	Number of Measurements	Mean	Minimum	Maximum	Standard Deviation
Inlet	6	7.84	7.17	8.88	0.75
Outlet	5	6.34	3.70	8.62	2.22

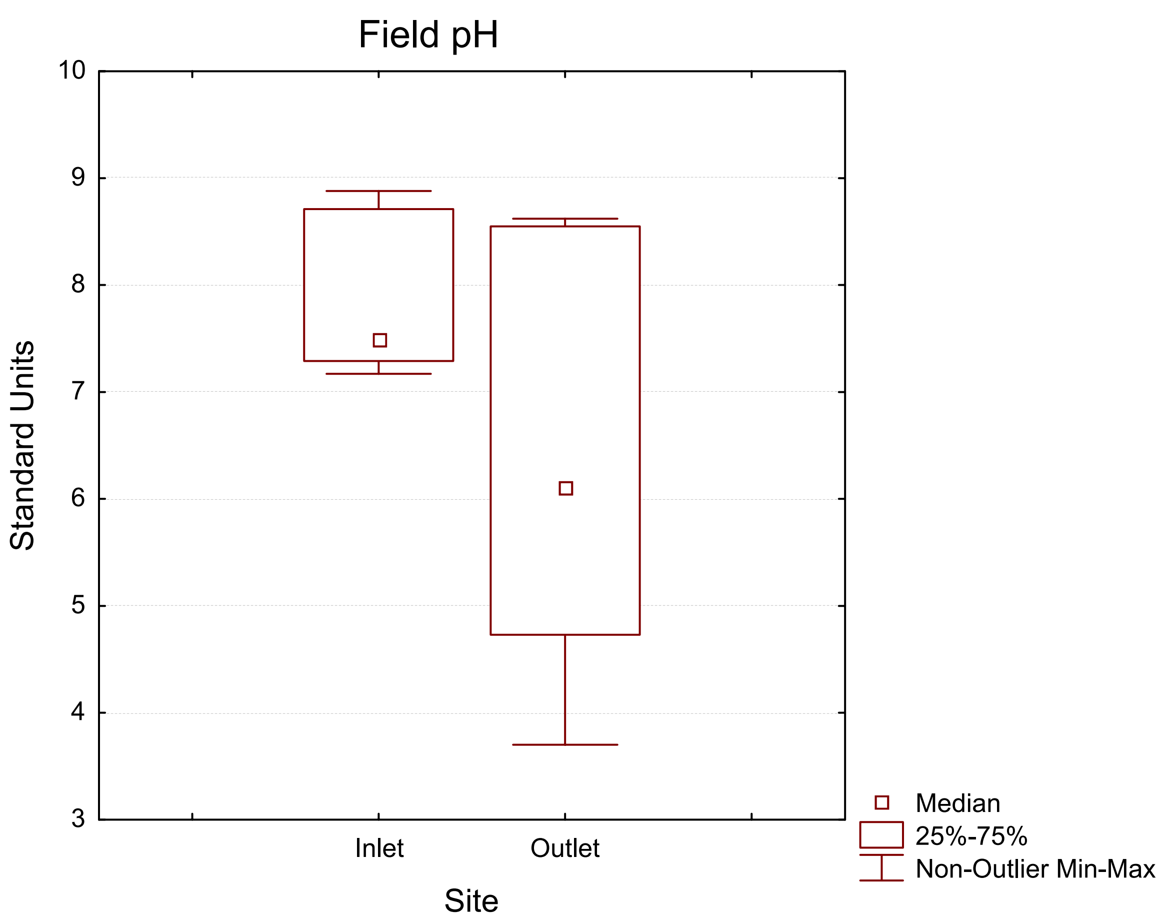

Figure 5. Box plot of field pH by site for Dry Run Creek.

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

Average alkalinity concentrations from inlet and outlet samples were similar, although somewhat higher at the outlet site (Table 9). Greater variability in alkalinity concentrations was observed at the outlet site, which was most likely due to lake effects (Figure 6). The alkalinity standard of ≤1313 mg/L was not violated at either site.

Table 9. Descriptive statistics of alkalinity (mg/L) for Dry Run Creek samples.

	Number of Measurements	Mean	Minimum	Maximum	Standard Deviation
Outlet	7	225	14	507	179
Inlet	6	206	78	542	175

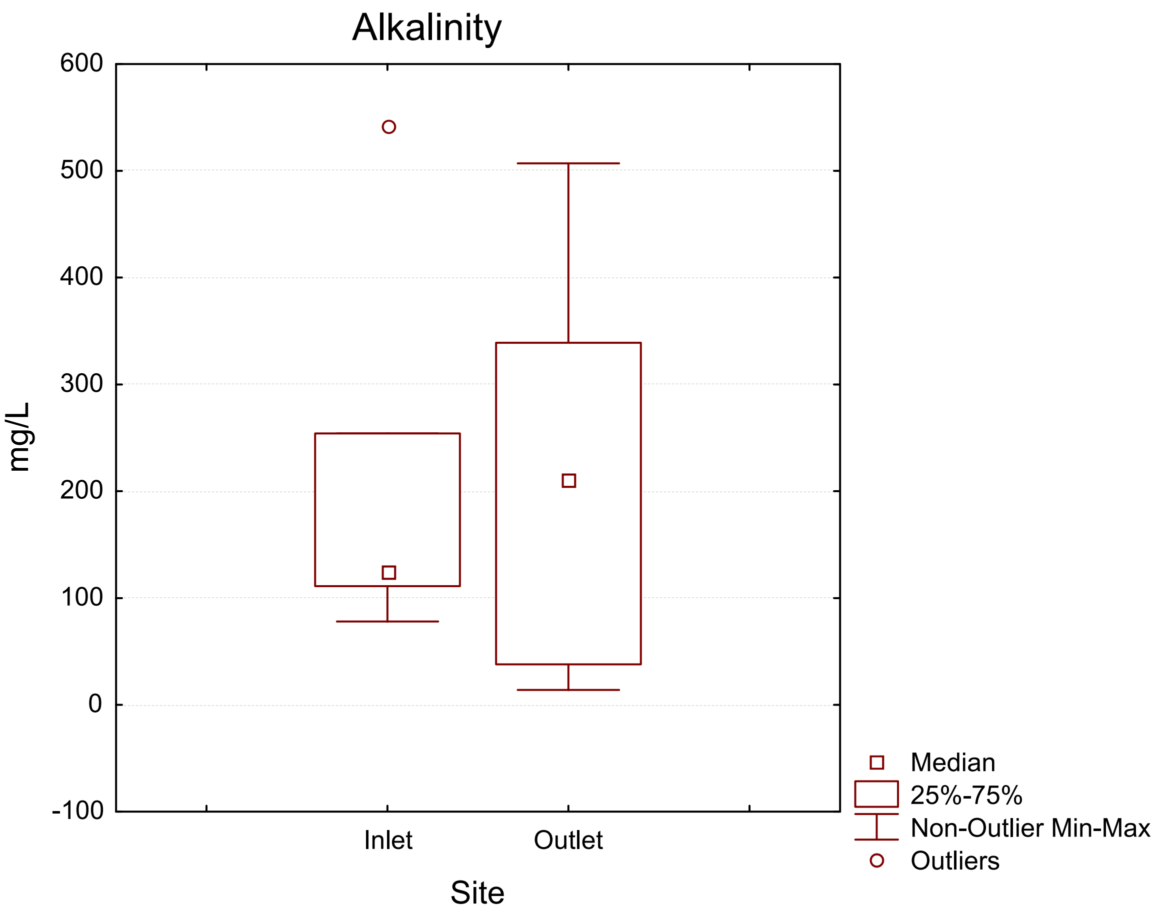

Figure 6. Box plot of alkalinity by site for Dry Run Creek.

Solids

"Solids" is a general term that refers to suspended or dissolved materials that are present in the waterbody. Four solids parameters were examined in this assessment: total solids, total suspended solids, total dissolved solids, and total volatile suspended solids. Total solids include the sum of dissolved and suspended solids. Dissolved solids are those materials small enough to pass through a 2.0 um filter. 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. Organic solids (total suspended volatile solids) are determined by combustion of the filtered residue.

Concentrations of total solids were comparable at the inlet and outlet sites. Inlet sample concentrations ranged from 312 to 3,327 mg/L (mean = 981). However, the maximum concentration was considered an extreme outlier in the data set. Outlet sample concentrations ranged from 162 to 1,554 mg/L (mean = 753) (Table 10). Surprisingly, inlet total solids concentrations displayed less variability than outlet concentrations with outliers removed (Figure 7). FLUX estimates an annual load of nearly 1,245,000 kg (1,373 tons) of total solids delivered to Loyalton Dam from the watershed. This equates to an average of 428 kg per watershed acre.

Table 10. Descriptive statistics of total solids (mg/L) for Dry Run Creek samples.

	Number of Measurements	Mean	Minimum	Maximum	Standard Deviation
Outlet	7	753	162	1554	520
Inlet	6	981	312	3327	1159

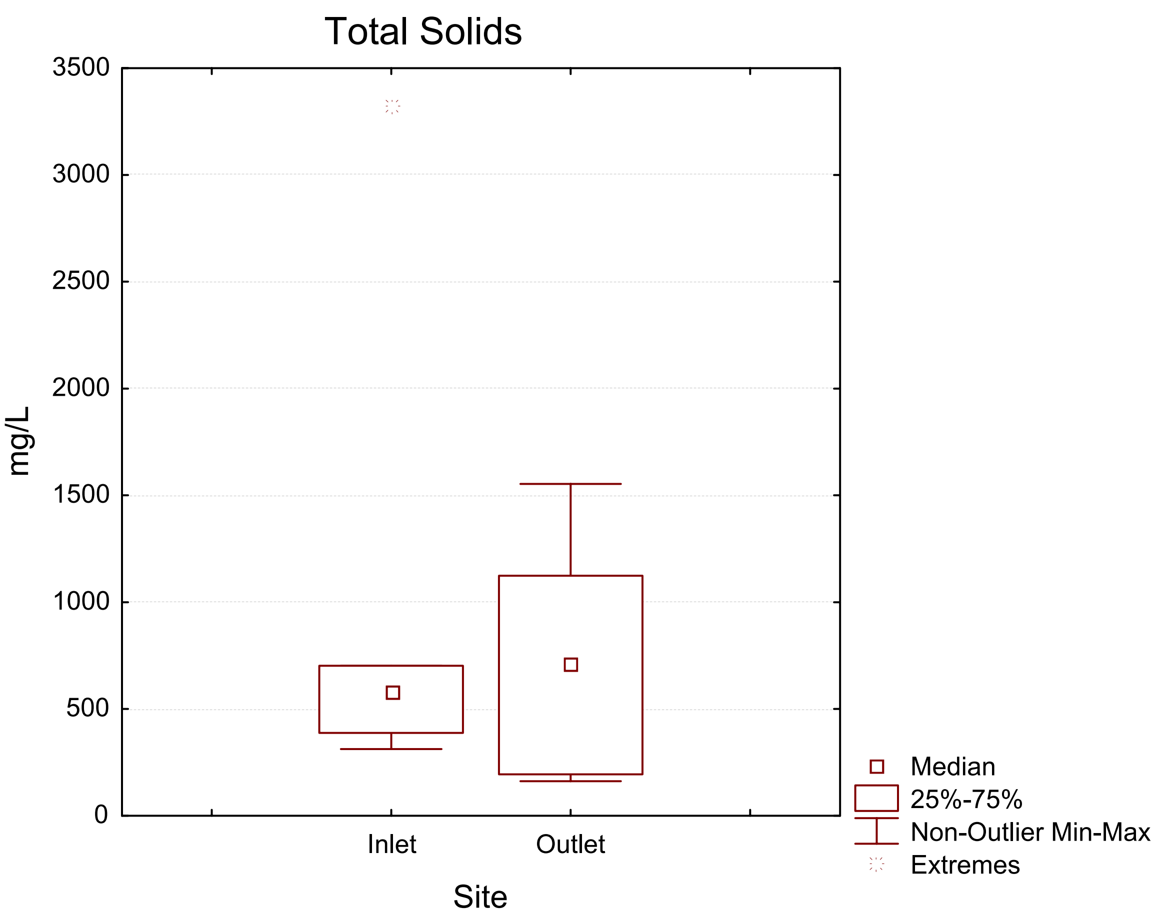

Figure 7. Box plot of total solids by site for Dry Run Creek.

Typically, lakes or dams on the course of a stream allow large amounts of suspended solids to settle out before the water is discharged from the lake or dam. However, sample data indicates suspended solids concentrations were slightly greater at the outlet (Table 11 and Figure 8). Concentrations of suspended solids at the inlet ranged from 6 to 94 mg/L (mean = 26), while concentrations at the outlet ranged from 12 to 68 mg/L (mean = 34). Slightly higher suspend solid concentrations at the outlet could be attributed to algal production in the reservoir.

The FLUX model estimates an annual load of 53,347 kg (58.8 tons) of suspended solids delivered to Loyalton Dam from the watershed, or 8.3 kg per watershed acre.

Table 11. Descriptive statistics of total suspended solids (mg/L) for Dry Run Creek samples.

	Number of Measurements	Mean	Minimum	Maximum	Standard Deviation
Outlet	7	34	12	68	20
Inlet	6	26	6	94	34

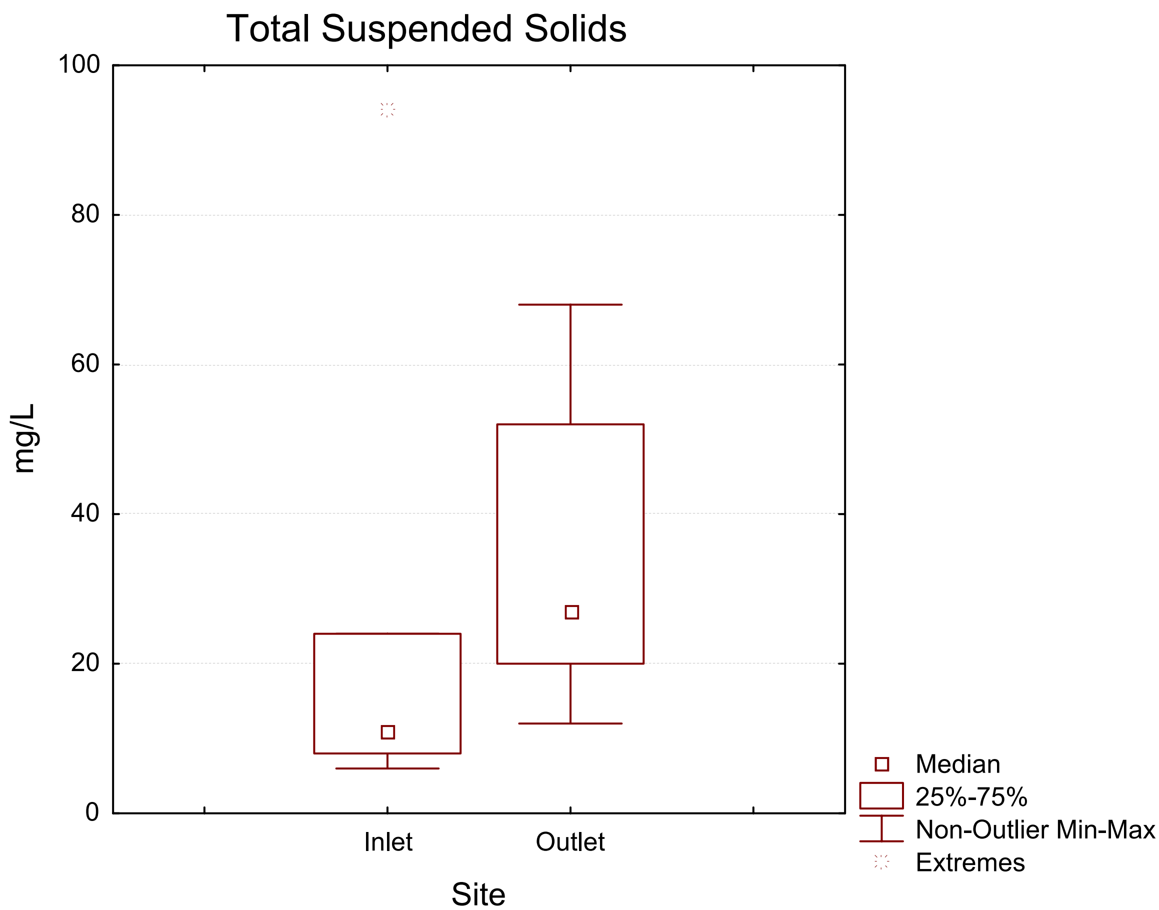

Figure 8. Box plot of total suspended solids (TSS) by site for Dry Run Creek.

On average, one-third of total suspended solids in stream samples was organic. This was measured by concentrations of total volatile suspended solids (TVSS). Stream sites displayed comparable concentrations of TVSS. Concentrations of TVSS at the inlet ranged from 4 to 36 mg/L (mean = 11), while outlet concentrations ranged from 1 to 30 mg/L (mean = 11) (Table 12 and Figure 9).

Table 12. Descriptive statistics of total volatile suspended solids (mg/L) for Dry Run Creek samples.

	Number of Measurements	Mean	Minimum	Maximum	Standard Deviation
Outlet	7	11	1	30	10
Inlet	6	10	4	36	13

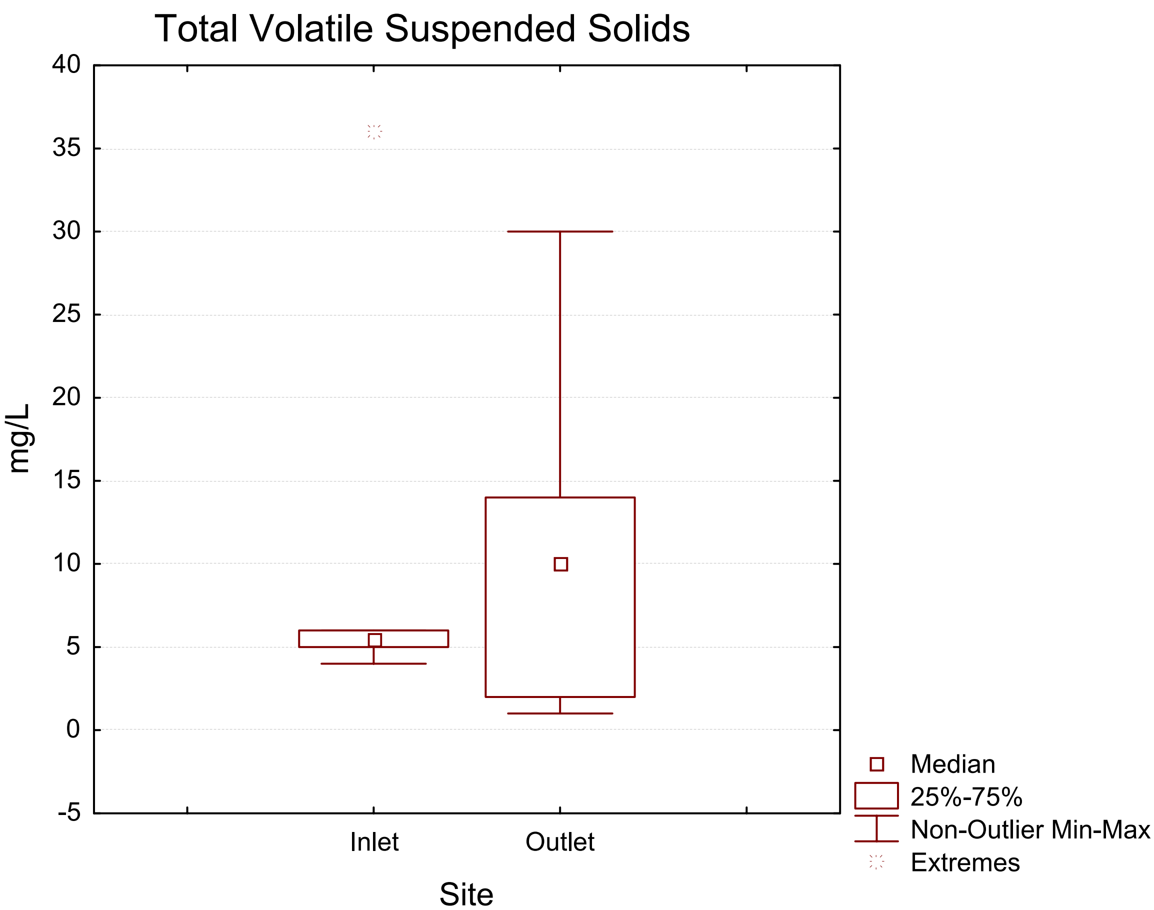

Figure 9. Box plot of total volatile suspended solids (TVSS) by site for Dry Run Creek.

Nitrogen

Three types of nitrogen were assessed in tributary samples: (1) nitrate/nitrite, (2) ammonia, and (3) Total Kjeldahl Nitrogen (TKN). With these three parameters, relative concentrations of organic and inorganic nitrogen can be determined, as well as total nitrogen concentrations. Average total nitrogen concentration for inlet samples was 4.02 mg/L. Outlet average concentration was 2.25 mg/L (Table 13). Total nitrogen concentrations of inlet samples were much more variable than outlet samples (Figure 10).

Annual loads for all assessed forms of nitrogen are listed in Table 5. FLUX model output indicated total nitrogen concentration at the inlet was 4.7 mg/L. FLUX estimated total nitrogen annual load was 13,047 kg (14.4 tons), which is equivalent to 2 kg per watershed acre.

Table 13. Descriptive statistics of total nitrogen (mg/L) for Dry Run Creek samples.

	Number of Measurements	Mean	Minimum	Maximum	Standard Deviation
Outlet	7	2.25	1.53	3.78	0.82
Inlet	6	4.02	1.16	7.90	2.32

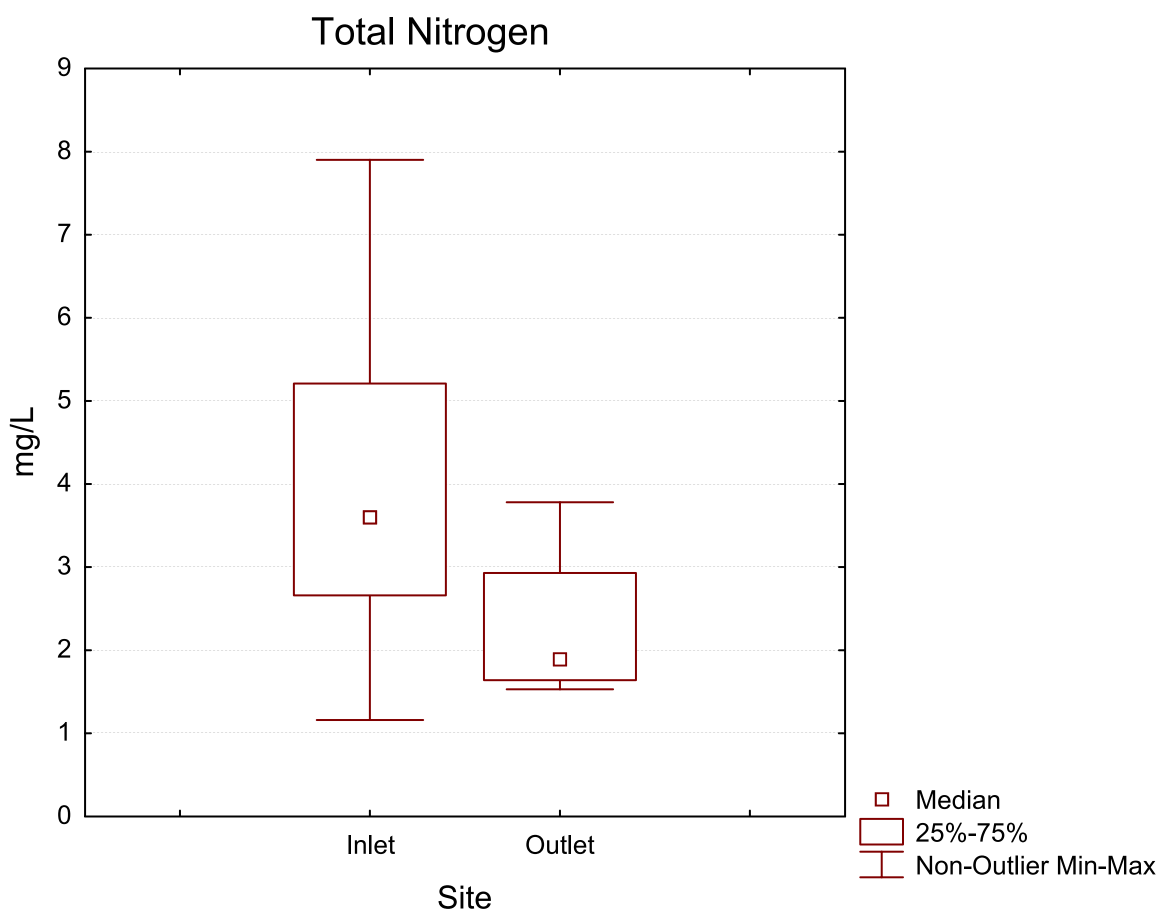

Figure 10. Box plot of total nitrogen by site for Dry Run Creek.

Concentrations of organic nitrogen exceeded concentrations of inorganic nitrogen (Figure 11). Possible sources of organic nitrogen in stream samples may include vegetation from the watershed, algae growth, and animal waste.

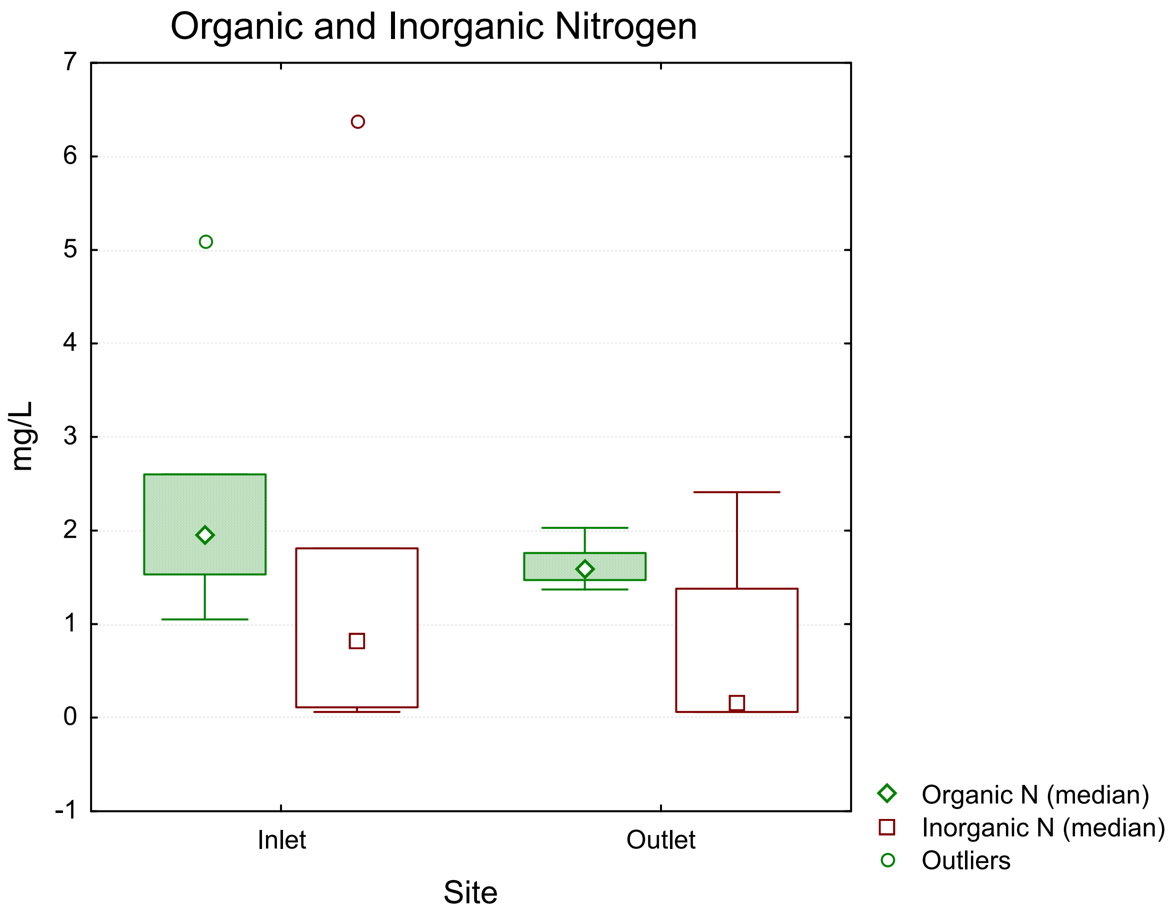

Figure 11. Box plot of organic and inorganic nitrogen concentrations by site for Dry Run Creek.

Average nitrate concentration for inlet samples was 1.37 mg/L. Average sample concentration for the outlet was 0.58 mg/L (Table 14). FLUX output indicated nitrate concentration at the inlet was 2.17 mg/L, and FLUX modeled outlet concentration was 0.64 mg/L. The nitrate standard for this portion of Dry Run Creek is ≤88 mg/L, much higher than modeled and observed concentrations.

Table 14. Descriptive statistics of nitrate (mg/L) for Dry Run Creek samples.

	Number of Measurements	Mean	Minimum	Maximum	Standard Deviation
Outlet	7	0.58	0.05	2.40	0.93
Inlet	6	1.37	0.05	6.00	2.34

Phosphorous

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

Effects of the dam are apparent when comparing inlet and outlet phosphorus concentrations (Figure 12). Total phosphorus concentrations at the inlet ranged from 0.396 to 2.920 mg/L (mean = 1.129), while concentrations at the outlet ranged from 0.074 to 0.610 mg/L (mean = 0.322) (Table 15). It is expected that much of the phosphorus load entering the lake is either incorporated into aquatic plant and algal biomass or attached to suspended solids that eventually settles to the bottom of the lake. FLUX model output indicated total phosphorus concentration at the inlet was 1.058 mg/L. FLUX estimated total phosphorus annual load was 2,938 kg (3.2 tons), which is equivalent to 0.46 kg per watershed acre.

Table 15. Descriptive statistics of total phosphorus (mg/L) for Dry Run Creek samples.

	Number of Measurements	Mean	Minimum	Maximum	Standard Deviation
Outlet	7	0.322	0.074	0.610	0.223
Inlet	6	1.129	0.396	2.920	0.927

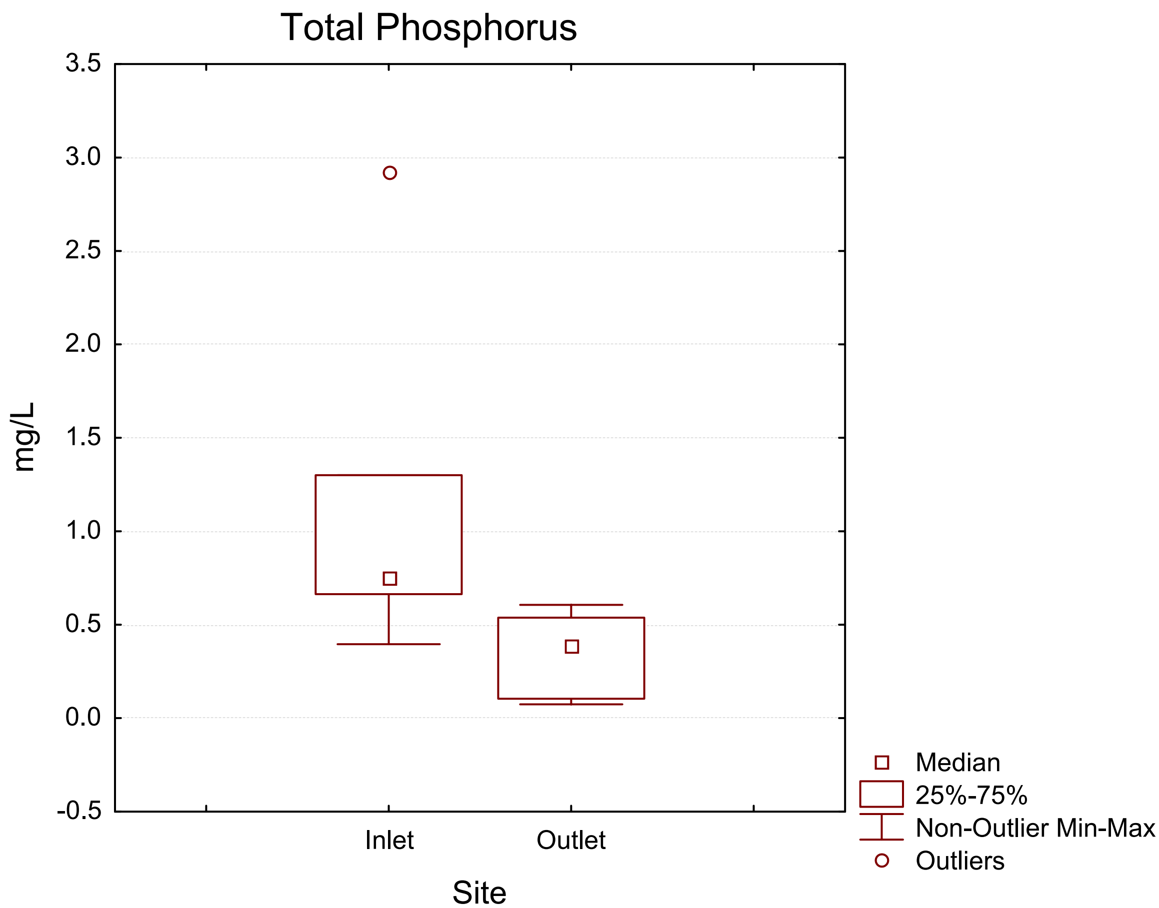

Figure 12. Box plot of total phosphorus by site for Dry Run Creek.

Total dissolved phosphorus (TDP) concentrations at the inlet ranged from 0.303 to 1.740 mg/L (mean = 0.790), while concentrations at the outlet ranged from 0.207 to 0.460 mg/L (mean = 0.207) (Table 16). Similar to all nutrient parameters, inlet TDP concentrations at the inlet were more variable than the outlet (Figure 13). FLUX model output indicated TDP concentration at the inlet was 0.839 mg/L. FLUX estimated TDP annual load was 2,331 kg (2.6 tons), which is equivalent to 0.36 kg per watershed acre.

Table 16. Descriptive statistics of total dissolved phosphorus (mg/L) for Dry Run Creek samples.

	Number of Measurements	Mean	Minimum	Maximum	Standard Deviation
Outlet	7	0.207	0.024	0.460	0.171
Inlet	6	0.790	0.303	1.740	0.561

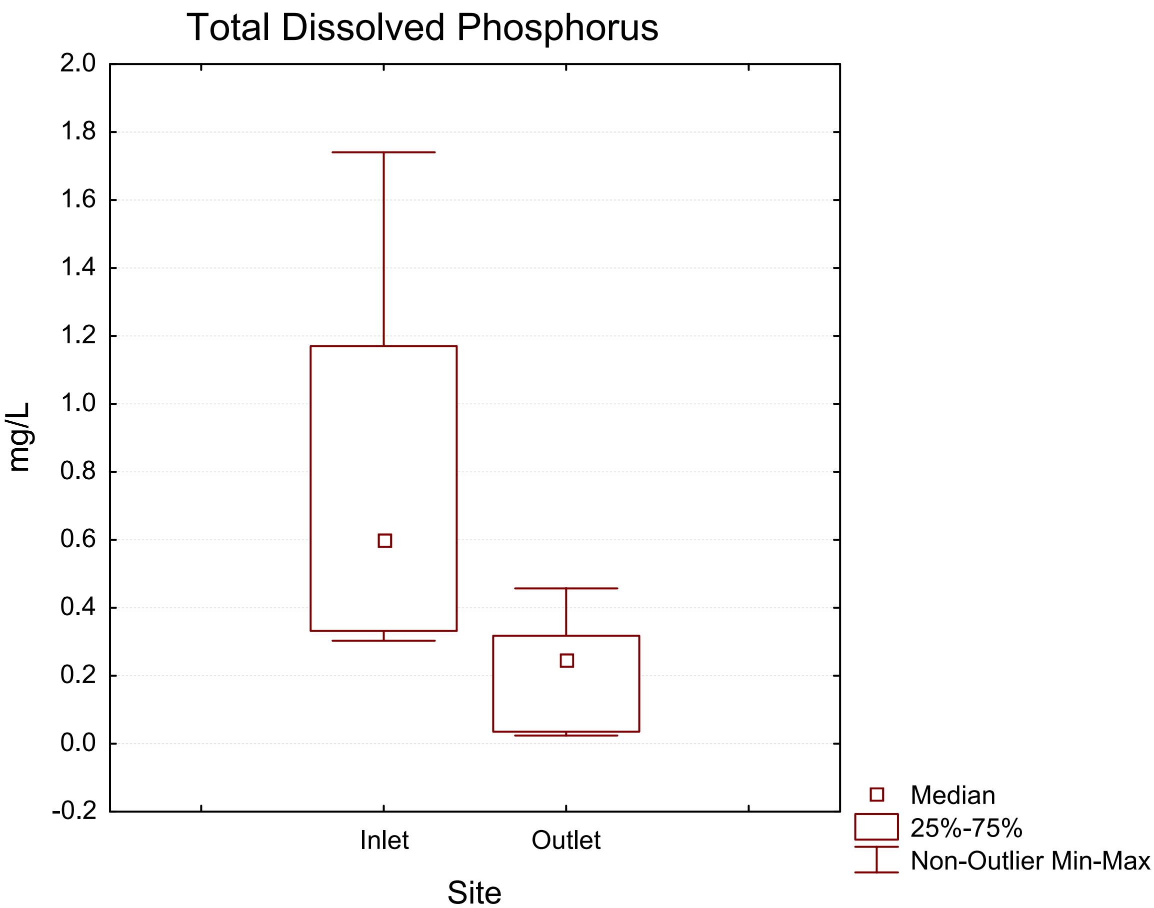

Figure 13. Box plot of total dissolved phosphorus by site for Dry Run Creek.

Tributary Biological Parameters

Fecal Coliform Bacteria

Fecal coliform bacteria are found in the intestinal tract of all warm-blooded animals. Although these organisms are not 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 (sunlight exposure, water temperature, etc.) can affect concentrations of fecal bacteria in a waterbody. 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.

Fecal bacteria concentrations at the inlet ranged from less than 10 to 17,000 bacteria colonies per 100 ml of sample (mean = 2,857). Concentrations at the outlet ranged from less than 10 to 280 colonies per 100 ml (mean = 77). The variability of this data is evident in the high standard deviations (Table 17). No fecal coliform bacteria standard exists for this portion of Dry Run Creek.

Table 17. Descriptive statistics of fecal coliform bacteria (number of colonies per 100 ml) for Dry Run Creek samples.

	Number of Measurements	Mean	Minimum	Maximum	Standard Deviation
Outlet	5	77	<10	280	116
Inlet	6	2,857	<10	17,000	6929

Lake Physical and Chemical Parameters

Water Temperature

Water temperature in Loyalton Dam ranged from 0.26 to 24.11 (mean = 11.9) degrees Celsius (Figure 14). State standards require water temperatures to be maintained below 32.2 degrees Celsius to support the beneficial use of warmwater semipermanent fish propagation. Maximum temperature was reached in August; however, this measurement did not exceed the standard.

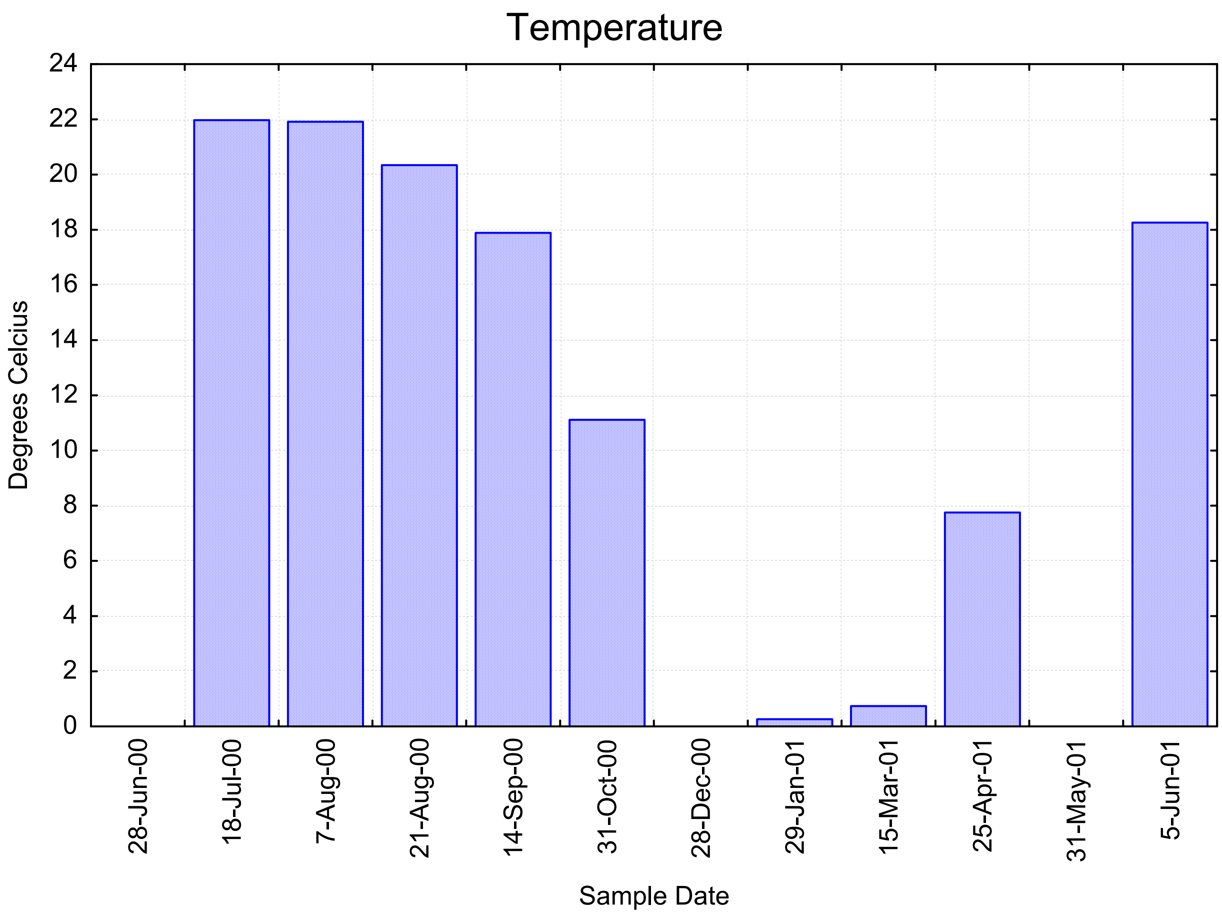

Figure 14. Average water temperature for Loyalton Dam by sample date. This is an average of both sites and all measured depths. NOTE: data were not collected on three sampling dates: 28-Jun-00, 28-Dec-00, and 31-May-01.

Dissolved Oxygen

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

DO values ranged from 2.18 to 16.75 mg/L (mean = 7.72). Lowest oxygen values were observed in August (Figure 15). A DO criterion of 5.0 mg/L is required to support both warmwater semipermanent fish propagation and immersion recreation. Nearly 30% of our measurements fell below this standard; however, these measurements were collected when the meter was not properly serviced (as indicated by the meter DO charge).

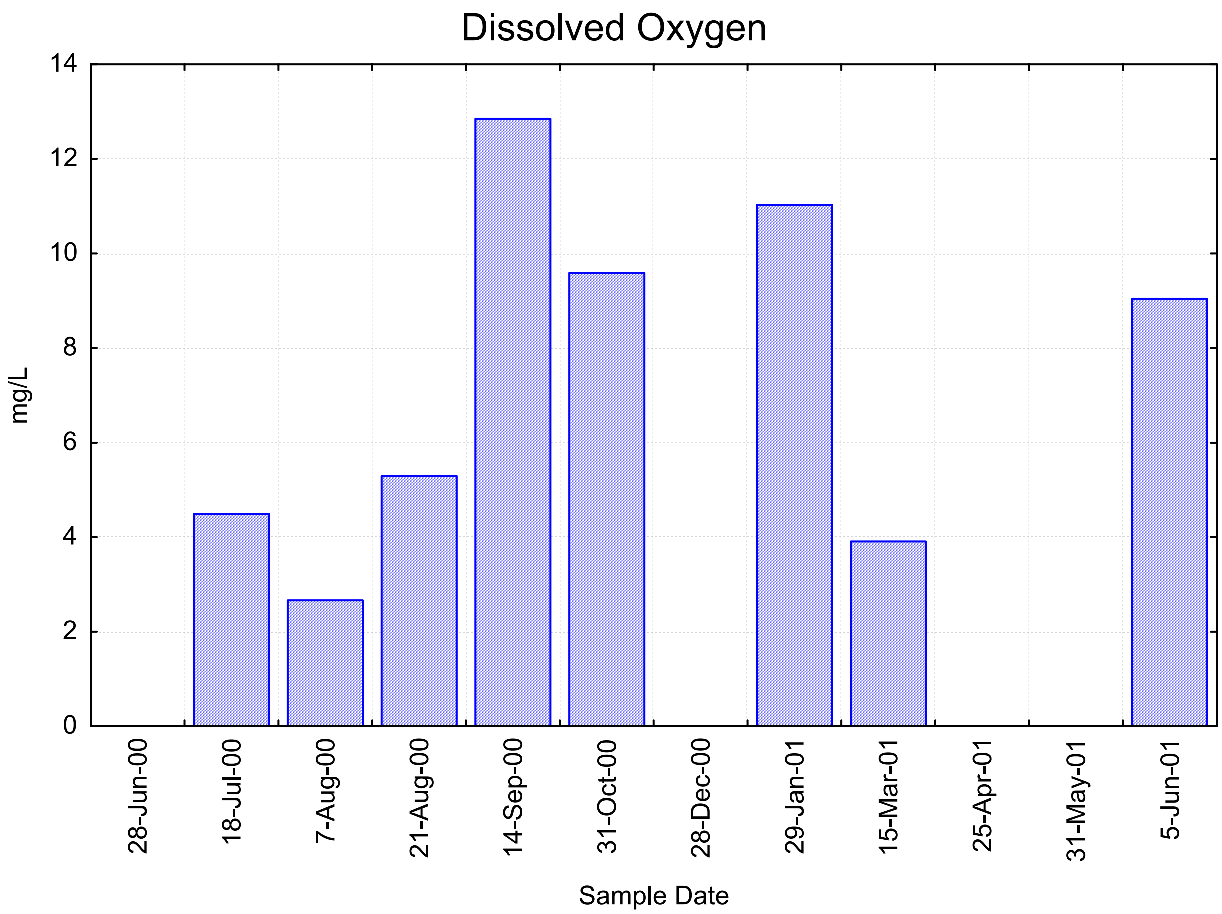

Figure 15. Average dissolved oxygen concentrations for Loyalton Dam by sample date. NOTE: data were not collected on four sampling dates: 28-Jun-00, 28-Dec-00, 25-Apr-01, and 31-May-01.

Temperature and dissolved oxygen (DO) profiles were measured to determine oxygen availability and temperature conditions throughout the water column and to detect stratification. Many lakes in temperate climates stratify, or form layers. This usually occurs during the summer, as large differences in water density are observed at higher temperatures (Monson, 2000).

No prolonged stratification was identified at either site. Figure 16 displays a profile of site LD1 in June. This was the only profile that displayed stratification. Site LD2 on the same sampling date displayed no stratification.

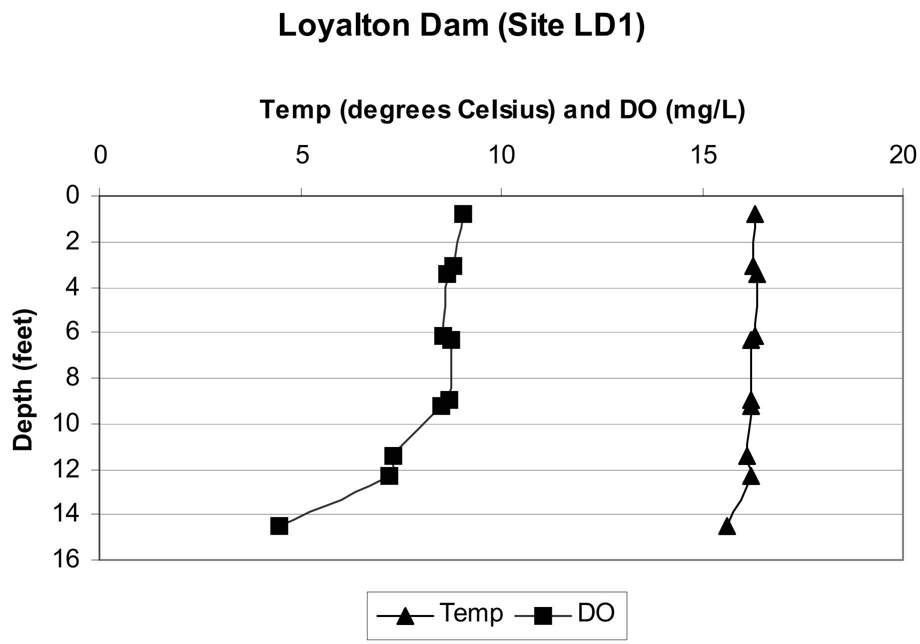

Figure 16. Dissolved oxygen and temperature profile for site LD1 of Loyalton Dam. These measurements were taken June 5, 2001.

Acidification and Alkalinity

As previously stated, the primary measurements of acidification are alkalinity and pH. In Loyalton Dam, pH values ranged from 7.20 to 8.84 (mean = 8.40). None of these measurements violated the state standard, which requires values within a range of 6.5 to 9.0 (Figure 17).

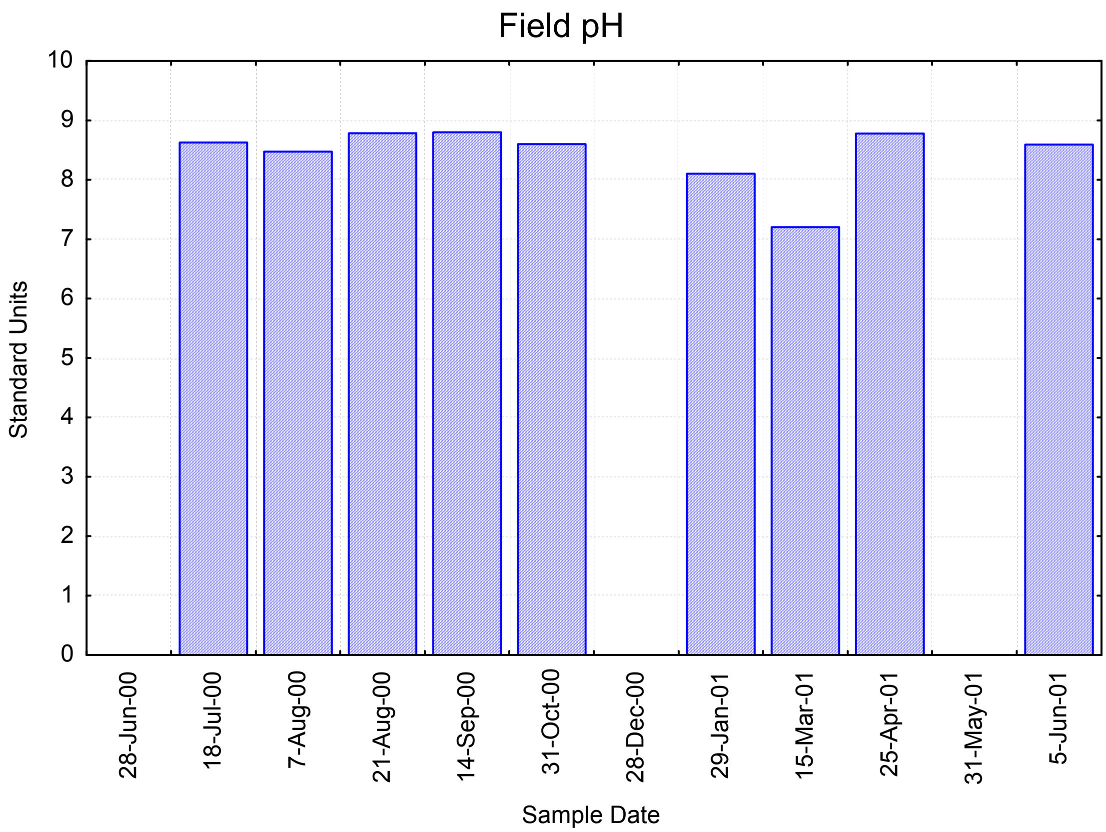

Figure 17. Average pH by sampling date for Loyalton Dam. NOTE: readings were not collected on three sampling dates: 28-Jun-00, 28-Dec-00, and 31-May-01.

Alkalinity measurements ranged from 103 to 539 mg/L (mean = 406). High alkalinity in Loyalton Dam could be attributed to dissolved solids loads from the watershed or biological activity in the sediment. Biological sources of alkalinity within the lake are generated from the reduction of sulfate and nitrate (Wetzel, 2001). Despite these high levels of alkalinity, no samples violated the state standard. The alkalinity standard for Loyalton Dam is ≤1313 mg/L (Figure 18).

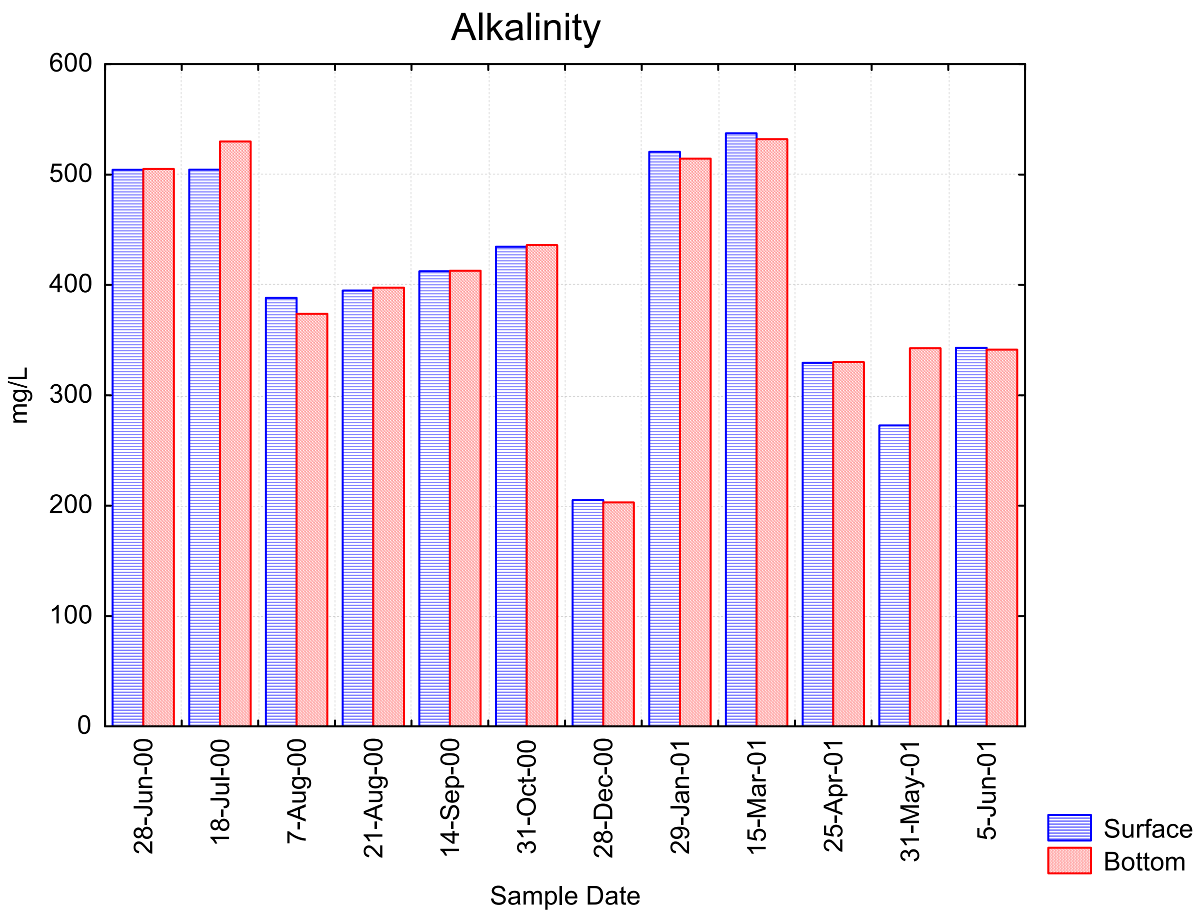

Figure 18. Average alkalinity of surface and bottom samples by sampling date for Loyalton Dam.

Solids

Total solids (suspended and dissolved) in Loyalton Dam ranged from 488 to 1659 mg/L (mean = 1256). With the exception of one sample date in December, total solids displayed little variation throughout the sampling period (Figure 19).

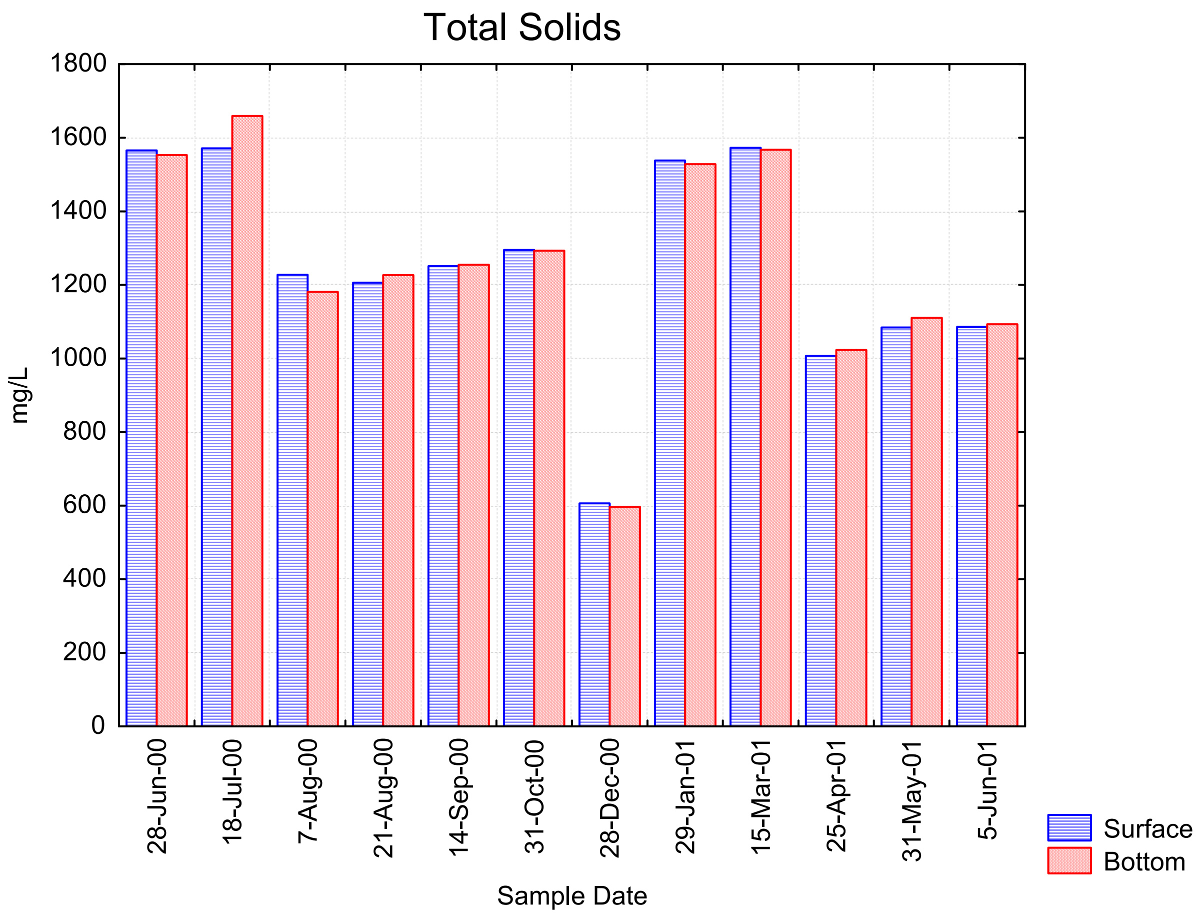

Figure 19. Average surface and bottom concentrations of total solids by sample date for Loyalton Dam.

Typical of most waterbodies, total solids were mostly comprised of dissolved solids. Dissolved solids consist of salts and compounds that increase alkalinity. This direct relationship was observed in Loyalton Dam. As total dissolved solids (TDS) increase, alkalinity increases (Figure 20). TDS ranged from 468 to 1567 mg/L (mean = 1229). The TDS standard for Loyalton Dam is ≤ 4,375 mg/L.

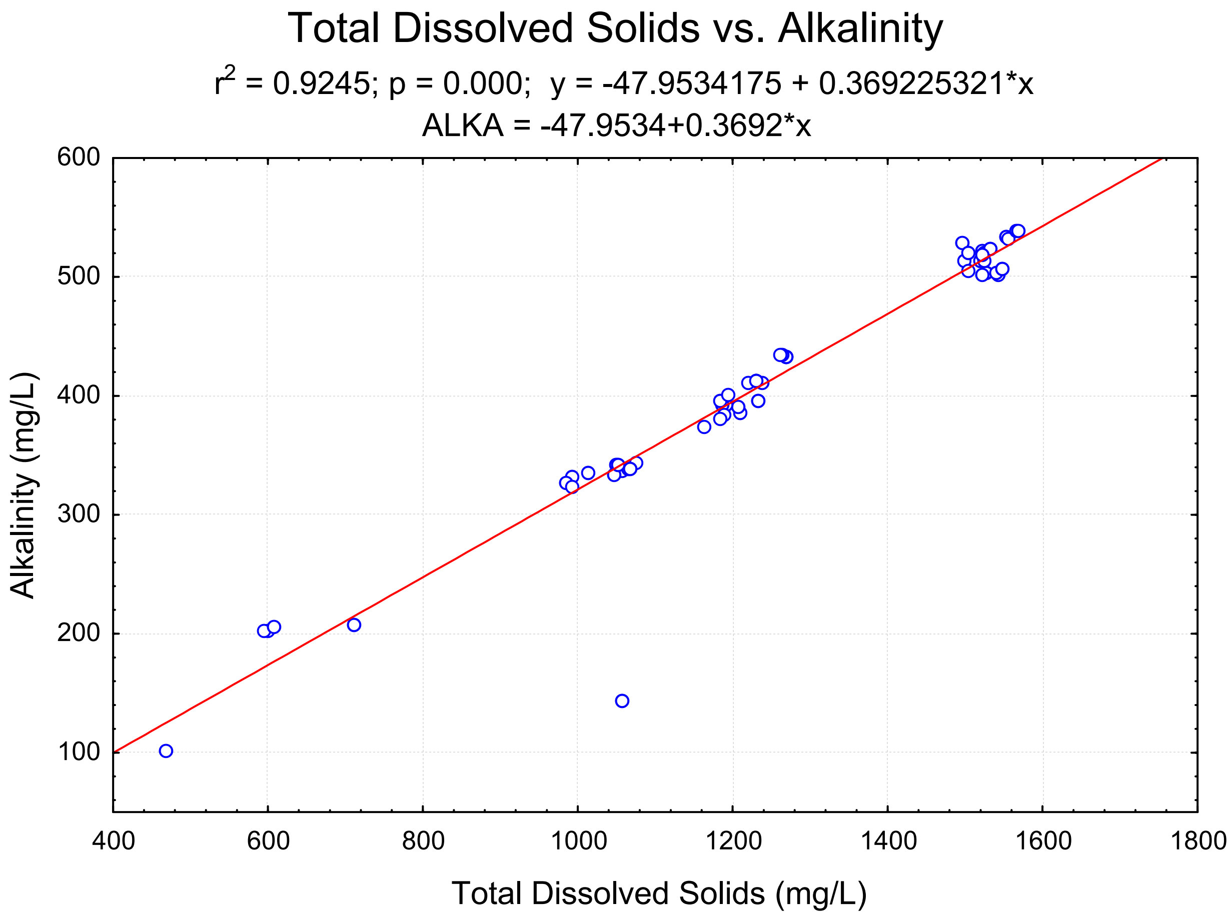

Figure 20. Scatterplot of total dissolved solids versus alkalinity with regression line.

Total suspended solids (TSS) ranged from 3 to 164 mg/L (mean = 27.3). TSS concentrations should be maintained below 158 mg/L in Loyalton Dam to support its fishery. One sample collected on July 18, 2000 exceeded this standard with a concentration of 164 mg/L (Figure 21). Samples collected on this date also showed the second highest algae counts during that sampling season, suggesting that the source of a large portion of the suspended solids is algae production. However, average concentration of inorganic forms of suspended solids was higher than concentrations of organic suspended solids. On average, 66% of TSS was inorganic.

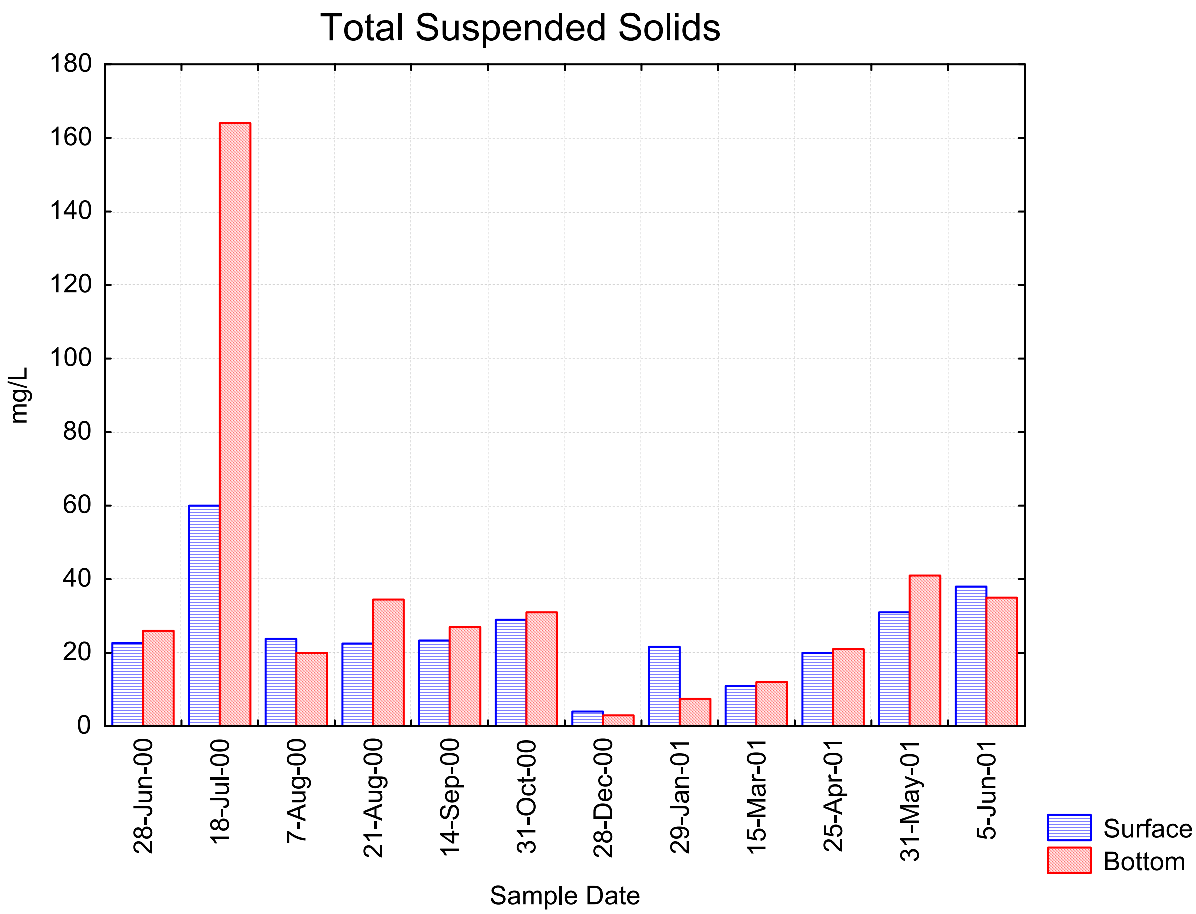

Figure 21. Average surface and bottom concentrations of total suspended solids by sample date for Loyalton Dam.

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, agricultural fertilizer applications, and livestock waste.

Total Kjeldahl Nitrogen (TKN) is a measure of organic nitrogen plus ammonia. Therefore, organic nitrogen can be calculated by subtracting ammonia from TKN. In Loyalton Dam, the amount of organic nitrogen far exceeded inorganic forms. In nearly half of the samples collected in Loyalton Dam, organic nitrogen concentrations were as much as ten times greater than inorganic nitrogen. Average organic nitrogen concentration was 1.55 mg/L. Average inorganic nitrogen (ammonia and nitrate/nitrite) concentration was 0.48 mg/L.

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

When samples are analyzed for ammonia, 0.02 mg/L is designated as the detection limit. In other words, a concentration of ammonia below 0.02 mg/L is considered undetectable. Ammonia levels were below the detection limit in almost half of the samples collected in Loyalton Dam. These samples were assigned values of half of the detection limit (0.01), assuming that a trace amount was present. Ammonia concentrations ranged from 0.01 to 0.59 mg/L (mean = 0.16) (Figure 22). Corrected for pH and temperature, un-ionized ammonia ranged from 0.001 to 0.025 mg/L (mean = 0.01). None of the un-ionized ammonia values were in violation of state standard.

Highest ammonia concentrations were observed during periods of low algal productivity. Algae can quickly consume ammonia for growth and reproduction. Chlorophyll *a* (produced by algae) concentrations were significantly correlated to ammonia concentrations ($r = -0.94$, $p < 0.05$). As chlorophyll *a* concentrations increased, ammonia concentrations decreased.

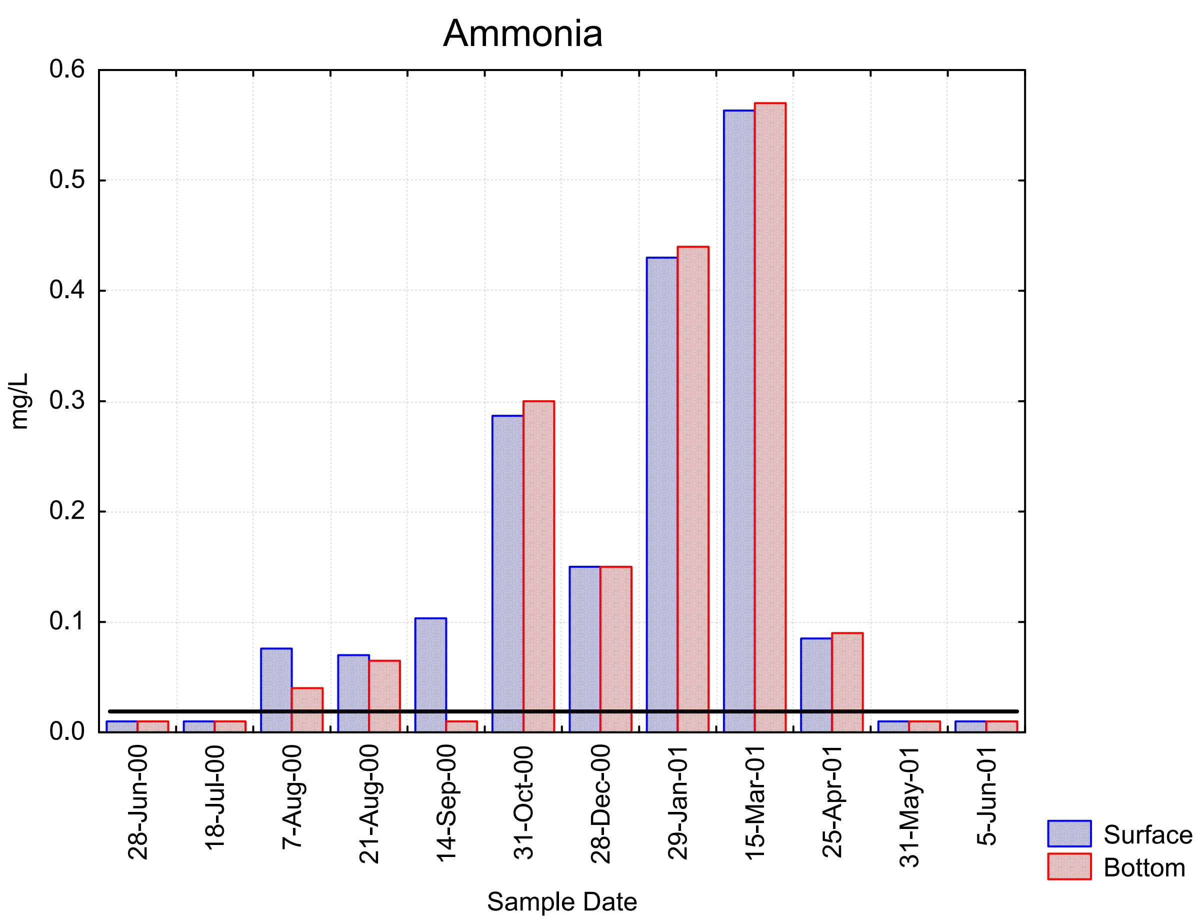

Figure 22. Average surface and bottom concentrations of total ammonia by sample date for Loyalton Dam. Line is detection limit (0.02 mg/L).

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

For nitrate analysis, 0.1 mg/L is designated as the detection limit. Nitrate levels were recorded below the detection limit in half of the samples collected in Loyalton Dam. These samples were assigned values of half of the detection limit (0.05). Nitrate concentrations in Loyalton Dam ranged from 0.05 to 3.80 mg/L (mean = 0.25) (Figure 23). Maximum nitrate concentration was observed in April 2001. This maxima was probably the result of agricultural practices in the watershed. No samples violated the nitrate standard (≤ 88 mg/L).

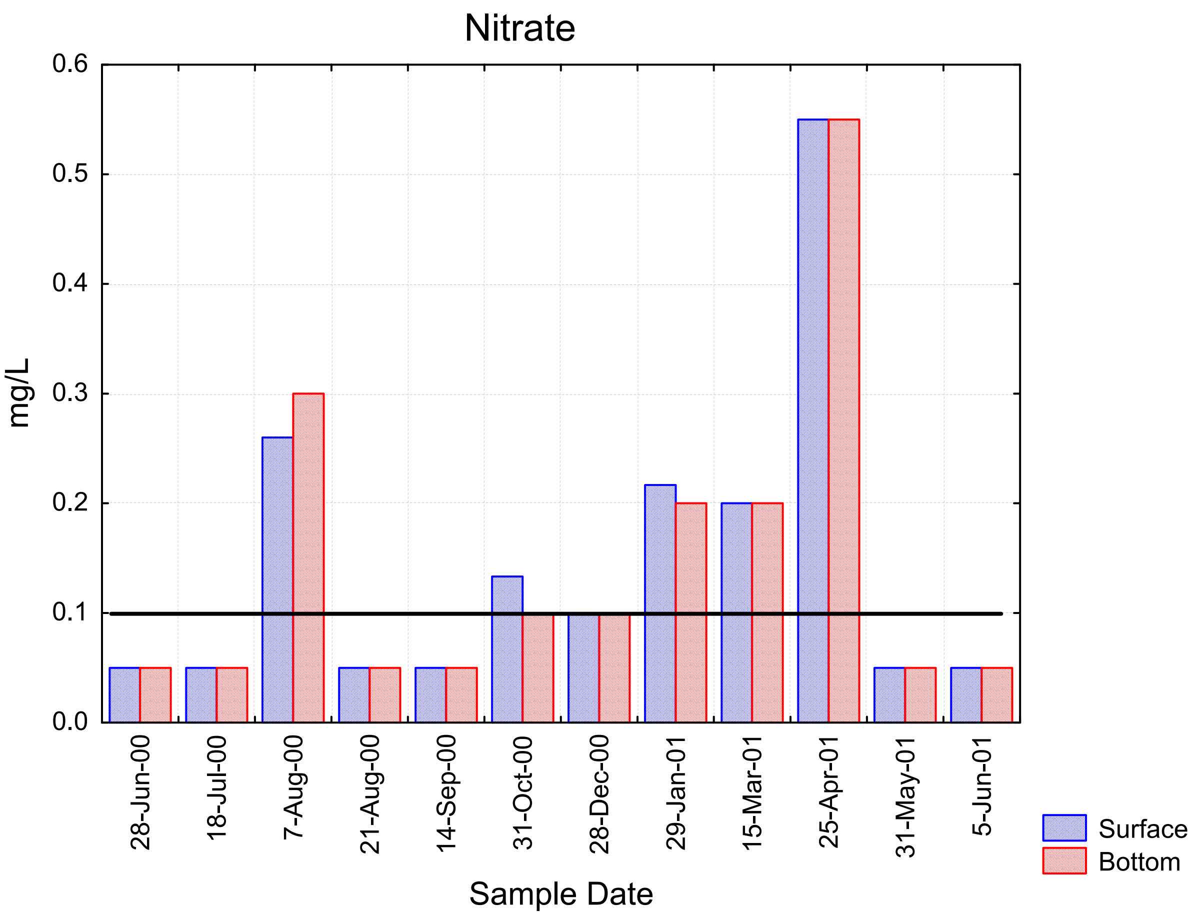

Figure 23. Average surface and bottom concentrations of nitrate by sample date for Loyalton Dam. Line is detection limit (0.1 mg/L).

Total nitrogen can be calculated by adding TKN and nitrate/nitrite concentrations. Total nitrogen values were used to determine whether nitrogen is a limiting nutrient in Loyalton Dam (see limiting nutrient section). Total nitrogen in Loyalton Dam ranged from 0 to 6.80 mg/L (mean = 2.03) (Figure 24).

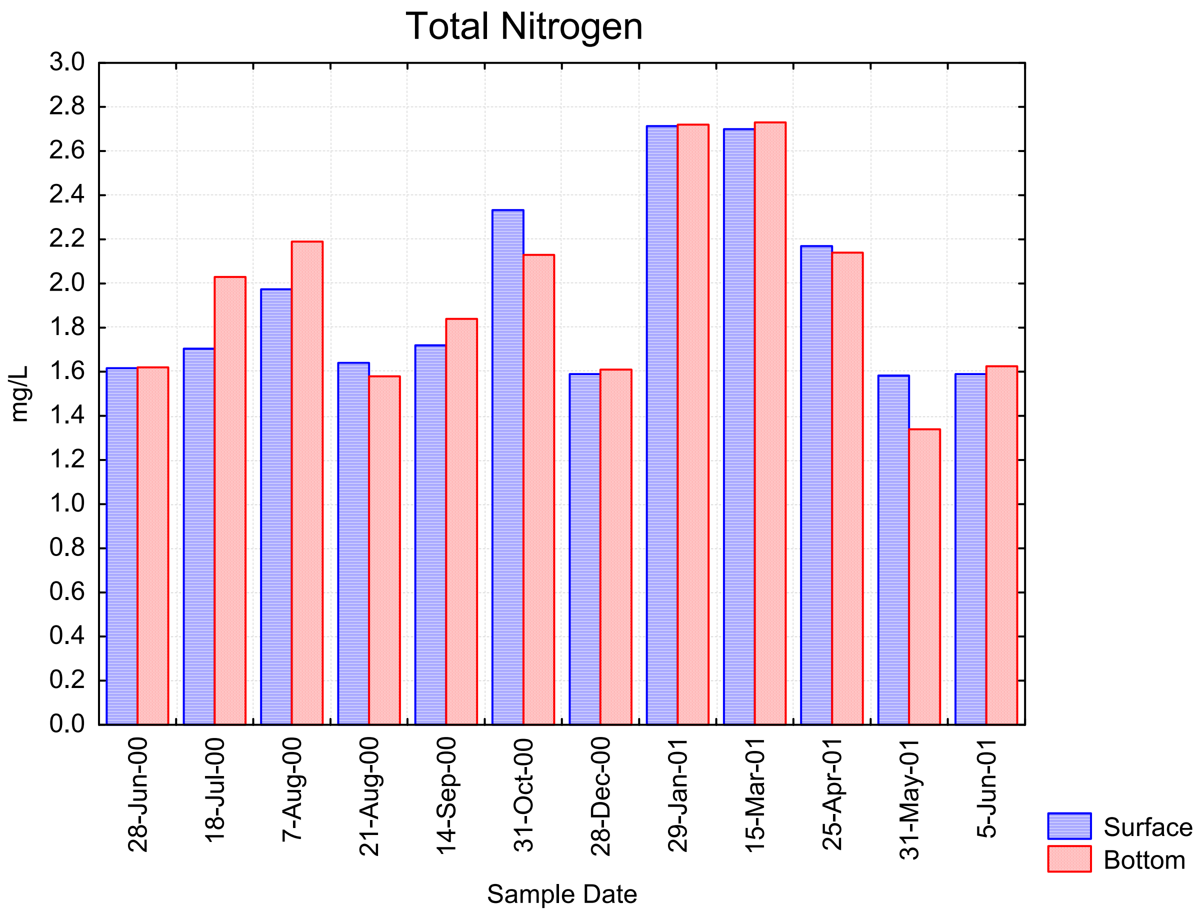

Figure 24. Average surface and bottom concentrations of total nitrogen by sample date for Loyalton Dam.

Phosphorus

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

Total phosphorus concentrations of non-polluted waters are usually less than 0.1 mg/L (Lind, 1985). Total phosphorus values in Loyalton Dam ranged from 0.022 to 0.352 mg/L (mean = 0.164). Maximum concentrations of phosphorus were observed in December (Figure 25). Elevated phosphorus concentrations during winter months are most likely the result of internal phosphorus loading from lake sediments.

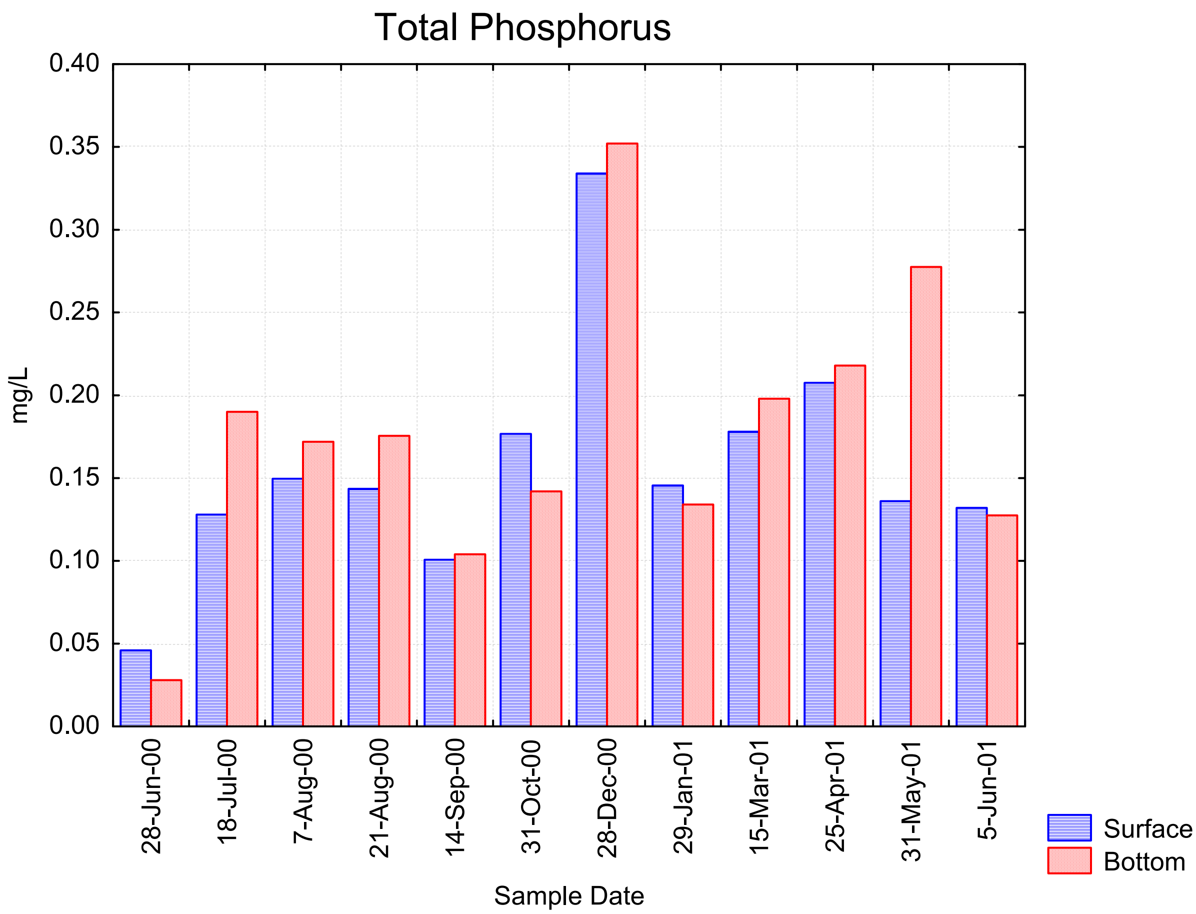

Figure 25. Average surface and bottom concentrations of total phosphorus by sample date for Loyalton Dam.

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. Agricultural practices are likely sources of external phosphorus loading in this watershed.

TDP is the portion of total phosphorus that is readily available for plant utilization. TDP concentrations of non-polluted waters are usually less than 0.01 mg/L (Lind, 1985). TDP concentrations in Loyalton Dam ranged from 0.026 to 0.461 mg/L (mean = 0.097). Concentrations were well above the minimum amount for rapid algal growth, which requires only 0.02 mg/L (Figure 26).

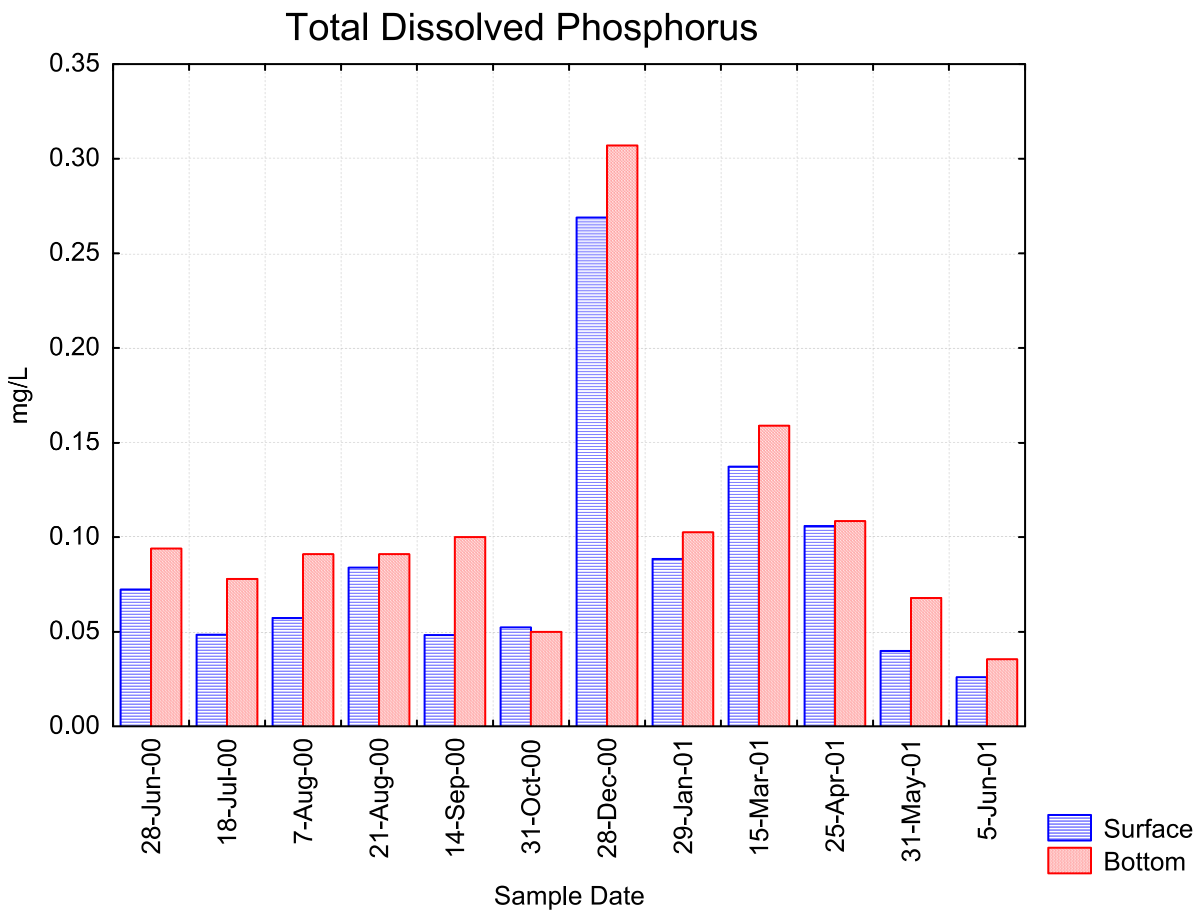

Figure 26. Average surface and bottom concentrations of total dissolved phosphorus by sample date for Loyalton Dam.

Limiting Nutrients

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

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

N:P ratios for Loyalton Dam ranged from 4:1 to 83:1 (Figure 27). Approximately 88% of samples collected in Loyalton Dam were phosphorus-limited. The average ratio across all sample dates was 16:1. Three samples collected in June revealed extreme cases of phosphorus limitation. The variability in N:P ratios suggests other possible limitations of productivity. Physical and biological factors, such as light availability and competition, respectively, may be more influential in controlling algal productivity rates in Loyalton Dam.

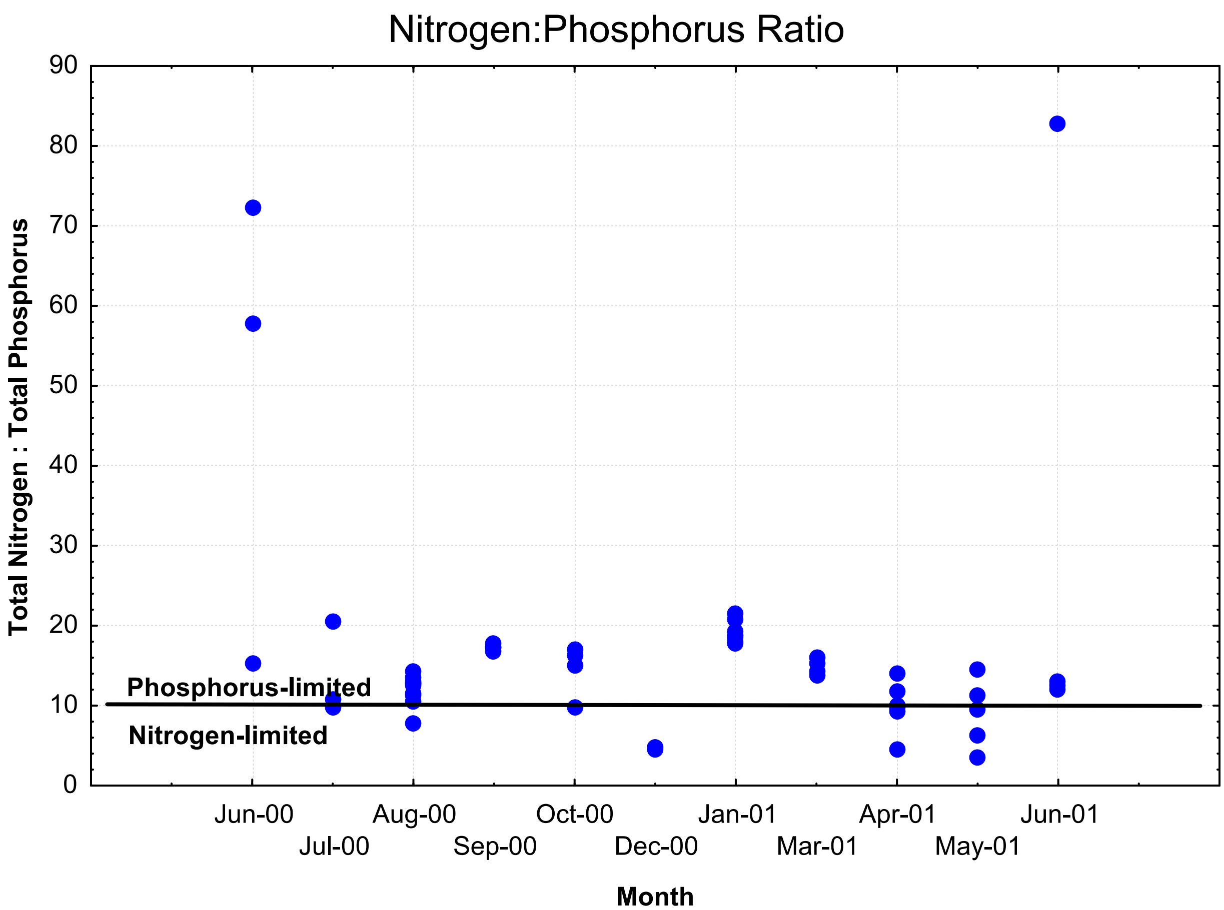

Figure 27. Nitrogen:phosphorus ratios for Loyalton Dam. Line represent optimal N:P ratio for aquatic plant production. Samples above line are phosphorus-limited, and samples below line are nitrogen-limited.

Trophic State

Wetzel (2001) defines 'trophy' of a lake as "the rate at which organic matter is supplied by or to a lake per unit time." Trophic state is often measured as the amount of algal production in a lake, 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 Loyalton Dam. 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 18) define Carlson's trophic levels, which include oligotrophic, mesotrophic, eutrophic, and hyper-eutrophic (in order of increasing productivity).

Table 18. Carlson's trophic levels and index ranges for each level.

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

TSI values were calculated for each of the three index parameters separately. Chlorophyll TSI values ranged from 57 to 70 (mean = 64), phosphorus TSI values ranged from 49 to 99 (mean = 76), and Secchi depth TSI values ranged from 50 to 77 (mean = 57) (Figure 28). These values were averaged to obtain an overall TSI value (mean TSI). Only four combined TSI values could be calculated due to limited chlorophyll and Secchi depth data. Despite limited data, mean TSI values indicate trophic levels comparable to individual TSI parameters (Table 19). Mean TSI average was 68, which is considered hyper-eutrophic. Approximately 94% of all phosphorus TSI values indicate hyper-eutrophic conditions in Loyalton Dam. Phosphorus TSI values displayed the greatest variability with spring and early summer months being the most variable (Figure 29). Generally, TSI values were within the eutrophic and hyper-eutrophic level ranges.

Table 19. Descriptive statistics for trophic state index (TSI) values calculated from direct measurements and samples collected in Loyalton Dam.

	Secchi TSI	Phosphorus TSI	Chlorophyll TSI	Mean TSI
Number of Observations	24	54	12	4
Average	56.62	76.48	64.25	68.49
Median	53.22	75.95	63.36	70.02
Minimum	50.00	48.74	56.69	60.77
Maximum	77.14	98.54	70.33	73.95
Standard Deviation	7.98	8.72	4.33	6.04

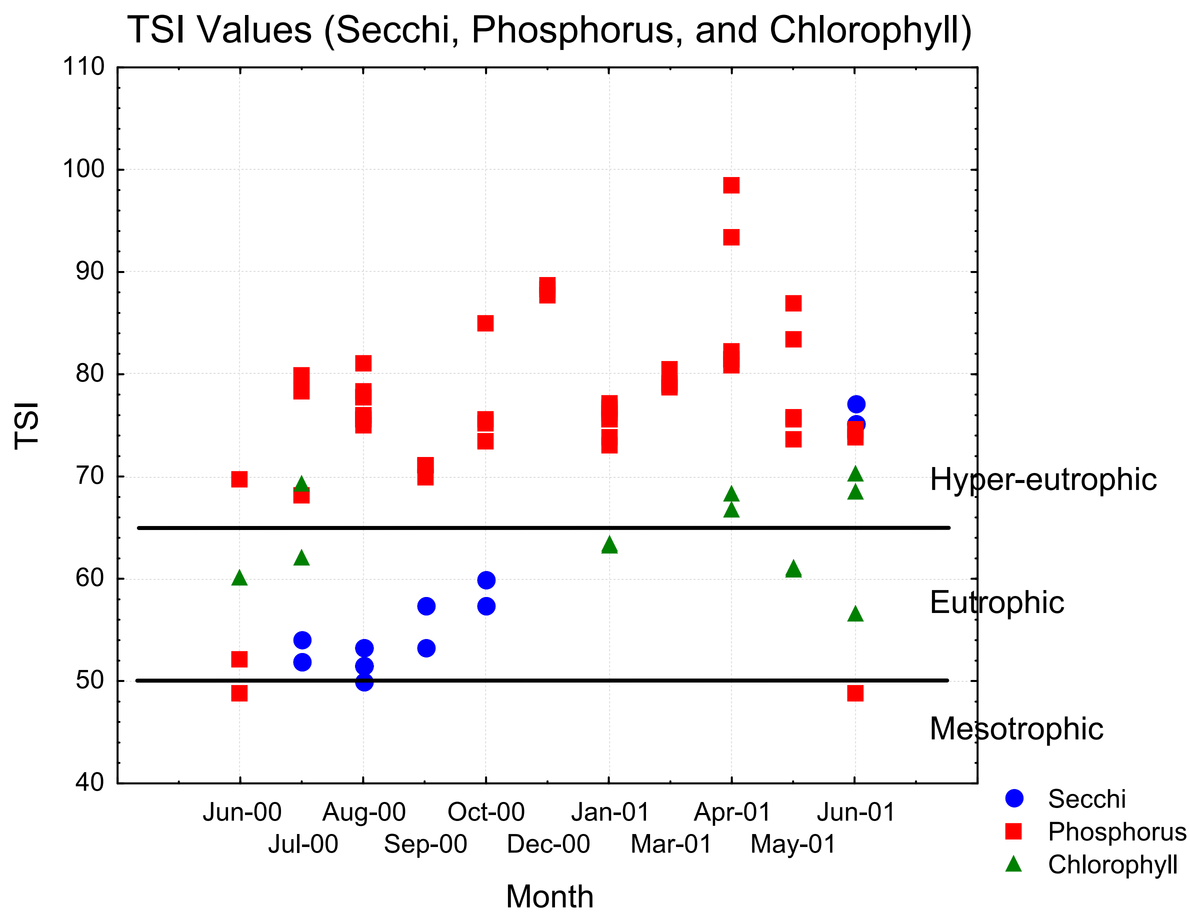

Figure 28. Loyalton Dam Secchi depth, phosphorus, and chlorophyll TSI values by date. Lines indicate Carlson's trophic levels.

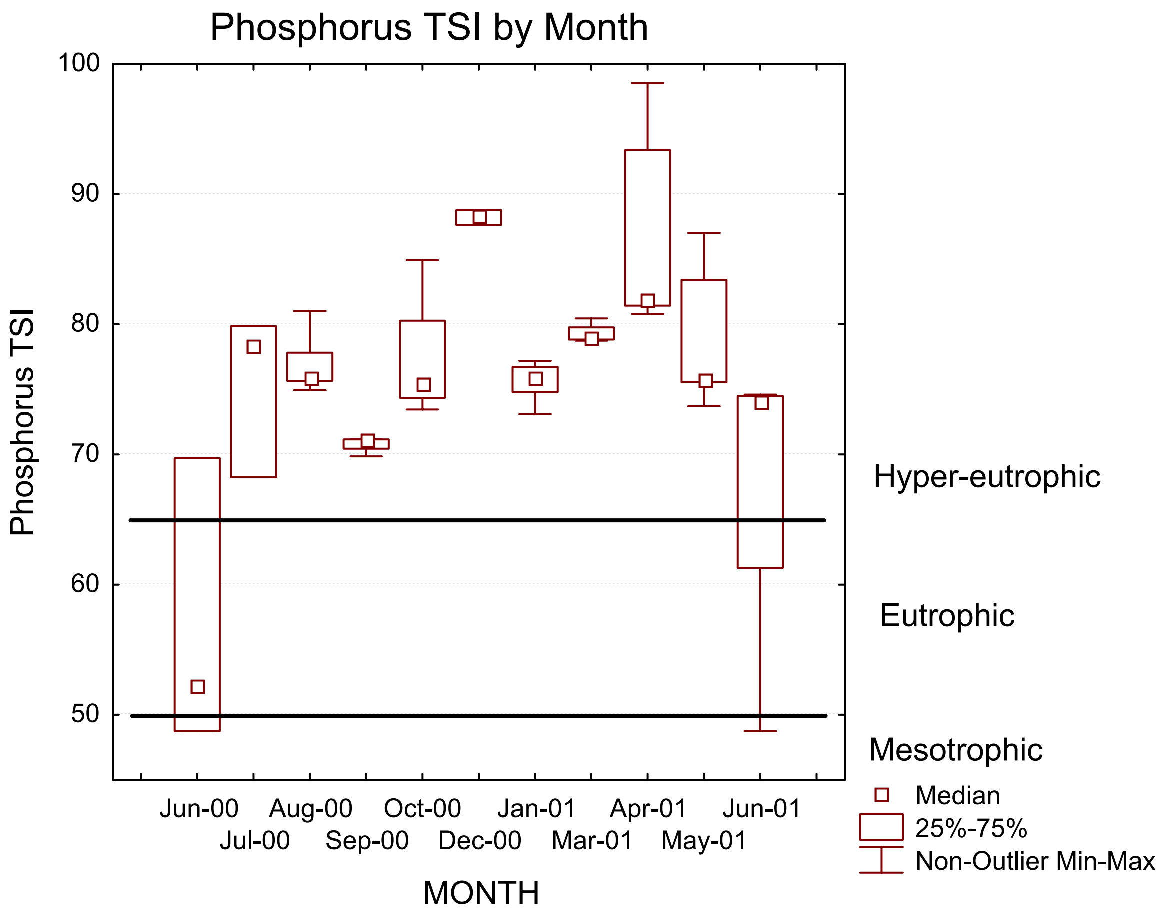

Figure 29. Phosphorus TSI by month for Loyalton Dam. Lines indicate Carlson's trophic levels (mesotrophic, eutrophic, and hyper-eutrophic).

Beneficial use attainment for Loyalton Dam was also assessed using TSI values. USEPA has approved the use of ecoregion specific criteria to evaluate beneficial use attainment. Stueven et al. (2000b) determined TSI criteria for support classifications that are specific to each South Dakota ecoregion. Loyalton Dam is located in the Northwestern Glaciated Plains Ecoregion. Numeric TSI criteria for support/non-support categories for the Northwestern Glaciated Plains Ecoregion are listed in Table 20. TSI values were plotted in Figure 30 using the ecoregion specific criteria. TSI values span all categories throughout the project period.

Table 20. Beneficial use categories for the Northwestern Glaciated Plains Ecoregion with TSI criteria.

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

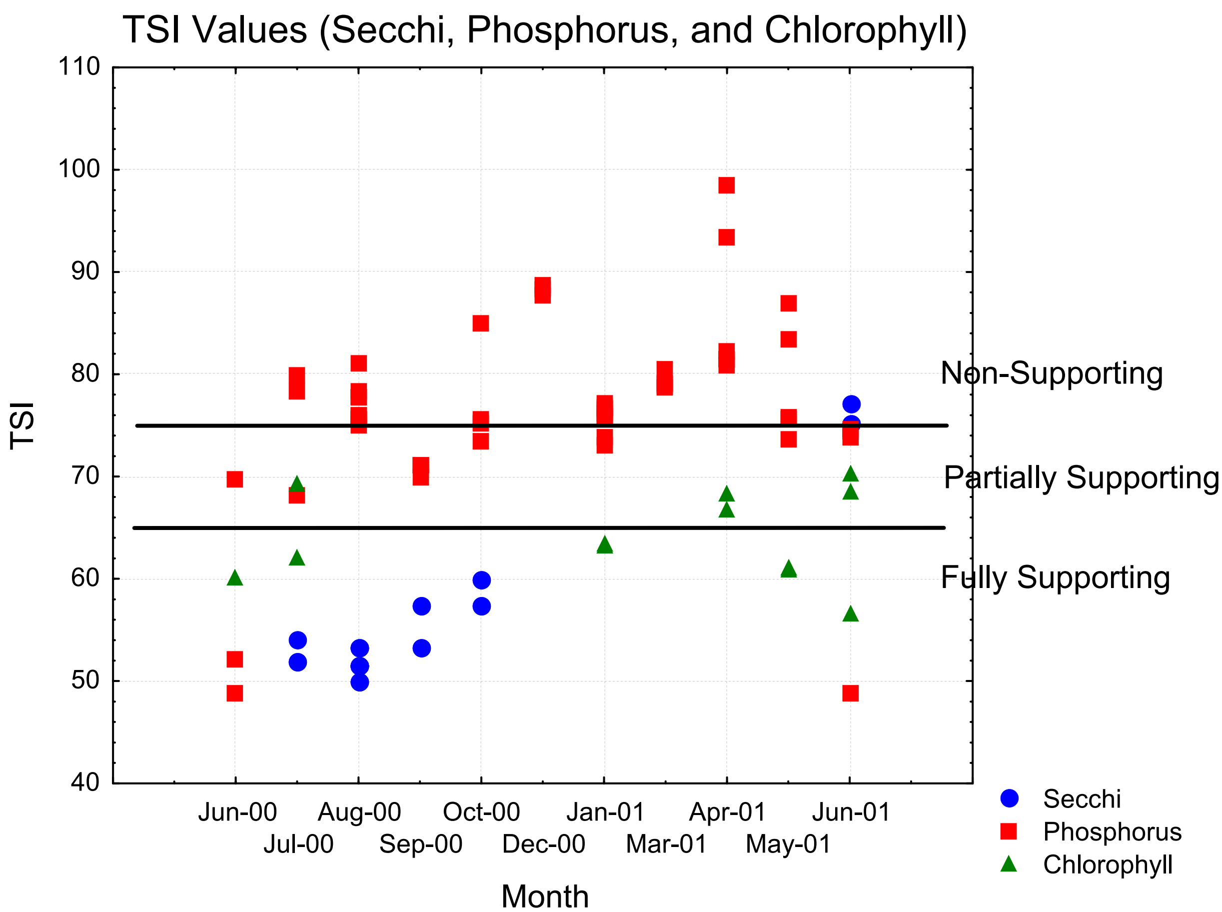

Figure 30. Loyalton Dam Secchi depth, phosphorus, and chlorophyll TSI values by date. Lines indicate beneficial use classifications for the Northwestern Glaciated Plains Ecoregion.

Reduction Response Model

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

As anticipated, the predicted inlake concentrations of total nitrogen and phosphorus decreased as modeled tributary loads decreased (Table 21). Individual parameter (phosphorus, chlorophyll, and Secchi) TSI values gradually decreased with the reduction of nitrogen and phosphorus load.

Phosphorus TSI values were markedly higher than chlorophyll and secchi TSI values. All predicted phosphorus TSI values with less than a 50% reduction in load were in the non-supporting beneficial use category (Figure 31).

Table 21. BATHTUB model-predicted concentrations of total phosphorus, total nitrogen, and TSI values with successive 10-percent reductions in nitrogen and phosphorus inputs. TSI values are plotted on the following graphs.

Percent Reduction	Total Nitrogen Concen.	Total Phosphorus Concen.	Model TSI Phosphorus	Model TSI Chlorophyll	Model TSI Secchi Depth	Model TSI Mean	Estimated TSI Mean
0%	1918.1	199.7	80.5	68.1	66.0	71.5	68
10%	1808.2	189.0	79.7	67.9	65.8	71.1	67.6
20%	1692.9	177.5	78.8	67.8	65.6	70.7	67.2
30%	1571.2	165.4	77.8	67.5	65.4	70.2	66.7
40%	1442.2	152.5	76.6	67.3	65.1	69.7	66.1
50%	1304.2	138.4	75.2	66.9	64.7	68.9	65.4
60%	1155.1	122.7	73.5	66.4	64.2	68.0	64.5
70%	991.5	105.2	71.3	65.7	63.5	66.8	63.3
80%	807.9	84.5	68.1	64.6	62.3	65.0	61.5
90%	595.5	57.8	62.6	62.0	59.8	61.5	57.9
95%	473.1	39.8	57.3	58.9	57.1	57.8	54.2
99%	363.2	18.7	46.4	50.4	51.7	49.5	46.0

Note: total nitrogen and phosphorus concentration units are parts per billion (ppb).

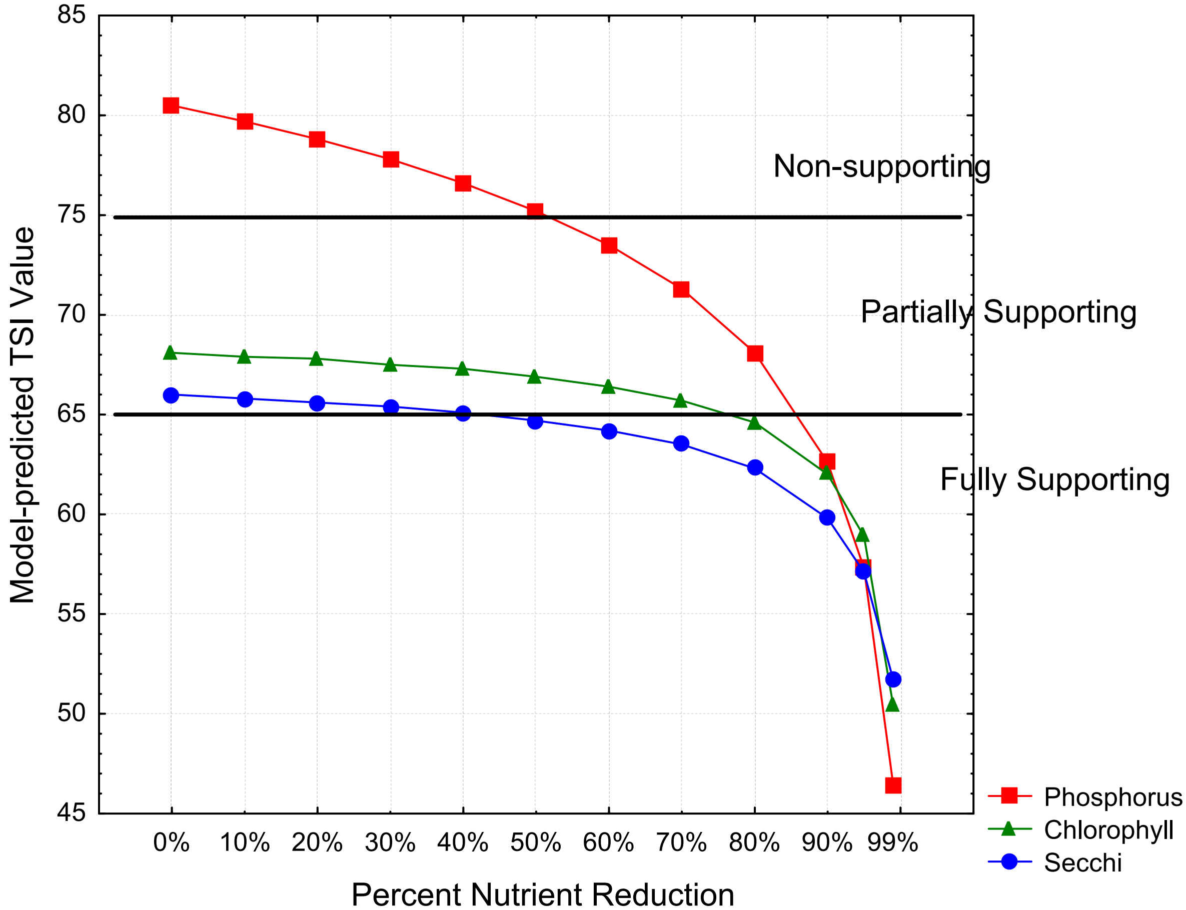

Figure 31. Model-predicted phosphorus, chlorophyll, and Secchi depth TSI values with successive 10-percent reductions in nutrient loading. Lines indicate beneficial use classifications for the Northwestern Glaciated Plains Ecoregion.

The mean TSI as measured from sample data with no reduction of load is 68, which is classified as partially supporting beneficial uses. The model indicates that a 60% reduction in nutrient load would lower the mean TSI by 3 points. A three-point reduction in measured mean TSI would reduce the trophic state of the lake from a hyper-eutrophic to a eutrophic state that fully supports its beneficial uses (Figure 32). Thus, a 60% reduction in nutrient load was set as the TMDL goal (see Appendix F for a TMDL summary).

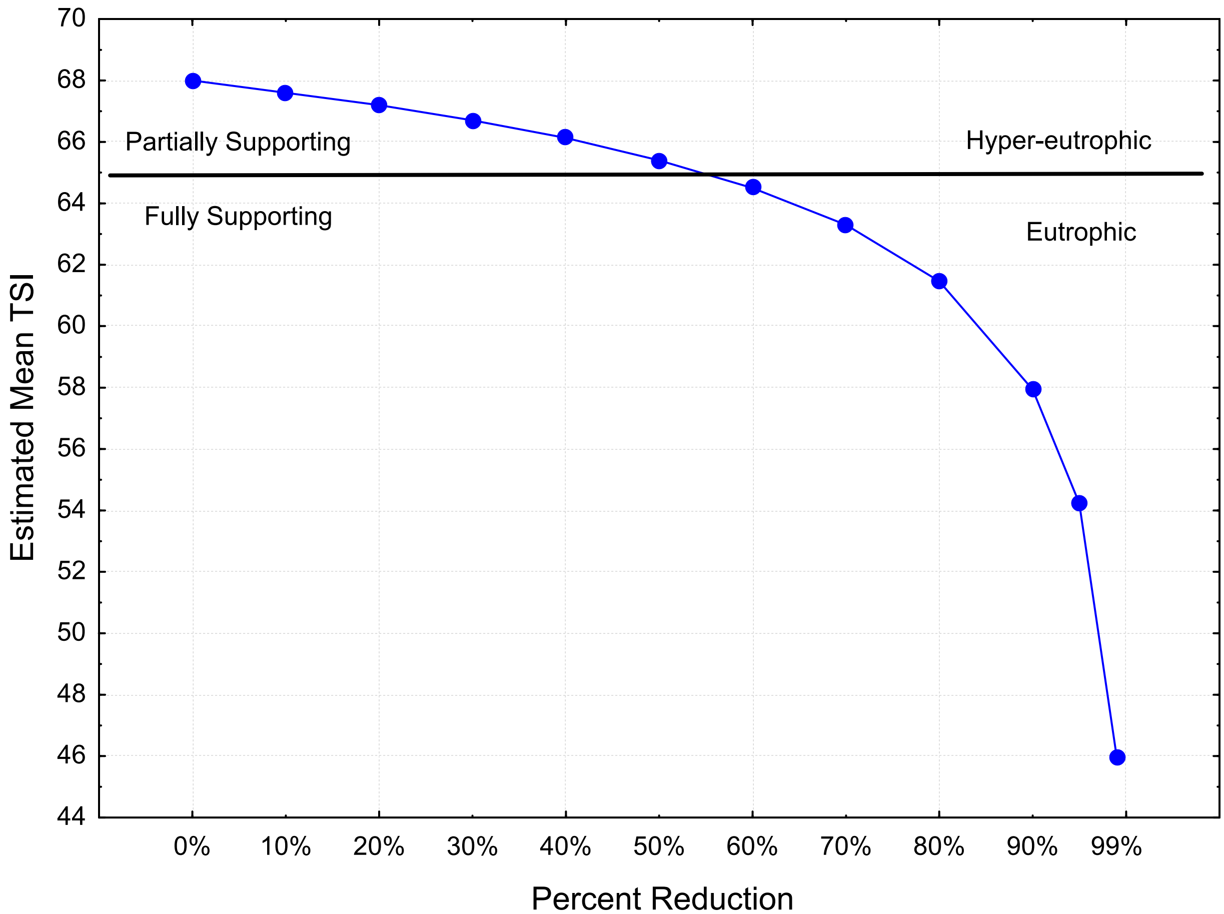

Figure 32. Estimated mean TSI values with successive 10-percent reductions in nutrient loading. Line indicates beneficial use classifications for the Northwestern Glaciated Plains Ecoregion and Carlson's trophic state classifications.

Lake Biological Parameters

Fishery

The South Dakota Department of Game, Fish and Parks (SDGF&P) last conducted a fish survey on June 7, 1994. Five-¾ in. frame nets and electrofishing methods were used to sample the fish community.

Four species were sampled in the frame nets. Two dominant species, bluegill and black crappie, comprised 97% of the net sample. Bluegill was the most abundant species sampled (54% of sample). Black crappie comprised 43% of the frame net samples. The remaining 2% of the sample consisted of black bullhead and walleye. The sampled walleye is suspected to originate from a remnant population from 1981 stocking or possibly angler-stocked. Electrofishing resulted in only one largemouth bass being collected. However, no inferences should be made about the largemouth bass population due to poor sampling conditions.

The SDGF&P researcher did not recommend stocking at the time the report was written. The complete fisheries report for Loyalton Dam may be found in Appendix B.

Phytoplankton

Phytoplankton samples were collected monthly from surface depth at two inlake sites from June 28, 2000 to June 5, 2001, with the exception of February 2001 (Figure 2). A total of 95 algal taxa were identified from this small 36-acre reservoir during this survey. Green algae (Chlorophyta) were the most diverse group of planktonic algae with 35 taxa collected, excluding 5 green flagellate species (Appendix A).

Flagellated (motile) algae represented the second most diverse group in Loyalton Dam with 30 taxa including an unidentified flagellate category. Diatoms were present as 21 taxa with blue-green algae (Cyanophyta) representing the least diverse algal group in the reservoir with only 9 taxa observed during this study.

Euglenoid flagellates (mainly *Euglena*, *Phacus*, and *Trachelomonas* spp.) were the most diverse phylum of the motile algae with 10 taxa, followed by dinoflagellates (Pyrrhophyta) with 7 taxa. Four other phyla of motile algae were less varied: green flagellates with 5 taxa, cryptomonads and yellow-brown flagellates with 3 taxa each, and chloromonads with only one taxon collected.

In terms of annual algal biomass produced for the period of this assessment, Loyalton Dam ranks in the lower 50% of recently monitored eutrophic state lakes. Algae biovolume ranged from 872,593 um^3/ml at the end of June 2000 to 14,193,789 um3/ml in August 2000 (Table 22). Corresponding algal density (abundance) for those dates amounted to 7,563 cells/ml and 153,520 cells/ml, respectively. A maximum algal density of 199,747 cells/ml was observed on May 31, 2001 with a corresponding volume of only 8,706,482 um^3/ml. That seeming disparity was due to the presence of a large number of comparatively small blue-green cells at that time (Table 22). Average monthly density and biovolume for the study period amounted to 84,909 cells/ml and 6,613,145 um3/ml, respectively.

The phytoplankton population during this study consisted of 57% non-motile green algae, which made up 65% of the total algal volume. Blue-green algae comprised 35% of the density but only 8% of the biovolume in contrast to flagellated algae which contributed only 6% to total algal abundance but made up 22% of the volume due mainly to the presence of relatively moderate numbers of large-sized dinoflagellates (Table 22). Diatoms represented the least common algae group in Loyalton Dam during this survey accounting for only 2% of density and 5% of annual biovolume.

Table 22. Density and Biovolume of algal groups for Loyalton Dam.

Date	Group	Cells/ml	Density %	BioVolume	BioVolume %
28-Jun-00	Blue-Green Algae	3,502	46.3%	409,734	47.0%
28-Jun-00	Diatom	525	6.9%	87,850	10.1%
28-Jun-00	Flagellated Algae	245	3.2%	38,640	4.4%
28-Jun-00	Non-Motile Green Algae	3,291	43.5%	336,369	38.5%
28-Jun-00	**Total**	**7,563**		**872,593**	
18-Jul-00	Blue-Green Algae	835	5.9%	63,569	3.0%
18-Jul-00	Diatom	828	5.8%	302,150	14.1%
18-Jul-00	Dinoflagellate	125	0.9%	175,000	8.2%
18-Jul-00	Flagellated Algae	352	2.5%	34,790	1.6%
18-Jul-00	Non-Motile Green Algae	12,052	84.9%	1,564,914	73.1%
18-Jul-00	**Total**	**14,192**		**2,140,423**	
07-Aug-00	Blue-Green Algae	3,341	4.4%	110,253	0.8%
07-Aug-00	Diatom	1,482	2.0%	266,960	2.0%
07-Aug-00	Flagellated Algae	1,357	1.8%	178,006	1.4%
07-Aug-00	Non-Motile Green Algae	68,798	90.9%	12,424,463	95.3%
07-Aug-00	**Total**	**74,978**		**12,979,682**	
21-Aug-00	Diatom	838	0.5%	151,220	1.1%
21-Aug-00	Flagellated Algae	94	0.1%	14,100	0.1%
21-Aug-00	Non-Motile Green Algae	152,588	99.4%	14,028,469	98.8%
21-Aug-00	**Total**	**153,520**		**14,193,789**	
14-Sep-00	Diatom	1,311	2.2%	258,620	3.0%
14-Sep-00	Flagellated Algae	781	1.3%	90,839	1.1%
14-Sep-00	Non-Motile Green Algae	57,852	96.5%	8,228,338	95.9%
14-Sep-00	**Total**	**59,944**		**8,577,797**	
31-Oct-00	Blue-Green Algae	40,333	29.7%	313,757	3.4%
31-Oct-00	Diatom	779	0.6%	247,400	2.7%
31-Oct-00	Flagellated Algae	4,213	3.1%	1,104,076	12.0%
31-Oct-00	Non-Motile Green Algae	89,080	65.5%	7,278,384	79.4%
31-Oct-00	Unidentified Algae	1,500	1.1%	225,000	2.5%
31-Oct-00	**Total**	**135,905**		**9,168,617**	
29-Jan-01	Blue-Green Algae	8,228	42.9%	33,461	1.0%
29-Jan-01	Diatom	28	0.1%	15,460	0.4%
29-Jan-01	Dinoflagellate	57	0.3%	102,600	2.9%
29-Jan-01	Flagellated Algae	6,082	31.7%	3,070,340	87.4%
29-Jan-01	Non-Motile Green Algae	4,478	23.4%	211,204	6.0%
29-Jan-01	Unidentified Algae	304	1.6%	79,650	2.3%
29-Jan-01	**Total**	**19,177**		**3,512,715**	
15-Mar-01	Blue-Green Algae	9,225	71.6%	36,900	1.2%
15-Mar-01	Diatom	15	0.1%	3,750	0.1%
15-Mar-01	Dinoflagellate	1,070	8.3%	2,889,000	90.4%
15-Mar-01	Flagellated Algae	1,195	9.3%	170,450	5.3%
15-Mar-01	Non-Motile Green Algae	1,375	10.7%	94,195	2.9%
15-Mar-01	**Total**	**12,880**		**3,194,295**	
25-Apr-01	Blue-Green Algae	16,782	59.3%	213,160	13.7%
25-Apr-01	Diatom	442	1.6%	174,463	11.2%
25-Apr-01	Dinoflagellate	60	0.2%	112,500	7.2%
25-Apr-01	Flagellated Algae	1,047	3.7%	193,080	12.4%
25-Apr-01	Non-Motile Green Algae	9,963	35.2%	862,617	55.4%
25-Apr-01	**Total**	**28,294**		**1,555,820**	
31-May-01	Blue-Green Algae	116,157	58.2%	639,888	7.3%
31-May-01	Diatom	646	0.3%	271,460	3.1%
31-May-01	Dinoflagellate	11	0.0%	38,100	0.4%
31-May-01	Flagellated Algae	1,134	0.6%	383,115	4.4%
31-May-01	Non-Motile Green Algae	81,479	40.8%	7,325,919	84.1%
31-May-01	Unidentified Algae	320	0.2%	48,000	0.6%
31-May-01	**Total**	**199,747**		**8,706,482**	
05-Jun-01	Blue-Green Algae	157,276	69.0%	783,552	10.0%
05-Jun-01	Diatom	686	0.3%	244,400	3.1%
05-Jun-01	Dinoflagellate	18	0.0%	72,000	0.9%
05-Jun-01	Flagellated Algae	791	0.3%	440,686	5.6%
05-Jun-01	Non-Motile Green Algae	68,515	30.1%	6,225,245	79.4%
05-Jun-01	Unidentified Algae	510	0.2%	76,500	1.0%
05-Jun-01	**Total**	**227,796**		**7,842,383**	

The seasonal distribution of algae abundance (population density) in the reservoir for the study period consisted of three peaks in algae numbers (Figure 33 and Table 22). Those peaks occurred on August 21 and October 31, 2000, and May 31- June 5, 2001. Green algae, primarily *Crucigenia quadrata*, were mainly responsible for the summer and fall maxima while a small blue-green alga tentatively identified as *Chroococcus minimus* and *Crucigenia quadrata* were major components of the late spring peak in 2001. The seasonal pattern for algal biovolume (approximately algal biomass) in Loyalton Dam can be characterized by what was essentially a single annual maximum in August 2000 followed by two smaller peaks on October 31 and May 31, 2001 (Figure 31). The August peak was produced almost entirely by the green algae species *Crucigenia quadrata* and *Sphaerocystis schroeteri.* The two subsequent maxima were also produced by green algae, primarily *Crucigenia quadrata*. The relationship between algal abundance and volume was not as close as might be expected (Figure 33). This may be due to the wide range in cell size of different algae species (sometimes more than a 100-fold difference) and the variation in size of cells of the same species among seasons and different lakes.

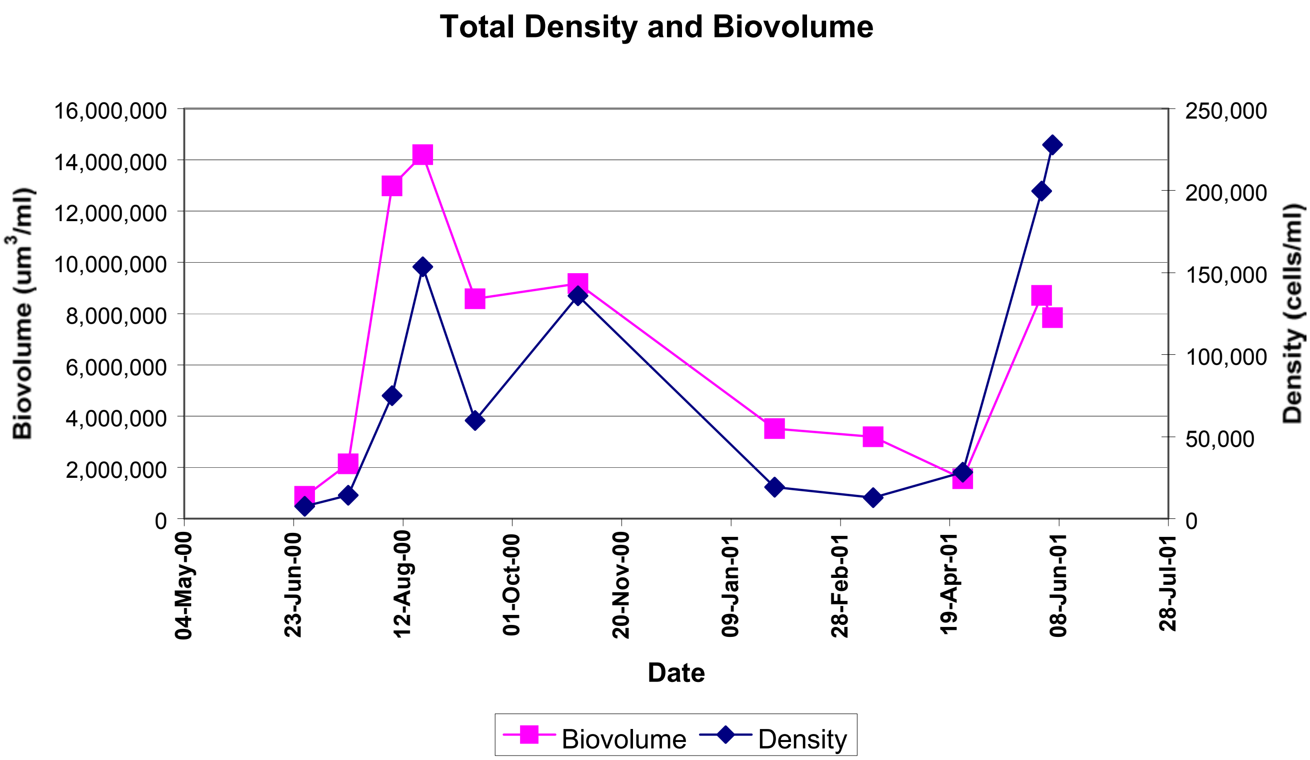

Figure 33. Total density and biovolume by date for Loyalton Dam.

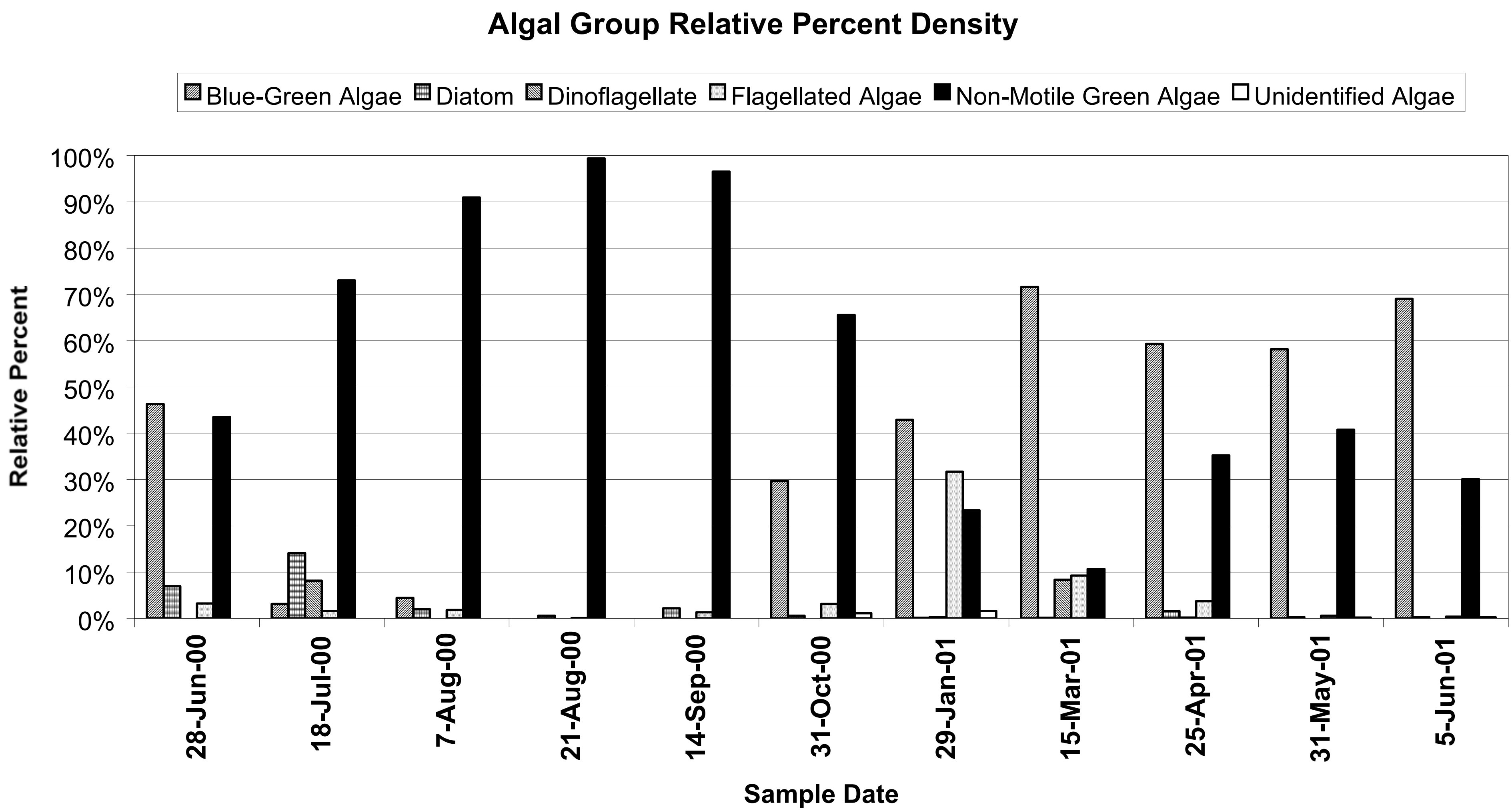

Figure 34. Algal group relative percent density by sample date for Loyalton Dam.

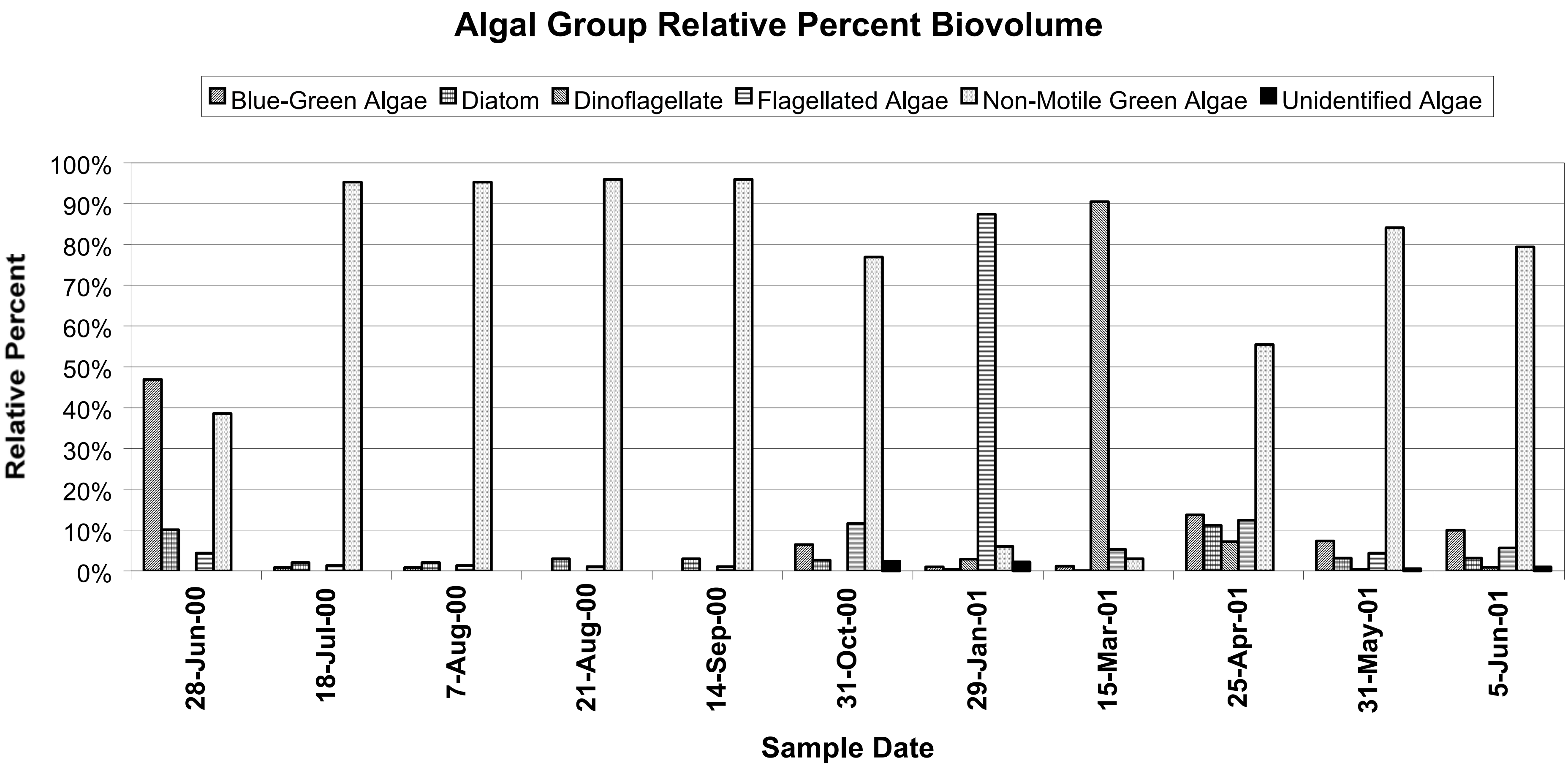

Figure 35. Algal group relative percent biovolume by sample date for Loyalton Dam.

The dominance of green algae in Loyalton Dam on most sampling dates, in numerical abundance and/or biovolume, was an unexpected observation during this survey (Figure 34 and Figure 35). Planktonic green algae (Chlorococcales) frequently dominate ponds and small, eutrophic waterbodies (Round, 1965). These waterbodies are typically less mineralized (lower alkalinity) and have a significantly lower pH (circumneutral), yet Loyalton Dam had high alkalinity concentrations. Alkaline lakes tend to favor the growth of blue-green algae, including the nuisance varieties (Shapiro, 1973). However, nuisance blue-green algae such as *Aphanizomenon*, *Anabaena*, and *Microcystis aeruginosa*, were scarce in Loyalton Dam during this study except for a moderate population of *Oscillatoria* on the first sampling date (June 28, 2000).

In eutrophic waters of near neutral pH, green algae can outcompete blue-greens due to the abundance of free dissolved CO_2. In alkaline waters like Loyalton Dam (pH ≥ 8), free CO_2 is nearly absent (Reid, 1961). Under these conditions, the advantage should shift to blue-greens that are more efficient in utilizing free CO_2 in low concentrations (Shapiro, 1973). Other sources of free CO_2 are most likely contributing to Loyalton Dam including decay of large amounts of vegetation and other organic matter, in addition to respiration and inputs from the watershed and atmosphere.

Chlorophyll

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

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

Chlorophyll *a* values ranged from 5.71 to 22.93 mg/m^3 (mean = 13.46). Total chlorophyll values ranged from 15.92 to 40.71 mg/m^3 (mean = 23.28) (Figure 36).

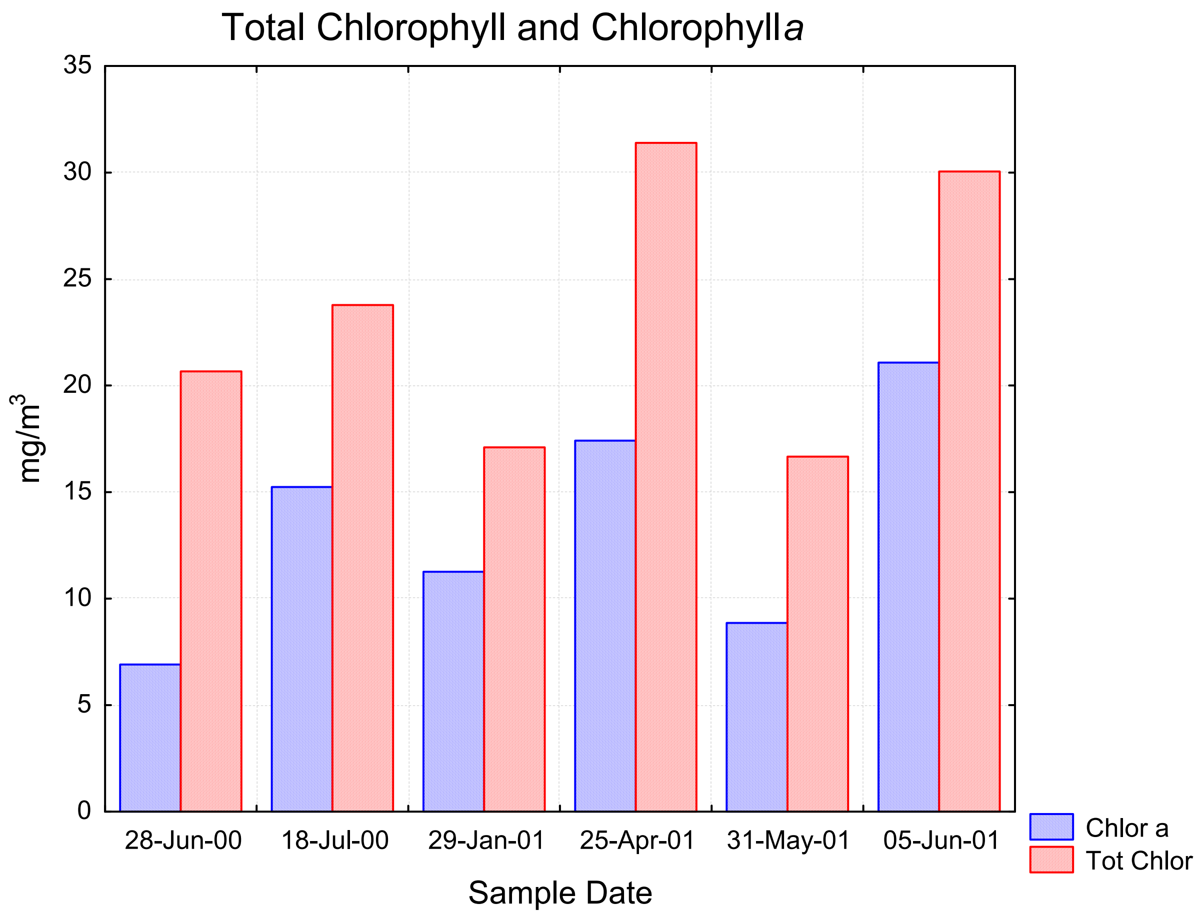

Figure 36. Total chlorophyll and chlorophyll a by sample date. Note: data for some sample dates were removed due to unacceptable chlorophyll:phaeophytin (C:P) ratios.

Aquatic Macrophyte and Habitat Survey

SD DENR staff conducted an aquatic plant survey for Loyalton Dam on August 13, 2001. Data was collected to document emergent and submergent plant species present, density of plant species, and distribution of plant species within the waterbody.

Eight locations were surveyed in Loyalton Dam (Figure 37). At each sampling location, four positions were sampled by dragging a rake across the lake bottom. Those four positions were located at the 3, 6, 9, and 12 o'clock positions with the 12 o'clock position being closest to the shore (Figure 38). Density ratings of plant species were estimated using these four positions. If a plant species was found in all four casts and very dense, it was given a density rating of five. If a plant was found in all four casts but in a limited amount, it was assigned a rating of four. If the plant was found in three casts it was given a density rating of three, and so on. Once the rake was pulled back into the boat, vegetation was removed and plants identified to lowest possible taxonomic level. Water depth and Secchi transparency were also measured at each of the eight sampling locations.

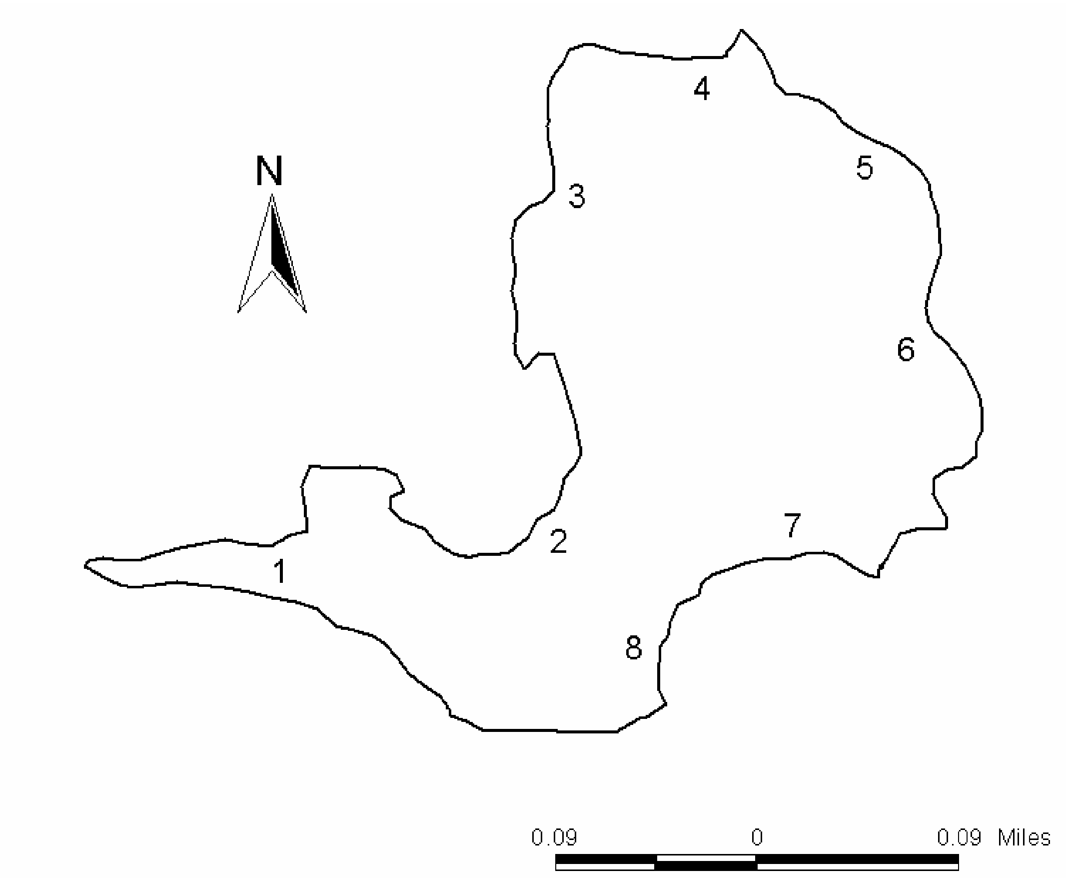

Figure 37. Macrophyte and habitat survey sampling locations for Loyalton Dam.

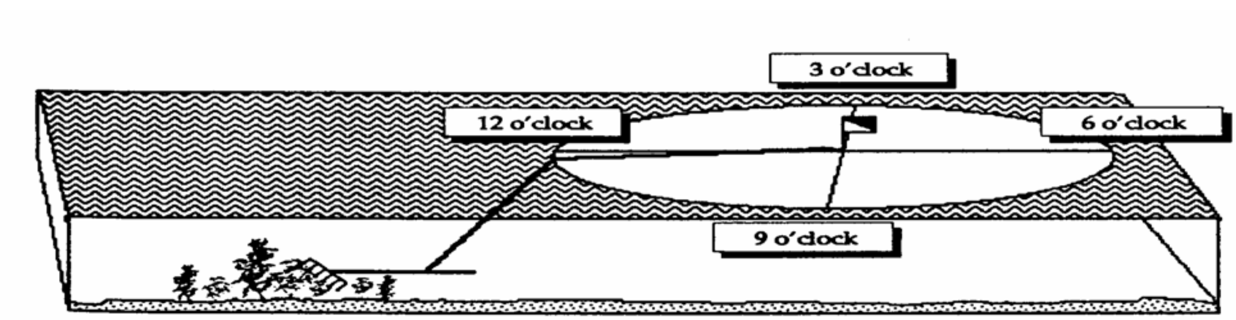

Figure 38. Macrophyte survey rake casting positions. Center flag indicates the boat location, and the 12 o'clock position was closest to shore.

Aquatic vascular plants were extremely sparse throughout most of the lake. *Potamogeton pectinatus*, commonly known as sago pondweed, was the only aquatic macrophyte species identified in Loyalton Dam. This submergent macrophyte was found at two of the eight sampling locations. Density ratings for this species ranged from 0 to 2. *P. pectinatus* is found in 47 states (Muenscher, 1994). This wide distribution suggests tolerance of a wide range of water quality conditions. *P. pectinatus* is common in ponds, lakes, and slow streams in non-acidic waters. Furthermore, *P. pectinatus* is found in more brackish waters than is tolerated by other *Potamogeton* species or most other genera of freshwater plants. For example, *P. pectinatus* was the only *Potamogeton* species found in Waubay Lake, Day County, SD during 1979 (average conductivity = 6,200 uhom/s) and was the most frequently occuring *Potamogeton* species in South Dakota lakes during that year (Koth, 1981).

Average water depth at the macrophyte sampling locations was 1.6 m. Average Secchi depth was 0.4 m (Table 23).

Table 23. Water depth, Secchi depth, and density ratings for *Potamogeton pectinatus* for each sampling location in Loyalton Dam.

Sampling Location	Secchi depth (meters)	Water depth (meters)	Potamogeton pectinatus (density rating)
1	0.5	3.1	0
2	0.4	1.5	0
3	0.4	2.2	0
4	0.4	1.1	0
5	0.4	0.6	0
6	0.4	0.8	2
7	0.3	1.5	0
8	0.4	1.9	1

Habitat conditions were also assessed at each sampling location. Bank stability, vegetative protection, and riparian vegetative zone width was visually assessed and scored at each macrophyte survey location. Each habitat parameter was scored on a scale of 0 to 10 (increasing habitat quality with increasing scores) and scores were summed to get an overall habitat score for each sampling location (Table 24).

Sites with highest habitat scores were located in areas with little or no grazing pressure. This allowed for the establishment of healthier riparian zones with stable, vegetated banks. Sites with lower habitat scores were near areas of higher sedimentation, as indicated by the sediment survey.

Table 24. Habitat parameter scores for each sampling location in Loyalton Dam. Habitat quality increases with increasing scores.

Sampling Location	Bank Stability	Vegetative Protection	Riparian Width	Total Score
1	8	9	10	27
2	10	9	9	28
3	4	5	3	12
4	7	3	1	11
5	7	5	2	14
6	8	4	2	14
7	4	5	3	12
8	8	8	3	19

Fecal Coliform Bacteria

Loyalton Dam is listed for the beneficial use of immersion recreation, which requires that no single sample exceed a concentration of 400 fecal bacteria colonies per 100ml of sample or a 30-day average (five samples) of 200 colonies per 100ml. Approximately 9% of inlake samples (n=5) violated the single-sample standard, all of which were collected in August 2000. The stream sample collected in August was also the highest. These high concentrations were attributed to significant hydrologic load from a large rain event that occurred on August 5, 2000. Stream sample concentrations ranged from less than 10 to 17,000 colonies per 100ml. Inlake sample concentrations ranged from less than 10 to 7,800 colonies per 100ml.

Quality Assurance/Quality Control

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

Seven replicate and five blank samples were collected on randomly chosen dates from Loyalton Dam. Only three values were reported above the detection limit from all blank samples (nitrate = 0.1 mg/L, total phosphorus = 0.003 mg/L, and total dissolved phosphorus = 0.004mg/L). These instances of slight contamination were possibly caused by use of different distilled water brands or field contamination during handling.

Percent difference was calculated for each replicate and routine sample pair. Average percent difference ranged from 0.5% to 61.5%. The following three parameters had an average percent difference greater than 10%: total suspended solids, total volatile suspended solids, and total dissolved phosphorus. 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 or a laboratory error. Approximately 73% of all sample pair difference estimates were less than 10%. See Appendix E for all QA/QC data.

Other Monitoring

Sediment Survey

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

A sediment survey was conducted on Loyalton Dam on January 10, 2000. Water depth and sediment depth was measured through holes drilled in the ice. A steel probe was lowered through the holes and pushed through the soft sediment until solid substrate was reached. Water and sediment depth was recorded at each site (123 sampling locations) with Global Positioning System (GPS) equipment (Figure 39).

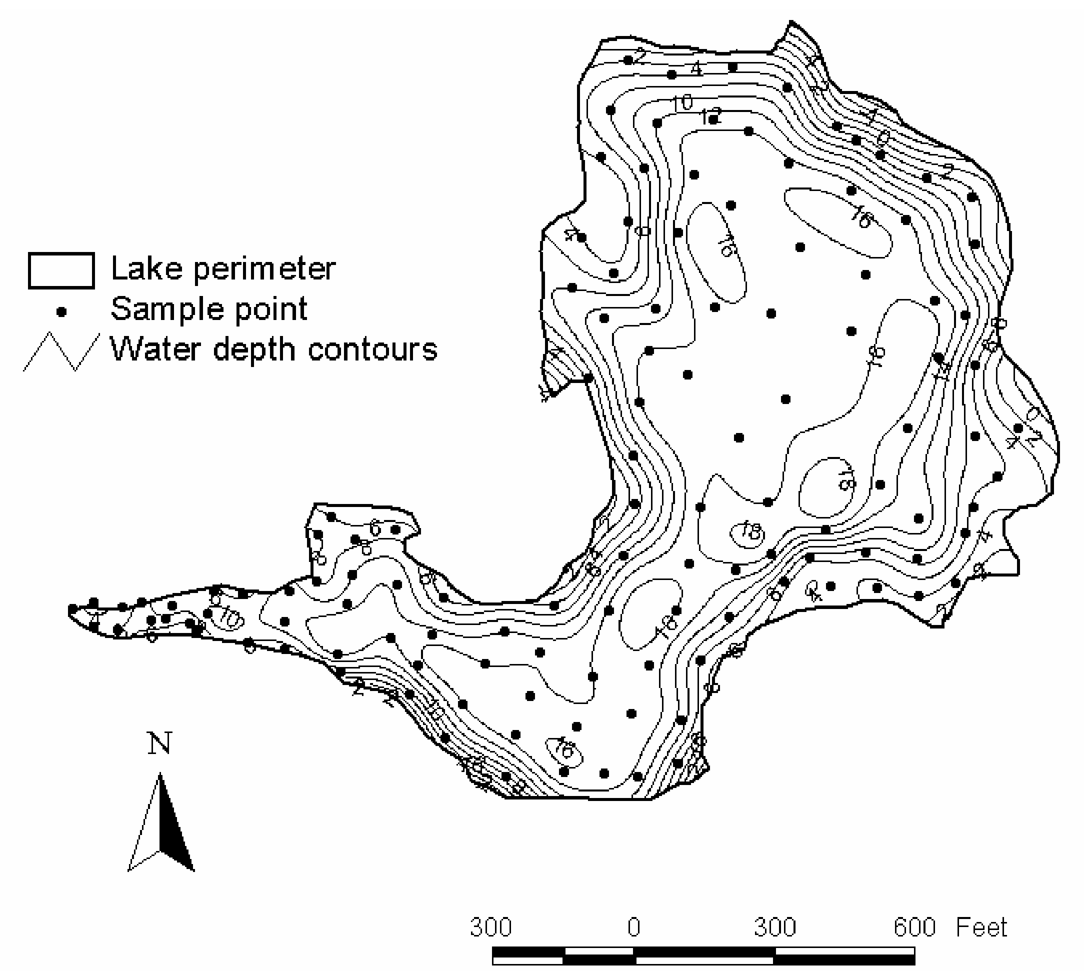

Figure 39. Water depth contours and sample points from sediment survey in Loyalton Dam.

Average sediment depth for Loyalton Dam was 1.7 ft. Sediment depths ranged from 0.4 to 6.0 ft (Figure 40). Total sediment volume in Loyalton Dam was calculated using ArcView Spatial Analyst. Using this survey data, sediment volume is 3.0 acre-feet or approximately 8,800 tons. This represents only 3% of the total lake volume. Areas of maximum sediment depth were found near the shoreline and adjacent to areas of livestock grazing and cropland using conventional tillage.

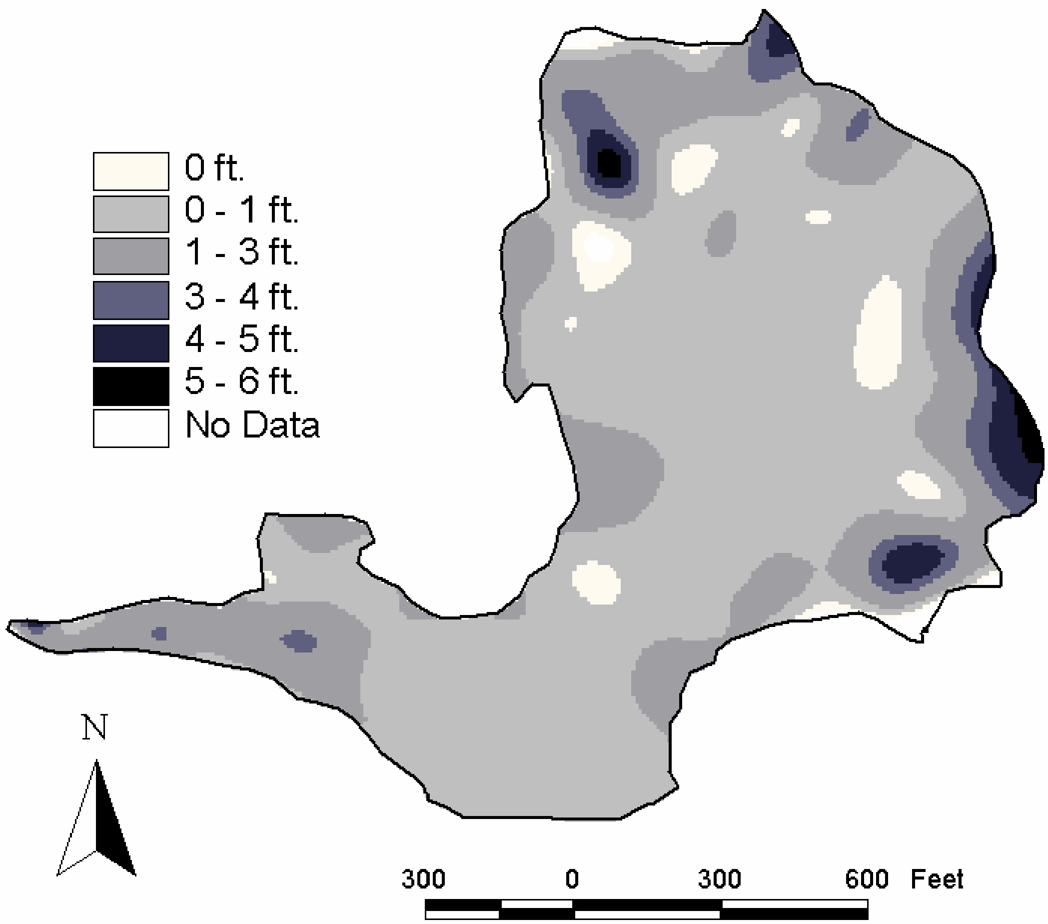

Figure 40. Estimated sediment depths for Loyalton Dam.

Agricultural Non-Point Source Model

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

The watershed was divided into 40-acre cells with dimensions of 1,320 feet by 1,320 feet. Landuse and other field data were compiled for each of the 190 watershed cells. Table 25 lists the 21 field parameters collected for each cell. This information was then incorporated into the AGNPS model.

Table 25. Agriculture Non-Point Source model input parameters.

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

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

Annual loadings were estimated for 7,600 acres by calculating the non-point source loadings from rainfall events during an average year. This includes a one-year, 24-hour event of 1.85 inches (energy intensity = 20), two six-month events (energy intensity = 11.2), and nine one-month events (energy intensity = 3) for a total rainfall factor (R-factor) of 69.4. The R-factor established by the Natural Resource Conservation Service for Edmunds County is 70.

AGNPS nutrient output indicates that the Dry Run Creek watershed (at the Loyalton Dam inlet) has a total nitrogen (soluble + sediment-bound) delivery rate of 0.94 lbs/acre/year (3.6 tons/year) and a total phosphorus (soluble + sediment-bound) delivery rate of 0.29 lbs/acre/year (1.1 tons/year). AGNPS estimated sediment delivery rate was 0.06 tons/acre/year (456 tons/year).

A total of 20 sediment critical cells were identified in the Dry Run Creek watershed (Figure 41), which have an annual sediment yield greater than 1.36 tons/acre. Approximately 11% of the total number of watershed cells were identified as critical sediment cells or high erosion cells. The yields for each of these cells are listed in Table 26. The location of these cells can be found on the AGNPS cell number grids in Figure 42 and on the United States Geological Survey (USGS) topographic quadrangle map (Figure 43). Common characteristics of these cells include cover-management factors (C-factor) greater than 0.20 (conventional tillage) and land slopes greater than 3%.

Twenty-four nitrogen critical cells were identified in the Dry Run Creek watershed (Figure 44). Approximately 13% of the modeled cells were considered critical nitrogen cells, which deliver greater than 4.64 lbs/acre annually. Table 26 lists the nitrogen yields for each critical cell.

Thirty phosphorus critical cells were identified in the Dry Run Creek watershed (Figure 45), which deliver greater than 1.78 lbs/acre. This equates to approximately 16% of the modeled cells. Table 26 lists the yields for each phosphorus critical cell.

A large portion of the nutrients delivered from the watershed was sediment-bound. Approximately 66% of the total nitrogen and 84% of the total phosphorus delivered from the watershed was sediment-bound. This indicates that erosion from cropland may be the major contributor of nutrients to Loyalton Dam.

Several different BMPs were modeled using AGNPS, including converting conventional tillage to conservation tillage. To do this, critical cell C-factors were reduced to 0.10 to represent an improvement in cover management. By converting critical cells to this level of conservation tillage and installing grassed waterways, a 6.4% reduction in nitrogen, 10.3% reduction in phosphorus, and 16.7% reduction in sediment load could be achieved (Table 27).

Table 26. Critical cell sediment, nitrogen, and phosphorus loads.

Sediment Critical Cells		Phosphorus Critical Cells		Nitrogen Critical Cells	
Cell Number	Sediment Load (tons/acre)	Cell Number	Phosphorus Load (lbs/acre)	Cell Number	Nitrogen Load (lbs/acre)
175	6.93	175	6.38	175	13.95
40	3.08	166	3.41	120	9.04
166	2.91	116	3.37	47	8.63
116	2.91	40	3.15	97	7.97
41	2.44	101	2.72	45	8.57
12	2.35	41	2.63	44	7.95
101	2.14	120	2.53	110	8.45
107	1.92	107	2.53	166	8.45
167	1.92	167	2.52	116	8.00
176	1.92	12	2.52	46	7.92
3	1.89	176	2.53	124	7.76
103	1.80	47	2.28	123	7.76
60	1.79	97	2.29	101	6.66
52	1.67	103	2.28	40	6.23
158	1.67	44	2.21	167	6.23
2	1.59	45	2.21	107	6.23
13	1.55	3	2.12	176	6.32
49	1.49	160	2.13	160	5.38
131	1.45	135	2.06	103	5.26
160	1.45	60	2.01	135	5.18
135	1.38	106	2.01	41	5.28
		110	1.98	12	4.94
		158	1.98	106	5.26
		46	1.89	181	5.25
		52	1.95	37	4.79
		123	1.93		
		124	1.80		
		181	1.89		
		2	1.89		
		13	1.86		
		37	1.81		

Table 27. Modeled percent reductions of nutrients and sediment from the Dry Run Creek watershed with the installation of BMPs.

	Before BMPs	After BMPs	% Reduction
Total Nitrogen	0.94 lbs/acre/yr	0.88 lbs/acre/yr	6.4%
Total Phosphorus	0.29 lbs/acre/yr	0.26 lbs/acre/yr	10.3%
Sediment	0.06 tons/acre/yr	0.05 tons/acre/yr	16.7%

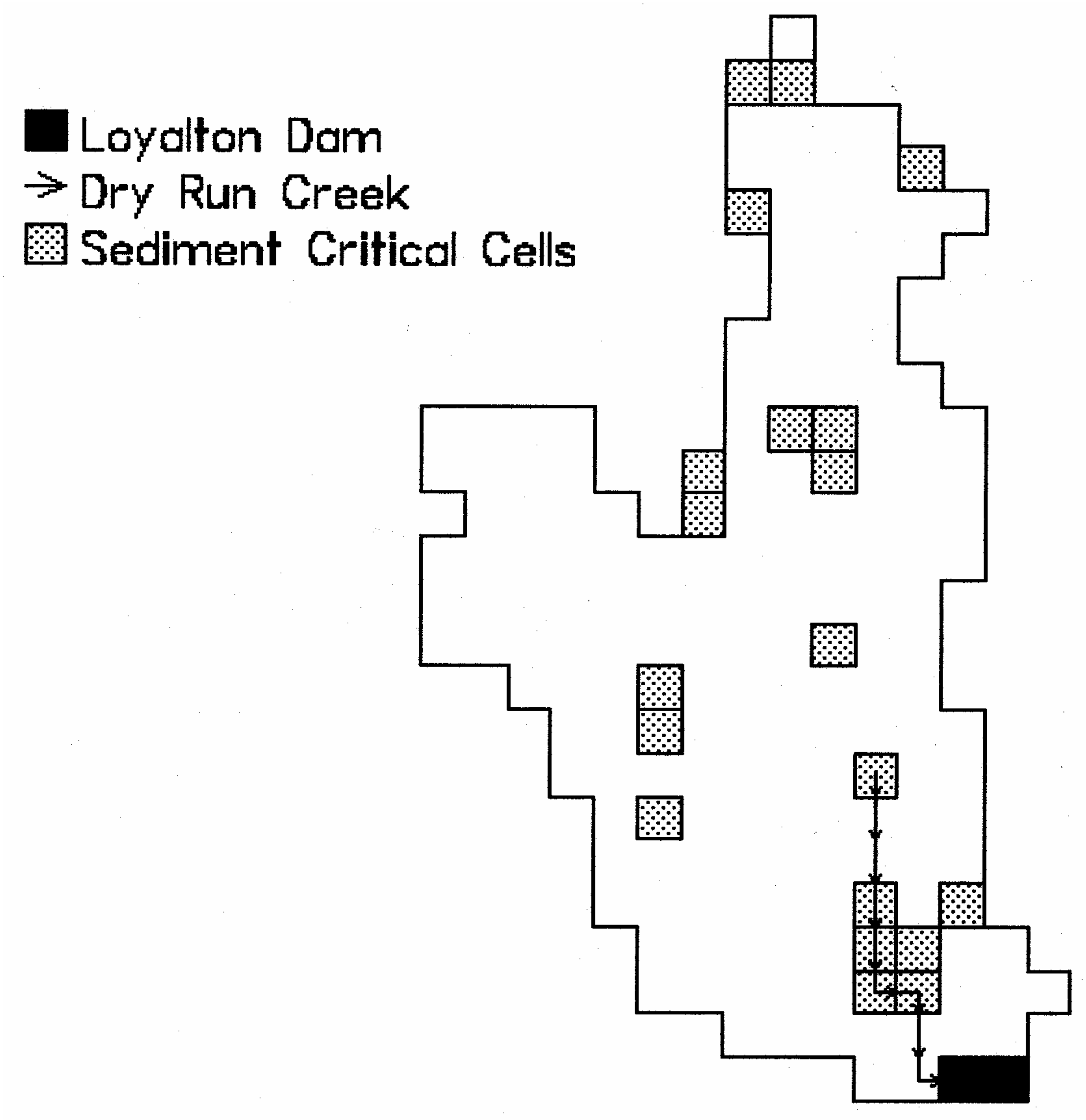

Figure 41. Location of sediment critical cells for the Dry Run Creek watershed.

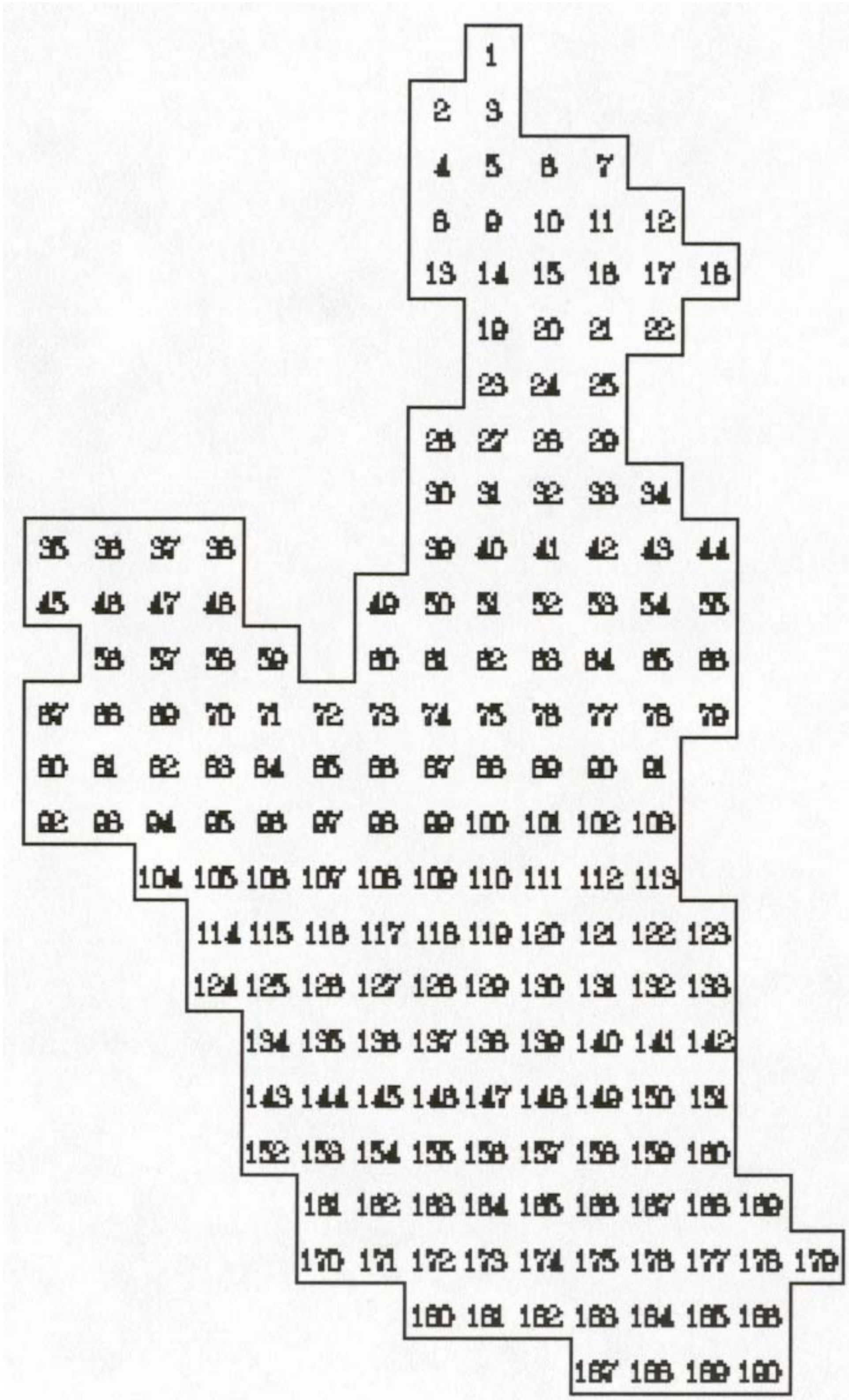

Figure 42. Dry Run Creek watershed cell numbers from AGNPS model (40-acre cells).

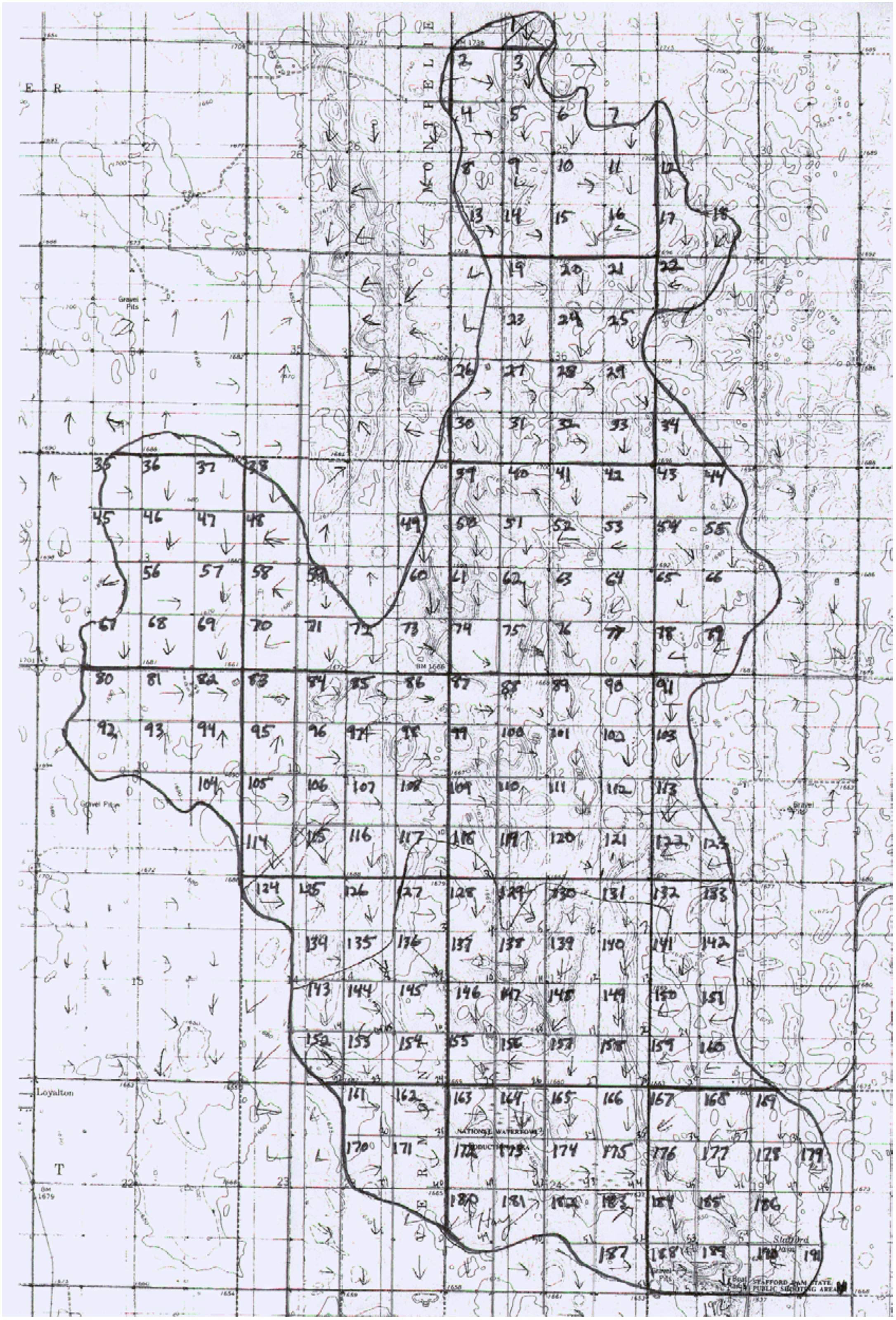

Figure 43. USGS topographic quadrangle map with delineation of the Dry Run Creek watershed.

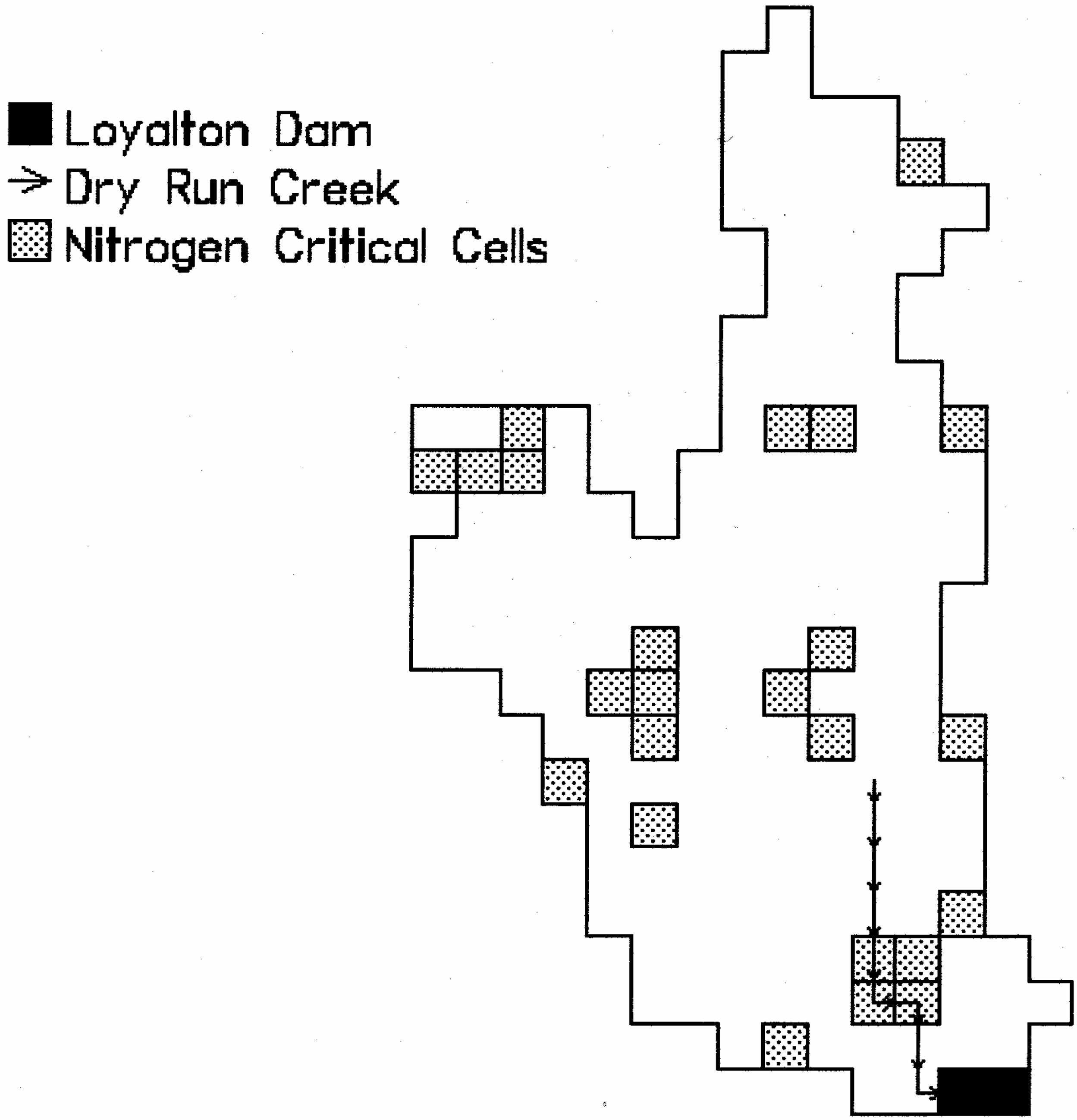

Figure 44. Location of nitrogen critical cells for the Dry Run Creek watershed.

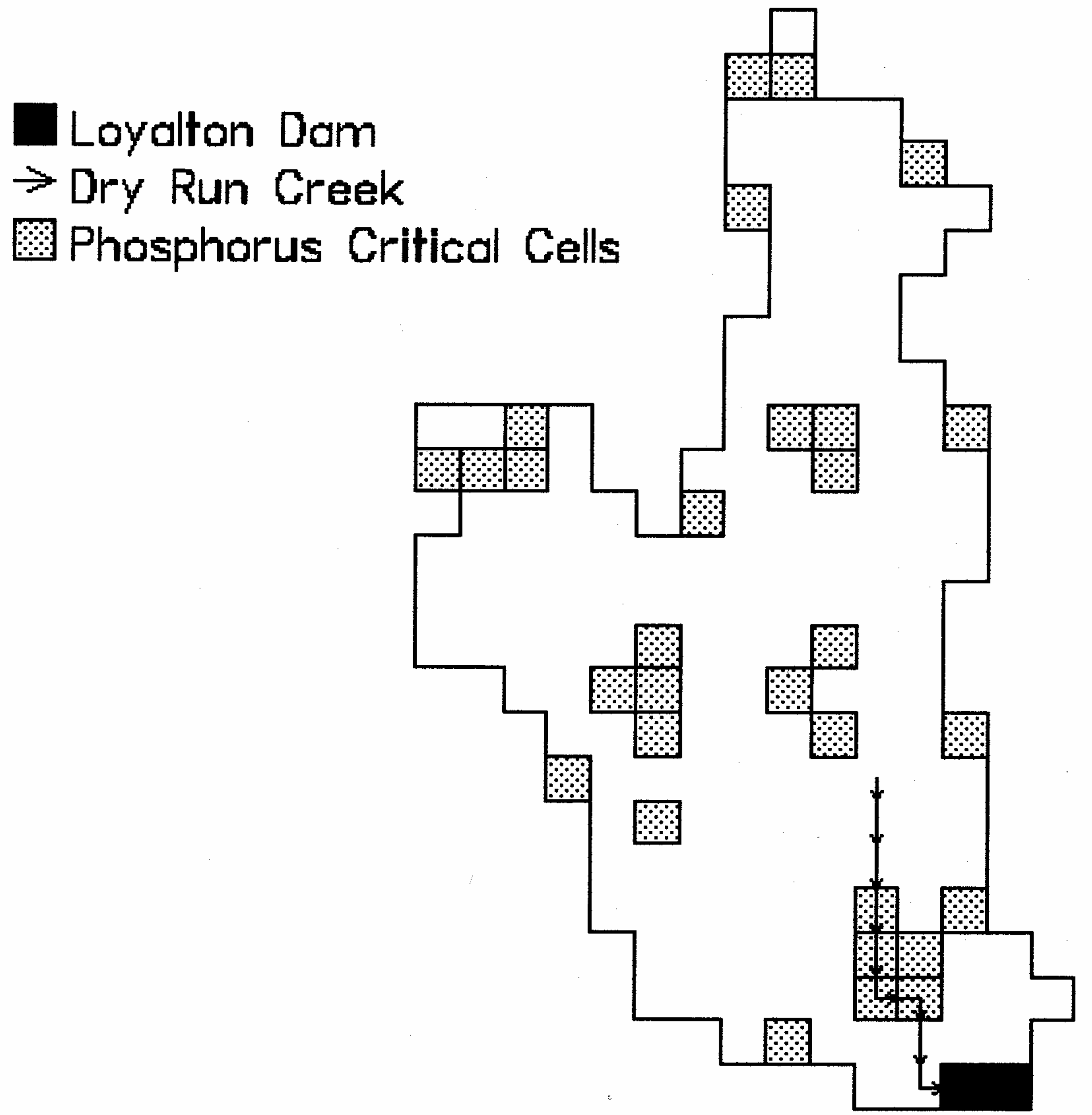

Figure 45. Location of phosphorus critical cells for the Dry Run Creek watershed.

Future Activity Recommendations

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

Watershed Management

Several high fecal coliform bacteria samples were collected during this study. The elevated concentrations were all collected during August 2000 from both lake and inlet stream sites. Since no municipalities are found in this watershed, grazing livestock is a probable source. Grazing management strategies including lakeshore and stream bank fencing, alternative livestock watering sources, and improved riparian buffer zones are suggested to reduce loadings of fecal coliform bacteria.

Efforts to reduce sediment and nutrient loads from the watershed should include the installation of appropriate BMPs including conversion of highly erodible cropland to rangeland or CRP, improvement of land surface cover (C-factor) on cropland and rangeland, installation of grassed waterways, and enhancement of riparian buffer zones. The AGNPS model displayed little nutrient and sediment reduction with the installation of grassed waterways, because the model lacks the ability to accurately simulate this practice. Still, grassed waterways should be considered on critical cells with a defined drainage (AGNPS model cells 158, 166, 175, and 176). The nitrogen, phosphorus, and sediment critical cells should be given high priority when installing any future BMPs. An estimated 1,240 acres should be targeted for cover management, which includes all AGNPS phosphorus critical cells. AGNPS cells targeted for management should also be field-verified prior to the installation of any BMPs. Installing BMPs in critical watershed areas should produce the most cost-effective treatment plan in reducing sediment and nutrient loads to Loyalton Dam.

Based on BATHTUB model reduction-response curves, an estimated 60% reduction in phosphorus concentrations would be necessary to bring Loyalton Dam to a beneficial use classification of fully supporting. Thus, the TMDL goal was set at a 60% reduction, and the TMDL target was set for a mean TSI of 65. The current mean TSI of Loyalton Dam is 68. The model indicates that a 60% reduction in nutrient load would lower the mean TSI by 3 points. A three-point reduction in mean TSI would improve the trophic status of the lake from a hyper-eutrophic to a eutrophic state.

Slight reductions achieved by modeled watershed BMPs would not improve the water quality in Loyalton Dam enough to meet the above criteria. Modeled BMPs, including conservation tillage and grassed waterways, yield only a 10% reduction in external phosphorus load. Management practices in the watershed should be considered first, as large amounts of nutrients and sediment are delivered from this source. However, internal phosphorus loading sources must also be addressed. A 50% reduction of internal phosphorus loading could be achieved with the inlake management techniques suggested below. This 50% internal load reduction plus the 10% external load reduction will achieve the TMDL goal.

In most lakes, the internal loading contribution is relatively small in comparison to external sources. Loyalton Dam is not an exception. Nevertheless, a significant amount of loading could be reduced within the lake itself. Highest inlake total dissolved phosphorus and total phosphorus concentrations were observed in samples collected in December. These elevated concentrations are most likely the result of internal phosphorus loading. While watershed management activities will be necessary to maintain relatively low nutrient and sediment loadings from the watershed, reducing internal phosphorus loading is a pertinent objective. Therefore, additional management recommendations will focus on inlake management.

Aluminum Sulfate (Alum) Treatment

Sediment-bound phosphorus loads from erosion of agricultural land 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 inlake phosphorus is a two-part process: keeping phosphorus out and eliminating phosphorus the lake already contains.

Alum treatment involves the addition of an 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. For shallow, unstratified lakes, Welch and Cooke (1995) predict a phosphorus reduction of approximately 50%.

Aquatic Macrophytes

One of the effects of the alum treatment will be 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 the establishment of emergent and submersed aquatic vegetation, which will further improve water quality. As algal density decreases and macrophytes 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).

As indicated by the macrophyte survey, aquatic vegetation is extremely sparse throughout Loyalton Dam. *Potamogeton pectinatus*, commonly known as sago pondweed, was the only aquatic macrophyte species identified. If submergent vegetation does not recolonize naturally, manual planting of desirable aquatic species should be considered.

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Appendix A

Loyalton Dam Algae Data

Algae species list with algal type and percent density of each taxa for Loyalton Dam.

Taxa	Algal Type	Density %	Taxa	Algal Type	Density %
Crucigenia quadrata	Green Algae	43.51%	*Closterium aciculare*	Green Algae	0.01%
Chroococcus minimus	Blue Green Algae	32.75%	*Navicula cryptocephala*	Diatom	0.01%
Sphaerocystis schroeteri	Green Algae	6.36%	*Scenedesmus quadricauda*	Green Algae	0.01%
Chrysochromulina parva	Flagellated Algae	3.89%	*Cosmarium sp.*	Green Algae	0.01%
Microcystis sp.	Blue Green Algae	2.08%	*Nitzschia paleacea*	Diatom	0.01%
Oocystis pusilla	Green Algae	1.73%	*Characium limneticum*	Green Algae	0.01%
Oocystis sp.	Green Algae	1.53%	*Ochromonas sp.*	Flagellated Algae	0.01%
Kirchneriella sp.	Green Algae	1.47%	*Entomoneis paludosa (Amphiprora)*	Diatom	0.01%
Aphanocapsa sp.	Blue Green Algae	0.91%	*Coelastrum cambricum*	Green Algae	0.00%
Rhodomonas minuta	Flagellated Algae	0.63%	*Oscillatoria sp.*	Blue Green Algae	0.00%
Cyclotella meneghiniana	Diatom	0.48%	*Botryococcus braunii*	Green Algae	0.00%
Oscillatoria agardhii	Blue Green Algae	0.42%	*Entomoneis ornata (Amphiprora)*	Diatom	0.00%
Microcystis aeruginosa	Blue Green Algae	0.34%	*Staurastrum cingulum*	Green Algae	0.00%
Selenastrum minutum	Green Algae	0.33%	*Elakatothrix sp.*	Green Algae	0.00%
Ankistrodesmus sp.	Green Algae	0.32%	*Peridinium sp.*	Flagellated Algae	0.00%
Coelastrum microporum	Green Algae	0.31%	*Scenedesmus acuminatus*	Green Algae	0.00%
Carteria sp.	Flagellated Algae	0.29%	*Gymnodinium sp.*	Flagellated Algae	0.00%
Unidentified green algae	Green Algae	0.27%	*Chroococcus dispersus*	Blue Green Algae	0.00%
Cryptomonas sp.	Flagellated Algae	0.26%	*Peridinium divergens*	Flagellated Algae	0.00%
Unidentified flagellates	Flagellated Algae	0.25%	*Phacus helikoides*	Flagellated Algae	0.00%
Dictyosphaerium pulchellum	Green Algae	0.20%	*Cocconeis placentula*	Diatom	0.00%
Chaetoceros elmorei	Diatom	0.18%	*Gyrosigma spencerii*	Diatom	0.00%
Ankistrodesmus falcatus	Green Algae	0.17%	*Nitzschia innominata*	Diatom	0.00%
Nephrocytium sp.	Green Algae	0.13%	*Peridinium cinctum*	Flagellated Algae	0.00%
Chlamydomonas sp.	Flagellated Algae	0.13%	*Phacus sp.*	Flagellated Algae	0.00%
Oocystis lacustris	Green Algae	0.12%	*Spermatozoopsis sp.*	Flagellated Algae	0.00%
Gymnodinium palustre	Flagellated Algae	0.12%	*Lepocinclis sp.*	Flagellated Algae	0.00%
Quadrigula sp.	Green Algae	0.07%	*Spirulina sp.*	Blue Green Algae	0.00%
Scourfieldia sp.	Flagellated Algae	0.06%	*Euglena sp.*	Flagellated Algae	0.00%
Staurastrum tetracerum	Green Algae	0.06%	*Trachelomonas hispida*	Flagellated Algae	0.00%
Dactylococcopsis sp.	Blue Green Algae	0.06%	*Oscillatoria limnetica*	Blue Green Algae	0.00%
Pediastrum duplex	Green Algae	0.06%	*Pascheriella tetras*	Flagellated Algae	0.00%
Cryptomonas erosa	Flagellated Algae	0.05%	*Navicula sp.*	Diatom	0.00%
Closteriopsis longissima	Green Algae	0.05%	*Cosmarium subcrenatum*	Green Algae	0.00%
Stephanodiscus astraea minutula	Diatom	0.05%	*Epithemia sp.*	Diatom	0.00%
Coelastrum sp.	Green Algae	0.04%	*Massartia sp.*	Flagellated Algae	0.00%
Chromulina sp.	Flagellated Algae	0.04%	*Phacus pleuronectes*	Flagellated Algae	0.00%
Elakatothrix viridis	Green Algae	0.03%	*Phacus pseudonordstedtii*	Flagellated Algae	0.00%
Stephanodiscus hantzschii	Diatom	0.03%	*Synedra sp.*	Diatom	0.00%
Vacuolaria virescens	Flagellated Algae	0.01%	*Trachelomonas scabra*	Flagellated Algae	0.00%
Scenedesmus sp.	Green Algae	0.01%	*Euglena oxyuris*	Flagellated Algae	0.00%
Glenodinium sp.	Flagellated Algae	0.01%	*Nitzschia acicularis*	Diatom	0.00%
Nitzschia sp.	Diatom	0.01%	*Surirella sp.*	Diatom	0.00%
Crucigenia tetrapedia	Green Algae	0.01%	*Gyrosigma sp.*	Diatom	0.00%
Trachelomonas sp.	Flagellated Algae	0.01%	*Melosira granulata v. angustissima*	Diatom	0.00%
Staurastrum sp.	Green Algae	0.01%	*Pleurosigma delicatulum*	Diatom	0.00%
Closteriopsis sp.	Green Algae	0.01%	*Rhopalodia gibba*	Diatom	0.00%
Staurastrum gracile	Green Algae	0.01%			

Algae taxa list for Loyalton Dam sorted by density in descending order (continued on next page).

Number	Taxa	Density (cells/ml)	Biovolume (um3/ml)	Density %	Biovolume %
1	*Crucigenia quadrata*	423,056	35,860,310	43.51%	44.52%
2	*Chroococcus minimus*	318,476	1,273,904	32.75%	1.58%
3	*Sphaerocystis schroeteri*	61,835	16,571,780	6.36%	20.58%
4	*Chrysochromulina parva*	37,843	4,567,437	3.89%	5.67%
5	*Microcystis sp.*	20,200	80,800	2.08%	0.10%
6	*Oocystis pusilla*	16,785	906,390	1.73%	1.13%
7	*Oocystis sp.*	14,910	2,236,500	1.53%	2.78%
8	*Kirchneriella sp.*	14,284	266,652	1.47%	0.33%
9	*Aphanocapsa sp.*	8,880	34,420	0.91%	0.04%
10	*Rhodomonas minuta*	6,103	311,235	0.63%	0.39%
11	*Cyclotella meneghiniana*	4,641	1,201,250	0.48%	1.49%
12	*Oscillatoria agardhii*	4,105	475,455	0.42%	0.59%
13	*Microcystis aeruginosa*	3,341	110,253	0.34%	0.14%
14	*Selenastrum minutum*	3,183	63,660	0.33%	0.08%
15	*Ankistrodesmus sp.*	3,105	78,375	0.32%	0.10%
16	*Coelastrum microporum*	3,038	947,008	0.31%	1.18%
17	*Carteria sp.*	2,780	2,513,120	0.29%	3.12%
18	*Unidentified green algae*	2,634	429,150	0.27%	0.53%
19	*Cryptomonas sp.*	2,540	1,034,000	0.26%	1.28%
20	*Unidentified flagellates*	2,440	78,150	0.25%	0.10%
21	*Dictyosphaerium pulchellum*	1,960	29,400	0.20%	0.04%
22	*Chaetoceros elmorei*	1,783	169,450	0.18%	0.21%
23	*Ankistrodesmus falcatus*	1,618	40,450	0.17%	0.05%
24	*Nephrocytium sp.*	1,310	124,450	0.13%	0.15%
25	*Chlamydomonas sp.*	1,289	293,850	0.13%	0.36%
26	*Oocystis lacustris*	1,138	350,504	0.12%	0.44%
27	*Gymnodinium palustre*	1,127	2,991,600	0.12%	3.71%
28	*Quadrigula sp.*	650	15,600	0.07%	0.02%
29	*Staurastrum tetracerum*	600	120,000	0.06%	0.15%
30	*Scourfieldia sp.*	600	75,480	0.06%	0.09%
31	*Dactylococcopsis sp.*	570	11,400	0.06%	0.01%
32	*Pediastrum duplex*	550	275,000	0.06%	0.34%
33	*Cryptomonas erosa*	530	266,060	0.05%	0.33%
34	*Closteriopsis longissima*	484	172,304	0.05%	0.21%
35	*Stephanodiscus astraea minutula*	470	164,500	0.05%	0.20%
36	*Coelastrum sp.*	436	87,636	0.04%	0.11%
37	*Chromulina sp.*	402	25,480	0.04%	0.03%
38	*Elakatothrix viridis*	300	12,600	0.03%	0.02%
39	*Stephanodiscus hantzschii*	280	56,000	0.03%	0.07%
40	*Vacuolaria virescens*	135	67,500	0.01%	0.08%
41	*Scenedesmus sp.*	120	9,000	0.01%	0.01%
42	*Glenodinium sp.*	100	70,000	0.01%	0.09%
43	*Nitzschia sp.*	99	11,880	0.01%	0.01%
44	*Crucigenia tetrapedia*	94	7,990	0.01%	0.01%
45	*Trachelomonas sp.*	85	170,000	0.01%	0.21%
46	*Staurastrum sp.*	84	20,160	0.01%	0.03%
47	*Closteriopsis sp.*	80	191,040	0.01%	0.24%
48	*Staurastrum gracile*	80	43,200	0.01%	0.05%
49	*Closterium aciculare*	77	57,750	0.01%	0.07%
50	*Navicula cryptocephala*	63	11,655	0.01%	0.01%
51	*Scenedesmus quadricauda*	54	8,478	0.01%	0.01%
52	*Cosmarium sp.*	51	10,710	0.01%	0.01%
53	*Nitzschia paleacea*	51	4,998	0.01%	0.01%
54	*Characium limneticum*	50	115,450	0.01%	0.14%
55	*Ochromonas sp.*	50	4,250	0.01%	0.01%
56	*Entomoneis paludosa (Amphiprora)*	49	196,000	0.01%	0.24%
57	*Coelastrum cambricum*	48	2,400	0.00%	0.00%
58	*Oscillatoria sp.*	45	420	0.00%	0.00%

59	*Entomoneis ornata (Amphiprora)*	43	107,200	0.00%	0.13%
60	*Botryococcus braunii*	43	3,870	0.00%	0.00%
61	*Staurastrum cingulum*	41	9,840	0.00%	0.01%
62	*Elakatothrix sp.*	35	1,470	0.00%	0.00%
63	*Peridinium sp.*	32	33,600	0.00%	0.04%
64	*Scenedesmus acuminatus*	32	1,920	0.00%	0.00%
65	*Gymnodinium sp.*	30	81,000	0.00%	0.10%
66	*Chroococcus dispersus*	28	616	0.00%	0.00%
67	*Peridinium divergens*	27	108,000	0.00%	0.13%
68	*Phacus helikoides*	26	254,826	0.00%	0.32%
69	*Peridinium cinctum*	25	105,000	0.00%	0.13%
70	*Phacus sp.*	25	25,000	0.00%	0.03%
71	*Cocconeis placentula*	25	11,500	0.00%	0.01%
72	*Gyrosigma spencerii*	25	11,250	0.00%	0.01%
73	*Spermatozoopsis sp.*	25	3,200	0.00%	0.00%
74	*Nitzschia innominata*	25	1,200	0.00%	0.00%
75	*Lepocinclis sp.*	24	480,000	0.00%	0.60%
76	*Spirulina sp.*	22	31,086	0.00%	0.04%
77	*Euglena sp.*	21	12,180	0.00%	0.02%
78	*Trachelomonas hispida*	15	31,500	0.00%	0.04%
79	*Pascheriella tetras*	12	280	0.00%	0.00%
80	*Oscillatoria limnetica*	12	120	0.00%	0.00%
81	*Navicula sp.*	10	2,500	0.00%	0.00%
82	*Cosmarium subcrenatum*	8	1,680	0.00%	0.00%
83	*Epithemia sp.*	5	1,500	0.00%	0.00%
84	*Phacus pleuronectes*	3	20,358	0.00%	0.03%
85	*Phacus pseudonordstedtii*	3	5,427	0.00%	0.01%
86	*Trachelomonas scabra*	3	4,800	0.00%	0.01%
87	*Massartia sp.*	3	1,146	0.00%	0.00%
88	*Synedra sp.*	3	840	0.00%	0.00%
89	*Euglena oxyuris*	2	26,000	0.00%	0.03%
90	*Surirella sp.*	2	1,000	0.00%	0.00%
91	*Nitzschia acicularis*	2	560	0.00%	0.00%
92	*Rhopalodia gibba*	1	4,000	0.00%	0.00%
93	*Pleurosigma delicatulum*	1	900	0.00%	0.00%
94	*Gyrosigma sp.*	1	500	0.00%	0.00%
95	*Melosira granulata v. angustissima*	1	250	0.00%	0.00%

Appendix B

Loyalton Dam Fishery Survey Report
Prepared by South Dakota Department of Game, Fish, and Parks

SOUTH DAKOTA STATEWIDE FISHERIES SURVEY

2102-F21-R-28

Name: Loyalton County(ies): Edmunds
Legal description: T121N, R65W, Sect. 19.
Location from nearest town: 1 south, 3 1/2 miles east of Loyalton
Dates of present survey: June 7,1994
Date last surveyed: June 21, 1989
Most recent lake management plan: F21-R-24 Date: 1990
Management classification: Warm-water semi permanent
Contour mapped: Y Date: 1973
Report prepared by: Matthew Hubers

Primary Species: (game and forage)
1. Black Crappie
2. Bluegill
3. Black Bullhead
4. Largemouth Bass
5. Walleye
6.
7.

Secondary and other species:
1.
2.
3.
4.
5.
6.
7.

PHYSICAL CHARACTERISTICS

Surface Area: 38 acres; Watershed: 3100 acres
Maximum depth: [illegible] feet; Mean depth: 10 feet
Lake elevation at survey (from known benchmark): Full feet

1. Describe ownership of lake and adjacent lakeshore property:

Loyalton Dam is owned by the State of South Dakota and managed by the Dept. of Game, Fish and Parks. Adjacent property is owned by the Game, Fish and Parks Dept. and private landowners.

2. Describe watershed condition and percentages of land use:

Grasslands comprise approximately 30% and cropland 70% of the watershed.

3. Describe aquatic vegetative condition:

Cattail and bullrush cover approximately 45% of the shoreline and emergent vegetation can be found throughout the lake.

4. Describe pollution problems:

Nutrient inflow and siltation are occurring.

5. Condition of structures, i.e. spillway, boatramps, etc.:

All structures are in working order.

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Chemical Data

No water chemistry was conducted.

BIOLOGICAL DATA

Methods:

Loyalton Lake was netted with five ¾ in frame nets on June 7, 1994. Electrofishing was conducted on June 7, 1994 from 9:45-10:30 PM. Total shocking time was 45 minutes. The settings for the unit were pulsed AC at 110 volts and 9 amps. Lengths and weights were taken from the frame net sample and results summarized in table 1. Only one largemouth bass was sampled electrofishing.

Discussion:

A total of four species were sampled in the frame nets. Black crappie comprised 43% of the sample. Fourteen of the twenty-six fish samples were less than 127 mm in length, eleven ranged from 127-202 mm, and one was greater than 253 mm. The fishery will improve as the stock and sub-stock fish move to quality length. The CPUE of 5.2 does not indicate high abundance but should provide some opportunity.

Bluegill were the most abundant species sampled with a CPUE of 6.6. Size structure (Figure1) was good and the sample had a PSD of 45. Reproduction appears to be fairly consistent as fish in almost all cm groups from 8-18 were present. The Wr of 164 indicates that bluegill were in pre-spawn condition. Bluegill are not overly abundant but should be able to provide a fishery.

One Walleye of 552 mm in length was sampled. Walleye fry were last stocked in 1981. A remnant population may exist or may have been angler stocked.

Electrofishing resulted in one largemouth bass (330 mm) being sampled. Conditions were not optimum for electrofishing as several storms had moved through the area and during the time of sampling rain and 15-20 mph winds were prevalent. No inferences should be made in regard to the largemouth bass population.

RECOMMENDATIONS

1. Resurvey more intensively in 1995 to further assess panfish and largemouth bass populations.
2. Manage for largemouth bass and panfish. No further stockings are recommended at this time.

Table 1. Total catch of five 3/4 in. mesh frame net sets in Loyalton Lake, Edmunds County, June 7, 1994.

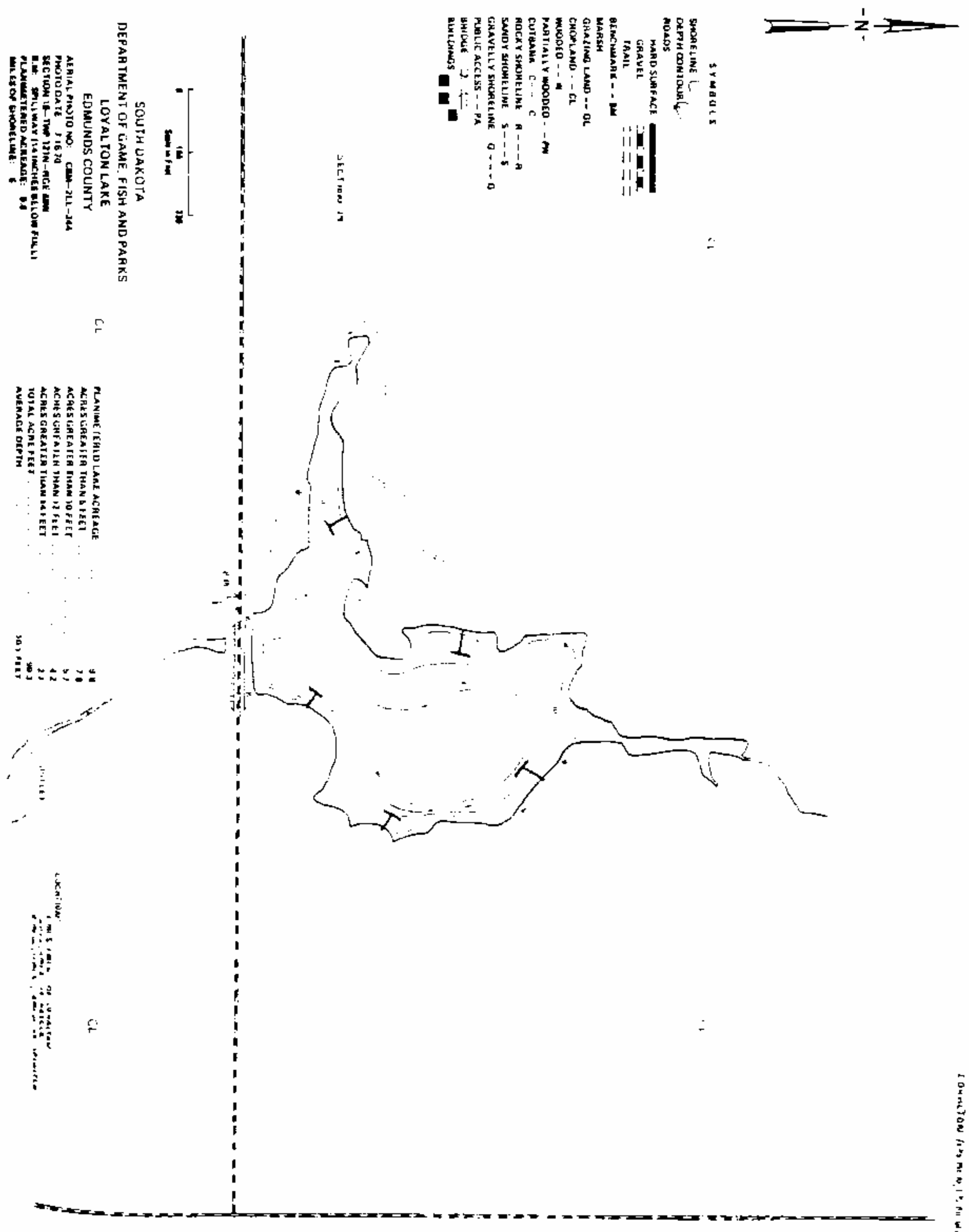
SPECIES	SAMPLE SIZE	%COMP	CPUE 80%C.I	1 YEAR MEAN CPUE	PSD	WR
BLC	26	42.6	5.2+−4.2	5.2	–	120
BLG	33	54.1	6.6+−4.3	6.6	45	164
BLB	1	1.6	0.2+−0.3	0.2	–	–
WAE	1	1.6	0.2+−0.3	0.2	–	–

000687

TABLE 2. STOCKING RECORD FOR LOYALTON LAKE, EDMUNDS COUNTY, 1985-

SPECIES	SIZE	NUMBER	YEAR
BLC	ADT	300	1985
BLG	FGL	11,400	1986
LMB	FGL	3,800	1987
LMB	FGL	3,800	1988
LMB	MFG	3,800	1989
LMB	MFG	3,800	1980
LMB	MFG	3,800	1991
LMB	MFG	3,800	1992

Figure 1
Approximate net locations for 1994 lake survey.



Appendix C

Lake Assessment Data

Loyalton Dam Field Measurements

SITE	TYPE	DATE	pH	SECCHI	TEMP	DO
LD01	REP	18-Jul-00		1.8	21.92	5.03
LD01	REP	18-Jul-00		1.8	21.92	5.03
LD02	REP	18-Jul-00	8.63	1.5	22.06	3.43
LD01	REP	7-Aug-00	8.68	1.8	24.11	3.15
LD01	REP	7-Aug-00	8.68	1.8	24.11	3.15
LD01	REP	7-Aug-00	8.68	1.8	24.11	3.15
LD02	DUP	7-Aug-00	8.27	1.6	19.71	2.18
LD02	REP	7-Aug-00	8.27	1.6	19.71	2.18
LD02	REP	7-Aug-00	8.27	1.6	19.71	2.18
LD01	REP	21-Aug-00	8.79	2.0	20.25	5.13
LD01	REP	21-Aug-00	8.79	2.0	20.25	5.13
LD02	REP	21-Aug-00	8.78	1.8	20.43	5.46
LD02	REP	21-Aug-00	8.78	1.8	20.43	5.46
LD01	REP	14-Sep-00	8.84	1.6	17.99	13.41
LD01	REP	14-Sep-00	8.84	1.6	17.99	13.41
LD02	REP	14-Sep-00	8.76	1.2	17.79	12.29
LD02	REP	14-Sep-00	8.76	1.2	17.79	12.29
LD01	DUP	31-Oct-00	8.7	1	11.11	2.43
LD01	REP	31-Oct-00	8.7	1	11.11	2.43
LD02	REP	31-Oct-00	8.5	1.2	11.11	16.8
LD02	REP	31-Oct-00	8.5	1.2	11.11	16.8
LD01	REP	29-Jan-01	8		0.27	13.7
LD01	REP	29-Jan-01	8		0.27	13.7
LD01	DUP	29-Jan-01	8		0.27	13.7
LD01	REP	29-Jan-01	8		0.27	13.7
LD02	DUP	29-Jan-01	8.3		0.26	8.4
LD02	REP	29-Jan-01	8.3		0.26	8.4
LD02	DUP	29-Jan-01	8.3		0.26	8.4
LD02	REP	29-Jan-01	8.3		0.26	8.4
LD01	REP	15-Mar-01	7.2		0.55	5.13
LD01	REP	15-Mar-01	7.2		0.55	5.13
LD02	REP	15-Mar-01	7.2		0.92	2.69
LD02	DUP	15-Mar-01	7.2		0.92	2.69
LD01	REP	12-Apr-01	8.6		3.02	14.2
LD01	REP	25-Apr-01	8.8		7.75	
LD01	REP	25-Apr-01	8.8		7.75	
LD02	REP	25-Apr-01	8.8		7.75	
LD02	REP	25-Apr-01	8.8		7.75	
LD01	REP	5-Jun-01	8.6	0.348	19.23	9.03
LD01	REP	5-Jun-01	8.6	0.348	19.23	9.03
LD02	REP	5-Jun-01	8.6	0.3048	16.3	9.07

Loyalton Dam Sample Data

SITE	DEPTH	TYPE	DATE	ALKA	TOTS	TSS	TDS	TVSS	AMMO	UNION	NIT	TKN	TOT N	ORG NIT	INOR NIT	TOT P	TDP
LD01	S	REP	28-Jun-00	502	1568	26.0	1542.0	7.0	0.01		0.05	1.39	1.44	1.29	0.15	0.094	0.030
LD01	S	REP	28-Jun-00	504	1565	25.0	1540.0	8.0	0.01		0.05	1.54	1.59	1.44	0.15	0.022	0.087
LD01	B	DUP	28-Jun-00	505	1553	26.0	1527.0	11.0	0.01		0.05	1.57	1.62	1.47	0.15	0.028	0.094
LD02	S	REP	28-Jun-00	507	1564	17.0	1547.0	4.0	0.01		0.05	1.77	1.82	1.67	0.15	0.022	0.100
LD01	S	REP	18-Jul-00	503	1550	30.0	1520.0	7.0	0.01		0.05	1.69	1.74	1.59	0.15	0.085	0.043
LD01	B	REP	18-Jul-00	530	1659	164.0	1495.0	32.0	0.01		0.05	1.98	2.03	1.88	0.15	0.190	0.078
LD02	S	REP	18-Jul-00	506	1592	90.0	1502.0	18.0	0.01	0.02	0.05	1.62	1.67	1.52	0.15	0.171	0.054
LD01	S	REP	7-Aug-00	392	1231	25.0	1206.0	12.0	0.01	0.02	0.30	1.72	2.02	1.62	0.40	0.141	0.042
LD01	S	REP	7-Aug-00	387	1229	21.0	1208.0	8.0	0.01	0.02	0.20	1.60	1.80	1.50	0.30	0.142	0.045
LD01	B	REP	7-Aug-00	374	1181	20.0	1161.0	9.0	0.04	0.01	0.30	1.89	2.19	1.85	0.34	0.172	0.091
LD02	S	DUP	7-Aug-00	382	1205	22.0	1183.0	9.0	0.04	0.00	0.30	1.77	2.07	1.73	0.34	0.165	0.059
LD02	S	REP	7-Aug-00	384	1212	24.0	1188.0	4.0	0.04	0.00	0.30	1.86	2.16	1.82	0.34	0.165	0.087
LD02	S	REP	7-Aug-00	396	1260	27.0	1233.0	12.0	0.01	0.01	0.20	1.62	1.82	1.52	0.30	0.135	0.054
LD01	S	REP	21-Aug-00	393	1205	20.0	1185.0	9.0	0.01	0.02	0.05	1.58	1.63	1.48	0.15	0.142	0.084
LD01	B	REP	21-Aug-00	394	1213	23.0	1190.0	7.0	0.01	0.02	0.05	1.49	1.54	1.39	0.15	0.145	0.094
LD02	S	REP	21-Aug-00	397	1208	25.0	1183.0	8.0	0.04	0.01	0.05	1.60	1.65	1.56	0.09	0.145	0.084
LD02	B	REP	21-Aug-00	401	1240	46.0	1194.0	14.0	0.03	0.01	0.05	1.57	1.62	1.54	0.08	0.206	0.088
LD01	S	REP	14-Sep-00	411	1254	18.0	1236.0	6.0	0.09	0.02	0.05	1.60	1.65	1.51	0.14	0.095	0.055
LD01	S	REP	14-Sep-00	414	1255	27.0	1228.0	12.0	0.12	0.02	0.05	1.73	1.78	1.61	0.17	0.103	0.040
LD02	S	REP	14-Sep-00	412	1244	25.0	1219.0	11.0	0.01	0.02	0.05	1.68	1.73	1.58	0.15	0.104	0.050
LD02	B	REP	14-Sep-00	413	1255	27.0	1228.0	10.0	0.01	0.02	0.05	1.79	1.84	1.69	0.15	0.104	0.100
LD01	S	DUP	31-Oct-00	434	1299	31.0	1268.0	11.0	0.27	0.02	0.20	2.46	2.66	2.19	0.47	0.270	0.046
LD01	S	REP	31-Oct-00	434	1296	28.0	1268.0	11.0	0.28	0.03	0.10	2.15	2.25	1.87	0.38	0.138	0.052
LD02	S	REP	31-Oct-00	436	1289	28.0	1261.0	11.0	0.31	0.02	0.10	1.99	2.09	1.68	0.41	0.122	0.059
LD02	B	REP	31-Oct-00	436	1293	31.0	1262.0	9.0	0.30	0.02	0.10	2.03	2.13	1.73	0.40	0.142	0.050
LD01	S	REP	28-Dec-00	203	602	4.0	598.0	1.0	0.15		0.10	1.44	1.54	1.29	0.25	0.326	0.296
LD01	B	REP	28-Dec-00	203	597	3.0	594.0	2.0	0.15		0.10	1.51	1.61	1.36	0.25	0.352	0.307
LD02	S	REP	28-Dec-00	207	611	4.0	607.0	1.0	0.15		0.10	1.54	1.64	1.39	0.25	0.342	0.242
LD01	S	REP	29-Jan-01	521	1533	9.0	1524.0	3.0	0.37	0.00	0.20	2.66	2.86	2.29	0.57	0.152	0.098
LD01	S	REP	29-Jan-01	515	1520	21.0	1499.0	6.0	0.41	0.00	0.20	2.56	2.76	2.15	0.61	0.154	0.074
LD01	S	DUP	29-Jan-01	521	1541	38.0	1503.0	7.0	0.45	0.00	0.20	2.53	2.73	2.08	0.65	0.148	0.086
LD01	S	REP	29-Jan-01	522	1530	10.0	1520.0	2.0	0.53	0.00	0.20	2.46	2.66	1.93	0.73	0.142	0.101
LD02	S	DUP	29-Jan-01	520	1530	10.0	1520.0	4.0	0.41	0.01	0.30	2.50	2.80	2.09	0.71	0.158	0.099
LD02	S	REP	29-Jan-01	524	1574	42.0	1532.0	7.0	0.41	0.01	0.20	2.27	2.47	1.86	0.61	0.119	0.074
LD02	B	DUP	29-Jan-01	515	1531	8.0	1523.0	4.0	0.47	0.01	0.20	2.52	2.72	2.05	0.67	0.126	0.106
LD02	B	REP	29-Jan-01	514	1525	7.0	1518.0	2.0	0.41	0.01	0.20	2.52	2.72	2.11	0.61	0.142	0.099
LD01	S	REP	15-Mar-01	534	1563	10.0	1553.0	5.0	0.54	0.00	0.20	2.33	2.53	1.79	0.74	0.178	0.115
LD01	B	REP	15-Mar-01	532	1567	12.0	1555.0	4.0	0.57	0.00	0.20	2.53	2.73	1.96	0.77	0.198	0.159
LD02	S	REP	15-Mar-01	539	1577	12.0	1565.0	5.0	0.56	0.00	0.20	2.61	2.81	2.05	0.76	0.176	0.151
LD02	S	DUP	15-Mar-01	539	1578	11.0	1567.0	3.0	0.59	0.00	0.20	2.56	2.76	1.97	0.79	0.180	0.146
LD01	S	REP	3-Apr-01	209	750	41.0	709.0	18.0	0.27		3.80	3.00	6.80	2.73	4.07	0.485	0.191
LD01	S	REP	12-Apr-01	103	488	20.0	468.0	3.0	0.02	0.00	1.40	1.68	3.08	1.66	1.42	0.694	0.461
LD01	S	REP	25-Apr-01	332	1011	20.0	991.0	7.0	0.09	0.01	0.50	1.36	1.86	1.27	0.59	0.203	0.100
LD01	B	REP	25-Apr-01	336	1032	19.0	1013.0	7.0	0.10	0.01	0.50	1.62	2.12	1.52	0.60	0.212	0.109
LD02	S	REP	25-Apr-01	327	1003	20.0	983.0	5.0	0.08	0.01	0.60	1.88	2.48	1.80	0.68	0.212	0.112
LD02	B	REP	25-Apr-01	324	1014	23.0	991.0	10.0	0.08	0.01	0.60	1.56	2.16	1.48	0.68	0.224	0.108
LD01	S	REP	31-May-01	338	1087	30.0	1057.0	10.0	0.01		0.05	1.32	1.37	1.22	0.15	0.143	0.027
LD01	B	REP	31-May-01	345	1126	53.0	1073.0	15.0	0.01		0.05	1.08	1.13	0.98	0.15	0.312	0.063
LD02	S	DUP	31-May-01	145	1090	34.0	1056.0	7.0	0.01		0.05	1.74	1.79	1.64	0.15	0.124	0.062
LD02	S	REP	31-May-01	335	1076	29.0	1047.0	10.0	0.01		0.05	1.54	1.59	1.44	0.15	0.141	0.031
LD02	B	REP	31-May-01	340	1095	29.0	1066.0	12.0	0.01		0.05	1.50	1.55	1.40	0.15	0.243	0.073
LD01	S	REP	5-Jun-01	343	1086	38.0	1048.0	9.0	0.01	0.01	0.05	1.54	1.59	1.44	0.15	0.132	0.026
LD01	B	REP	5-Jun-01	340	1100	35.0	1065.0	9.0	0.01	0.01	0.05	1.57	1.62	1.47	0.15	0.125	0.034
LD02	B	REP	5-Jun-01	343	1086	35.0	1051.0	7.0	0.01	0.01	0.05	1.58	1.63	1.48	0.15	0.130	0.037

Loyalton Dam Biological and TSI Data

SITE	DEPTH	TYPE	DATE	FECAL	CHLOR A	TOT CHLOR	SD TSI	P TSI	CHL TSI	MEAN TSI
LD01	S	REP	28-Jun-00	20	8.110	22.399		69.696	60.134	
LD01	S	REP	28-Jun-00	10				48.745		
LD01	B	DUP	28-Jun-00	20				52.224		
LD02	S	REP	28-Jun-00	20	5.707	18.934		48.745	56.687	
LD01	S	REP	18-Jul-00	30	9.943	20.171	51.926	68.244	62.133	60.768
LD01	B	REP	18-Jul-00	70			51.926	79.849		
LD02	S	REP	18-Jul-00	40	20.522	27.390	54.150	78.329	69.242	67.240
LD01	S	REP	7-Aug-00	2600			51.520	75.546		
LD01	S	REP	7-Aug-00	3900			51.520	75.648		
LD01	B	REP	7-Aug-00	7800			51.520	78.413		
LD02	S	DUP	7-Aug-00	5900			53.219	77.814		
LD02	S	REP	7-Aug-00	3300			53.219	77.814		
LD02	S	REP	7-Aug-00	3200			53.219	74.919		
LD01	S	REP	21-Aug-00	20			50.000	75.648		
LD01	B	REP	21-Aug-00	110			50.000	75.949		
LD02	S	REP	21-Aug-00	90			51.520	75.949		
LD02	B	REP	21-Aug-00	440			51.520	81.015		
LD01	S	REP	14-Sep-00	5			53.219	69.849		
LD01	S	REP	14-Sep-00	5			53.219	71.015		
LD02	S	REP	14-Sep-00	20			57.370	71.155		
LD02	B	REP	14-Sep-00	5			57.370	71.155		
LD01	S	DUP	31-Oct-00	5			60.000	84.919		
LD01	S	REP	31-Oct-00	10			60.000	75.236		
LD02	S	REP	31-Oct-00	20			57.370	73.458		
LD02	B	REP	31-Oct-00	5			57.370	75.648		
LD01	S	REP	28-Dec-00	5				87.638		
LD01	B	REP	28-Dec-00	5				88.745		
LD02	S	REP	28-Dec-00	5				88.329		
LD01	S	REP	29-Jan-01	5				76.630		
LD01	S	REP	29-Jan-01	5	11.314	16.376		76.818	63.400	
LD01	S	DUP	29-Jan-01	5				76.245		
LD01	S	REP	29-Jan-01	5				75.648		
LD02	S	DUP	29-Jan-01	5				77.188		
LD02	S	REP	29-Jan-01	5	11.214	17.820		73.099	63.313	
LD02	B	DUP	29-Jan-01	5				73.923		
LD02	B	REP	29-Jan-01	5				75.648		
LD01	S	REP	15-Mar-01	5				78.908		
LD01	B	REP	15-Mar-01	5				80.444		
LD02	S	REP	15-Mar-01	5				78.745		
LD02	S	DUP	15-Mar-01	5				79.069		
LD01	S	REP	3-Apr-01	5				93.369		
LD01	S	REP	12-Apr-01	5				98.538		
LD01	S	REP	25-Apr-01	5	15.920	22.069		80.804	66.751	
LD01	B	REP	25-Apr-01	5				81.430		
LD02	S	REP	25-Apr-01	5	18.924	40.714		81.430	68.446	
LD02	B	REP	25-Apr-01	5				82.224		
LD01	S	REP	31-May-01	20	8.711	17.408		75.749	60.835	
LD01	B	REP	31-May-01	5				87.004		
LD02	S	DUP	31-May-01	5				73.692		
LD02	S	REP	31-May-01	20	9.011	15.923		75.546	61.168	
LD02	B	REP	31-May-01	10				83.399		
LD01	S	REP	5-Jun-01	5	19.224	28.421	75.228	74.594	68.601	72.808
LD01	B	REP	5-Jun-01	5			75.228	73.808		
LD02	B	REP	5-Jun-01	20	22.929	31.680	77.141	74.374	70.330	73.948

Appendix D

Tributary Assessment Data

Tribulary Field Data

SITE	DATE	TEMP	COND	DO	PH
Inlet	30-Mar-01	2.79	95	19.87	7.29
Inlet	12-Apr-01	6.04	795	8.44	7.49
Inlet	12-Apr-01	6.04	795	8.44	7.49
Inlet	14-Apr-01	9.83	786	14.07	8.71
Inlet	27-Apr-01	19.76	786	7.1	8.88
Inlet	16-Aug-00	18.40		2.80	7.17
Outlet	5-Aug-00	22.10		1.10	3.70
Outlet	6-Aug-00	27.00		1.80	4.73
Outlet	12-Apr-01	3.02	745	14.24	8.55
Outlet	5-Jun-01	19.23		9.03	6.1
Outlet	14-Apr-01	3.02	745	14.28	8.62

Tributary Lab Data

SITE	DATE	FECAL	ECOLI	ALKA	TOT S	TSS	TDS	TVSS	AMMO	NIT	TKN	INOR N	ORG N	TOT N	TOT P	TDP
Inlet	16-Aug-00	17000		254	633	94	539	36	0.06	0.05	5.16	0.11	5.10	5.21	2.920	1.740
Inlet	26-Mar-01	20	56.3	111	388	8	380	5	1.31	0.50	3.32	1.81	2.01	3.82	1.300	1.170
Inlet	3-Apr-01	5	8.6	78	312	24	288	6	0.37	6.00	1.90	6.37	1.53	7.90	0.668	0.554
Inlet	10-Apr-01	5		118	523	6	517	5	0.01	1.50	1.89	1.51	1.88	3.39	0.828	0.642
Inlet	25-Apr-01	70	105	133	702	9	693	4	0.01	0.10	1.06	0.11	1.05	1.16	0.396	0.303
Inlet	31-May-01	40	37.3	542	3327	13	3314	6	0.01	0.05	2.61	0.06	2.60	2.66	0.664	0.332
Outlet	18-Jul-00	70		507	1554	27	1527	1	0.01	0.05	1.77	0.06	1.76	1.82	0.074	0.053
Outlet	5-Aug-00			14	194	52	142	30	0.05	0.10	2.08	0.15	2.03	2.18	0.538	0.315
Outlet	6-Aug-00			38	162	42	120	14	0.17	0.10	1.80	0.27	1.63	1.90	0.606	0.457
Outlet	10-Apr-01	5	5.2	132	463	12	451	4	0.01	2.40	1.38	2.41	1.37	3.78	0.431	0.318
Outlet	12-Apr-01	10	6.1	211	711	20	691	2	0.08	1.30	1.63	1.38	1.55	2.93	0.391	0.249
Outlet	31-May-01	20	41.3	339	1124	68	1056	14	0.01	0.05	1.59	0.06	1.58	1.64	0.109	0.024
Outlet	5-Jun-01	280	210	337	1062	20	1042	10	0.01	0.05	1.48	0.06	1.47	1.53	0.104	0.035

Appendix E

Quality Assurance/Quality Control (QA/QC) Data

QA/QC data for replicate and routine sample pairs

SITE	DEPTH	TYPE	DATE	ALKA	TOT S	TSS	TVSS	AMMO	NIT	TKN	TOT P	TDP
LD01	Bottom	DUP	28-Jun-00	505	1553	26.0	11.0	0.01	0.05	1.57	0.028	0.094
LD01	Bottom	REP	28-Jun-00	504	1565	25.0	8.0	0.01	0.05	1.54	0.022	0.087
				0.1%	**0.4%**	**2.0%**	**15.8%**	**0.0%**	**0.0%**	**1.0%**	**12.0%**	**3.9%**
LD01	Surface	DUP	31-Oct-00	434	1299	31.0	11.0	0.27	0.20	2.46	0.270	0.046
LD01	Surface	REP	31-Oct-00	434	1296	28.0	11.0	0.28	0.10	2.15	0.138	0.052
				0.0%	**0.1%**	**5.1%**	**0.0%**	**1.8%**	**33.3%**	**6.7%**	**32.4%**	**6.1%**
LD01	Surface	DUP	29-Jan-01	521	1541	38.0	7.0	0.45	0.20	2.53	0.148	0.086
LD01	Surface	REP	29-Jan-01	522	1530	10.0	2.0	0.53	0.20	2.46	0.142	0.101
				0.1%	**0.4%**	**58.3%**	**55.6%**	**8.2%**	**0.0%**	**1.4%**	**2.1%**	**8.0%**
LD02	Surface	DUP	7-Aug-00	382	1205	22.0	9.0	0.04	0.30	1.77	0.165	0.059
LD02	Surface	REP	7-Aug-00	384	1212	24.0	4.0	0.04	0.30	1.86	0.165	0.087
				0.3%	**0.3%**	**4.3%**	**38.5%**	**0.0%**	**0.0%**	**2.5%**	**0.0%**	**19.2%**
LD02	Surface	DUP	29-Jan-01	520	1530	10.0	4.0	0.41	0.30	2.50	0.158	0.099
LD02	Surface	REP	29-Jan-01	524	1574	42.0	7.0	0.41	0.20	2.27	0.119	0.074
				0.4%	**1.4%**	**61.5%**	**27.3%**	**0.0%**	**20.0%**	**4.8%**	**14.1%**	**14.5%**
LD02	Surface	DUP	15-Mar-01	539	1578	11.0	3.0	0.59	0.20	2.56	0.180	0.146
LD02	Surface	REP	15-Mar-01	539	1577	12.0	5.0	0.56	0.20	2.61	0.176	0.151
				0.0%	**0.0%**	**4.3%**	**25.0%**	**2.6%**	**0.0%**	**1.0%**	**1.1%**	**1.7%**
LD02	Surface	DUP	31-May-01	145	1090	34.0	7.0	0.01	0.05	1.74	0.124	0.062
LD02	Surface	REP	31-May-01	335	1076	29.0	10.0	0.01	0.05	1.54	0.141	0.031
				39.6%	0.6%	7.9%	17.6%	0.0%	0.0%	6.1%	6.4%	33.3%
			Average Percent Difference	**5.8%**	**0.5%**	**20.5%**	**25.7%**	**1.8%**	**7.6%**	**3.4%**	**9.7%**	**12.4%**

QA/QC data for blank samples

SITE	DEPTH	DATE	ALKA	TOT SOL	TSS	TVSS	AMMO	NIT	TKN	TOT P	TDP
LD01	Surface	31-Oct-00	3	3	0.5	0.5	0.01	0.05	0.18	0.003	0.004
LD01	Bottom	31-Oct-00	3	3	0.5	0.5	0.01	0.05	0.18	0.001	0.001
LD01	Surface	28-Dec-00	3	20	0.5	0.5	0.01	0.05	0.18	0.001	0.001
LD02	Bottom	15-Mar-01	3	9	0.5	0.5	0.01	0.10	0.18	0.001	0.001
LD02	Surface	15-Mar-01	3	3	0.5	0.5	0.01	0.05	0.18	0.001	0.001
LD02	Surface	3-Apr-01	3	13	0.5	0.5	0.01	0.05	0.18	0.001	0.001

Note: Shaded values indicate concentrations above detection limit.

Appendix F

Total Maximum Daily Load (TMDL) Summary

TOTAL MAXIMUM DAILY LOAD EVALUATION

For

Loyalton Dam

Dry Run Creek Watershed

(HUC 10160008)

Edmunds County, South Dakota

South Dakota Department of Environment and Natural Resources

7/2/2004

Loyalton Dam Total Maximum Daily Load

Waterbody Type: Lake (Impoundment)
303(d) Listing Parameter: TSI
Designated Uses: Recreation, Warmwater Marginal Aquatic Life
Size of Waterbody: 36 acres
Size of Watershed: 6,419 acres
Water Quality Standards: Narrative and Numeric
Indicators: Mean TSI, water chemistry
Analytical Approach: Models including AGNPS, BATHTUB, and FLUX
Location: HUC Code: 10160008
Goal: 10% reduction of external phosphorus load and 50% reduction of internal phosphorus load
Target: Mean TSI of 65

Objective

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

Introduction

Loyalton Dam is a 36-acre impoundment located within the James River Basin (HUC 10160008) in south central Edmunds County, South Dakota (Figure 1).

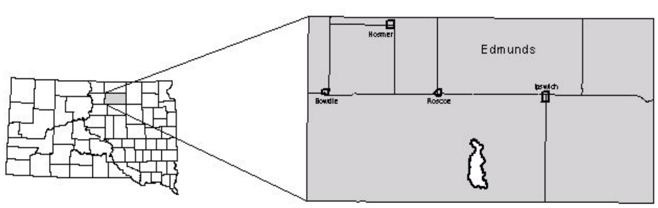


Figure 1. Location of the Loyalton Dam watershed in Edmunds County, South Dakota.

The lake reaches a maximum depth of 14.0 feet (4.3 m) and holds a total water volume of 214 acre-ft (at spillway elevation). The major inlet, Dry Run Creek, is located on the southeast side of the lake. Due to its shallow nature, the lake is not subject to stratification. The 1998 South Dakota 303(d) Waterbody List identified Loyalton Dam for TMDL development due to elevated trophic state index (TSI) values. Information supporting this listing was derived from statewide lake assessment data and the 1996 305(b) report.

Problem Identification

Dry Run Creek is the primary tributary to Loyalton Dam, and its watershed (6,419 acres) predominantly drains grazing and cropland acres (Figure 2). The stream carries sediment and nutrient loads, which degrade water quality in the lake and have caused increased eutrophication. An estimated 3,297 kg of phosphorus enter Loyalton Dam from the Dry Run Creek watershed annually.

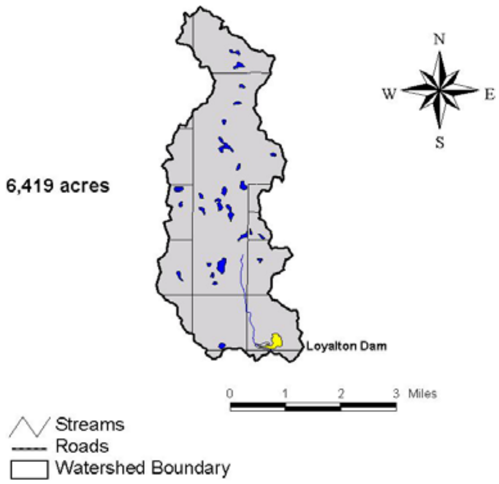


Figure 2. Loyalton Dam and Dry Run Creek watershed.

Loyalton Dam also experiences internal phosphorus loading from its sediment. This internal source will also be targeted for reductions.

Description of Applicable Water Quality Standards & Numeric Water Quality Targets

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

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

Individual parameters, including the lake's TSI value, determine the support of beneficial uses. Loyalton Dam experiences internal phosphorus loading from its sediments and external phosphorus loading from its watershed, which have caused its increasing eutrophication state. Loyalton Dam is identified in both the 1998 South Dakota Waterbody List and "Ecoregion Targeting for Impaired Lakes in South Dakota" as partially supporting its aquatic life beneficial use.

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

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

This protocol was used to assess impairment and determine a numeric target for Loyalton Dam. Loyalton Dam is currently considered partially-supporting its beneficial uses with a mean TSI of 68. The numeric target established to improve the trophic state of Loyalton Dam is a mean TSI of 65, which will require a 60% total reduction in phosphorus loading to the lake. A 60% reduction (10% reduction of external phosphorus load with watershed management plus a 50% reduction of internal phosphorus load with the alum treatment) will reduce the mean TSI by three points and improve the trophic level of the lake from a hyper-eutrophic to a eutrophic state that fully supports its beneficial uses.

Pollutant Assessment

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

Nonpoint Sources
A large portion of the nutrients delivered from the watershed were sediment bound. The AGNPS model estimated 66% of the total nitrogen and 84% of the total phosphorus delivered from the watershed was sediment bound. This indicates that erosion from cropland may be the major contributor of nutrients to Loyalton Dam.

Linkage Analysis
Water quality data was collected at two lake sites and two tributary sites (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 the State Health Laboratory in Pierre for analysis. Quality Assurance/Quality Control samples were collected on 10% of the samples according to South Dakota's EPA approved Non-point Source Quality Assurance/ Quality Control Plan. Details concerning water sampling techniques, analysis, and quality control are addressed in the assessment final report.

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

The impacts of phosphorus reductions on the condition of Loyalton Dam were calculated using BATHTUB, an Army Corps of Engineers model. The model predicted that reductions of phosphorus loadings to the lake by 60 percent would result in a reduction of mean TSI score by 3 points. This would lower the current mean TSI from 68 to 65, the TMDL target. This reduction would also change the trophic state of the lake from hyper-eutrophic to eutrophic.

TMDL Allocations

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

Load Allocations (LAs)
A 10% reduction of external phosphorus load to Loyalton Dam may be achieved through the implementation of BMPs including conservation tillage and grassed waterways. A 50% reduction of internal phosphorus load may be achieved through the application of aluminum sulfate (alum treatment).

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

Margin of Safety
The margin of safety is implicit as all total phosphorus reductions were calculated using conservative estimations of modeled best management practices (cover management factors and grassed waterways) as well as a conservative

estimation of the percent reduction of total phosphorus achieved with the alum treatment.

Critical Conditions

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

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. Edmunds County Conservation District board meetings
2. Dakota Central Conservation Association board meetings
3. Articles in the local newspapers

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

Implementation Plan

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

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
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APR - 2 2003

Ref: 8EPR-EP

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

Re: TMDL Approvals
Jones Lake
Loyalton Dam
Mina Lake
Rose Hill Lake

Dear Mr. Pirner:

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

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

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

In the course of developing TMDLs for impaired waters, EPA has recognized that not all impairments are linked to water chemistry alone. Rather, EPA recognizes that *"Section 303(d) requires the States to identify all impaired waters regardless of whether the impairment is due to toxic pollutants, other chemical, heat, habitat, or other problems."* (see 57 Fed. Reg. 33040 for July 24, 1992). Further, EPA states that "*...in some situations water quality standards – particulary designated uses and biocriteria – can only be attained if nonchemical factors such as hydrology, channel morphology, and habitat are also addressed. EPA recognizes that it is* *chemical parameters that are preventing the attainment of water quality standards.*" (see Guidance for Water Quality-based Decisions: The TMDL Process; USEPA; EPA 440/4-91-001, April 1991; pg. 4). We feel the State has developed TMDLs that are consistent with this guidance, taking a comprehensive view of the sources and causes of water quality impairment within each of the watersheds. For example, in several of the TMDLs, the State considered nonchemical factors such as trophic state index (TSI) and its relationship to the impaired uses. Further, we feel it is reasonable to use factors such as TSI as surrogates to express the final endpoint of the TMDL.

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

Sincerely,

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

Enclosure

APPROVED TMDLS

Waterbody Name*	TMDL Parameter/ Pollutant	Water Quality Goal/Endpoint	TMDL	Section 303(d)1 or 303(d)3 TMDL	Supporting Documentation (not an exhaustive list of supporting documents)
Jones Lake*	phosphorus	TSI mean ≤ 70.0	10% reduction in tributary phosphorus loads and 35% reduction of inlake phosphorous	Section 303(d)(1)	■ Phase I Watershed Assessment and TMDL Final Report, Jones Lake/Turtle Creek, Hand County, South Dakota (SD DENR, May 2002)
Loyalton Dam*	phosphorus	TSI mean ≤ 65	10% reduction in tributary phosphorus loads and 50% reduction of inlake phosphorous	Section 303(d)(1)	■ Phase I Watershed Assessment Final Report and TMDL, Loyalton Dam Watershed, Edmunds County, South Dakota (SD DENR, October 2002)
Mina Lake*	phosphorus	TSI mean < 79.18	38.8% reduction of total phosphorus load	Section 303(d)(1)	■ Phase I Watershed Assessment Final Report and TMDL, Mina Lake/Snake Creek, Brown, Edmunds and McPherson Counties, South Dakota (SD DENR, March 2002)
Rose Hill Lake*	phosphorus	TSI mean < 65	20% reduction in tributary phosphorus loads and 30% reduction of inlake phosphorous	Section 303(d)(1)	■ Phase I Watershed Assessment and TMDL Final Report, Rose Hill Lake/Sand Creek, Hand County, South Dakota (SD DENR, January 2002)

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

■ TMDL Checklist ■

EPA Region VIII

State/Tribe: South Dakota
Waterbody Name: Loyalton Dam, Edmunds County
Point Source-control TMDL: Nonpoint Source-control TMDL: X (check one or both)
Date Received: December 24, 2002 Date Review completed: January 24, 2003 VEB

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

■ TMDL Checklist ■

EPA Region VIII

State/Tribe: South Dakota
Waterbody Name: Rose Hill Lake, Hand County
Point Source-control TMDL: Nonpoint Source-control TMDL: X (check one or both)
Date Received: December 24, 2002 Date Review completed: January 24, 2003 VEB

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

State/Tribe: South Dakota Waterbody Name: Jones Lake, Hand County Point Source-control TMDL: Nonpoint Source-control TMDL: X (check one or both) Date Received: December 24, 2002 Date Review completed: January 24, 2003 VEB	
A. Water Quality Standards - **Approved**	The State's submittal provides a good description of the geographic scope of the TMDL as well as information on the watershed and land use characteristics of Jones Lake. The South Dakota Department of Environment and Natural Resources (SD DENR) has identified Jones Lake as a water that is intended to support a range of designated uses including: warmwater semipermanent fish life propagation, immersion recreation, limited contact recreation, fish and wildlife propagation, recreation and stock watering. The narrative standards being implemented in this TMDL are: "*Materials which produce nuisance aquatic life may not be discharged or caused to be discharged into surface waters of the state in concentrations that impair a beneficial use or create a human health problem.*" (See ARSD §74:51:01:09) "*All waters of the state must be free from substances, whether attributable to human-induced point source discharges or nonpoint source activities, in concentration or combinations which will adversely impact the structure and function of indigenous or intentionally introduced aquatic communities.*" (See ARSD §74:51:01:12)
B. Water Quality Standards Targets - **Approved**	Water quality targets for this TMDL are based on interpretation of narrative provisions found in State water quality standards. In May 2000, SD DENR published *Ecoregion Targeting for Impaired Lakes in South Dakota*. This document proposed ecoregion-specific targeted Trophic State Index (TSI) values based on beneficial uses. EPA approved the use of these ecoregion-specific targets to evaluate lakes using beneficial use categories. In South Dakota algal blooms can limit contact and immersion recreation beneficial uses. Also algal blooms can deplete oxygen levels which can affect aquatic life uses. SD DENR considers several algal species to be nuisance aquatic species. TSI measurements can be used to estimate how much algal production may occur in lakes. Therefore, TSI is used as a measure of the narrative standard in order to determine whether beneficial uses are being met. The overall mean TSI for Jones Lake during the period of the assessment (June 2000 through spring 2001) was 71.1. Nutrient reduction response modeling was conducted with BATHTUB, an Army Corps of Engineers eutrophication response model. The results of the modeling show that 70% or more reduction in the total phosphorous loading from the watershed would be necessary to meet the ecoregion-based beneficial use TSI target of 65 or less. However, Jones Lake does not appear to fit the ecoregion-based beneficial use criteria due to legacy phosphorous loading to the lake and the technical and financial inability to fully treat new loading to the lake. Therefore, a higher TSI target has been established for Jones Lake. The target used in this TMDL is: ▪ TSI mean less than 70 (growing season average)

State/Tribe: South Dakota Waterbody Name: Jones Lake, Hand County Point Source-control TMDL: Nonpoint Source-control TMDL: X (check one or both) Date Received: December 24, 2002 Date Review completed: January 24, 2003 VEB	
C. Significant Sources - **Approved**	The TMDL identifies the major sources of phosphorous as coming from nonpoint source agricultural landuses within the watershed and internal loading from bottom sediments within the lake. In particular, a loading analysis was done for nutrients and sediment considering various agricultural land use and land management factors.
D. Technical Analysis - **Approved**	The technical analysis addresses the needed phosphorous reduction to achieve the desired water quality. The TMDL recommends a 10% reduction in phosphorous loading from the watershed to Jones Lake, and a 35% reduction in sediment released phosphorous to achieve the desired results. This reduction is based in large part on the BATHTUB mathematical modeling of the Lake and its predicted response to nutrient load reductions. The Agricultural Non-Point Source Model (AGNPS) model was used to simulate alterations in land use practices and the resulting nutrient reduction response. The analysis of which nutrient loading sources were in need of control was based on a identification of targeted or "critical" cells. Cell priority was assigned based on average nutrient loads produced that ultimately reach the outlet of the watershed. Cells that produce nitrogen *and* phosphorous loads greater than two standard deviations over the mean for the watershed were given a priority ranking of 1. Cells that produce nitrogen *or* phosphorous loads greater than two standard deviations over the mean were given a priority ranking of 2. The initial load reductions under this TMDL will be achieved through controls on the priority 1 and 2 cells within the watershed combined with modification of grazing practices. The reduction in sediment released phosphorous will be possible through inlake treatments such as the application of alum.
E. Margin of Safety & Seasonality - **Approved**	An appropriate margin of safety is included through conservative assumptions in the derivation of the target and in the modeling. Additionally, ongoing monitoring has been proposed to assure water quality goals are achieved. Seasonality was adequately considered by evaluating the cumulative impacts of the various seasons on water quality and by proposing that BMPs be tailored to seasonal needs.
F. TMDL - **Approved**	The TMDL established for Jones Lake is a 10% reduction in annual tributary loading phosphorus and a 35% reduction in sediment released phosphorous. Since the annual loading varies from year-to-year, this TMDL is considered a long term average reduction in phosphorous loading.
G. Allocation - **Approved**	This TMDL addresses the need to achieve further reductions in nutrients to attain water quality goals in Jones Lake. The allocation for the TMDL was a "load allocation" attributed to nonpoint sources. The allocation for phosphorous was attributed to such sources as animal feeding areas, internal loading and cropland tillage. There is a desire to move forward with controls in the areas of the basin where there is confidence that phosphorous reductions can be achieved through modifications to priority 1 and 2 cells within the watershed combined with modification of grazing practices and modest reductions in sediment released phosphorous. Additional phosphorous load reductions are possible if all of the cropping and grazing uses were converted to conservation reserve program (CRP) use (i.e., 68% reduction in phosphorus), or through extensive inlake restoration activities. However, much of the cropland within the watershed is already following conservation tillage practices and complete conversion to CRP is unrealistic. The size and location of this lake would make it difficult to obtain local support and funding for extensive inlake restoration activities necessary to achieve significantly higher phosphorous load reductions.

H. Public Participation - **Approved**	The State's submittal includes a summary of the public participation process that has occurred which describes the ways the public has been given an opportunity to be involved in the TMDL development process. In particular, the State has encouraged participation through public meetings in the watershed, articles in local newspapers, individual contact with over 95% of the residents in the watershed, and widespread solicitation of comments on the draft TMDL. The State also employed the Internet to post the draft TMDL and to solicit comments. The level of public participation is found to be adequate.

State/Tribe: South Dakota Waterbody Name: Mina Lake, Brown, Edmunds and McPherson Counties Point Source-control TMDL: Nonpoint Source-control TMDL: X (check one or both) Date Received: December 24, 2002 Date Review completed: January 24, 2003 VEB	
A. Water Quality Standards - **Approved**	The State's submittal provides a good description of the geographic scope of the TMDL as well as information on the watershed and land use characteristics of Mina Lake. The South Dakota Department of Environment and Natural Resources (SD DENR) has identified Mina Lake as a water that is intended to support a range of designated uses including: domestic water supply, warmwater permanent fish life propagation, immersion recreation, limited contact recreation, fish and wildlife propagation, recreation and stock watering. The narrative standards being implemented in this TMDL are: "*Materials which produce nuisance aquatic life may not be discharged or caused to be discharged into surface waters of the state in concentrations that impair a beneficial use or create a human health problem.*" (See ARSD §74:51:01:09) "*All waters of the state must be free from substances, whether attributable to human-induced point source discharges or nonpoint source activities, in concentration or combinations which will adversely impact the structure and function of indigenous or intentionally introduced aquatic communities.*" (See ARSD §74:51:01:12)
B. Water Quality Standards Targets - **Approved**	Water quality targets for this TMDL are based on interpretation of narrative provisions found in State water quality standards. In May 2000, SD DENR published *Ecoregion Targeting for Impaired Lakes in South Dakota*. This document proposed ecoregion-specific targeted Trophic State Index (TSI) values based on beneficial uses. EPA approved the use of these ecoregion-specific targets to evaluate lakes using beneficial use categories. In South Dakota algal blooms can limit contact and immersion recreation beneficial uses. Also algal blooms can deplete oxygen levels which can affect aquatic life uses. SD DENR considers several algal species to be nuisance aquatic species. TSI measurements can be used to estimate how much algal production may occur in lakes. Therefore, TSI is used as a measure of the narrative standard in order to determine whether beneficial uses are being met. The overall mean TSI for Mina Lake during the period of the assessment (June 1999 through spring 2000) was 79.4. Nutrient reduction response modeling was conducted with BATHTUB, an Army Corps of Engineers eutrophication response model. The results of the modeling show that 94% or more reduction in the total phosphorous loading from the watershed would be necessary to meet the ecoregion-based beneficial use TSI target of 65 or less. However, Mina Lake does not appear to fit the ecoregion-based beneficial use criteria due to legacy phosphorous loading to the lake and the technical and financial inability to fully treat new loading to the lake. Therefore, a higher TSI target has been established for Mina Lake. The target used in this TMDL is: ▪ TSI mean less than 79.2 (growing season average) ▪ Phosphorous TSI less than 98.4

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C. Significant Sources - **Approved**	The TMDL identifies the major sources of phosphorous as coming from nonpoint source agricultural landuses within the watershed and internal loading from bottom sediments within the lake. In particular, a loading analysis was done by sub-watershed for nutrients and sediment considering various agricultural land use and land management factors.
D. Technical Analysis - **Approved**	The technical analysis addresses the needed phosphorous reduction to achieve the desired water quality. The TMDL recommends a 38.8% reduction in total phosphorous loading from watershed and sediment released phosphorous sources to Mina Lake. This reduction is based in large part on the BATHTUB mathematical modeling of the Lake and its predicted response to nutrient load reductions. The Agricultural Non-Point Source Model (AGNPS) model was used to simulate alterations in land use practices and the resulting nutrient reduction response. The analysis of which nutrient loading sources were in need of control was based on a identification of targeted or "critical" cells. Cell priority was assigned based on average nutrient loads produced that ultimately reach the outlet of the watershed. Cells that produce phosphorous loads greater than 1, 2, and 3 standard deviations over the mean for each sub-watershed were given a priority ranking of 1, 2 and 3 respectively. The initial load reductions under this TMDL will be achieved through controls on the priority 1 and 2 cropland cells within the watershed such as reducing fertilizer application rates and conversion to conservation tillage (i.e., minimum or no-till) practices. Controls at critical livestock feeding area combined with modification of grazing practices will also be necessary to achieve the desired results. The reduction in sediment released phosphorous will be possible through inlake treatments such as the application of alum.
E. Margin of Safety & Seasonality - **Approved**	An appropriate margin of safety is included through conservative assumptions in the derivation of the target and in the modeling. Additionally, ongoing monitoring has been proposed to assure water quality goals are achieved. Seasonality was adequately considered by evaluating the cumulative impacts of the various seasons on water quality and by proposing that BMPs be tailored to seasonal needs.
F. TMDL - **Approved**	The TMDL established for Mina Lake is a 38.8% reduction in total annual phosphorus loading from the watershed and sediment released sources. Since the annual loading varies from year-to-year, this TMDL is considered a long term average reduction in total phosphorous loading.
G. Allocation - **Approved**	This TMDL addresses the need to achieve further reductions in nutrients to attain water quality goals in Mina Lake. The allocation for the TMDL was a "load allocation" attributed to nonpoint sources. The allocation for phosphorous was attributed to such sources as cropland tillage, fertilizer application, animal feeding areas, and internal loading. There is a desire to move forward with controls in the areas of the basin where there is confidence that phosphorous reductions can be achieved through modifications to priority 1 and 2 cropland cells within the watershed combined with animal feeding area controls, modification of grazing practices and modest reductions in sediment released phosphorous. Additional phosphorous load reductions are possible if all of the cropping and grazing uses were converted to conservation reserve program (CRP) use and other drastic changes in land use and management. However, historic data indicate that Mina Lake has been hyper-eutrophic for the entire period of data collection (beginning in 1979). Therefore, the goal is to reverse the TSI trend. It would be technically and economically very difficult to implement enough BMPs within the watershed to achieve long term TSI values in eutrophic range.

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H. Public Participation - **Approved**	The State's submittal includes a summary of the public participation process that has occurred which describes the ways the public has been given an opportunity to be involved in the TMDL development process. In particular, the State has encouraged participation through public meetings in the watershed, articles in local newspapers, individual contact with landowners in the watershed, and widespread solicitation of comments on the draft TMDL. The State also employed the Internet to post the draft TMDL and to solicit comments. The level of public participation is found to be adequate.