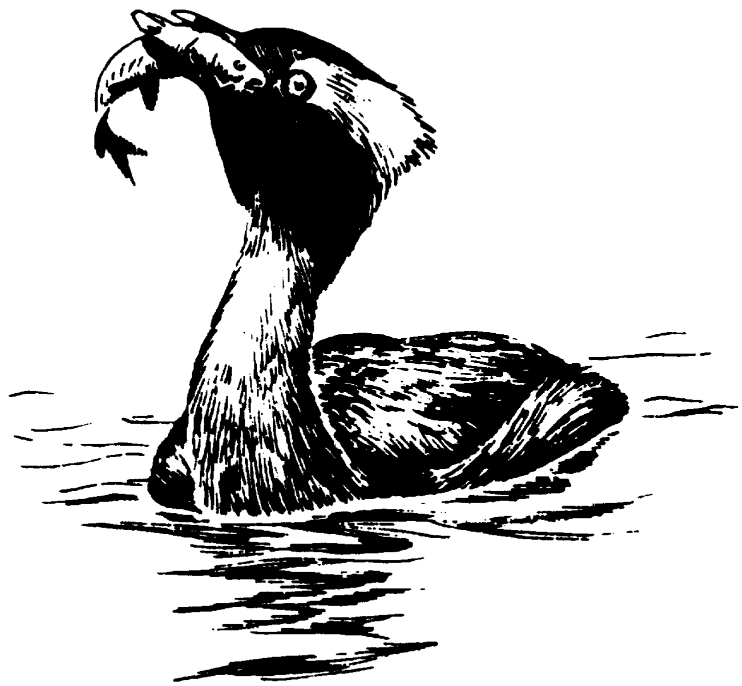
PHASE I
WATERSHED ASSESSMENT
FINAL REPORT

AMSDEN DAM RESERVOIR
&
MINNEWASTA LAKE
DAY COUNTY, SOUTH DAKOTA



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

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SECTION 319 TMDL
ASSESSMENT/PLANNING PROJECT FINAL REPORT

AMSDEN DAM RESERVOIR AND MINNEWASTA LAKE WATERSHED ASSESSMENT FINAL REPORT

By

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Sponsor

Day County Conservation District

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SD Department of Environment and Natural Resources – Water Rights Program

South Dakota Department of Game, Fish, and Parks

South Dakota Nonpoint Source Task Force

Water Resources Institute, South Dakota State University

Day County Conservation District

Natural Resources Conservation Service

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Abbreviations

AFO(s)	Animal Feeding Operation(s)
AnnAGNPS	Annualized Agricultural Non-Point Source Model
ATV	All Terrain Vehicle
BMP(s)	Best Management Practice(s)
° C	Degrees Celsius
CFS	Cubic Feet Per Second
DO	Dissolved Oxygen
EPA	Environmental Protection Agency
GPM	Gallons Per Minute
GPS	Global Positioning System
GRTS	Grant Reporting and Tracking System
MBE/WBE	Minority Business Enterprise/Women Business Enterprise
mg/L	Milligrams Per Liter
NRCS	Natural Resources Conservation Service
PIP	Project Implementation Plan
QA/QC	Quality Assurance/Quality Control
SD DENR	South Dakota Department of Environment and Natural Resources
SDGF&P	South Dakota Department of Game, Fish & Parks
su	Standard Units
TALKA	Total Alkalinity
TDPO4	Total Dissolved Phosphorus
TPO4	Total Phosphorus

TDSOL	Total Dissolved Solids
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load
TSI	Trophic State Index
TSOL	Total Solids
TSSOL	Total Suspended Solids
USDA	United States Department of Agriculture

Executive Summary

PROJECT TITLE: Amsden Dam and Minnewasta Lake Watershed Assessment Project

PROJECT START DATE: 9/1/2004 PROJECT COMPLETION DATE: 05/01/2006

FUNDING:	INITIAL BUDGET:	$113,800.00
	TOTAL BUDGET:	$113,800.00

TOTAL EPA GRANT:	$68,480.00
TOTAL EXPENDITURES OF EPA FUNDS	$32,689.06
TOTAL SECTION 319 MATCH ACCRUED:	$27,893.46
BUDGET AMENDMENTS:	N/A
TOTAL EXPENDITURES:	$60,582.52

SUMMARY OF ACCOMPLISHMENTS

The Amsden Dam Reservoir and Lake Minnewasta Watershed Assessment Project began in September 2004 and ended in October 2005 when data collection was complete. Milestones were met for sediment, macrophyte, and invertebrate sampling, in-lake water quality monitoring, and tributary stream flow data collection. Milestones for sampling several tributary monitoring sites were not met due to a lack of spring snowmelt. Only two tributary monitoring sites had perennial flow during the project period. Twenty active animal feeding operations (AFOs) were identified in the two watersheds and data for each AFO was entered into the AnnAGNPS model.

An EPA Section 319 grant ($68,480) provided 60% of the funding for the Amsden/Minnewasta project. The State of South Dakota provided 22% of the required match by awarding a $25,320 Natural Resources Fee Fund grant to the project sponsor. Local matching funds were to be used to meet the remaining 18% of the required match funds ($20,000).

In-lake and tributary water quality monitoring and watershed modeling resulted in the identification of several sources of nonpoint source pollutants affecting the quality of Amsden Dam Reservoir and Minnewasta Lake. Utilization of Best Management Practices (BMP) through an implementation and information and education will reduce nonpoint source loadings to both Amsden Dam Reservoir and Minnewasta Lake which will result in an improvement to lake trophic status. The primary goal of this project was to determine sources of impairment to the two water bodies and their watersheds, and provide sufficient background data to drive an implementation project. The goal was successfully achieved and interest has been shown for the development of an implementation project.

Introduction

Purpose

The purpose of this assessment was to determine the sources of impairments to Amsden Dam Reservoir and Lake Minnewasta, both located in Day County, South Dakota. Amsden Dam Reservoir and Lake Minnewasta were listed in the South Dakota 2006 Integrated Report. Both lakes were impaired for TSI based on their fishery classification standard.

General Lake Descriptions

Amsden Dam Reservoir

Amsden Dam is a man-made reservoir located in west central Day County (Figure 1). The reservoir was built in 1936 on Pickerel Creek, the lake's main tributary. Amsden Dam's surface area is 95 hectares (235 acres) with a maximum depth of 8.2 meters (27 feet) and a mean depth of 2.9 meters (9.4 feet). The reservoir has a shoreline length of 9.5 kilometers (5.9 miles).

There are no homes or commercial developments along the shoreline except for a small campground operated by the South Dakota Department of Game, Fish and Parks (SDGF&P). The majority of Amsden's shoreline is grazed to the waters edge or cropped with very little riparian buffer.

Amsden Dam's 32,000-acre watershed lies mainly in Day County with a small portion located in northern Clark County (Figure 1). Land use in the watershed is mainly agricultural with cropland typically planted to corn, bean, and wheat rotation. There are several thousand acres of native rangeland located on the west slope of the Coteau Des Prairie and on the steeper slopes of a large glacial moraine known as the Crandall-Crocker Hills. The Amsden Dam watershed is located within the larger James River Basin watershed.

Minnewasta Lake

Minnewasta is a natural lake with a historical surface area of 247 hectares (601 acres), a maximum depth of 4.3 meters (14 feet) and a mean depth of 3.2 meters (10.5 feet). There is 9 kilometers (5.5 miles) of shoreline.

The lake has one small development with nine cabins. In the future, the number of lakeshore homes could increase as agricultural land recently offered for sale is developed. If development of Minnewasta Lake's shoreline follows the trend of other lakes in northeast Day County, large four-season homes will be built on the new development and will eventually replace the small traditional one-season cabins that exist along the lakeshore.

The lake has a small immediate watershed of 2,564 acres. However, a topographic low area on the lake's south shore acts as both an inlet and outlet to Sunnybrook Slough which is connected hydrologically to the Rush Lake watershed (Figure 2). This low acts as an inlet or outlet depending on the water levels of either lake at a given time. There are no measurable tributaries draining in from the lake's watershed. The lake is recharged by a large subsurface aquifer. During periods of low water, the western end of the lake becomes separated from the main body by a gravel bar, forming two separate water bodies. The western basin of Minnewasta Lake has a clay-based shoreline while the main body has a predominately gravel shoreline. Due to the difference in shoreline materials, water quality parameters varied between the basins. Land use in the watershed is mostly agricultural.

Lake Identification and Location

Lake Name: ***Amsden Dam Reservoir***
State: South Dakota
County: Day
Township: 122N
Range: 59W
Sections: 19, 20, 30, 29
Nearest Municipality: Andover
Latitude: 45.358333
Longitude: -97.968333
Primary Tributary: Pickerel Creek
HUC Code: 10160005
EPA Region: VIII

Lake Name: ***Minnewasta Lake***
State: South Dakota
County: Day
Township: 122N
Range: 54W, 55W
Sections: 12, 7
Nearest Municipality: Waubay
Latitude: 45.390000
Longitude: -97.361667
Primary Tributary: none
HUC Code: 10160010
EPA Region: VIII

Amsden Dam Watershed

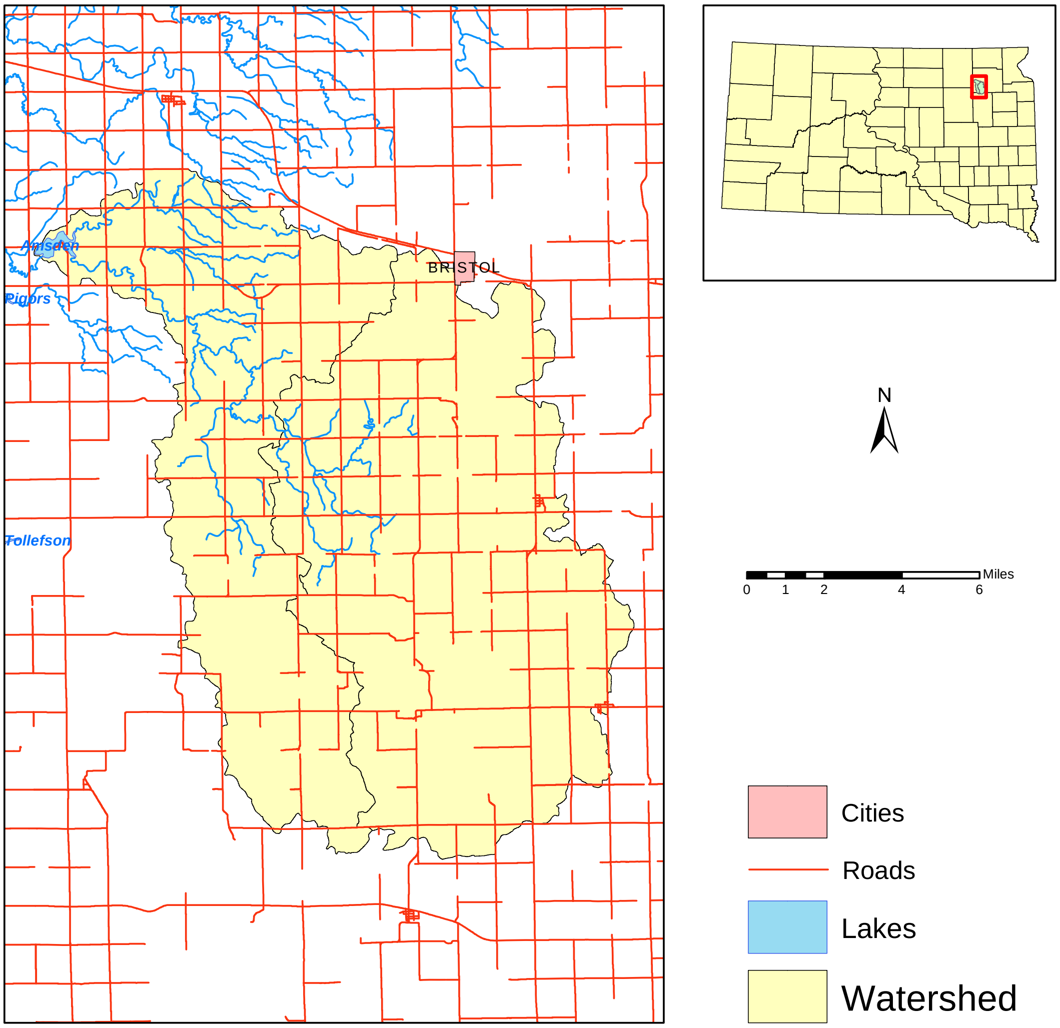

Figure 1. Amsden Dam Reservoir Watershed

Minnewasta Lake Watershed

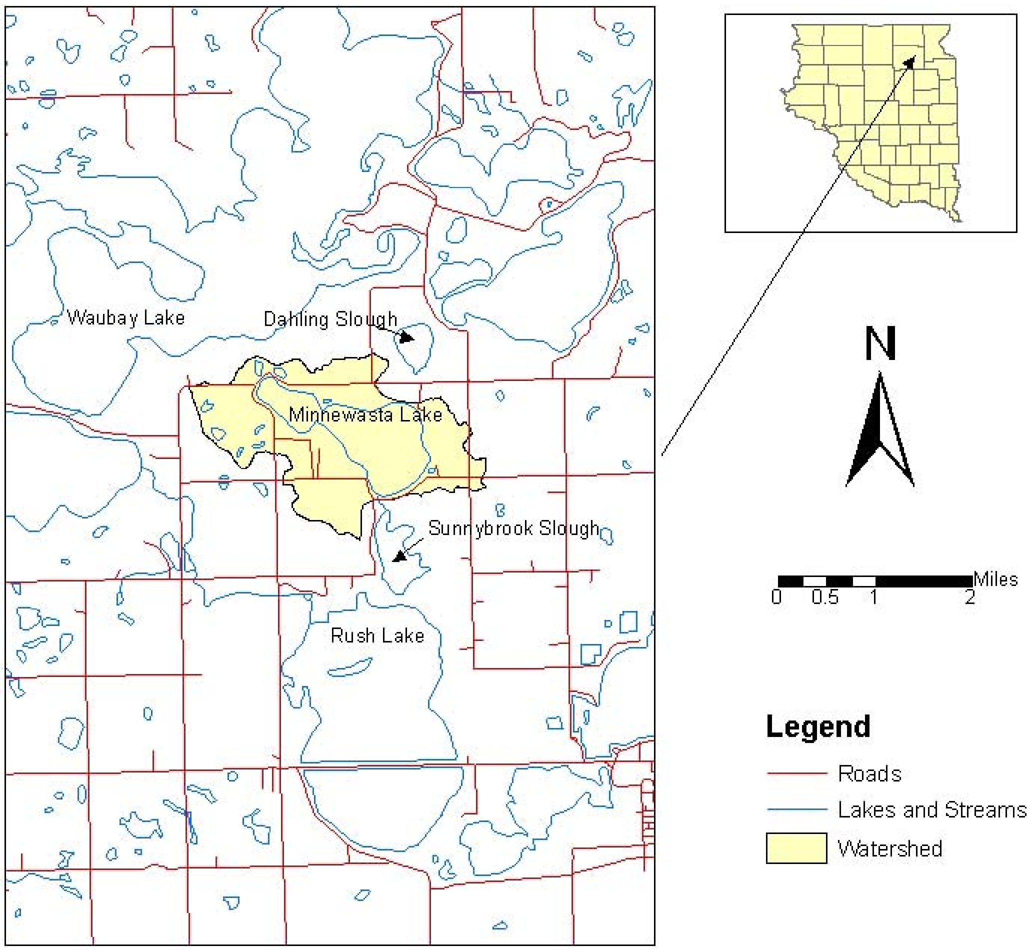

Figure 2. Minnewasta Lake Watershed

Trophic State Comparison

The Trophic State Index (Carlson, 1977) is a numerical value used to compare lake productivity or enrichment. The more productive or nutrient-rich a lake is, the more likely it will have water quality impairments that prevent it from meeting all of its beneficial uses. High TSI values (51-100) denote lakes that are eutrophic (highly productive) or hyper-eutrophic (excessively productive). Eutrophic and hyper-eutrophic lakes exhibit frequent and severe algal blooms and occasional winter (and sometimes summer) fish kills. Low TSI values (0-50) denote lakes that are comparatively nutrient poor. These lakes typically have water quality that meets all beneficial uses. Table 1 shows a comparison of median TSI combining chlorophyll *a* and Secchi disc transparency based on all available data.

Table 1. TSI Comparisons for Area Lakes and Reservoirs

Lake	Nearest Municipality	TSI	Mean Trophic State
Minnewasta Lake	Waubay	56.6	Eutrophic
Blue Dog Lake	Waubay	66.4	Hyper -eutrophic
Enemy Swim Lake	Waubay	51.1	Eutrophic
Pickerel Lake	Roslyn	51.1	Eutrophic
Reservoirs			
Amsden Dam	Andover	54.1	Eutrophic
Pierpont Lake	Pierpont	50.9	Eutrophic
Richmond Lake	Aberdeen	61.6	Eutrophic

Beneficial Use Assignment and Water Quality Standards

Each water body 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 water body. Water quality standards have been defined in South Dakota state statutes in support of these uses. These standards consist of a set of criteria that provide physical and chemical benchmarks from which management decisions can be developed (Table 2).

Amsden Dam Reservoir has been assigned the following beneficial uses:

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

Minnewasta Lake has been assigned the following beneficial uses:

(5) Warmwater semi-permanent fish life propagation waters;

(7) Immersion recreation waters;
(8) Limited contact recreation waters;
(9) Fish and wildlife propagation, recreation, and stock watering waters;

Table 2. State surface water quality standards for Amsden Dam Reservoir and Minnewasta Lake

Parameter	Standard	Use Requiring Standard
Alkalinity	< 750 mg/L[1] < 1313 mg/L[2]	(9) Fish, wildlife propagation, recreation and stock watering
Fecal coliform bacteria	< 400 colonies/100 ml < 2,000 colonies/100 ml	(7) Immersion recreation (8) Limited contact recreation
Conductivity	< 4,000 umhos/cm[1] < 7,000 umhos/cm[2]	(9) Fish, wildlife propagation, recreation and stock watering
Undissociated Hydrogen Sulfide	< 0.002 mg/L	(4) Warmwater permanent fish life propagation (5) Warmwater semipermanent fish life propagation
Unionized Ammonia	0.04[1]/1.75 x the criterion	(4) Warmwater permanent fish life propagation (5) Warmwater semipermanent fish life propagation
Nitrate as N	< 50 mg/L[1] or < 88 mg/L[2]	(9) Fish, wildlife propagation, recreation and stock watering
Dissolved Oxygen	$\geq$ 5.0	(4) Warmwater permanent fish life propagation (5) Warmwater semipermanent fish life propagation (7) Immersion recreation (8) Limited contact recreation
pH (standard units)	6.0 - 9.5 6.5 - 9.0	(9) Fish, wildlife propagation, recreation and stock watering (4) Warmwater permanent fish life propagation (5) Warmwater semipermanent fish life propagation
Suspended Solids	< 90 mg/L[1] <158 mg/L[2]	(4) Warmwater permanent fish life propagation (5) Warmwater semipermanent fish life propagation
Total Dissolved Solids	< 2,500 mg/L[1] <4,375 mg/L[2]	(9) Fish, wildlife propagation, recreation and stock watering
Temperature (°F)	< 80°F < 90° F	(4) Warmwater permanent fish life propagation (5) Warmwater semipermanent fish life propagation

[1] 30-day average, [2] daily maximum

Recreational Use

Amsden Dam Reservoir

Recreation and visitation to the reservoir includes swimming, water skiing, tubing, and jet skiing. None of these activities were observed during the assessment project. Amsden Dam is one of the few water bodies in South Dakota where fisherman can catch trophy size muskellunge (*Esox masquinongy*). Fishing appears to be the main recreational use of this water body.

Minnewasta Lake

Minnewasta Lake is located in the heart of the Glacial Lakes area of northeastern South Dakota. It is one of the least developed lakes in the area with less than a dozen seasonal cabins. The lake appears to have little recreational use other than by adjacent property owners and occasional fishermen. This may be due to a lack of public access with one small temporary boat ramp and dock and no vault toilets. A larger public use area located on the lake's north shore has not been accessible for several years due to high water conditions that flooded access roads in the mid–1990s. Recreational use will no doubt increase as lake access is improved and lakeshore development proceeds.

Geology

Both Amsden and Minnewasta watersheds lie atop high tableland. Early explorers named it the Coteau Des Prairie or Hill of the Prairies. The current topography of the Coteau was formed by the stagnation of glacial ice during the late Wisconsin glaciation approximately 12,000 years ago. As this glacier stagnated and began to break up and melt, large blocks of ice were buried in meltwater outwash. The melting of these ice blocks left depressions in the outwash of various size and depth that created thousands of potholes, sloughs, and lakes found on the Coteau Des Prairie.

Amsden Dam Reservoir

The majority of Amsden Dam's watershed lies atop of the Coteau which rises approximately 300 feet above the dam. The reservoir was built on Pickerel Creek, a small perennial stream whose main tributary flows through the remains of a large melt water channel formed as the stagnant ice of the Late Wisconsin glacier melted. This channel drained snowmelt from atop the Coteau into ancient Lake Dakota to the west, which became the James River Basin. Rothrock (1935) stated there were several empty lake basins in the Crandall-Crocker Hills; an area that comprises a majority of Amsden's watershed. Based on old beaches and other shoreline indicators, these basins held as much water in the past as the larger lakes in the eastern half of Day County. Rothrock's observations proved correct after several years of above average precipitation in the mid-1990s filled these basins; flooding farms, roads, and fields that had not experienced water in historical times.

The major soil associations found in the Amsden Dam watershed are Forman-Aastad-Parnell, Nutely, Kranzberg, Forman-Buse, Poinsett-Waubay, Renshaw-Fordville, and Peever-Caour. There are a variety of soil types represented in these associations. Most are well-drained and range from level to strong sloping and include clayey, silty and loamy, soils. Subsoils are glacial till, sand-gravel, or clay pan.

Minnewasta Lake

Minnewasta Lake was formed by an ice block deposited during the late Wisconsin glaciations.

The lake has extensive contact with the Eastern Lakes Subsystem aquifer (Leap, 1988). This aquifer typically surrounds each lake in the subsystem with a gravel apron. The gravel aprons are connected to each other by bodies of outwash sand. Since Minnewasta Lake has only a small immediate watershed, the Eastern Lakes Subsystem aquifer is the main source of recharge to the lake. The Eastern Lakes Subsystem aquifer includes the following water bodies described as the Waubay chain of lakes; North Waubay Lake, South Waubay Lake, Spring Lake, Hillebrands Lake, Minnewasta Lake, and Rush Lake.

The major soil associations found around Lake Minnewasta are Renshaw-Fordville-Sioux. There is a variety of soil types represented in these associations. Most are well drained to excessively drained, nearly level to steep loamy soils that are shallow, moderately deep, and very shallow over sand and gravel.

History

<u>Amsden Dam Reservoir</u>
Construction of Amsden Dam began in 1934 as a joint Works Program Administration (WPA) project between Day and Brown Counties. The dam was completed in 1936 and the reservoir was full by 1937. The reservoir is named after the original landowner, Arthur Amsden. Tragedy struck shortly after the reservoir filled in August 1937 when six people drowned during a picnic.

<u>Minnewasta Lake</u>
The name Minnewasta is reported to mean "good water." Historically, the majority of land along Minnewasta Lake has been utilized for agricultural purposes. The lake was completely dry in the early 1900s and again in 1936 when local farmers hayed the lake bottom. Several years of above normal precipitation in the mid-1990s resulted in increased surface elevations of this and several other lakes in what are described as the Waubay Lakes Chain (FEMA, 1999). The lake's surface elevation rose 9.2 feet from the fall of 1991 to the fall of 1998. The lake's surface area also increased from 734 acres in 1991 to 1,212 acres in 1998, an increase of 478 acres mainly due to its current connection to a large wetland on the lakes north shore. This flooding caused severe shoreline erosion and killed a majority of the trees along the lakeshore. The lake's surface elevation has since returned to 1799.1 msl, approximately three feet lower than the 1998 surface elevation.

Both Amsden Dam Reservoir and Minnewasta Lake have been listed as being impaired and not fully supportive of their beneficial uses. In 2003, the South Dakota Department of Environment and Natural Resources asked the Day County Conservation District to sponsor a watershed assessment project for Amsden Dam Reservoir. The District agreed to sponsor the project which began in September 2004. Early in 2004, the Project Implementation Plan (PIP) was amended to add an assessment of Minnewasta Lake. Due to the fact that both lakes have little lakeshore development or recreational use, there were no lake associations or other conservation groups interested in contributing financially to the project; though local support for water quality projects is high in the county. Personnel and student interns from the Water Resources Institute, located on the campus of South Dakota State University in Brookings, South Dakota, helped with in-lake sampling and macrophyte surveying. The Day County Conservation District has been active in Section 319 grant assessment and implementation projects since 1993.

Project Goals, Objectives, and Activities

Planned and Actual Milestones, Products, and Completion Dates

Objective 1: Determine Watershed Loadings to Amsden Dam Reservoir.

Task 1. Select a reference site.

No reference site was selected. DENR determined there were no representative sites in close proximity to the project for use as a reference.

Task 2. Develop the hydrologic load to Amsden Dam.

Stage recorders and staff gauges were placed in the field on August 30, 2004. Three Ott Thalimedes data loggers and one ISCO 4230 stage recorder were placed at four sites to record continuous tributary stage data. Tributary sites are shown in Figure 3 and directions to the sites are given in Table 3. A metal staff gauge was placed along the reservoir's outlet below Amsden Dam. However, beavers constructed several dams downstream, impounding water shortly after the project began. Outlet stage was recorded from the top of the dam's spillway for the duration of the project. A metal staff gauge was placed in the reservoir near the boat ramp to record lake surface elevations. Stage recorders and data loggers were downloaded no more than bi-weekly during the months the equipment was in the field. Stage recorders and data loggers were removed from the field on November 1, 2004 due to freeze-up. Stage recording equipment was placed back in the field on April 5, 2005 and removed on September 23, 2005.

Stages and flows were recorded weekly for base flows and during storm events. The number of stage and flow measurements recorded for each tributary site and outlet are as follows: outlet site ADT01 (31), tributary sites ADT02 (31), ADT03 (33), ADT04 (34), and ADT05 (13). A minimum of eight stage and flow measurements were required for each site. Sites ADT03 and ADT04 were located along the reservoirs main tributary, Pickerel Creek, which had a perennial flow during the project period. Site ADT02 was located on an intermittent tributary stream that flowed throughout the project period. Site ADT05 was located on an intermittent tributary that flowed only for a few weeks after heavy rainfalls in June 2005. Due to a lack of snowfall, there was no spring runoff.

Table 3. Amsden Watershed Tributary Site Location Descriptions

Site ID	Description
ADT01	Outlet to Amsden Dam
ADT02	1 mile east and 0.5 miles north of the lake
ADT03	1 mile east and 0.5 miles south of the lake
ADT04	3 miles east and 2 miles south of the lake
ADT05	5 miles east and 4.5 miles south of the lake

Task 3. Collect water chemistry samples at tributary sites in Amsden Dam Reservoir's watershed.

Water quality samples were collected from four tributary sites and one outlet site during the project. The total number of samples collected for each site are as follows: outlet site ADT01 (12 samples), tributary sites ADT02 (14 samples), ADT03 (13 samples), ADT04 (12 samples), and ADT05 (8 samples). The projects goal of thirteen samples per site was obtained at two sites, ADT03 and ADT04. These were the only tributary sites with perennial flow during the project period. Four sample sets were collected for Quality Assurance/Quality Control (QA/QC) purposes (sample set = 1 replicate and 1 blank). Samples were sent to the South Dakota State Health Lab in Pierre, SD for analysis. Due to a lack of snowfall, there was no spring runoff to sample but there were several storm events sampled during October 2004 and June 2005. A four-inch rainfall was recorded on the evening of June 28, 2005. This storm event caused considerable flooding in the lower reaches of the Amsden Dam watershed. Roads leading to the lake were inundated with water and impassable for several days following the storm.

Task 4. Collect discrete samples to help target nonpoint pollution sources.

Only two discrete grab samples were collected during the project. These samples were taken two miles upstream of tributary site ADT03 downstream of a large animal feeding operation (AFO) (Figure 32). This AFO is the probable source of high fecal coliform counts recorded during storm events. There were extremely high fecal coliform counts recorded at tributary site ADT05 but the project coordinator could find no identifiable upstream nonpoint sources or sites to sample. Samples were sent to the South Dakota State Health Lab in Pierre, SD for analysis.

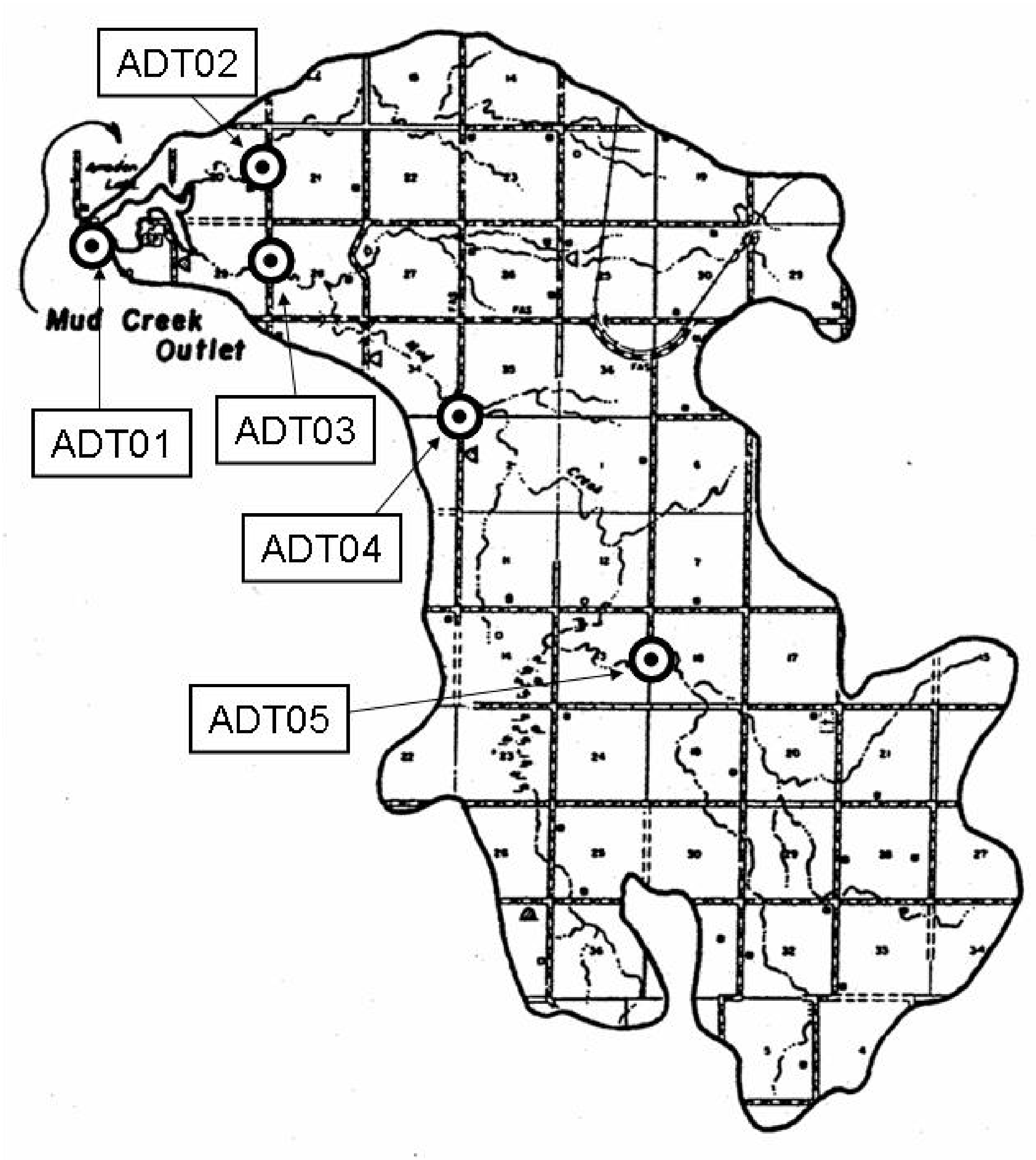

Figure 3. Amsden Watershed Tributary Monitoring Site Locations

Task 5. Collect biological samples at all reference and monitoring sites.

Benthic macroinvertebrate samples were collected from the two tributary sites that had perennial flows to support macroinvertebrate populations during the project period. Tributary sites ADT03 and ADT04 were sampled on September 6, 2004. A total of three composite samples were collected from transects located upstream of ADT03 and three upstream from ADT04. Samples were collected using a D-net following the protocol described in the SD DENR Standard Operating Procedures for Field Samplers, Volume II, Biological and Habitat Sampling. Benthic macroinvertebrates and periphyton samples were collected one time during the project period. The projects goal was to collect these parameters twice during the project period but as a cost-cutting measure, biological samples were collected only once. Identification and metric analysis of biological samples was contracted to Natural Resource Solutions, Brookings, SD who completed the analysis and provided voucher collections of macroinvertebrates and periphyton collected during the project. Phytoplankton was analyzed by staff from Water Resources Assistance Program in the Matthews Training Center Laboratory, DENR, Pierre, SD.

Objective 2: In-lake Data Collection

Task 6. In-lake water quality sampling – Amsden Dam Reservoir

Lake sampling of Amsden Dam Reservoir began in September 2004 and continued through October 2004. Due to unsafe ice conditions during the months of November and December, no further sampling occurred until January 2005 when ice conditions were favorable for sampling. Samples were collected through the ice during the months of January and February; unsafe ice conditions prevented sampling in March. Ice-out occurred early in April allowing in-lake sampling to begin by mid-April. Samples were collected once a month from September 2004 through May 2005. Samples were collected twice monthly during the moths of June, July, and August 2005. A total of 22 bottom samples and 26 surface samples were collected from two in-lake sites, AD06 and AD07 (Figure 4). Only surface samples were collected during the months of January and February. The project goal was to collect a total of 52 lake samples. Samples were sent to the South Dakota State Health Lab in Pierre, SD for analysis. Latitude/longitude locations for each sampling site are listed in Table 4.

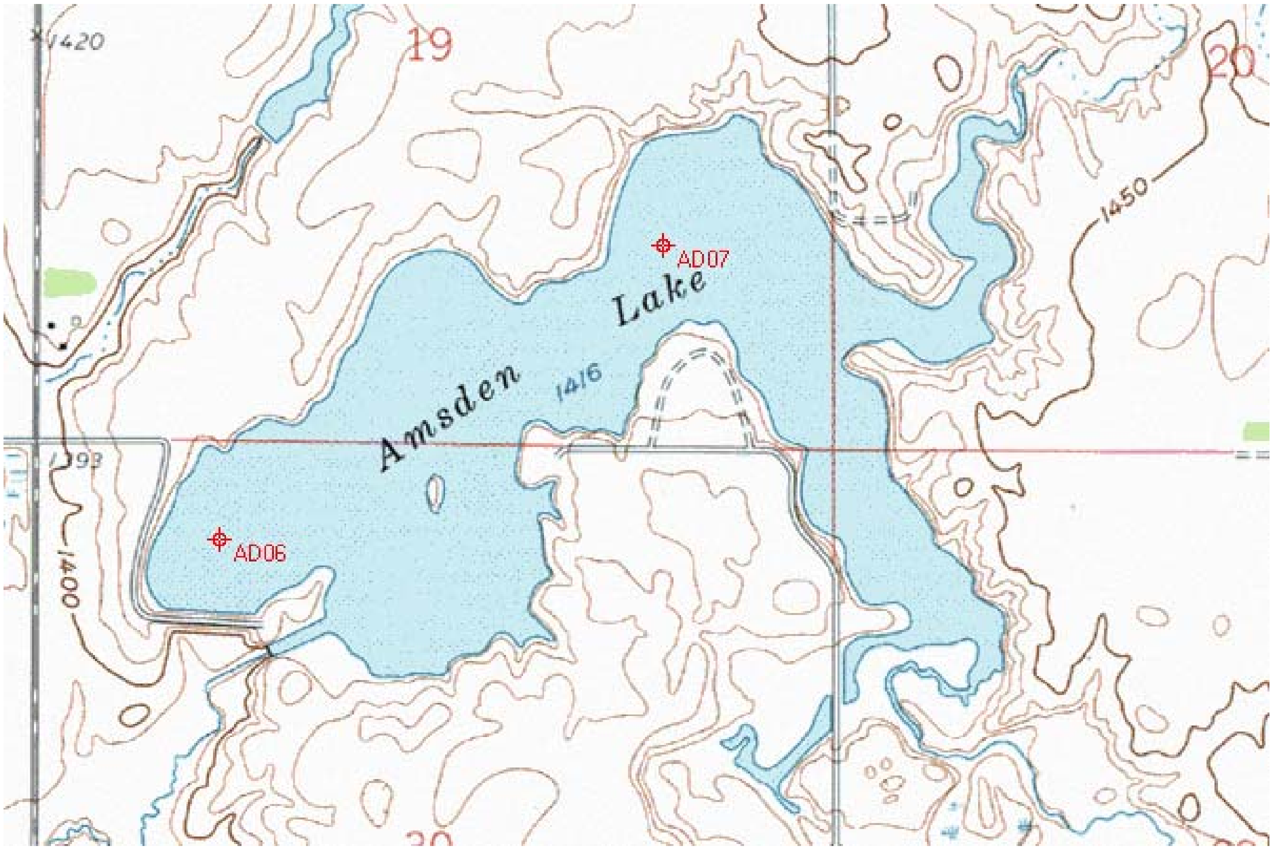

Figure 4. Amsden Dam Reservoir In-lake Sampling Sites

Task 6. In-lake water quality sampling – Minnewasta Lake

Lake sampling of Minnewasta Lake began in September 2004 and continued through October 2004. Due to unsafe ice conditions during the months of November and December no further sampling occurred until January 2005. Samples were collected through the ice during the months of January, February and March. Ice-out occurred early in April allowing lake sampling to begin again mid-April. Samples were collected only once a month from September 2004 through May 2005. Samples were collected twice monthly during June, July, and August 2005. A total of 4 bottom samples and 28 surface samples were collected from two in-lake sites, MW01 and MW02 (Figure 5). Only surface samples were collected after October 2004 due to the lake's shallow depth and as a cost-cutting measure. Three sample sets were collected for QA/QC purposes (sample set = 1 duplicate and 1 blank). The project goal was to collect a total of 52 in-lake samples. Samples were sent to the South Dakota State Health Lab in Pierre for analysis. Latitude/longitude for each sampling site are given in Table 4.

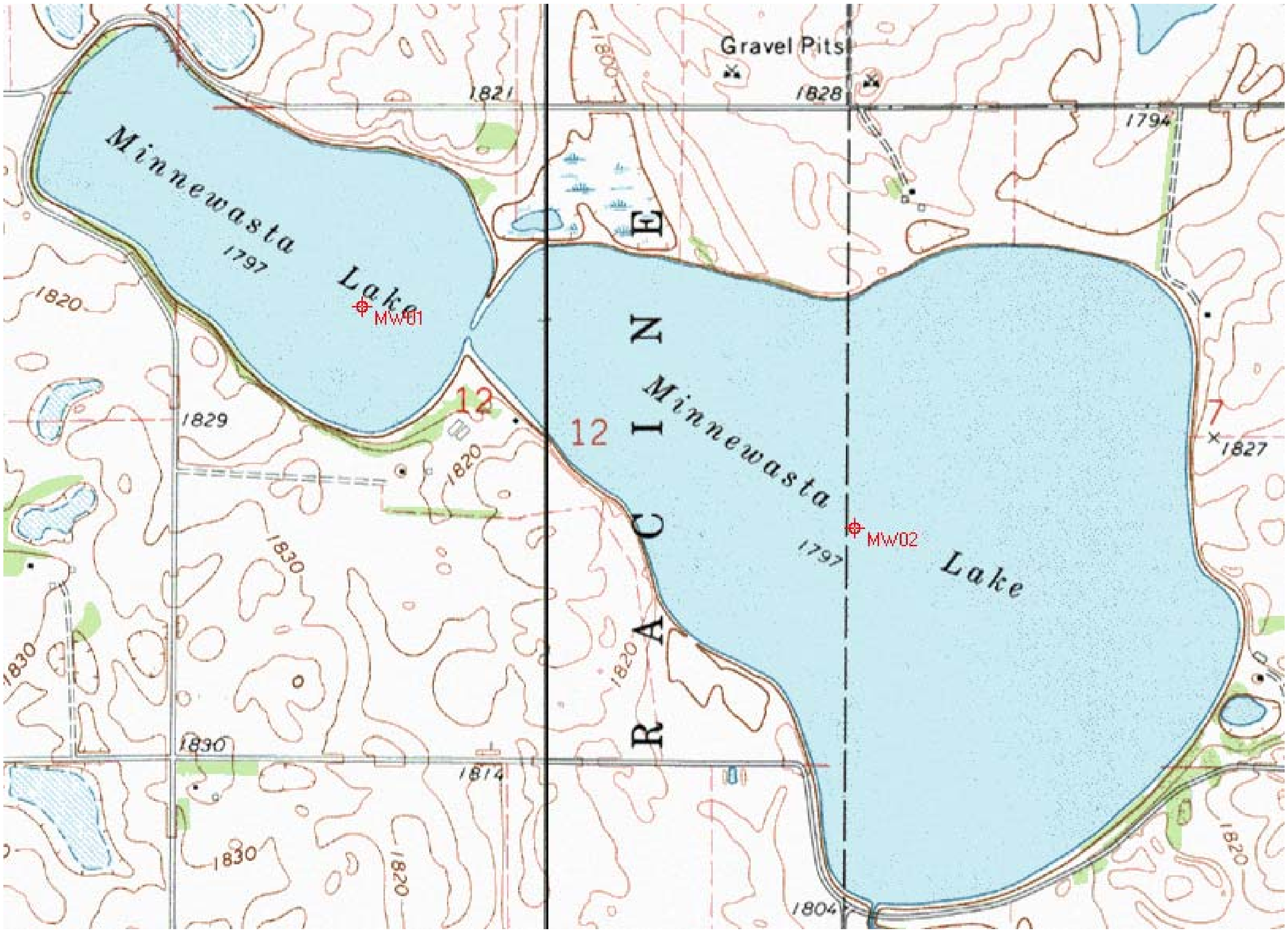

Figure 5. Minnewasta In-lake Sampling Sites

Table 4. Amsden Dam Reservoir and Minnewasta In-lake Sampling Site Locations and Depth

Waterbody	Sampling Site	Lat/Long	Maximum Depth (meters)
Amsden Dam Reservoir	AD06	45° 21' 16.4" / 97° 58' 32.7"	7.31 m
	AD07	45° 21' 35.5" / 97° 57' 51.7"	3.66 m
Minnewasta Lake	MW01	45° 23' 40.2" / 97° 22' 50.3"	4.27 m,
	MW02	45° 23' 22.8" / 97° 21' 55.5"	4.27 m

Task 7. Macrophyte/shoreline survey

Amsden Dam Reservoir
A macrophyte survey was conducted on August 2 and August 3, 2005. A total of 20 transects were sampled. Five species of submergent macrophytes were collected with coontail (*Ceratophyllum demersum)* being the most common aquatic plant collected. Other species observed include: *Potamogeton friesii, Potamogeton pectinatus, Potamogeton richardsonii*, and *Zosterella dubia*.

Minnewasta Lake
A macrophyte survey was conducted on July 26, 28, and 29, 2005. A total of 30 transects were sampled. Only two species of submergent macrophytes were collected with sago pondweed (*Potamogeton pectinatus)* being the dominant species. The only other species observed was a small patch of *Potamogeton richardsonii.* A large bloom of *Aphanizomenon* was observed in the summer during the survey.

Task 8. Elutriate sampling

One elutriate sample set was to be collected from Amsden Dam Reservoir and Minnewasta Lake during the project. As a cost-saving measure, only bottom sediment samples were collected on July 19, 2005 from each lake sampling site. Samples were sent to the South Dakota State Health Lab in Pierre, SD for analysis of total phosphorus concentrations.

Task 9. Historical sedimentation determination

Amsden Dam Reservoir
A sediment survey of Amsden Dam Reservoir was conducted on January 11, 2005. Eighty-four test holes were drilled through the ice at predetermined GPS locations to determine water and sediment depth present in the lake. Results indicate an average sediment depth of 0.73 meter (2.4 feet) occurs throughout the reservoir.

Minnewasta Lake
A sediment survey of Minnewasta Lake was conducted on January 12, 2005. Ninety-seven test holes were drilled through the ice at predetermined GPS locations to determine the lake's water and sediment depths. Results indicate an average sediment depth of 0.46 meter (1.5 feet) occurs throughout the lake.

Objective 3: QA/QC

Task 10. QA/QC sampling

Field water quality samples were collected in accordance with Standard Operating Procedures for Field Samplers distributed by the South Dakota Non-point Source Program. Replicate and blank samples were collected during the course of the project to provide defendable proof that sample data were collected in a scientific and reproducible manner. A minimum of 10 percent of all water quality samples needed to be QA/QC. There were a total of 139 samples collected from the Amsden Dam Reservoir and its tributaries, and Minnewasta Lake. Only 7 QA/QC samples were collected during the project, 3 in-lake and 4 tributary samples. The projects goal of 10 percent QA/QC was not met. All QA/QC samples were replicate samples.

Objective 4: AnnAGNPS Watershed Model Evaluation

Task 11. AnnAGNPS data collection

An evaluation of agricultural impacts to the water quality of Amsden Dam Reservoir from its watershed was undertaken utilizing the Annualized Agricultural Nonpoint Source (AnnAGNPS) model. AnnAGNPS is a comprehensive land use model that estimates sediment and nutrient loss and delivery, and evaluates the impacts of animal feeding operations (AFO). The watershed was divided into an appropriate number of cells. After collecting parameters for each cell that included soil type and slope, land use, and information on each AFO, the model was run to determine and locate areas that may be contributing nonpoint source pollutants in the reservoir's watershed. A feedlot survey was mailed to thirty-one producers to obtain data on the type and number of livestock in the Amsden Dam watershed. Twenty-three surveys were completed and returned to the project coordinator. Twenty-one active AFOs were located. Parameters for each AFO were entered into a database that calculated the input values for the AnnAGNPS model. Soils were checked and corrected for all AnnAGNPS cells. The model identified critical areas of nonpoint source pollution to Amsden Dam Reservoir. Critical areas identified by the model were used to determine attainable targets and goals of the TMDL.

Due to the small size of the Minnewasta Lake watershed, the AnnAGNPS model was not utilized to determine critical areas of nonpoint source pollution from agricultural land. The model was only used to calculate the effects of three AFOs located in this lake's watershed.

Objective 5: Public Participation

Task 12. Public meetings, news releases

Monthly project updates were given at the Day County Conservation District board meetings, which are open to the public. A news release describing the project was published in the local newspaper, Webster Reporter and Farmer. Project information was available at the Day County Conservation District's booth during the Webster Farm, Home, and Sports Show on January 14 and 15, 2005. Additional information was made available through news releases printed in the quarterly Day County Conservation District newsletters. Neither Amsden Dam Reservoir nor Minnewasta Lake had lake associations or other conservation groups to help sponsor or participate in the assessment project. A final meeting was held during the 2006 Webster Farm, Home, and Sports Show to report on the assessment study findings and to gather support for an implementation project. The project's goal of four public meetings and four news releases was met.

Amsden Dam Reservoir's watershed will be part of the Natural Resources Conservation Service's Conservation Security Program (CSP) in 2006. As Amsden watershed landowners visit the Webster USDA Field Office to apply for this program, they will be given a survey and information sheet to determine their conservation needs and willingness to participate in cost share programs that may be made available through a watershed implementation project.

Objective 6: Reporting

Task 13. Sponsor's reporting duties

The Day County Conservation District, the project sponsor, was responsible for reporting on the progress of the watershed assessments. The conservation district completed and submitted two annual and two semi-annual GRTS, and two MBE/WBE procurement reports to SD DENR. The district also submitted eight payment vouchers with documentation of project expenses and incurred local match and in-kind contributions.

Evaluation of Goal Achievements

The goal of the Amsden Dam Reservoir and Minnewasta Lake watershed assessments was to determine and document sources of impairment to the lakes and to develop feasible alternatives for restoration. The goals were accomplished through the collection of tributary and in-lake data aided by the completion of the AnnAGNPS watershed modeling tool. Through data analysis and modeling, identification of impairment sources was possible. Modeling and sampling found significant nonpoint pollution sources to both Amsden Dam Reservoir and Minnewasta Lake. Through the use of properly installed BMPs in these two watersheds cost-shared through an implementation project and other agencies conservation programs, problems found during the assessment can be resolved. Table 5 lists completion dates for all of the project's milestones.

Table 5. Proposed and Actual Milestone Completion Dates

Objective #	Proposed Completion Date	Actual Completion Date
# 1 Stream Sampling		
Task 1-Water Quality Analysis	October 2005	June 2005
Task 2- Macroinvertebate Sampling	October 2005	September 2004
Task 3- Periphyton Sampling	October 2005	September 2004
Task 4-Biomass (Ash-Free Dry Weight)	October 2005	September 2004
#2 Lake Sampling		
Task 5-Water Quality Analysis	September 2005	September 2005
Task 6-Elutriate	January 2005	Task Eliminated
#3 QA/QC		
Task 7-Water Quality Analysis	October 2005	September 2005
Task 8-Macroinvertebrate Sampling	October 2005	September 2004
Task 9-Periphyton Sampling	October 2005	September 2004
Task 10-Biomass (Ash-Free Dry Weight)	October 2005	September 2004
#4 Landuse Modeling		
Task 11-AnnAGNPS Date Collection	February 2005	October 2005
#5 Public Participation		
Task 12-Meetings and News Releases	November 2005	January 2006
#6 Reporting		
Task 13-Sponsor Duties	March 2006	March 2006

Monitoring Results

Surface Water Chemistry

Tributary Flow Calculations

A total of 5 tributary monitoring sites were selected for Amsden Dam Reservoir and its tributaries. Of the 5 monitoring sites, four sites were in-stream, and one outlet site located below the dam's spillway. The stream sites were selected to determine which portions of the watershed were contributing the greatest amount of nutrient and sediment load to Amsden Dam Reservoir. The stream sites were equipped with one Isco 4230 bubble-type stage recorder and three Ott Thalimedes recorders. Water stages were monitored and recorded to the nearest $1/100^{th}$ of a foot at each of the five sites. A Marsh-McBirney Model 210D flow meter was used in conjunction with a staff gage and stage recorders to measure flows at various water levels in Amsden's watershed. The stages and flows were then used to create a stage-to-discharge table for each monitoring site. Stage-to-discharge tables may be viewed in Appendix D of this report. There were no tributaries in the Minnewasta Lake watershed large enough to monitor.

The following is a brief summary for each tributary site in the Amsden Dam watershed:

ADT01
This tributary site is located on the outlet of the Amsden Dam Reservoir (figure 3). Water quality samples and flows were collected and recorded below the spillway. During periods of high flows when this site was not accessible, flow measurements were taken from the top of the spillway's concrete weir. A staff gage was placed on a bridge abutment downstream of the dam; however, this area became ponded after beavers built several small impoundments. Thereafter, outlet stage recordings were measured at the north end of the spillway from the top of the concrete weir. Twelve (12) water quality samples and thirty-one (31) stage and flow measurements were taken at this site.

ADT02
Site ADT02 was located on an intermittent stream one mile east and one half mile north of the Amsden Dam Reservoir (figure 3). An OTT Thalimedes data logger and staff gage were placed on the east side of the road next to the south culvert to record stream stage. Flows were measured approximately ten feet downstream of this culvert where the channel narrowed. During high flows, water passed through a second culvert adjacent to this site. Apparently, obstructions in the channel prevented flow through the north culvert during all but high tributary flows. On these occasions, flows were recorded from both channels and a composite water sample was collected. Fourteen (14) water quality samples and thirty-one (31) stage and flow measurements were recorded at this site. A large rain storm event on June 29, 2005, flooded roads leading to this site. High water dislodged the staff gage, which was never found, and tipped over the data logger. The data logger was reset and the staff gage replaced on July 20, 2005.

ADT03
Site ADT03 was located on a perennial stream one mile east and one half mile south of the Reservoir (figure 3). An ISCO 4230 stage recorder was placed on the east side of the road to record stream stage. Thirteen (13) water quality samples and thirty-three (33) stage and flow measurements were taken at this site. One AFO was located adjacent to this site and livestock were observed on several occasions utilizing the stream for watering in an adjacent pasture. One of the largest animal feeding operations in this watershed is located on an intermittent tributary upstream of ADT03. These AFOs may be the source of the high bacteria counts that were detected in several water samples collected during summer rainstorm events at this site.

ADT04
Site ADT04 was located on a perennial stream three miles east and two miles south of the Reservoir (figure 3). An OTT Thalimedes data logger and staff gage were placed downstream along the south wing wall of a box culvert bridge. Twelve (12) water quality samples and thirty-four (34) stage and flow measurements were taken at this site. Livestock in adjacent upstream and downstream pastures were observed in the stream bed on several occasions.

ADT05.
Site ADT05 was located on an intermittent stream five miles east and four and one half miles south of the Reservoir (figure 3). An OTT Thalimedes data logger was placed downstream on a bridge's north abutment. Only eight (8) water quality samples and thirteen (13) stage and flow measurements were taken at this site. The tributary below and downstream of the bridge was

ponded and downstream flow was not observed until stream stage reached a certain level. Some of the highest bacteria counts recorded during the assessment project were collected at this site during summer rainstorm events. The source of these bacteria may have been from either a leaching on-site septic system or a small hog barn located just upstream from the bridge. Other possible upstream sources were sought, however, none were found. This tributary passes through several upstream wetlands.

Tributary Load Calculations

Total nutrient and sediment loads were calculated with the use of the U.S. Army Corps of Engineers eutrophication model known as FLUX. FLUX uses individual sample data in correlation with daily average discharges to develop six loading calculations for each given parameter. As recommended in the application sequence, a stratification scheme and method of calculation was determined using the total phosphorus load. This stratification scheme is then used for each of the additional parameters. The stratification scheme and calculation methods used for Amsden Dam Reservoir are listed in the following table. Tributary water quality data collected for Amsden Dam Reservoir are found in Appendix C of this report.

Table 6. FLUX Calculation Methods

SITE	STRATIFICATION SCHEME	CALCULATION METHOD
ADT01	1 strata - Flow	IJC
ADT02	2 strata - Flow	Q WTD C
ADT03	2 strata - Flow	Q WTD C
ADT04	2 strata - Flow	IJC
ADT05	1 strata - Flow	IJC

Tributary Sampling Schedule

Water samples were collected at all five stream monitoring sites for Amsden Dam Reservoir from September 2004 through June 2005. Most samples were collected using the grab sample method. Water samples were then filtered, preserved, and packed in ice for shipping to the State Health Laboratory in Pierre, SD, for analysis.

The Laboratory analyzed the following parameters:

Fecal Coliform Counts
Total Solids
Total Suspended Solids
Nitrate
Total Phosphorus
Total Dissolved Phosphorus
E. coli Bacteria Counts
Alkalinity
Total Dissolved Solids
Ammonia
Total Kjeldahl Nitrogen (TKN)
Volatile Total Suspended Solids
Un-ionized Ammonia

Personnel conducting the sampling at each of the sites recorded visual observations of weather and tributary characteristics:

Precipitation
Odor
Water Depth
Water Color
Wind Speed
Film
Ice Cover
Dead Fish

Parameters measured in the field by sampling personnel were:

Stream stage and flow
Air Temperature
Field pH
Water Temperature
Dissolved Oxygen

In-Lake Sampling Schedule

Lake sampling of Amsden Dam Reservoir and Minnewasta Lake began in September 2004 and continued through September 2005. Both water bodies were sampled in the morning hours, Minnewasta Lake from 8:00 to 9:00 A.M. and Amsden Dam Reservoir from 10:00 to 11 A.M. (CST) the same day. There were two pre-selected sampling sites on each water body (Figures 4 and 5). Water samples were collected once a month during the months of September through May and twice monthly June through August. Only surface samples were taken from Minnewasta Lake after October 2004 and during the months of January and February on Amsden Dam Reservoir. Water samples were taken to the Day County Conservation District office where they were filtered, preserved, and packed in ice for shipping to the State Health Lab in Pierre, SD. Lake water quality data for Amsden Dam Reservoir and Minnewasta Lake are given in Appendices A and B.

The Laboratory analyzed the following parameters:

Fecal Coliform Bacteria
Total Solids
Ammonia
Total Kjeldahl Nitrogen (TKN)
Total Volatile Suspended Solids
E coli/Enterococci
Alkalinity
Total Suspended Solids
Nitrate
Total Phosphorus
Total Dissolved Phosphorus

Personnel conducting the sampling at each in-lake site recorded visual observations of the following weather and lake characteristics:

Precipitation
Odor
Film
Ice Cover
Wind Speed
Dead Fish
Water Color

Parameters measured in the field by sampling personnel were:

Water Temperature
Dissolved Oxygen
Air Temperature
Sample Depth

Field pH
Secchi Depth
Total Water Depth

Seasonal Loading

During the project period, seasonal loadings to Amsden Dam were heavily influenced by early summer runoff. Table 7 depicts the percentage of discharge occurring in the watershed that entered the lake at different times of the sampling season. As shown in the Table below, in 2004 and 2005 almost all of the seasonal loading came during the summer. BMPs implemented during an implementation project for the Amsden Dam watershed should be designed with maximum protection to the lake during the summer months. However, spring and fall should also be taken into consideration due to the year-to-year variability in the pattern of rainfall and snowfall in the area.

Due to a lack of tributaries in the Lake Minnewasta watershed, there is no seasonal loading data from tributary sites. Instead, average inlake total phosphorus concentrations by season are illustrated in Table 8 below.

Table 7. Estimated Seasonal Loading for Amsden Dam.

Date (2004 and 2005)	Days	Total Phosphorus Seasonal Discharge (kg)	Seasonal Percent of Total Discharge
Fall 2004	85	121.9	2.03%
Spring 2005	92	309.7	5.16%
Summer 2005	92	5,543.1	92.42%
Fall 2005	22	23.1	0.39%
TOTAL	291	5,997.8	100%

Table 8. Seasonal Average Total Phosphorus Concentrations for Lake Minnewasta.

Date (2004 and 2005)	Number of Samples	Average Total Phosphorus Inlake Concentrations (mg/L)
Winter	4	0.190
Spring	6	0.128
Summer	12	0.077
Fall	6	0.165

In-Lake Water Quality Parameters

Water Temperature

Water temperature is of great importance to any aquatic ecosystem as it can affect chemical and biological processes. Many organisms are temperature sensitive. Blue-green algae tend to dominate the warmer waters of summer while green algae and diatoms are more prevalent in the cooler waters of spring and fall. Water temperature also affects physical/chemical processes.

Cooler water has the capacity to hold more dissolved oxygen than warm water. Warm water can also increase the un-ionized fraction of ammonia that, if high enough, can cause fish kills.

Amsden Dam Reservoir

Surface water temperature in Amsden Dam Reservoir exhibited little variation from site AD06 to AD07. The highest surface temperature recorded was 25.5 ^{o} C at site AD07 on August 8, 2005. This is below the state standard that requires a maximum temperature of equal to or less than 26.7^{o} C. The single lowest surface water temperature 1.5° C was recorded just below the surface of the ice at site AD07 on February 24, 2005. As expected, the highest dissolved oxygen level in Amsden Dam Reservoir was recorded at 16.1 mg/L. on this date. There was a weak thermal stratification observed at site AD06 from June through early August 2005. The temperature difference from surface to bottom ranged from 2 to 4° C during these months. Site AD06 was located at the reservoir's deepest part of 7.3 meters (24 feet). No stratification was observed at site AD07 due to its shallow depth of 3.7 meters (12 feet).

Minnewasta Lake

Surface water temperature in Minnewasta Lake exhibited little variation from site MW01 to MW02. The highest surface temperature of 24.0 ^{o} C was recorded at both sampling sites on August 8, 2005. This reading is below the state standard that requires a maximum temperature of equal to or less than 32.2^{o} C. The single lowest surface water temperature 0.8° C was recorded just below the ice on January 25, 2005. As expected, the highest dissolved oxygen level in Minnewasta Lake was recorded at 14.3 mg/L. on this date. There was no thermal stratification observed during the project, probably due to Minnewasta's shallow depth and the fact that wind and wave action kept the lake's water column mixed. Ammonia levels (Figure 13) were below detection limits during the highest summer temperatures, preventing any problems with un-ionized ammonia.

Surface water temperatures for both Amsden Dam Reservoir and Minnewasta Lake showed seasonal variations that are consistent with their geographic location in the Northern Great Plains, steadily increasing in spring and summer and consistently decreasing in fall and winter (Figures 6 and 7). Due to its lower elevation, Amsden Dam Reservoir had slightly higher year-round surface temperatures than Minnewasta Lake. It can be expected that during most years, lake surface temperatures will be within a few degrees of those observed during the project on their respective dates.

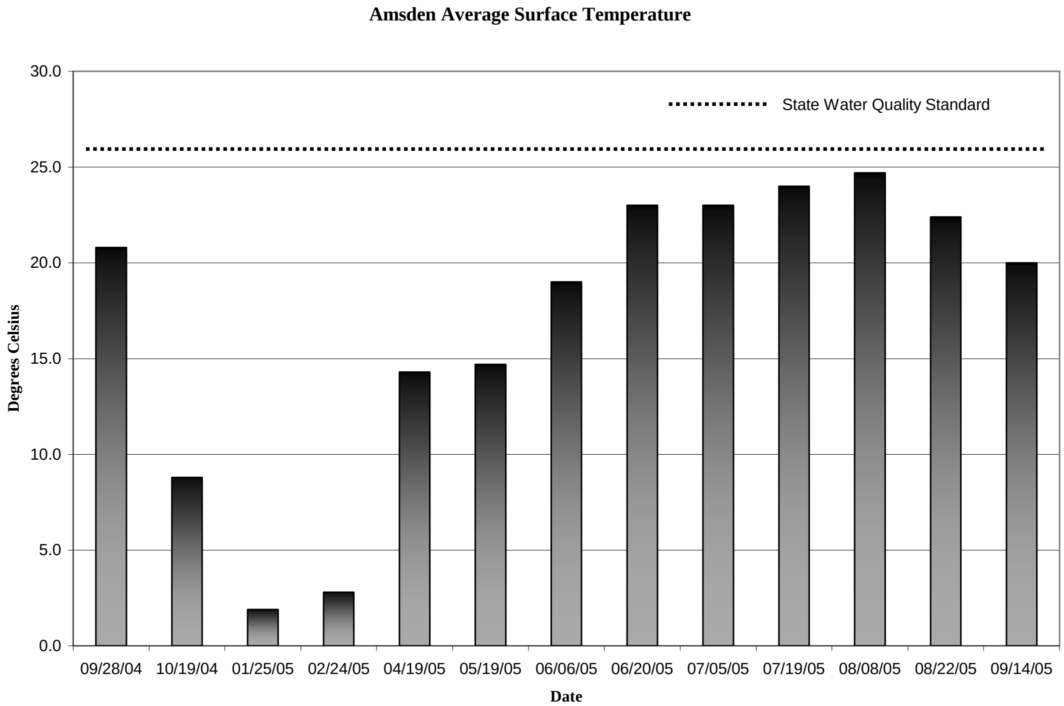

Figure 6. Amsden Dam Reservoir Average Daily Surface Temperatures

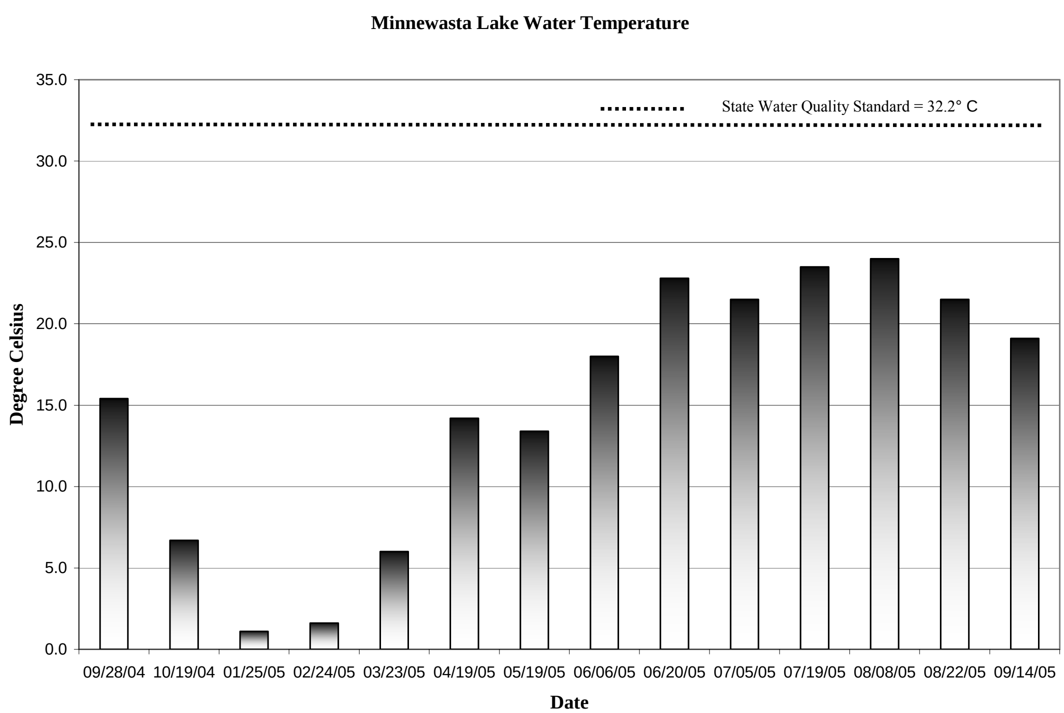

Figure 7. Minnewasta Lake Daily Average Surface Temperatures

Dissolved Oxygen

Dissolved oxygen (DO) is one of the more important water quality parameters in regard to the health and diversity of aquatic organisms in a lake. Lakes with good oxygen concentrations throughout the year are more likely to have a diverse population of aquatic organisms than lakes with low oxygen concentrations. Lakes with poor DO usually lack diversity and stability, and are dominated by a few hardy species.

Many factors can influence DO concentrations in a water body. Daily and seasonal fluctuations in DO may occur in response to algal and bacterial action (Bowler, 1998). As algae photosynthesize during daylight hours, they produce oxygen that raises the concentration in the epilimnion. As photosynthesis ceases at night, respiration utilizes available oxygen causing a decrease in DO concentration. During winters when heavy snow covers ice, light penetration in a lake may be reduced to the point that photosynthesis ceases and algae and aquatic macrophytes cannot produce enough oxygen to keep up with consumption (respiration) rates. This can result in oxygen depletion that may lead to a winter fish kill.

Dissolved oxygen concentrations can also affect chemical parameters in a lake. When anoxic conditions form in a lake's benthic zone or bottom due to the complete lack of DO; dissolved phosphorus, ammonia, hydrogen sulfide and other undesirable substances are released from lake sediments into the water column. Dissolved phosphorus can contribute to algal growth when stratified lakes turn over or shallow non-stratified lakes are mixed by wind. Ammonia and hydrogen sulfide can be toxic to aquatic organisms if present in sufficient concentrations.

<u>Amsden Dam Reservoir</u>

Dissolved oxygen levels in Amsden Dam Reservoir at site AD06 ranged from 4.9 mg/L to 13.5 mg/L on the surface and 1.4 mg/L to 11.3 mg/L on the bottom. DO levels at site AD07 ranged from 5.1 mg/L to 16.1 mg/L on the surface and 5.3 mg/L to 11.4 mg/L at or near the bottom. The highest surface DO levels of 16.1 mg/L. (AD07) and 13.5 mg/L. (AD06) were recorded on February 24, 2005. On this date a heavy diatom bloom was noted and may explain the high DO levels recorded just below the ice. Six DO levels fell below the state standard of 5.0 mg/L in one surface sample and five bottom samples (Figure 8). All of these were recorded at site AD06 near the reservoir's dam where water depths are deepest at 7.3 meters (24 feet). The five bottom DO levels recorded below state standards ranged from 1.4 mg/L to 4.8 mg/L. These low DO levels were recorded during a slight thermal stratification observed during the months of June, July, and early August 2005. The reservoir may have stratified during this period due to algal blooms and/or the dark-stained water that was prevalent throughout the reservoir after a four inch rainfall. Elevated levels of total phosphorus during this same period indicate the reservoir's benthic zone at site AD06 was anoxic (Figure 14). As stated above, anoxic conditions will release phosphorus from a lake's sediment. Although DO levels were low at or near the bottom of site AD06 during June, July and August 2005, the remainder of the reservoir's water column had DO levels sufficient enough to meet state standards and maintain a healthy fishery. One surface DO level was recorded at 4.9 mg/L, just below the state standard. On September 14, 2005, low DO levels were recorded at both sampling sites throughout the water column probably due to an algal die-off and/or fall turnover. DO levels on this date ranged from 4.6 mg/L to 5.1

mg/L at site AD06 and 5.0 mg/L to 5.4 mg/L at site AD07. All DO levels recorded during the project for Amsden Dam Reservoir are given in Appendix A.

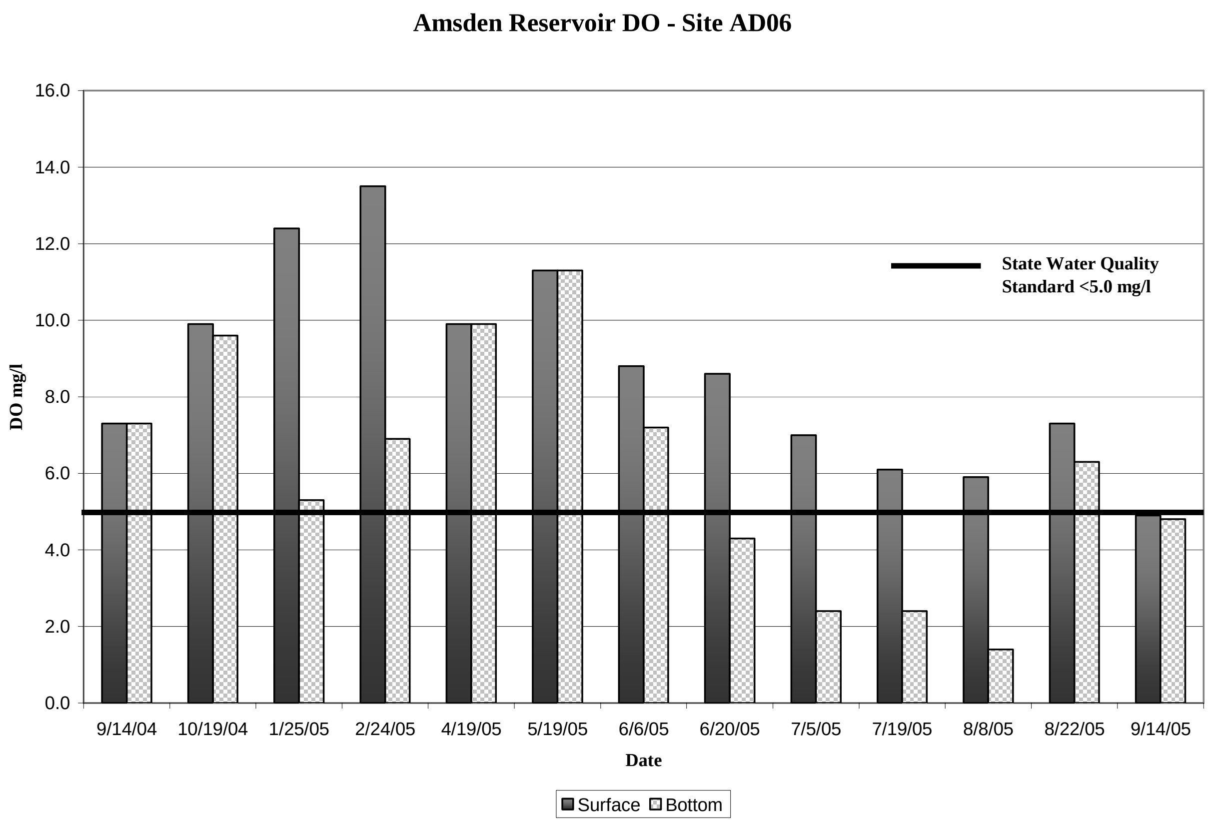

Figure 8. Amsden Dam Reservoir Dissolved Oxygen

<u>Minnewasta Lake</u>

Dissolved oxygen levels in Minnewasta Lake at site MW01 ranged from 5.3 mg/L to 11.7 mg/L on the lake's surface and 5.3 mg/L to 11.3 mg/L on the lake's bottom. DO levels at site MW02 ranged from 5.3 mg/L to 14.3 mg/L on the lake's surface and 5.6 mg/L to 13.7 mg/L on the lake's bottom. All DO levels recorded during the project were above the state standard of 5.0 mg/L. DO levels showed the lake's water column was well-mixed throughout the project period with little difference between surface and bottom DO concentrations. This mixing is due to the lake's shallow depth, and, during all but the winter months, the effect of wind and waves on the water column.

The DO levels of both water bodies showed expected seasonal variations due to temperature. The lowest DO levels were recorded during the months of June through August when water temperatures were warmest. The highest DO levels were recorded during the winter months when water temperatures were at their coldest. There was very little snow cover on Amsden Dam Reservoir during the project period. In contrast, there was moderate snow cover observed on Minnewasta Lake all winter, although not heavy enough to inhibit the production of oxygen in the water column.

pH

pH is a measure of free hydrogen ions (H+) or potential hydrogen. Simply stated, it indicates the balance between acids and bases in a water body. pH is measured on a logarithmic scale between 0 and 14 and is recorded as standard units (su). Each pH point represents a 10-fold increase or decrease in hydrogen ion concentration. At neutrality (pH of 7) acid ions (H+) equal the base ions (OH-). Values less than 7 are considered acidic (more H+ ions) and greater than 7 are basic (more OH- ions).

Biological and chemical processes in a lake or reservoir can decrease pH. The decomposition of organic matter in a lake's benthos releases carbon dioxide into the water column. This carbon dioxide reacts with the water and is converted to carbonic acid, decreasing a lake's pH. The extent to which this process affects pH is determined by a lake's alkalinity. High alkalinity (>200 mg/L.) in a water body represents a considerable buffering capacity that will reduce any large fluctuations in pH caused by decomposition. Most aquatic plants and organisms (especially fish) are sensitive to acidity and will not survive at a pH below 6.0 su.

The state standard for pH on both Amsden Dam Reservoir and Minnewasta Lake is 6.0 to 9.5 su. All pH measurements taken during the project were within state standards. The relatively high alkalinity (>200 mg/L.) of Amsden Dam Reservoir and Minnewasta Lake buffer these two water bodies from any dramatic changes in pH. All pH measurements taken during the project for Amsden Dam Reservoir are given in Appendix A, and Appendix B for Minnewasta Lake.

Amsden Dam Reservoir
Surface pH measurements in Amsden Dam Reservoir ranged from 8.07 to 8.83 with an average pH of 8.53. Bottom pH measurements ranged from 7.88 to 8.82 with an average pH of 8.47. There were no seasonal pH variations observed.

Minnewasta Lake
Surface pH measurement in Minnewasta Lake ranged from 8.40 to 8.93 with an average pH of 8.72. There were no bottom pH measurements taken due to the lake's shallow depth. No seasonal variations in the lake's measured pH were observed. Sampling site MW01 had slightly lower pH measurements than site MW02 during the assessment.

Alkalinity

Alkalinity measures the water's capacity to neutralize acids. Alkalinity exists due to the complex interaction of several compounds in water that include bicarbonates, carbonates, and hydroxides. In natural environments alkalinity usually ranges from 20 to 200 mg/L (Lind,1985) and is dependant on local soils. An alkalinity of >200 mg/L will buffer changes in a lake's pH caused by increased or decreased acids.

Amsden Dam Reservoir
The alkalinity in Amsden Dam Reservoir varied from a minimum concentration of 177 mg/L in July to a maximum concentration of 309 mg/L recorded in January (Appendix A). The average alkalinity was 246 mg/L with a median of 245 mg/L.

Minnewasta Lake
The alkalinity in Minnewasta Lake varied from a minimum concentration of 355 mg/L in August to a maximum concentration of 509 mg/L. in February (Appendix B). The average alkalinity was 427 mg/L with a median of 432 mg/L.

Secchi Depth

Secchi depth is a measure of lake transparency or clarity. Secchi depth is measured using a Secchi disk, a 20 cm (8 in) or larger diameter metal or plastic disk with alternating black and white colored quadrants. The disk is lowered into the water until it is no longer visible. The point where the disk disappears is called the Secchi depth. Secchi depth is measured in meters or feet, usually by attaching a measuring tape to the disk. Secchi depth is one of the parameters used to determine the Trophic State Index (TSI) of a water body. The TSI of a lake indicates whether the body is nutrient-rich or nutrient-poor. Low Secchi depth measurements are typically due to algal blooms or high suspended sediments and may indicate a eutrophic or hyper-eutrophic TSI.

Amsden Dam Reservoir
The deepest Secchi depth readings for Amsden Dam Reservoir were recorded on January 25, 2005 (Figure 9). On this date, the Secchi depth reached to the bottom at both sampling sites. Secchi depths were recorded at 7.32 meters (24 feet) at site AD06 and 3.66 meters (12 feet) at site AD07. The lowest Secchi depth recorded was 1.22 meters (4 feet) which occurred just four weeks later on February 24 , 2005 at site AD07. The increased turbidity observed at both sampling sites on this date was due to a large diatom bloom, the result of several weeks of above average temperatures and clear ice that promoted algal growth. Secchi depths improved through early June. After a four-inch rainfall on June 14, 2005, the reservoir's water became stained, reducing transparency. All Secchi depths measured during the project are given in Appendix A.

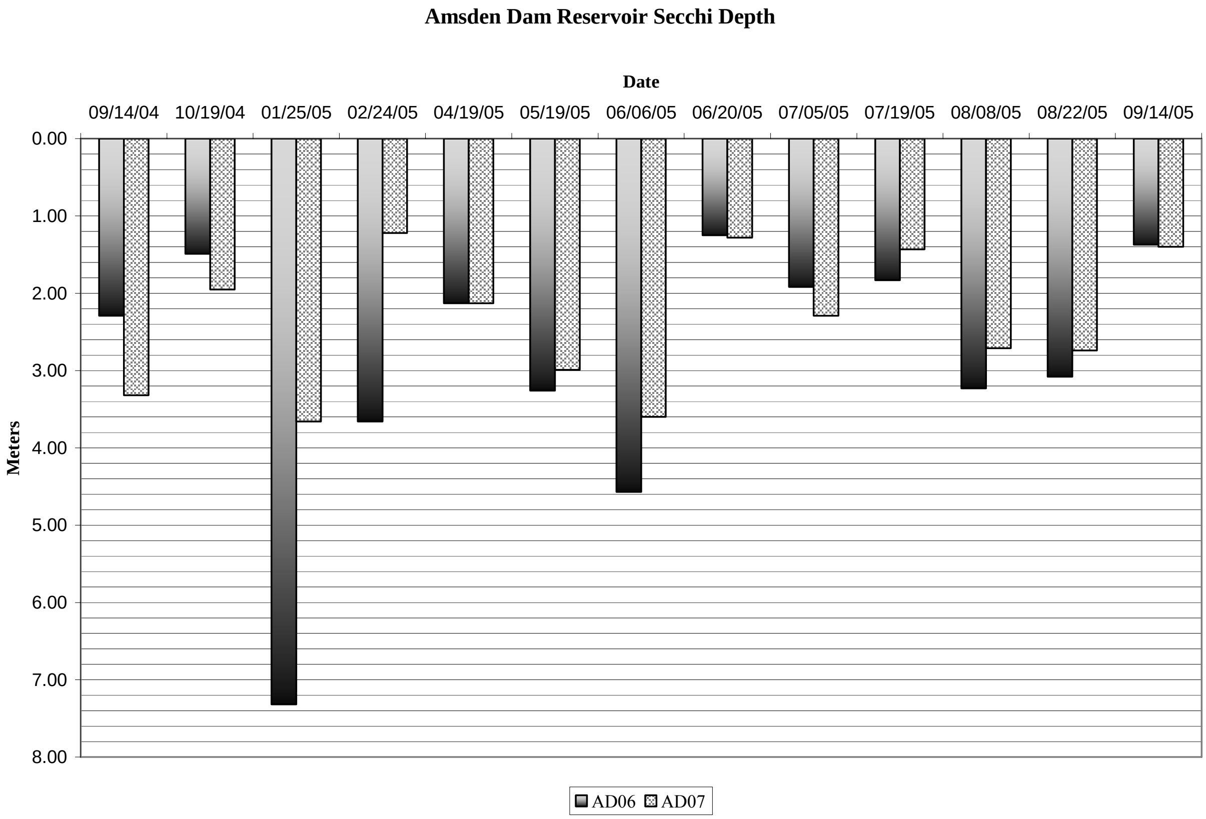

Figure 9. Amsden Dam Reservoir Secchi Depths

<u>Minnewasta Lake</u>

On January 25, 2005, the Secchi depth reached the bottom of Minnewasta Lake at 4.5 meters (15 feet). The lowest Secchi depth was 0.49 meter (1.6 ft.) recorded on two dates in July. These low depths were a result of an extensive algal bloom observed across the entire lake. Site MW01 typically had lower Secchi depths than site MW02 due to higher turbidity (Figure 10). The high turbidity at this site was caused by re-suspended sediments due to wind and wave action. The shoreline around this portion of Minnewasta Lake is predominately clay in contrast to the main body of the lake which has gravel banks. Suspended solids at site MW01 averaged 10 mg/L. higher than site MW02 on dates when MW01 had lower Secchi depths. Secchi depths in Minnewasta Lake followed the expected seasonal trends with lower Secchi depths observed during the summer months when algal production is highest, to greater Secchi depths recorded during the winter months when algal production is low. All Secchi depths measured during the project are given in Appendix B.

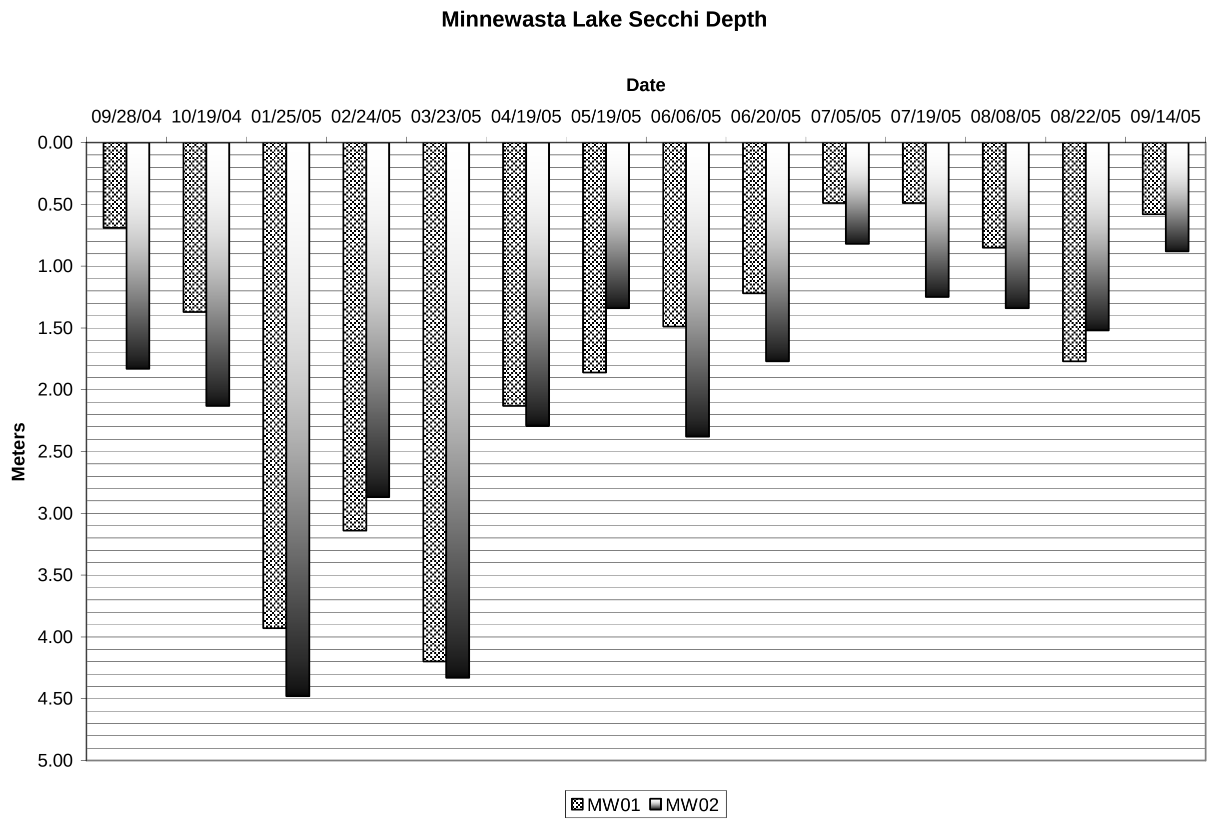

Figure 10. Minnewasta Lake Secchi Depths

Solids

Solids are represented by four parameters in the assessment; total solids, total dissolved solids, suspended solids, and volatile suspended solids. Total solids are the materials, suspended and dissolved, present in a given volume of water. Suspended and dissolved solids are made up of organic and inorganic materials. Total dissolved solids are the material in a water sample that will pass though a 0.45 micron filter. Suspended solids are comprised of larger material like soil, algae, and other organic matter that will not pass through a filter. Total dissolved solid concentrations are derived by subtracting the suspended solid value from the total solid value. Suspended volatile solids (VTSS) are a measurement of organic matter in a sample that burns in a 500° C furnace.

Suspended solids are deposited on the bottoms of stream channels and lakes in the form of silt. Excessive silt deposition can destroy aquatic habitats and reduce the diversity of organisms inhabiting a lake or stream. Siltation can also fill a lake basin leading to reduced water depth, increased turbidity and water temperature, and an increase in the growth of aquatic macrophytes and nuisance algae.

Amsden Dam Reservoir

Suspended solids ranged from 2 mg/L to 17 mg/L in surface samples and from 2 mg/L to 20 mg/L in bottom samples. Total dissolved solids ranged from 788 mg/L to 1583 mg/L in surface samples and 801 mg/L to 1451 mg/L in bottom samples. All suspended solids and total dissolved solids samples were below state standards for these parameters (Appendix A).

Total solids declined from approximately 1400 mg/L to 1000 mg/L between June 6, 2005 and June 20, 2005. This decline was probably caused by dilution from high tributary flows following a 4-inch rain on June 14, 2005. Total dissolved solids declined further in July as high tributary flow continued.

Minnewasta Lake

Suspended solids ranged from 1 mg/L to 35 mg/L in surface samples collected from Minnewasta Lake (Appendix B). Total dissolved solids ranged from 1199 mg/L to 1856 mg/L in surface samples. All suspended solids and total dissolved solids samples were below the state standard. The suspended solids at site MW01 were higher than site MW02 in 69% of the samples (Figure 11). This is probably due to sediment being re-suspended by wind and wave action. Field notes recorded during sample collection indicated the presence of non-algal turbidity on several sampling dates. Exposed clay, especially on the north shoreline of the west basin, was observed during aquatic plant surveys in 2005. The bottom sediments in these shallow littoral areas adjacent to the clay banks are soft and may be easily suspended by wave action. In contrast, the shallow sediments in the east basin are more consolidated. This was also evident by the lower Secchi depths observed at site MW01 (Figure 10).

The highest concentrations of total solids in both lakes were observed during periods of ice cover. When ice forms, minerals in the water are excluded from the ice and therefore become more concentrated in the water column under the ice.

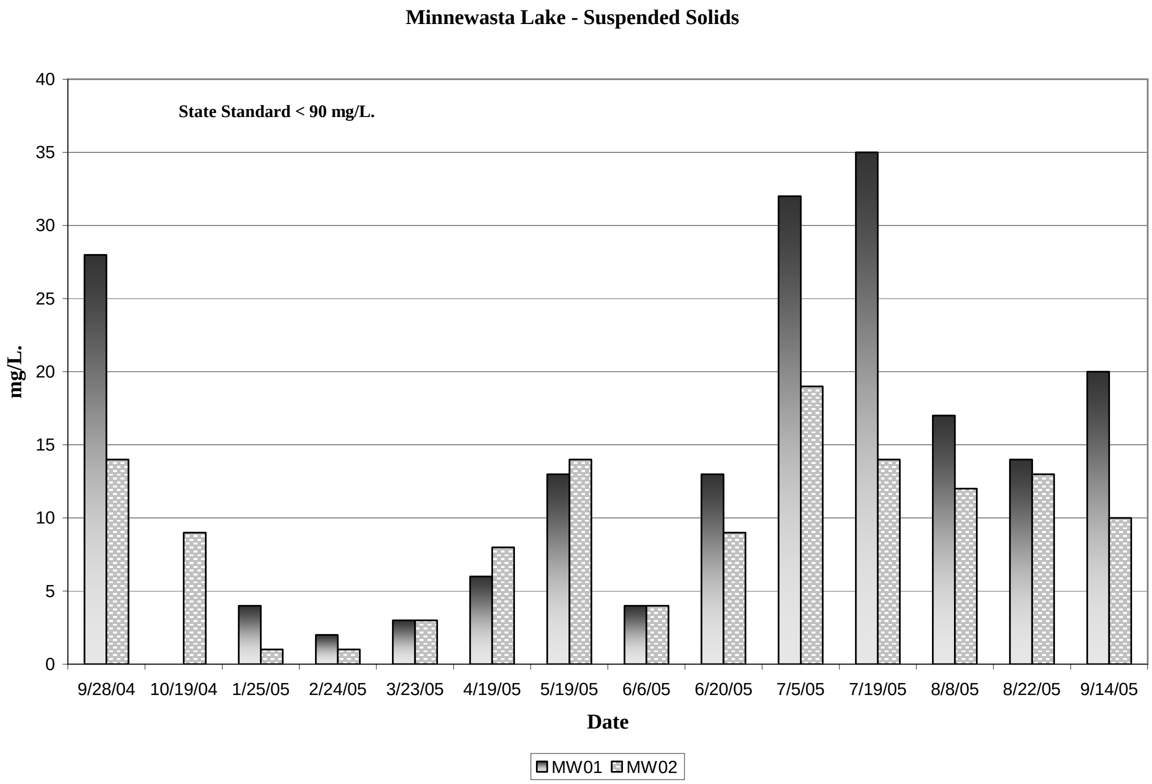

Figure 11. Minnewasta Lake Suspended Solids

Nitrogen

Nitrogen was analyzed in three forms: nitrate/nitrite, ammonia, and Total Kjeldahl Nitrogen (TKN). From these three forms, total, organic, and inorganic nitrogen may be calculated. Nitrogen compounds are major cellular components of organisms. Because its availability may be less than the biological demand, environmental sources may limit productivity in freshwater ecosystems. Nitrogen is difficult to manage because it is highly soluble and very mobile. In addition, some blue-green algae fix atmospheric nitrogen, adding it to the nutrient supply in the lake.

Ammonia is a form of nitrogen produced by bacterial decomposition. This nutrient is readily available for plant growth, especially algae. Ammonia is produced by decaying organic matter in a lake's benthos and by bacterial conversion of other nitrogen compounds found in the lake. Decomposing bacteria in a lake's sediment and some blue-green algae species in the water column are able to convert free nitrogen (N^2) to ammonia. Algae can assimilate several forms of nitrogen; however their growth rate will greatly increase when ammonia is available (Wetzel, 1983). Animal feeding operations and anhydrous fertilizer applied on cropland are two possible sources of ammonia from watershed runoff. The South Dakota State Health Laboratory cannot detect ammonia levels below 0.02 mg/L.

Amsden Dam Reservoir

Ammonia concentrations in Amsden Dam Reservoir surface samples ranged from below the detection limit of 0.02 mg/L on several dates to 0.35 mg/L on September 14, 2005 (Appendix A). In bottom samples, ammonia concentrations ranged from below detection limit on several dates to 0.77 mg/L at AD06 on July 19, 2005 (Figure 12).

A small spike of ammonia was observed in the surface sample at AD07 on June 20, 2005 (Figure 12). Since adequate oxygen was present, the source of this ammonia may have been from watershed runoff. Larger spikes of ammonia were observed in bottom samples from AD06 in July and August (Figure 12). The source of these ammonia spikes was probably due to sediment release of ammonia due to low oxygen concentrations (Figure 8) on these dates. Ammonia concentrations in all samples in September were approximately 0.35 mg/L. Increased ammonia in September may be a combination of decay of organic matter deposited from the watershed during high flows in June and July and senescence of algae and macrophyte populations as the water cooled. There were no ammonia violations in Amsden Dam during the sampling period.

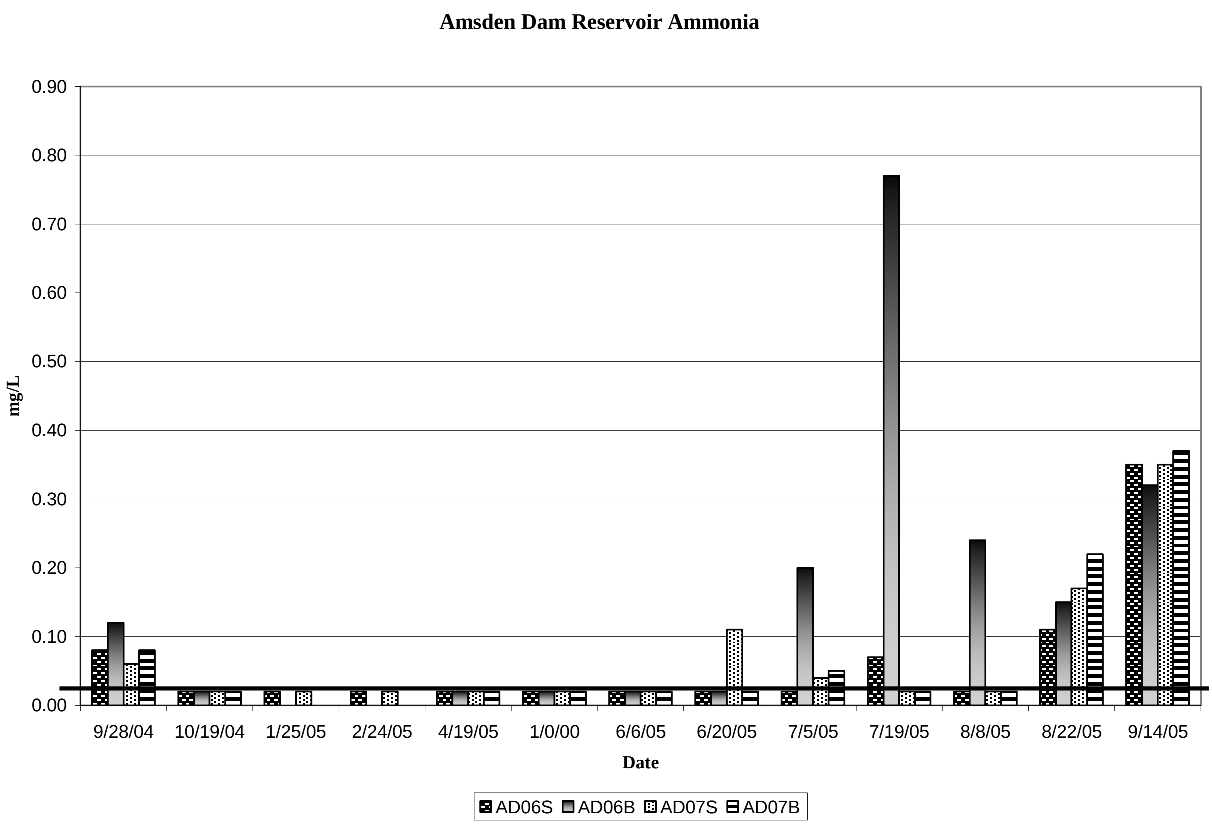

Figure 12. Amsden Dam Reservoir Ammonia

Minnewasta Lake
There was no evidence of sediment release of ammonia in Minnewasta Lake in 2005 (Figure 13). Concentrations of DO remained above 5 mg/L on all sampling dates (Appendix B). Temporary stratification and low oxygen concentrations could have occurred between sampling dates but it apparently did not cause the release of ammonia beyond what the algae and macrophytes could utilize. Elevated concentrations of ammonia (Figure 13) observed in September and October of 2004 and September 2005 were probably associated with senescence and decay of algae and macrophyte populations. There were no ammonia violations in Minnewasta Lake during the sampling period.

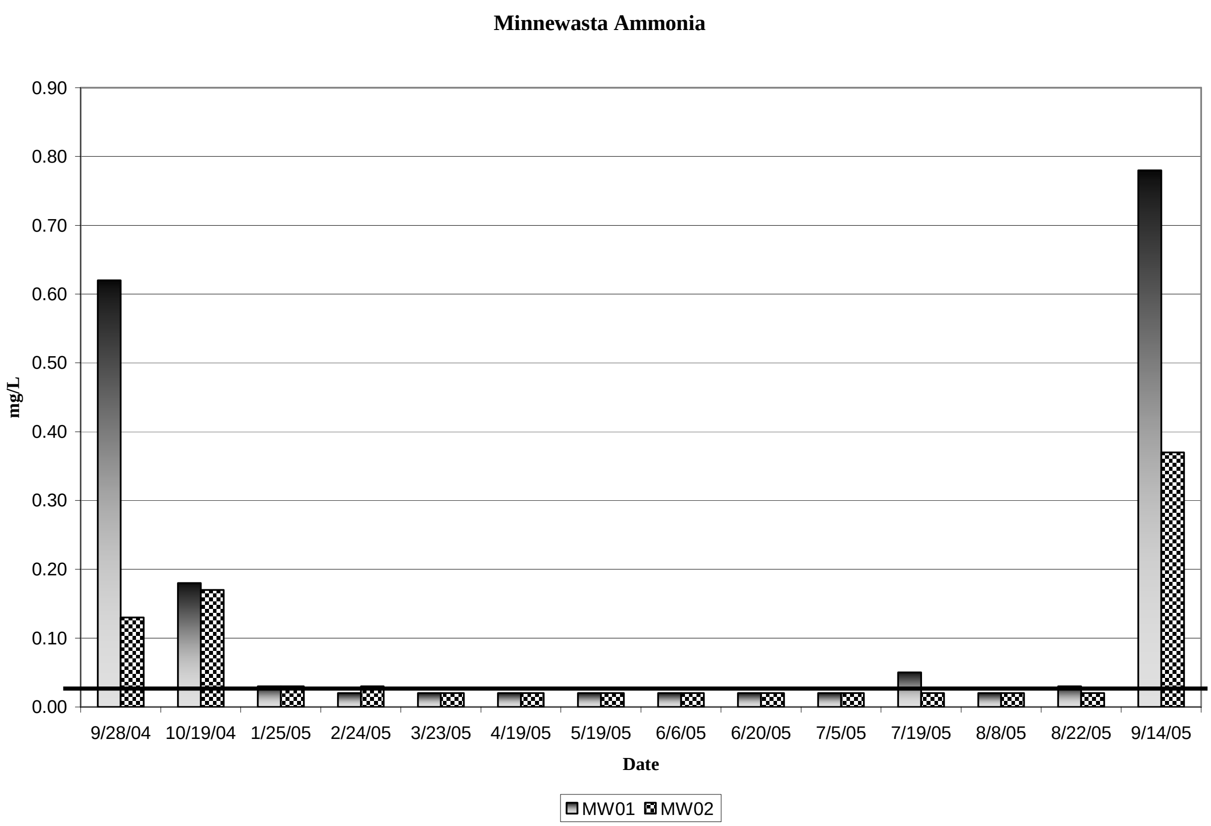

Figure 13. Minnewasta Lake Ammonia

Total Phosphorus

Phosphorus is one of the macronutrients required for primary production. When compared with carbon, nitrogen, and oxygen, it is typically the least abundant (Wetzel, 2001). Total phosphorus is the sum of all attached and dissolved phosphorus in the lake. The attached phosphorus is directly related to the amount of total suspended solids present. An increase in the amount of suspended solids increases the fraction of attached phosphorus. Phosphorus loading to lakes can be of an internal or external nature. External loading refers to surface runoff over land, dust, and precipitation.

Internal loadings of phosphorus can occur when oxygen concentrations near the sediment surface approach zero (anoxia). Phosphorus, ammonia and other compounds are released from the sediment under anoxic conditions. If a lake is stratified, phosphorus can accumulate in the deeper waters of stratified lakes and can suddenly become available to support algae growth after the water column is mixed by wind or fall turnover. Amsden Dam Reservoir exhibited stratification in 2005 but Minnewasta Lake remained un-stratified throughout the assessment study. Total phosphorus is also used to calculate TSI values.

Amsden Dam Reservoir

Total P concentration in surface waters of Amsden Dam Reservoir ranged from 0.049 mg/L on February 24, 2005 to 0.592 mg/L on August 22, 2005 (Appendix A). Mean lake total phosphorus in surface samples was 0.284 mg/L. Total phosphorus concentrations at all stations was about 0.25 mg/L in September 2004 and declined to below 0.1 mg/L in the winter and remained there until the large runoff event in June 2005.

Amsden Dam Reservoir had a large amount of external loading of phosphorus due to heavy rains in June and July 2005 (see Table 7). This resulted in large concentrations of total phosphorus (Figure 14) for the remainder of the summer. Some internal loadings of phosphorus from sediment release may have occurred due to low oxygen concentrations in July and August 2005 (Figure 8). Ammonia concentrations were also elevated in bottom samples from AD06 during July and August 2005. It appears, however, that Amsden Dam Reservoir was dominated by external phosphorus loads in 2005.

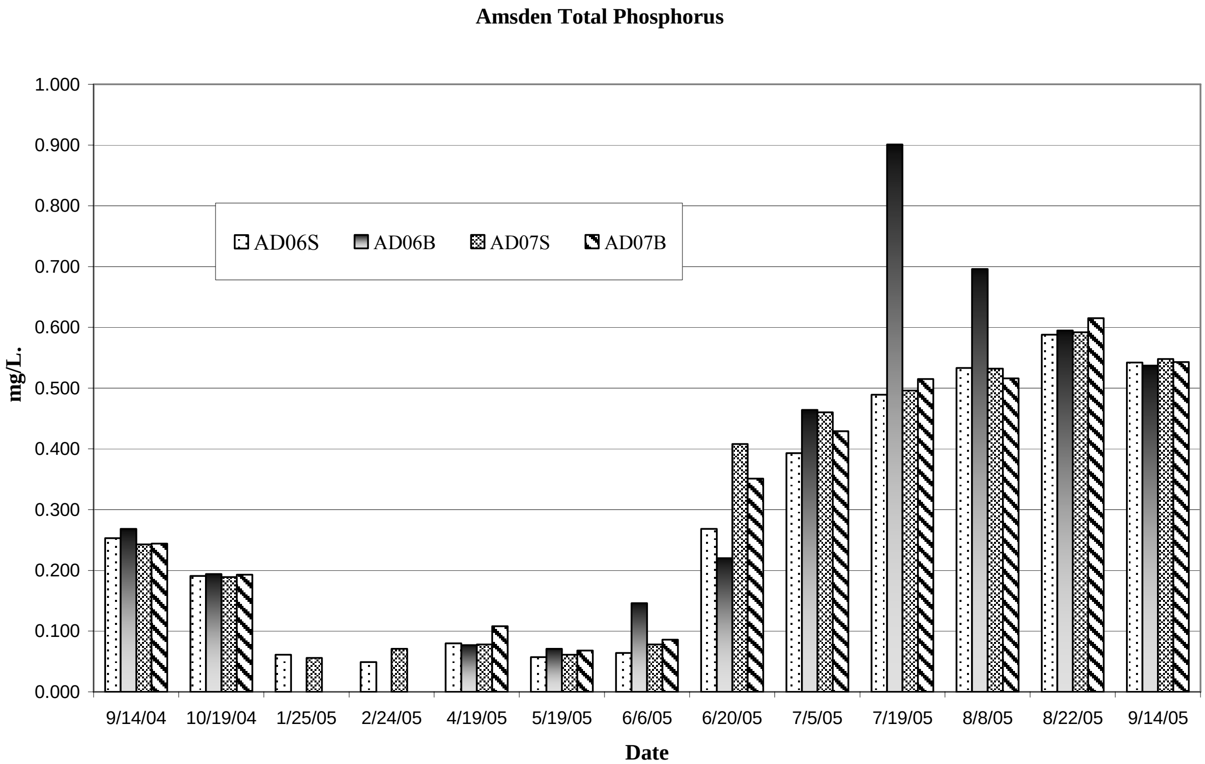

Figure 14. Amsden Dam Reservoir Total Phosphorus

<u>Minnewasta Lake</u>

Lake concentrations of total phosphorus were remarkably stable during the assessment period. The mean lake total phosphorus during the assessment was 0.169 mg/L. Concentrations ranged from 0.098 mg/L on July 19, 2005 to 0.251 mg/L on September 28, 2004 (Figure 15). This is a sufficient amount of phosphorus to support algae blooms which have been typical of Minnewasta Lake in recent years. The source of phosphorus in Minnewasta Lake is probably from both watershed sources and internal loading. As algae floats up from the bottom, total phosphorus in the water column increases. Sediment samples from Site MW02 indicate (Table 9), there are high levels of phosphorus in the benthos that may be the source of internal loading. There was little evidence of low oxygen (Appendix B) but it is likely that some release of phosphorus from the sediment occurred during the assessment. It is unlikely that watershed loading alone could account for the high concentrations of total phosphorus (Figure 15) and chlorophyll *a* observed in Minnewasta Lake.

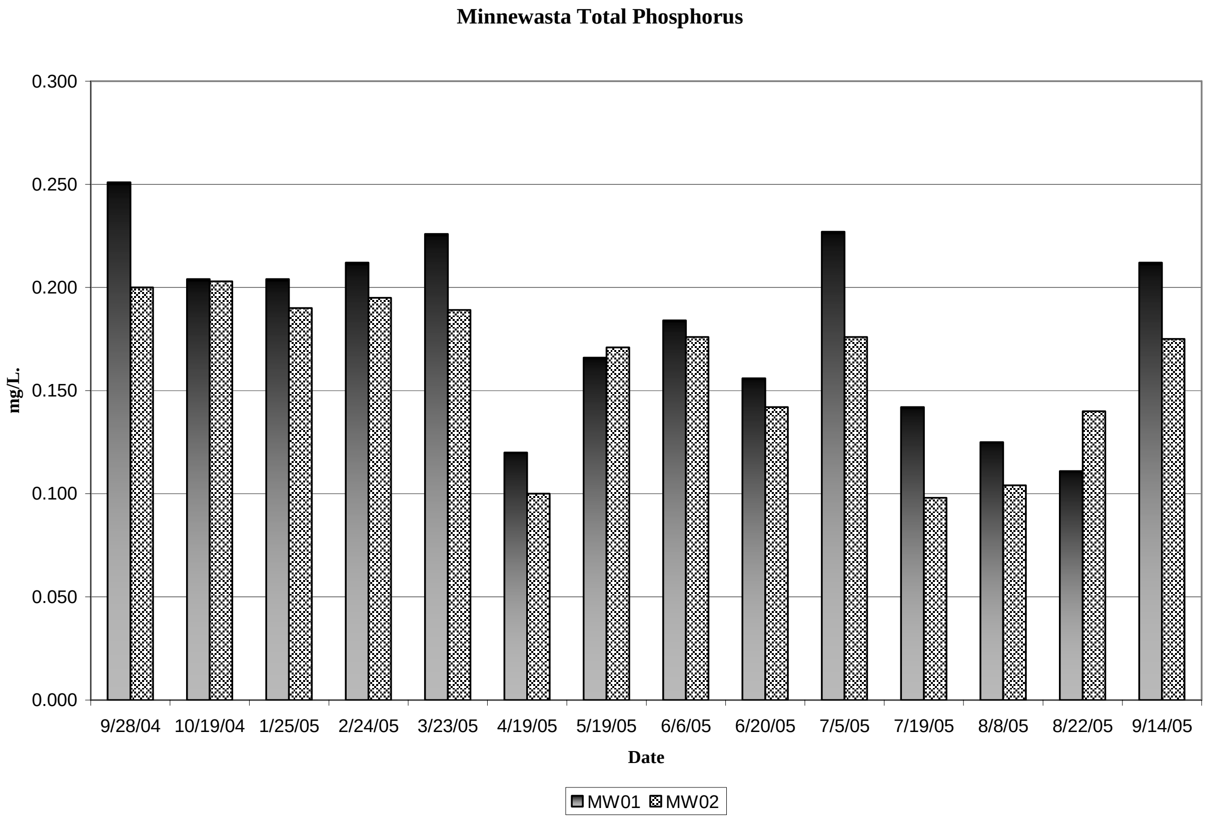

Figure 15. Minnewasta Lake Total Phosphorus

Total Dissolved Phosphorus

Total dissolved phosphorus is the unattached portion of the total phosphorus load. It is found in solution but readily binds to soil particles when they are present. Total dissolved phosphorus, including soluble reactive phosphorus, is more readily available to plant life.

<u>Amsden Dam Reservoir</u>
Total dissolved phosphorus concentrations in surface samples ranged from 0.038 mg/L on May 19, 2005 to 0.578 mg/L on August 22, 2005 (Appendix A). The mean concentration during the assessment was 0.254 mg/L. Total dissolved phosphorus was the dominant fraction of phosphorus throughout the assessment (Figure 16). It ranged from 100% on June 20, 2005 at AD06 to 50% on April 19, 2005 at AD07. It was available in very large concentrations following the large runoff events in June and July 2005 (Figure 17). Large concentrations of phosphorus during this period indicate that phosphorus was not a limiting factor for algal growth in 2005.

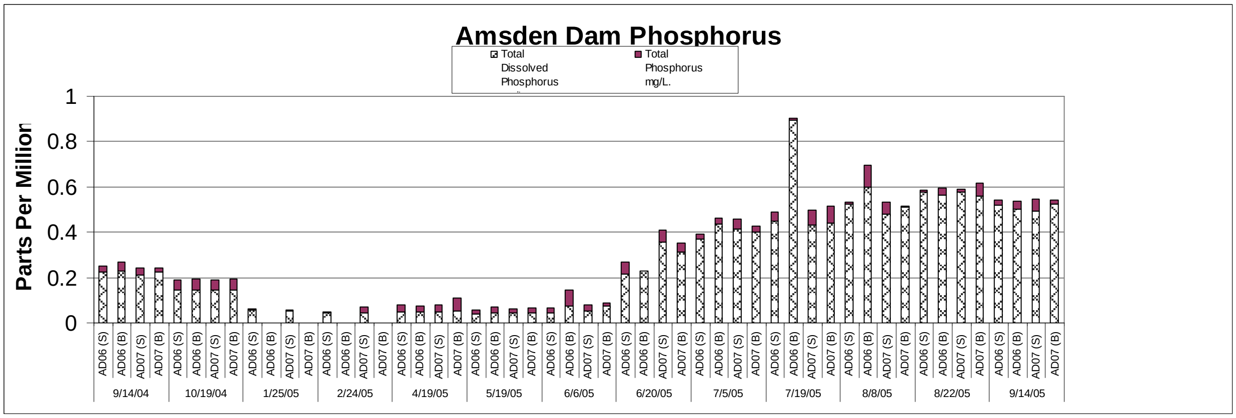

Figure 16. TDP to TP Comparison – Amsden Dam Reservoir

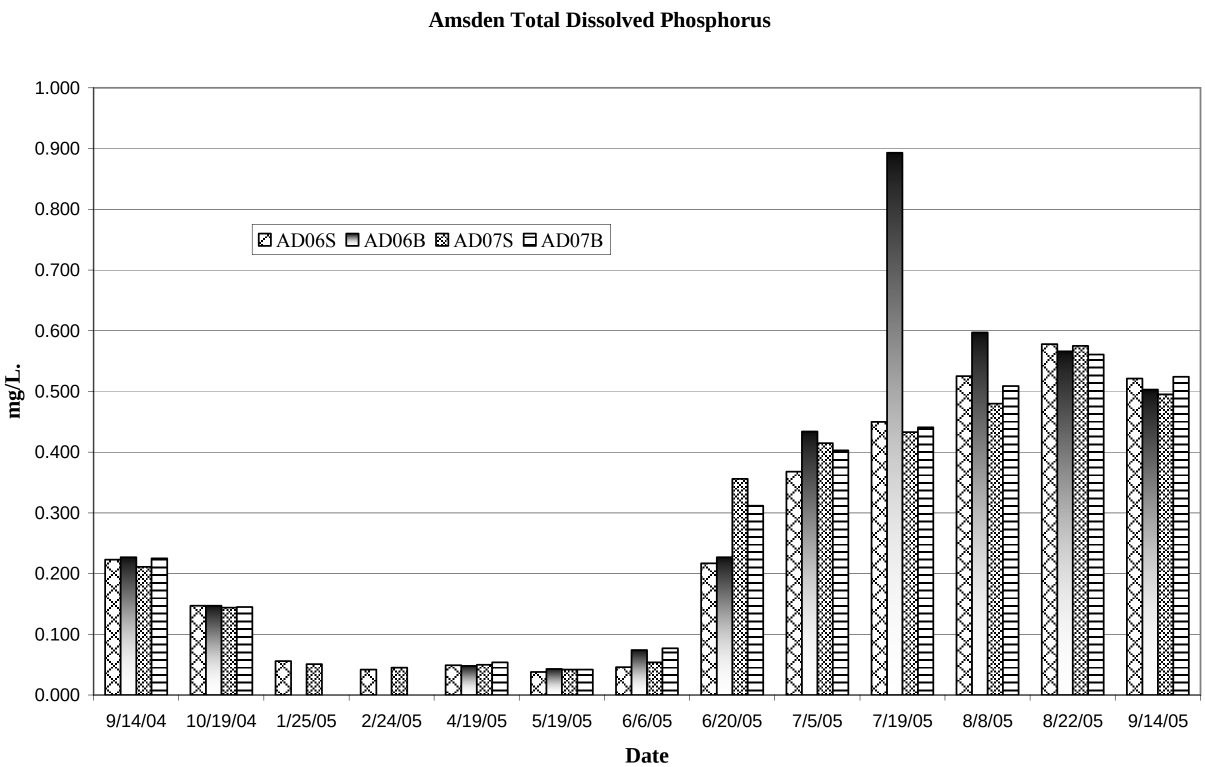

Figure 17. Amsden Dam Reservoir Total Dissolved Phosphorus

Minnewasta Lake

Total dissolved phosphorus concentrations in surface samples from Minnewasta Lake ranged from 0.035 mg/L on July 19, 2005 to 0.198 mg/L on January 25, 2005 (Figure 18).

Percent total dissolved phosphorus ranged from 25% of total phosphorus at station MW01 in July of 2005 to 99% of total phosphorus in January 2005 at site MW02. Total dissolved phosphorus was the dominant fraction of total phosphorus during the early portion of the assessment.

From September 2004 to June 2005, most of the total phosphorus was in the dissolved form (Figure 19). Rapid growth of algae in late June and early July converted much of the dissolved phosphorus into biomass as indicated by a large increase in chlorophyll between June 20, 2005 and July 5, 2005. Particulate phosphorus became the dominant fraction by July 5.

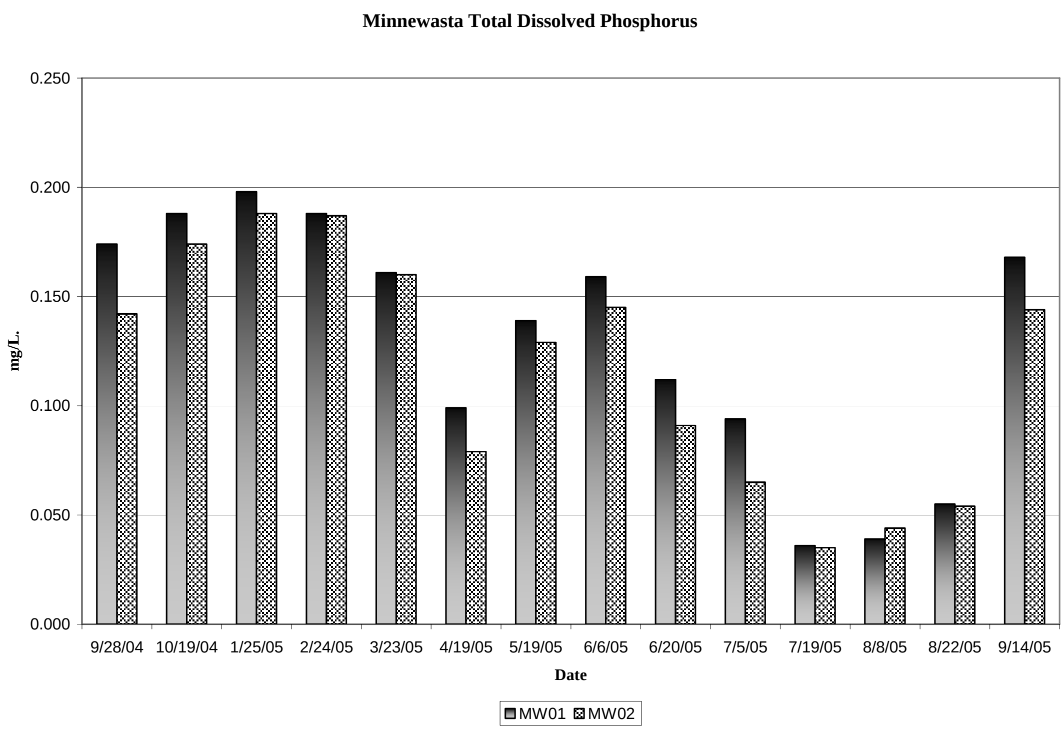

Figure 18. Minnewasta Lake Total Dissolved Phosphorus

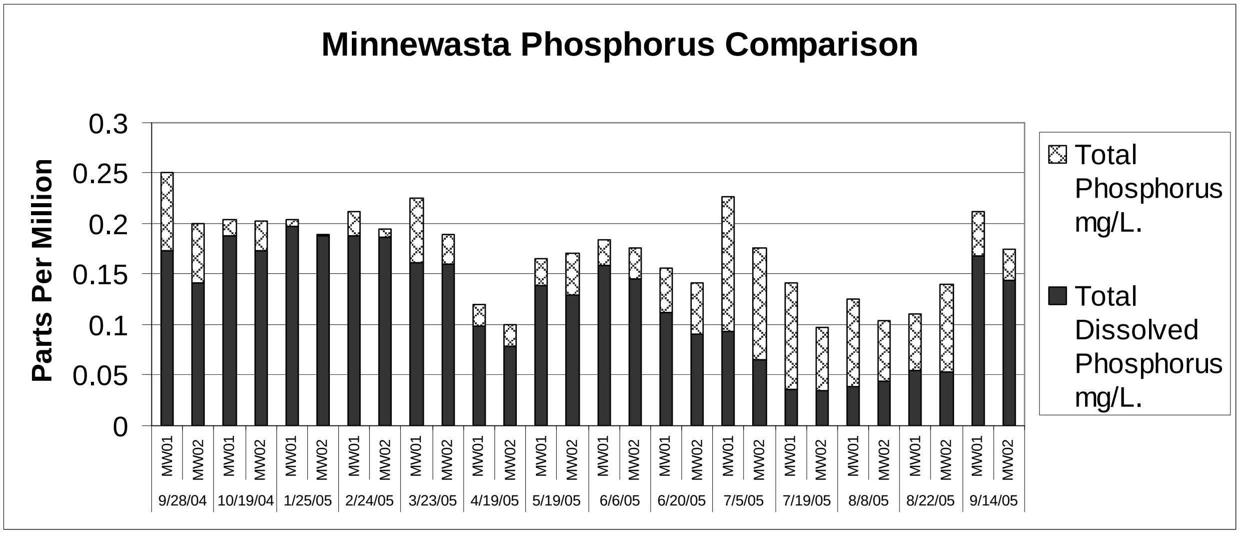

Figure 19. TDP to TP Comparison – Minnewasta Lake

Fecal Coliform Bacteria

Fecal coliform bacteria are found in the intestinal tracts of warm-blooded animals. Fecal coliform bacteria are used to indicate the presence of animal waste and pathogens in a water body. Some common types of bacteria are *E. coli*, S*almonella,* and *Streptococcus,* which are associated with livestock, wildlife, and human waste (Novotny, 1994). In-lake concentrations of fecal coliform bacteria are typically low because exposure to sunlight kills the bacteria, however the nutrients associated with animal waste may remain in high concentrations. High fecal counts are typically found in tributary samples taken during storm events and snowmelt, especially samples taken downstream of animal feeding operations.

Both Amsden Dam Reservoir and Minnewasta Lake are listed for the beneficial use of immersion recreation (7), which requires that no single fecal coliform bacteria sample exceed 400 colonies/100 ml.

Amsden Dam Reservoir
Of the twenty-six samples collected from Amsden Dam Reservoir, 77% of the fecal coliform concentrations were below detection limits (Appendix A). The maximum concentration (20 colonies/100 ml) was collected on September 14, 2005 from both sampling sites. All but one of the six samples with detectable levels of fecal coliform bacteria (10 colonies/100 ml) were collected from site AD07. This site is closest to the reservoir's tributary inlets and areas of shoreline heavily grazed by livestock.

Minnewasta Lake
Of the twenty-eight samples collected from Minnewasta Lake, 86% of the fecal coliform concentrations were below detection limits (Appendix B). The highest concentrations (30 colonies/100 ml. and 140 colonies/100 ml.) were collected on September 14, 2005. On this date,

several thousand migrating Franklin gulls were observed on the lake, the probable source of the fecal coliform bacteria. All other detections were at 10 colonies/100 ml.

Chlorophyll *a*

Chlorophyll *a* is the green pigment in plants (including algae) that allows them to capture sunlight and produce food using nutrients in the water. Other pigments are also used by different types of algae, but chlorophyll *a* is the most abundant. Measuring chlorophyll levels in a lake provides a means to assess algal abundance, since almost all chlorophyll that occurs in open water is due to phytoplankton growing within the lake. It does have limitations, however, since chlorophyll content of phytoplankton cells can vary seasonally (Nicholls and Dillon, 1978). It is best used as an indicator rather than a direct measure of algal biomass. Chlorophyll *a* is also used to calculate TSI values.

<u>Amsden Dam Reservoir</u>
The median chlorophyll *a* concentration in Amsden Dam Reservoir during the assessment was 6.04 mg/L. The average chlorophyll *a* concentration during the assessment was 9.4 mg/L. Chlorophyll *a* concentration in Amsden Dam Reservoir ranged from 1.07 mg/L in January 2005 to 28.15 mg/L in July 2005 (Appendix A). Peak production of algae during the summer months is typical of northern temperate lakes. Based on the amount of available phosphorus and nitrogen during 2005 higher concentrations of chlorophyll *a* would be expected. Flushing of a large volume of water through the reservoir may have prevented the build-up of large algae populations or their growth may have been limited due to the high color or turbidity in the water column. Because of the frequent variations in inorganic turbidity in reservoirs, the limiting effect of light penetration on photosynthetic activity is more severe than that of nutrients (e.g., Henry *et al.*, 1985) cited in Wetzel (2001).

<u>Minnewasta Lake</u>
The median chlorophyll *a* concentration in Minnewasta Lake during the assessment was 4.9 mg/L. The average chlorophyll *a* concentration during the assessment was 36.1 mg/L. Chlorophyll *a* concentrations ranged from 0.84 mg/L on January 25, 2005 to 165 mg/L on August 8, 2005 (Appendix B). Unlike Amsden Dam Reservoir, the nutrients available in the spring season in Minnewasta Lake were converted into algal biomass by the end of the summer as indicated by the large increase in chlorophyll *a* by August 2005 (Figures 29 & 30).

Limiting Nutrients

Four primary nutrients are required for cellular growth in organisms. Two of these nutrients are phosphorus and nitrogen. Nitrogen is difficult to limit in aquatic environments due to its highly soluble nature. Phosphorus is easier to control making it the primary nutrient targeted for reduction when attempting to control a lake's eutrophication. The ideal ratio of nitrogen to phosphorus for aquatic plant growth is 10:1 (EPA, 1994). Ratios higher than 10 indicate a phosphorus-limited system. Those that are less than 10 represent nitrogen-limited systems.

Amsden Dam Reservoir
When chlorophyll *a* TSI values are less than phosphorus TSI values, it is likely that something other than phosphorus is limiting algal growth. This was true in Amsden Dam Reservoir throughout the summer period in 2005 (Figure 22).

The N:P ratios for Amsden Dam Reservoir (Figure 20) were calculated using total nitrogen and total phosphorus. Open water N:P ratios ranged from 2 to 5 indicating nitrogen limitation. One must be careful looking at only the ratios, however. In order to be limiting, the available form of the nutrient must be in low concentrations. Both nitrogen and phosphorus have been shown to limit photosynthesis in reservoirs but light is often a greater limitation (Wetzel, 2001). This was probably true for Amsden during 2005 since both ammonia and nitrate were available in measurable concentrations in June and July, indicating they were probably not limiting algae growth.

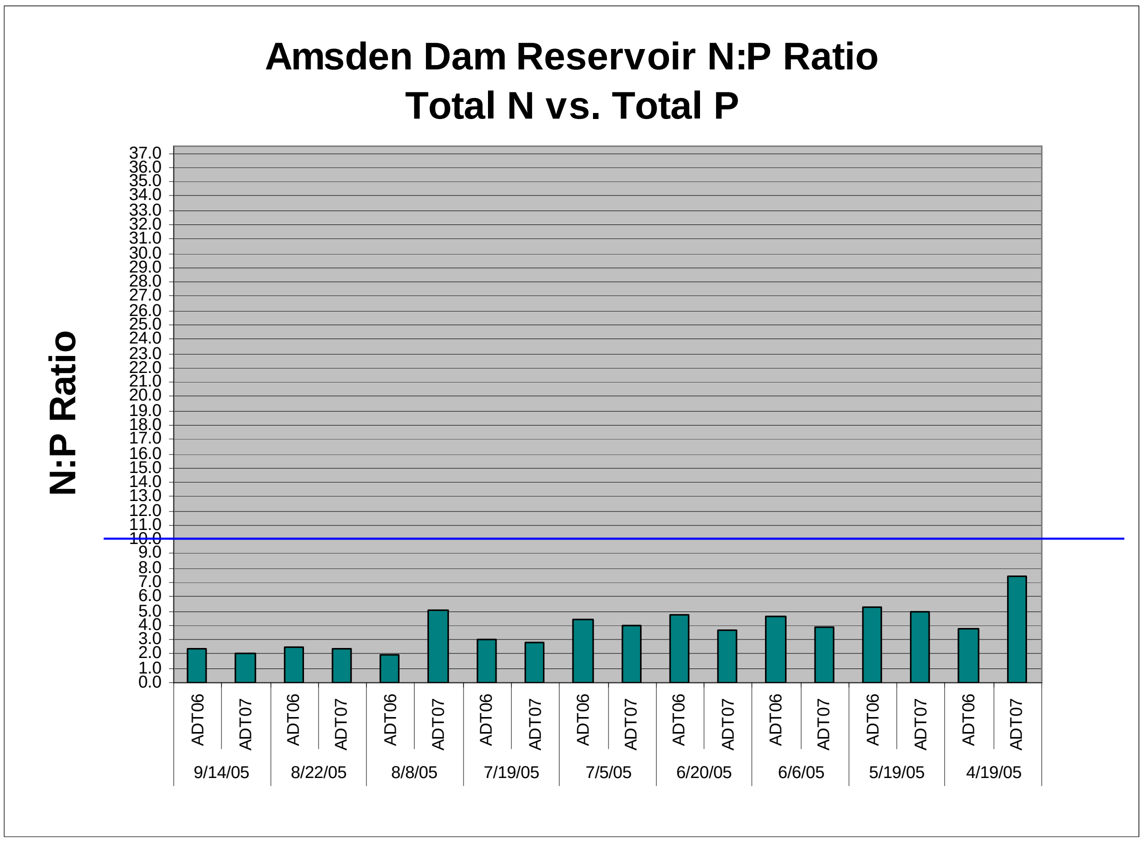

Figure 20. Amsden Dam Reservoir N:P Ratio

Minnewasta Lake
The N:P ratios calculated for Minnewasta Lake during the open water period in 2005 ranged from 11 to 35 (Figure 21). The N:P ratios tended to increase as the summer progressed. When chlorophyll *a* TSI values are less than phosphorus TSI values it is likely that something other than phosphorus is limiting algal growth. This was true of Minnewasta Lake in June and early

July but TSIs based on chlorophyll *a* were greater than those based on total phosphorus after July 19, 2005. This indicates that Minnewasta Lake had a tendency toward phosphorus limitation by mid-July 2005. Minnewasta Lake exhibited an increase in N:P ratios (Figure 21) and a reduction in total dissolved phosphorus (Figure 18) in late July which also supports this conclusion. During dense blooms of algae, self-shading can also limit additional algal growth. This was probably occurring during the late summer in Minnewasta Lake based on high chlorophyll and low Secchi disc transparency in July 2005.

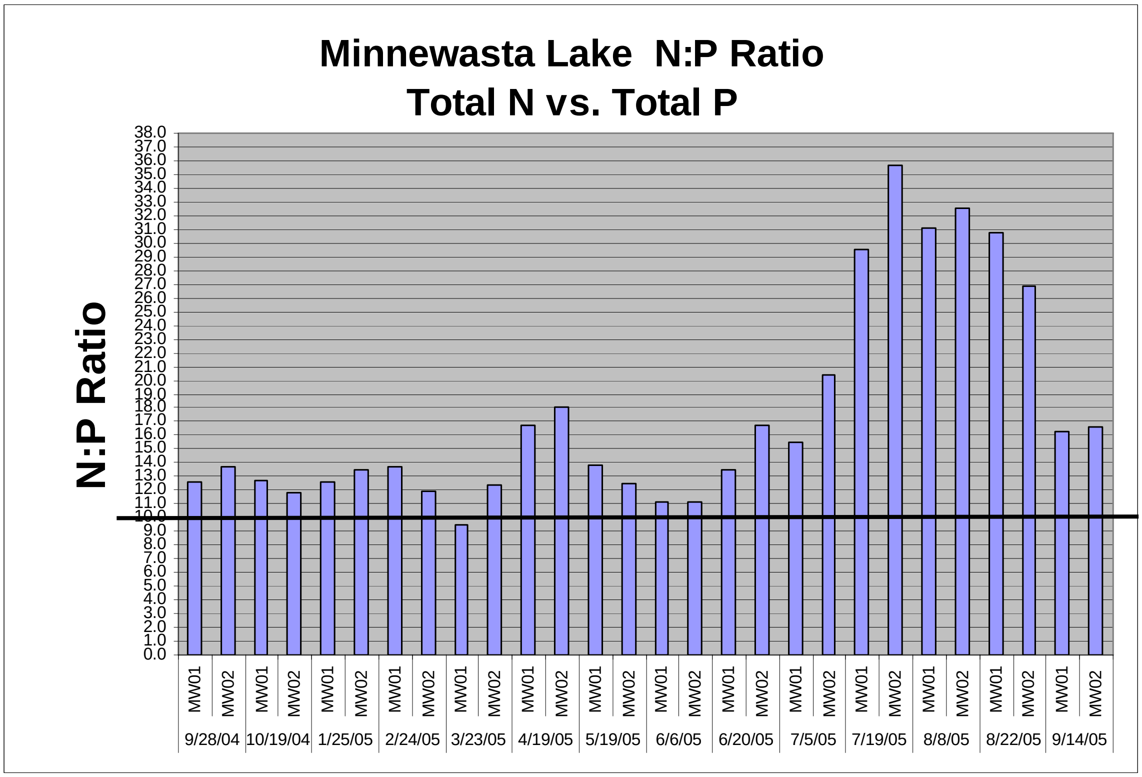

Figure 21. Minnewasta Lake N:P Ratio

Trophic State

Trophic state refers to the degree of nutrient enrichment within a lake and its relation to primary production and water clarity. The Trophic State Index (TSI) developed by Carlson (1977) is a commonly used and widely accepted method for quantifying the trophic state of lakes. The TSI transforms measures of total phosphorus (nutrient), chlorophyll-*a* (algal biomass), and Secchi depth (water clarity) using linear regression models and logarithmic transformation to produce unitless index scores typically ranging from 0-100. The greater the index scores; the more phosphorus, primary production and correspondingly water clarity water bodies are expected to exhibit. Carlson (1977) assigned numeric ranges to classify the trophic state of a waterbody (Table 9).

Table 6. Trophic state categories established by Carlson (1977).

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

Lakes with TSI values less than 35 are considered to be oligotrophic and contain very small amounts of nutrients, low primary production and are very clear. Lakes that obtain a score of 35 to 50 are considered to be mesotrophic and have more nutrients and primary production than oligotrophic lakes. Eutrophic lakes have a score between 50 and 65 and have moderate to high nutrients and are susceptible to algae blooms and reduced water clarity. Hyper-eutrophic lakes have scores greater than 65 and contain excessive nutrients, sustained nuisance algae blooms and poor water clarity leading to impairment of beneficial uses and aesthetic beauty (Table Xx).

The three TSI indices are expected to be interrelated as a function of the regression models. Therefore, it is assumed that any one of the three indices could be used to classify the trophic state of a waterbody. When the TSI is presented as an average or median value it is imperative that all three indices are interrelated. Carlson (1991) suggests that if any TSI parameter deviates significantly ($\pm$ 5 TSI points) from the chlorophyll TSI (main measure of primary production) then that parameter is contributing to the misclassification of the trophic state.

The South Dakota DENR, Water Resource Assistance Program (WRAP) uses the median of Secchi depth transparency and chlorophyll-*a* TSI to classify the trophic state of lakes and reservoirs. The phosphorus TSI was eliminated from the median calculation to avoid misclassification. According to the document entitled Targeting Impaired Lakes in South Dakota the phosphorus TSI deviates more than $\pm$ 5 TSI points from the chlorophyll-*a* TSI in 82% of 119 lakes assessed (WRAP 2005).

Many lakes in South Dakota have sufficient phosphorus concentrations to support excessive growth and maintenance of algae. However, several other environmental factors can limit algae biomass (Carlson 1991, Wetzel 2004). By placing emphasis on chlorophyll-*a* and Secchi depth transparency as primary indicators of trophic state; resource managers can identify other limnological factors, in addition to phosphorus, as the primary cause of impairment. If significant deviation exists between Secchi and chlorophyll TSI, the parameter weighing heaviest on the median is targeted. Phosphorus reductions are always warranted to improve trophic state in situations where excessive concentrations exist.

The DENR's TSI approach for targeting impaired lakes utilizes the fishery beneficial use designation as a classification tool to set impairment targets for lakes with similar physical, chemical and biological characteristics. Therefore, a non-support status for TSI implies that the trophic state is impaired, which may have a direct impact on all the designated beneficial uses. Amsden Dam is classified for warmwater permanent fish life propagation and Lake Minnewasta is classified for warmwater semi-permanent fish life propagation as determined in "Targeting Impaired Lakes in South Dakota" (WRAP 2006). Lakes in the permanent category should have a median TSI Secchi-chlorophyll value of 58.4 or less to be fully supporting the fishery beneficial use. Lakes in the semi-permanent category should have a median TSI Secchi-chlorophyll value of 63.4 or less to be fully supporting the fishery beneficial use.

Amsden Dam Reservoir

TSIs for Amsden Dam Reservoir based on Secchi disk transparency and chlorophyll *a* in 2005 are presented in Figure 22. In early June, TSIs based on Secchi disk transparency are similar to each other and indicate eutrophic conditions but chlorophyll *a* TSIs in the reservoir are much lower. It appears that adequate phosphorus is available in June to support algal growth but has not been converted to algal biomass. Chlorophyll *a* TSI values were less than Secchi disc TSIs and chlorophyll *a* TSI values were less than total phosphorus TSI values for the entire summer period in 2005 (Figure 22). This indicates that reduced transparency from non-algal factors is likely. This condition could have been caused by the presence of color from dissolved organic matter or small particles of non-algal turbidity in the water column following the large rain events in June 2005.

The large rain event that occurred between the June sampling dates caused a large rise in total phosphorus concentrations (Figures 14 & 17). Most of the total phosphorus was in the dissolved phase for the remainder of the summer (Figure 16). The large influx of phosphorus was not converted to algal biomass during 2005 creating a discrepancy between TSI values (Table 7 and Figure 22). Chlorophyll *a* TSIs indicated mesotrophic to eutrophic conditions while TSIs based on phosphorus were near the top of the scale indicating extreme hyper-eutrophic conditions. This condition indicates that something other than phosphorus was limiting algae growth in Amsden Dam Reservoir in 2005. The TSIs based on phosphorus may be a better indicator of the current trophic state of Amsden Dam Reservoir. If the phosphorus remains available it may support extensive blooms in 2006.

Table 7. Trophic State Indices for Amsden Dam Reservoir - 2005

		6/6/2005	6/20/2005	7/5/2005	7/19/2005	8/8/2005	8/22/2005
TSI Values	Mean:	51.91	69.50	68.61	74.98	69.21	71.71
Secchi Disk		56.94	73.73	66.45	70.19	61.49	61.75
Total Phosphorus		60.52	85.30	90.21	91.97	93.82	95.82
Chlorophyll a		38.28	49.47	49.17	62.77	52.33	57.57

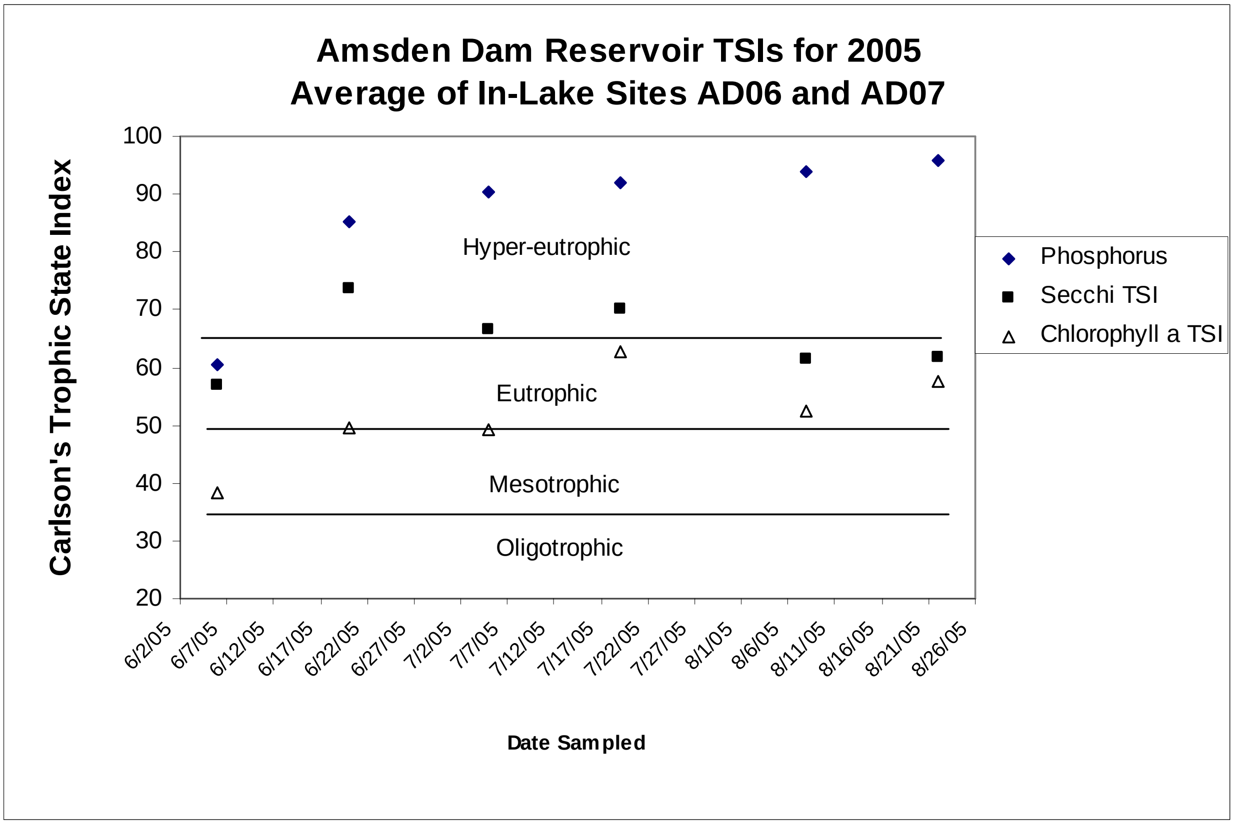

Figure 22. Amsden Dam Reservoir Trophic State Indices

<u>Minnewasta Lake</u>

TSIs for Minnewasta Lake based on total phosphorus, Secchi disk transparency and chlorophyll *a* in 2005 are presented in Figure 23. Chlorophyll *a* TSIs in June do not agree with TSIs based on Secchi disc transparency and total phosphorus. When chlorophyll *a* TSI values are less than Secchi disc TSIs and chlorophyll *a* TSI values are less than total phosphorus TSI values, reduced transparency from non-algal factors is likely. This was true in June in Minnewasta Lake. It appears that adequate phosphorus was available in June 2005 to support algal growth but had not been converted to algal biomass. A large fraction of total phosphorus was in the dissolved phase until late June and early July (Figure 19). By July the dissolved phosphorus was converted to algal biomass and TSIs were in agreement indicating hyper-eutrophic conditions for Minnewasta Lake during the remainder of the summer (Figure 23).

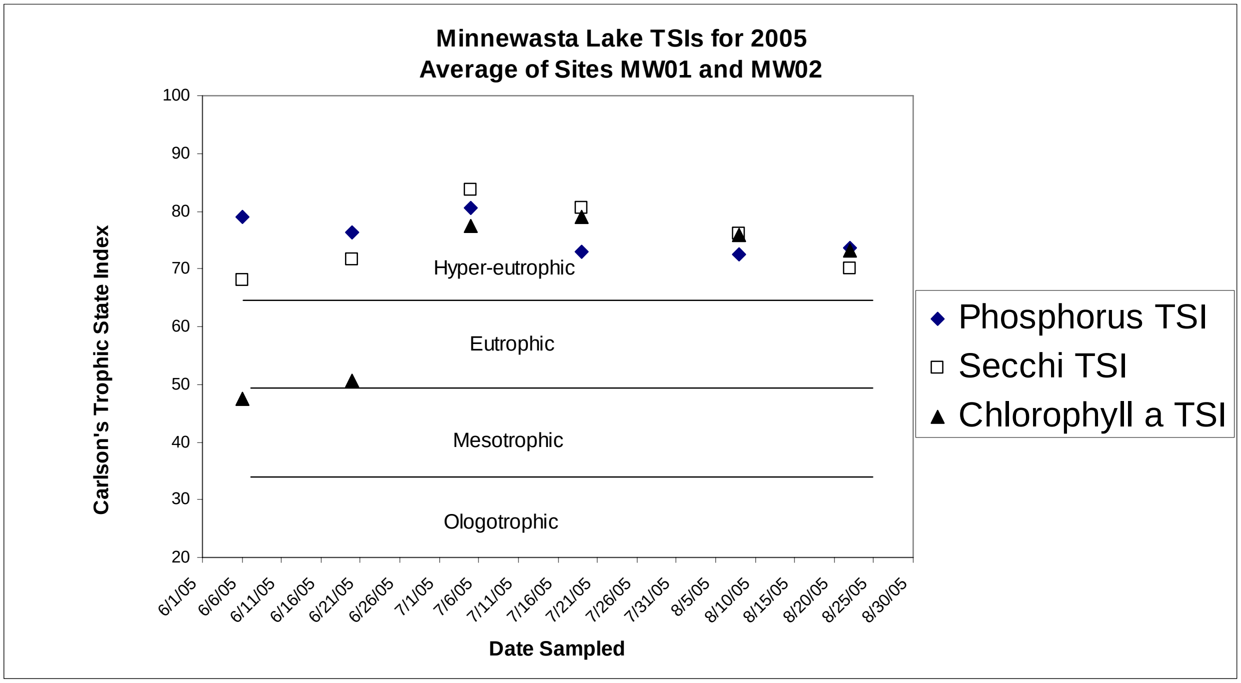

Figure 23. Minnewasta Lake Trophic State Indices

To allow a comparison of water quality in 2005 with previous years, TSIs based on total phosphorus, Secchi disk transparency and chlorophyll *a* using data from 1989 to 2005 are presented in Table 8. Only data from June, July and August was used to make TSI calculations. TSIs based on total phosphorus from 1989 to 2005 are consistently above 65 indicating a hyper-eutrophic condition (Table 8). Secchi disk and chlorophyll *a* TSIs are consistently lower than those based on total phosphorus and, except for 1989, indicate a eutrophic condition. This is probably due to a clear-water phase that typically occurs in June in Minnewasta Lake that is associated with relatively low algal biomass and high transparency (German, 1997).

Table 8. Trophic State Indices for Minnewasta Lake 1989-2005

	1989	1991	1992	1993	1994	1995	2005
Mean TSI Values	75.52	60.54	62.19	62.86	66.10	59.23	67.03
Secchi Disk	72.29	57.82	54.89	53.99	60.47	55.90	57.89
Total Phosphorus	78.74	69.30	71.01	73.92	76.99	75.48	75.83
Chlorophyll A		54.50	60.68	60.68	60.86	46.32	67.38

Mean TSIs based on total phosphorus, Secchi disk transparency and chlorophyll *a* from 1989 to 2005 are presented in Figure 24. No overall trend is indicated but periods of improving and declining water quality are apparent. Declining water quality was observed from 1991 to 1994 followed by an improvement in 1995. Fluctuations in mean TSIs do not appear to be random but rather exhibit a pattern of gradual change from hyper-eutrophic to eutrophic and back. Data is not available on runoff and watershed conditions that may help explain these oscillations. This data indicates that Minnewasta Lake may be sensitive to changes in nutrient loadings and may respond to watershed treatment. This pattern could also reflect fluctuations in internal loadings which would make water quality improvement more difficult.

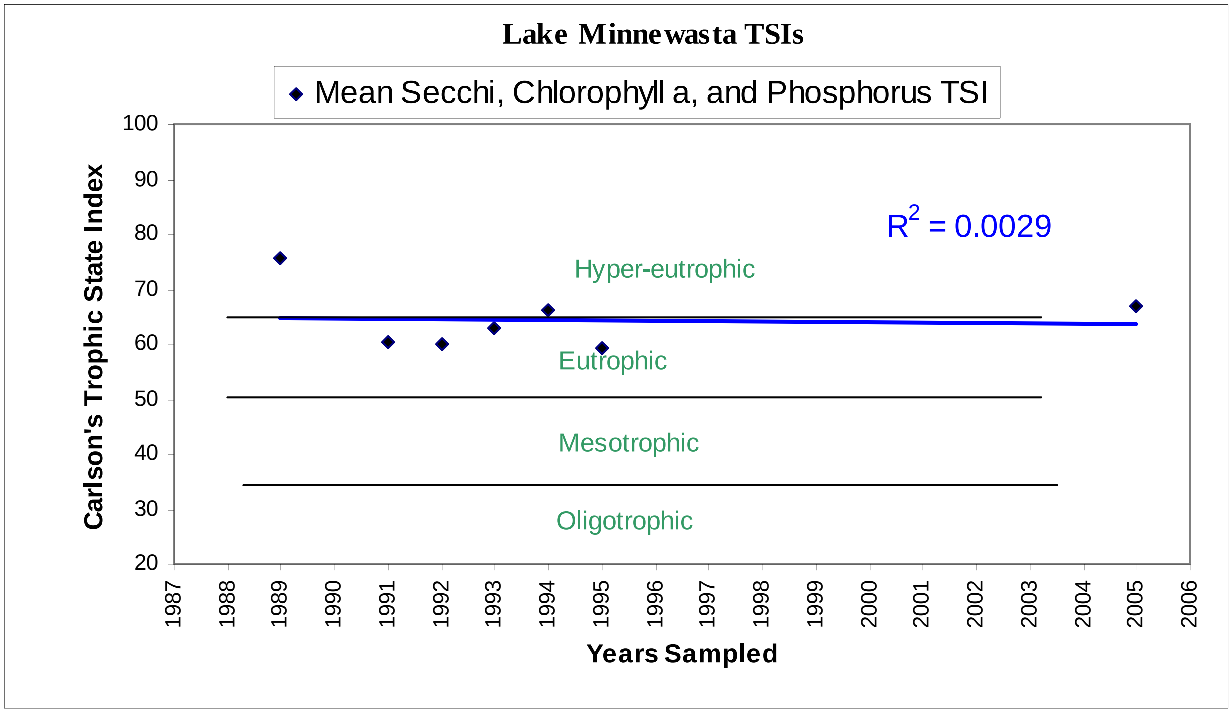

Figure 24. Minnewasta Lake Mean Trophic State Indices 1989 – 2000

Trophic State Lake Minnewasta

Lake Minnewasta is classified for warmwater semi-permanent fish life propagation. As determined in "Targeting Impaired Lakes in South Dakota" (WRAP 2006), lakes in this category should have a median TSI Secchi-chlorophyll value of 63.4 or less to be fully supporting the fishery beneficial use. Secchi-chlorophyll TSI values for the lake ranged from 47.4 to 73.2 and 50.3 to 78.1, respectively. During the study, the median trophic state for Lake Minnewasta during 2004 and 2005 was 67.4, placing it in the hypereutrophic category.

Biological Monitoring

Fisheries

Amsden Dam Reservoir
The fish community in Amsden Dam Reservoir was last sampled in 2004. Gill and frame net sets were the methods employed to sample fish populations. An updated fisheries report for Amsden Dam will be published in the spring of 2006 by the South Dakota Department of Game, Fish and Parks, Wildlife Division. The report will show survey dates and netting information, current mean and historic catch rates, age and length, and stocking data.

Amsden Dam Reservoir's warm-water fishery is managed for the following primary species; black bullhead, muskellunge, rock bass, and walleye; and the following secondary species; black crappie, bluegill, common carp, northern pike, smallmouth bass, white sucker, and yellow perch. The SDGF&P frequently stocks Amsden Dam with fingerling and juvenile muskellunge and walleye.

Minnewasta Lake
The fish community in Minnewasta Lake was last sampled in 2004. Gill and frame net sets were the methods employed to sample fish populations. An updated fisheries report for Amsden Dam will be published in the spring of 2006 by the South Dakota Department of Game, Fish and Parks, Wildlife Division. The report will show survey dates and netting information, current mean and historic catch rates, age and length, and stocking data.

Minnewasta Lake's warm-water fishery is managed for the following primary species; black crappie, bluegill, northern pike, walleye, and yellow perch; and the following secondary species; black bullhead, common carp, fathead minnow, Iowa darter, and white sucker. The SDGF&P frequently stocks Minnewasta Lake with fry and fingerling walleye.

Threatened and Endangered Species

The US Fish and Wildlife Service listed the following federally threatened and endangered species for the Amsden Dam and Minnewasta Lake watersheds; bald eagle (*Haliaeetus leucocephalus*), piping plover (*Charadrius melodus*), and western prairie-fringed orchid (*Platanthera praeclara*). All of these species are currently classified as "threatened". None of the listed species were encountered during the assessment project.

Elutriate

As a cost-saving measure, no elutriate samples were collected from Amsden Dam Reservoir and Minnewasta Lake. In lieu of elutriate testing; a bottom sediment sample was collected from each sample site on Amsden Dam and Minnewasta Lakes on July 19 , 2005. These samples were tested for total phosphorus. Results are listed in Table 9.

**Table 9. Amsden Dam Reservoir and Minnewasta La
Lake Bottom Sediment Samples**

Sample Site	AD06	AD07	MW01	MW02
Total Phosphorus mg/kg. (wet)	4.72	3.73	18.8	134.0
Total Phosphorus mg/kg. (dry)	27.3	11.2	117	691.0

There was little phosphorus detected in the Amsden samples and little difference between sample sites. On Minnewasta Lake, the larger basin (MW02) had nearly six times the total phosphorus (wet and dry samples) in the sediment sample as compared to the sample from the smaller west basin (MW01). This could be a cause of considerable internal loading since there is no tributary draining into the lake. As stated on page 45 of this report, it is unlikely the high levels of total phosphorus found in Minnewasta Lake's surface water samples came from watershed loading alone. One possible source of phosphorus in the immediate watershed is an animal feeding operation along the lake's shoreline that appears to drain directly into this basin.

Sediment Survey

Sediment surveys were conducted on Amsden Dam Reservoir and Minnewasta Lake in January of 2005. Predetermined sampling sites were located on both water bodies using a global positioning system (GPS). Water depth was measured using an electronic depth finder and sediment depth was measured using a 20-foot steel probe at each sampling site. The probe was lowered through holes in the ice into the soft sediment until it reached a solid substrate, giving a sediment depth.

<u>Amsden Dam Reservoir</u>
The survey results indicated an average sediment depth of 0.73 meter (2.4 feet). The maximum sediment depth was 1.83 meters (6 feet) (Figure 25). Several areas near the dam were not surveyed due to water depths greater than the 20-foot probe's length. The survey showed the reservoir's maximum depth at 7.93 meters (26 feet), and an average water depth of 3.87 meters (12.7 feet). A total of 84 holes were drilled through the ice to determine water and sediment depth on the reservoir.

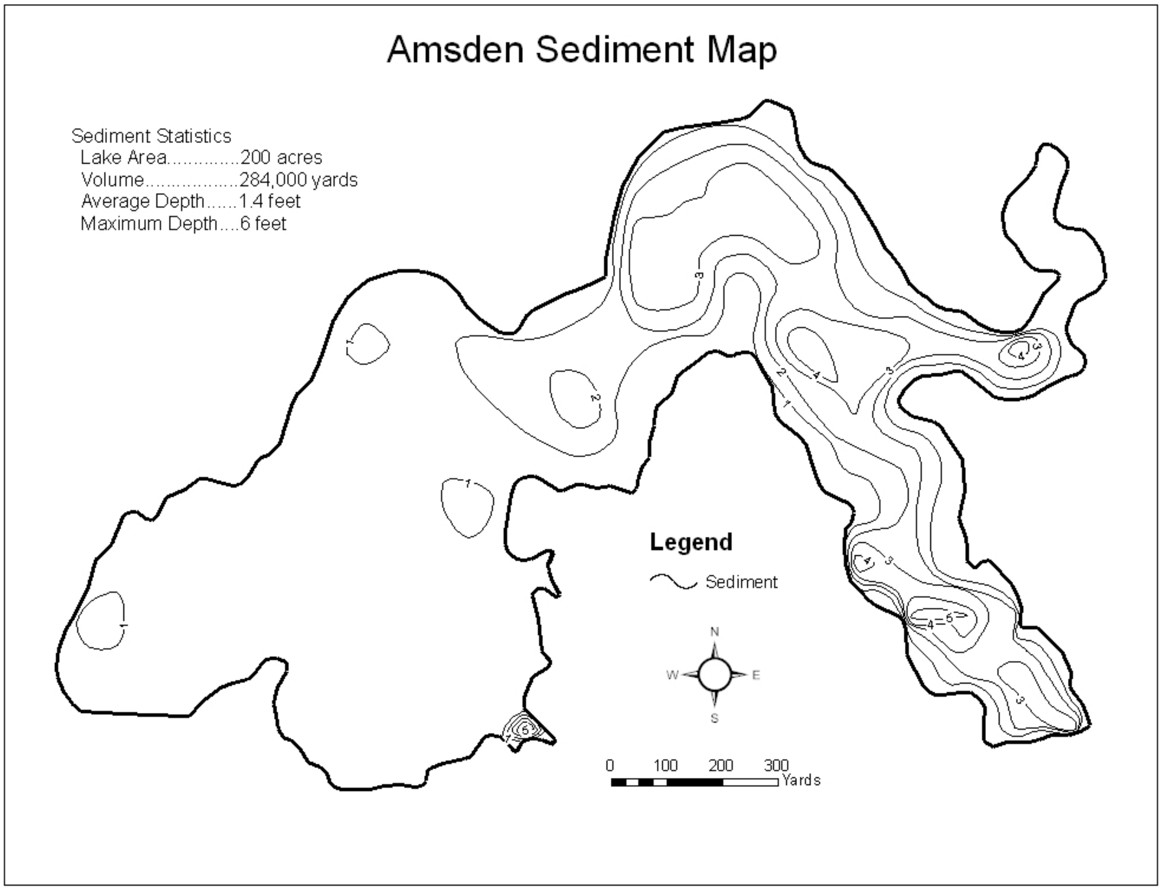

Figure 25. Amsden Dam Reservoir Sediment Survey Results

Minnewasta Lake

The survey results indicated an average sediment depth of 0.46 meter (1.5 feet). The maximum sediment depth was 1.52 meters (5 feet) (Figure 26). The survey indicated the lake's maximum depth at 4.88 meters (16 feet) with an average water depth of 3.78 meters (12.4 feet). A total of 97 holes were drilled through the ice to determine water and sediment depth on the reservoir.

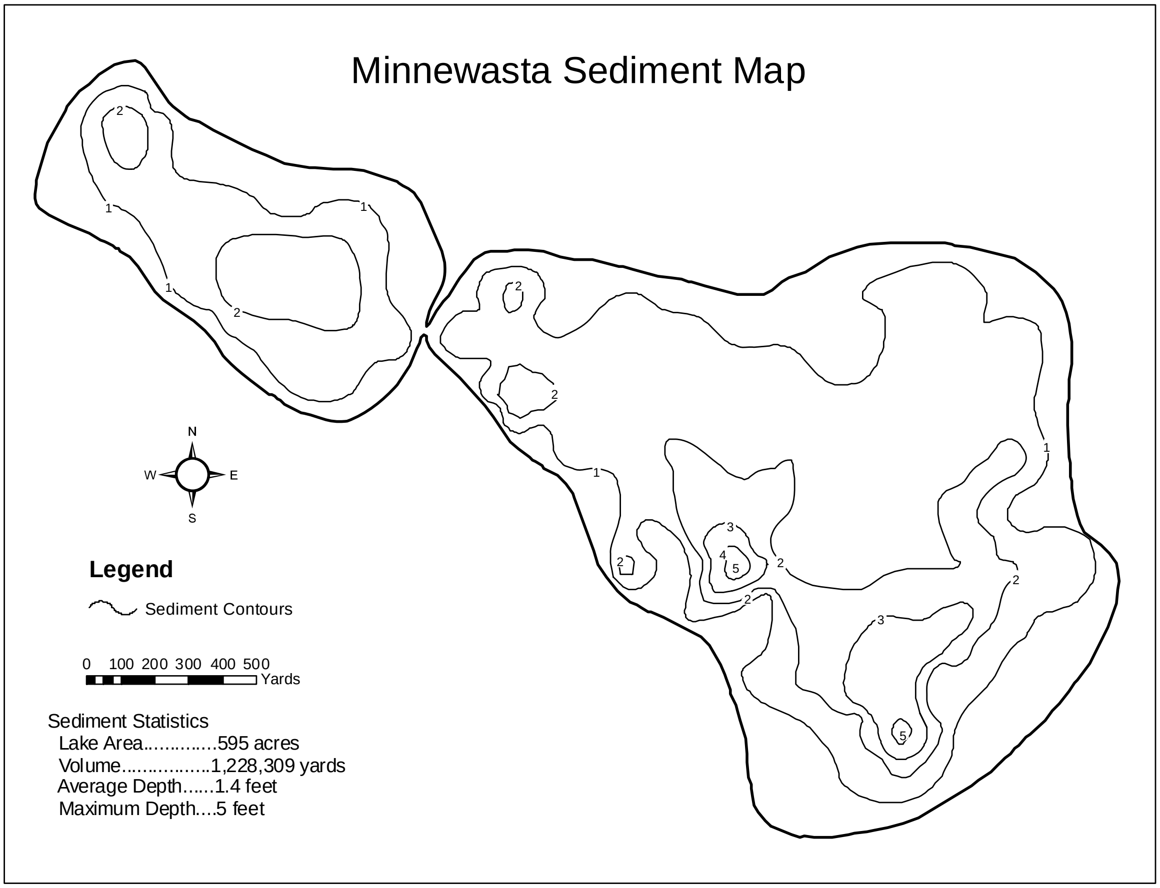

Figure 26. Minnewasta Lake Sediment Survey Results

Macrophyte Survey

Macrophyte survey protocol was in accordance to the "Standard Operating Procedures for Field Sampling, Vol. II, Biological and Habitat Sampling" published by SD DENR. Sampling points for each transect were located by stringing a 100-meter poly-rope perpendicular to the shoreline at each transect point. Styrofoam floats placed along the rope at 10-meter intervals marked each sampling point location. Zero was located at the shoreline water's edge.

Amsden Dam Reservoir

A macrophyte survey was conducted on Amsden Dam Reservoir on August 2 and 3, 2005. A total of 20 transects were sampled for aquatic plant life along the reservoir's 7.2 kilometers (4.5 miles) of shoreline. Transects were located using predetermined GPS coordinates that were placed approximately every 0.33 kilometers (0.21 miles) of adjacent shoreline. The first transect (AM1) was located at the boat ramp and subsequent transects continued south following the shoreline to the west (Figure 27).

The only emergent macrophyte observed was the common cattail *(Typha latifolia)* found sporadically around the lake's shoreline. This species did not intersect with any of the survey transects. This species dominates the shoreline south of transects AM15 and AM14 where the lake's main tributary, Pickerel Creek, enters into the lake. This area was not surveyed due to the shallow water depth and deep sediment which made wading and boating impossible.

A total of five species of submergent aquatic macrophytes were encountered. Coontail (*Ceratophyllum demersum*) was the predominant species collected from all but one transect. Water stargrass (*Zosterella dubia*) was the rarest species collected from only one transect. Other species collected were *Potamogeton fresii, Potamogeton pectinatus*, and *Potamogeton richardsonii*. *Potamogeton fresii* and *Zosterella dubia* were not reported by Stewart and Stueven (1994).

The average maximum depth for growth of submergent macrophytes in Amsden Dam Reservoir was 3.22 meters (10.5 feet). The maximum depth recorded was 6.09 meters (20 feet) and the minimum depth being 0 meter along the shoreline. The average Secchi disk depth recorded during the survey was 1.65 meters (5.4 feet), with a maximum depth of 2.35 meters (7.7 feet) and a minimum depth of 0.82 meter (2.7 feet). During the survey it was noted that the reservoir's water color was stained brown and there was a slight algal bloom.

A shoreline habitat assessment was also conducted during the macrophyte survey. The shoreline assessment consisted of scoring three habitat parameters with a numerical value; bank stability, vegetative protection, and riparian vegetative zone width. Numerical values ranged from 10 (denoting the optimal condition) to a 0 (denoting the poorest condition). For Amsden Dam Reservoir, bank stability had an average score of 6.6, a suboptimal condition rating. Vegetative protection had an average score of 6.7, a suboptimal condition rating, and the riparian vegetative zone width had an average score of 5.5, a marginal condition rating. The low ratings are likely due to a majority of the reservoir's shoreline being heavily grazed by cattle with little or no riparian vegetation remaining. There were several areas of severe shoreline erosion. Some erosion may have been a result of flooding in the mid-1990s. Field data for this survey is given in Appendix G.

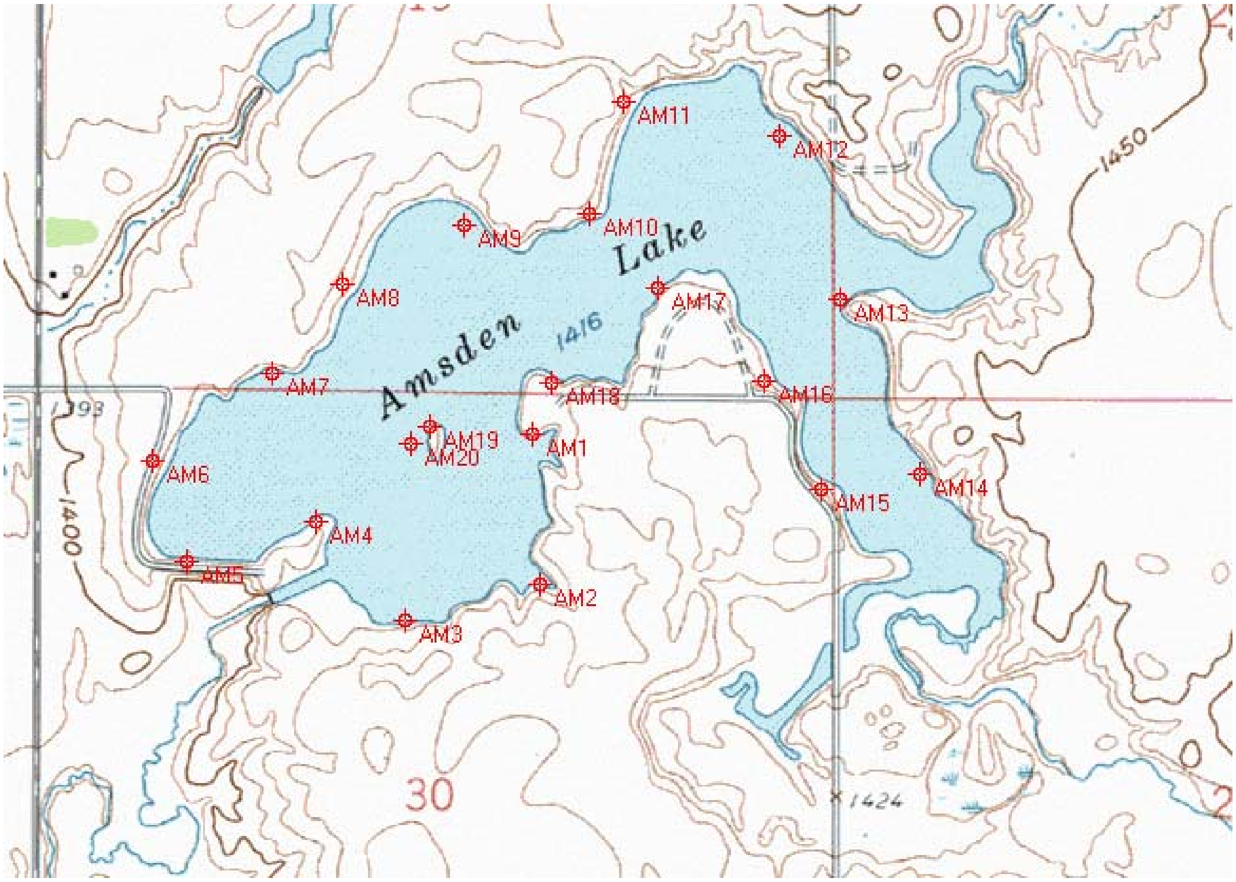

Figure 27. Amsden Dam Reservoir Macrophyte Survey Transect Locations

Minnewasta Lake

A macrophyte survey was conducted at Minnewasta Lake on July 26, 28, and 29, 2005. A total of 30 transects were sampled for aquatic plant life along the lake's 8.4 kilometer (5.25 miles) shoreline. Transects were located using predetermined GPS coordinates that were placed approximately every 0.27 kilometer (0.17 miles) of adjacent shoreline. The first transect (MM1) began at the old north lake access boat ramp and subsequent transects continued west along the lake's north shore (Figure 28).

The only emergent macrophytes observed were common cattail *(Typha latifolia)* and several species of *Scirpus* found sporadically around the lake's shoreline. These species did not intersect with any of the survey transects.

Only two species of submergent aquatic macrophytes were encountered. Sago pondweed (*Potamogeton pectinatus*) was collected from twenty of the thirty transects sampled. One small patch of clasping leaf pondweed (*Potamogeton richardsonii*) was observed between transects MM8 and MM9. Previously, only *Potamogeton pectinatus* was reported as occurring in Minnewasta Lake (Stewart and Stueven, 1994).

The average maximum depth for growth of submergent macrophytes in Minnewasta Lake was 1.8 meters (5.9 feet). The maximum depth recorded was 3.66 meters (12 feet) and the minimum depth being 0 meter along the shoreline. The average Secchi disk depth recorded during the survey was 0.9 meter (3.1 feet), with a maximum depth of 1.16 meters (3.8 feet) and a minimum depth of 0.70 meter (2.3 feet). During the survey a heavy algal bloom was observed.

A shoreline habitat assessment was also conducted during the macrophyte survey. The shoreline assessment consisted of scoring three habitat parameters with a numerical value; bank stability, vegetative protection, and riparian vegetative zone width. Numerical values ranged from 10 (denoting the optimal condition) to a 0 (denoting the poorest condition). For Minnewasta Lake, bank stability had an average score of 8.0. Vegetative protection had an average score of 8.1, and the riparian vegetative zone width had an average score of 7.6. All three parameters had suboptimal condition ratings. There were several areas of severe shoreline erosion which were likely caused by flooding in the mid-1990s. Field data for this survey is given in Appendix G.

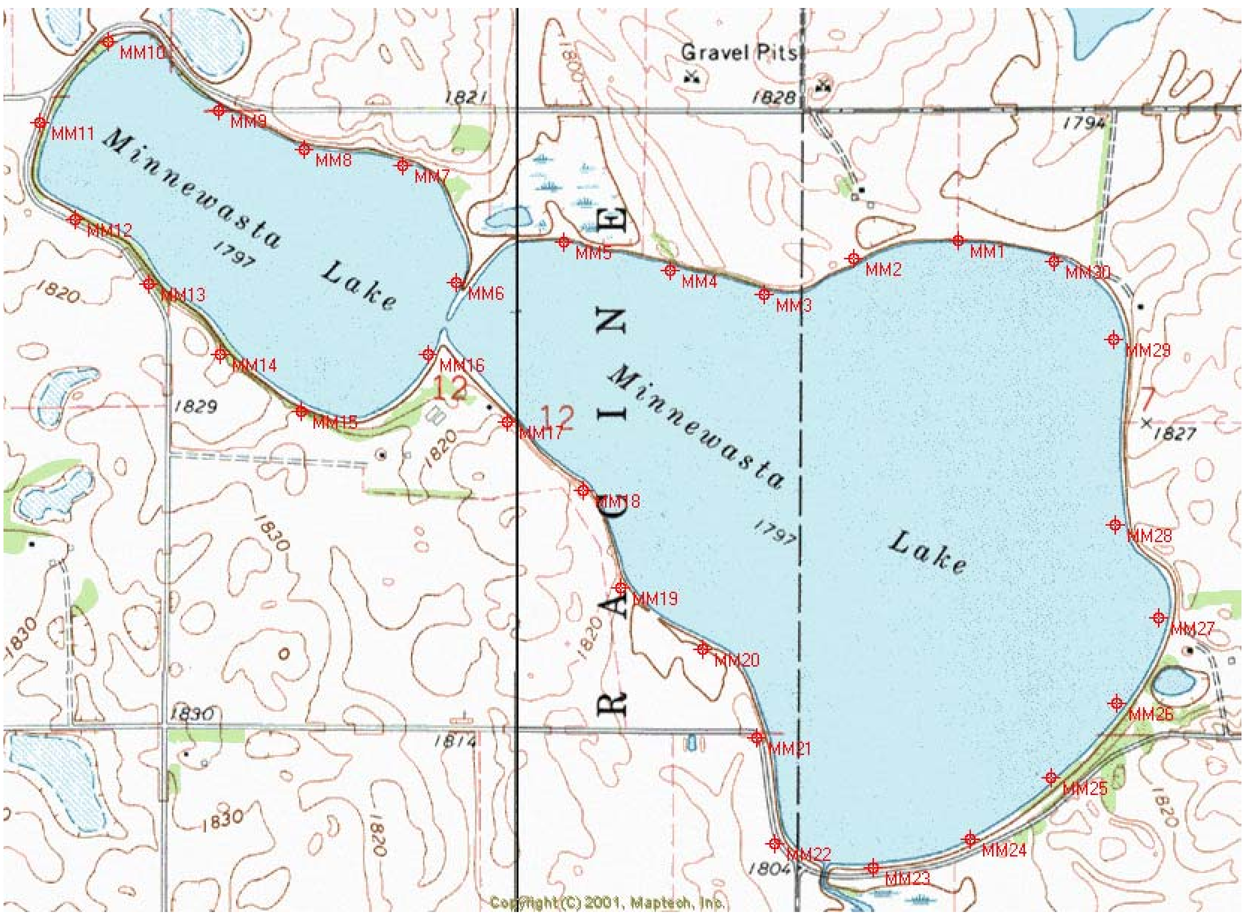

Figure 28. Minnewasta Lake Macrophyte Survey Transect Locations

Macroinvertebrate Survey

A macroinvertebrate survey was conducted at two Amsden tributary sites on September 6, 2005. Samples were collected with a D-net at sites ADT03 and ADT04, the only two tributary sites that had perennial flows during the project. Identification and metric analysis of macroinvertebrate samples was contracted to Natural Resource Solutions located in Brookings, South Dakota. A complete report detailing metric analysis and species collection is given in Appendix E.

<u>Amsden Dam Reservoir Tributary Site ADT03</u>
A total of three composite samples were collected from Site ADT03. Macroinvertebrates were collected from eleven transects spaced 18 feet apart. Total transect length was 198 feet. All transects were categorized as depositional sites. Two of the samples collected represented a poor biotic condition supporting only a highly tolerant benthic macroinvertebrate community. One sample represented a fair biotic condition supporting a marginally tolerant benthic macroinvertebrate community. Metric data suggests this tributary site has moderately to severely impaired water quality.

<u>Amsden Dam Reservoir Tributary Site ADT04</u>
A total of three composite samples were collected from Site ADT04. Macroinvertebrates were collected from eleven transects spaced 13 feet apart. Total transect length was 143 feet. Eight transects were categorized as depositional sites and three transects were listed as erodible sites. Two of the samples represented a fair biotic condition able to support a marginally tolerant benthic macroinvertebrate community. One sample represented a poor biotic condition only able to support a very highly tolerant benthic macroinvertebrate community. Metric data suggests this tributary site has moderately to severely impaired water quality.

Periphyton Survey

A periphyton survey was conducted at two Amsden tributary sites on September 6, 2005. Samples were collected at sites ADT03 and ADT04, the only two tributary sites with perennial flows during the project. Periphyton identification was contracted to Natural Resource Solutions located in Brookings, South Dakota. A complete list of species collected and specimen photographs are listed in Appendix F.

Phytoplankton Survey

<u>Amsden Dam Phytoplankton</u>
Surface samples of planktonic algae were collected at two widely separated lake sites twice monthly from May 19 to Sept 14, 2005. In addition, four composite samples were previously collected on June 30 and Aug 11, 1998 and on June 24 and July 22, 2002, as part of the Statewide Lake Assessment Program (Table 10). A total of 20 samples were analyzed for this reservoir.

A total of 61 algal taxa, including several "unidentified algae" categories, were collected from this 235-acre impoundment (Table 11). Algae species richness (the number of algal taxa observed) and diversity for this survey was rated as somewhat "below average" when compared to 14 other recently monitored small lakes and reservoirs of 200 acres or less, which had a mean of 73 taxa.

Non-motile green algae (Chlorophyta) represented the most diverse group of algae in Amsden Dam with 20 species, followed by diatoms (Bacillariophyceae) with 17 taxa. Less varied algal groups were flagellated (motile) algae, comprising five phyla, with 13 taxa including an "unidentified flagellates" category, and blue-green algae (Cyanophyta) with 10 taxa.

The phytoplankton population during this survey consisted mostly of blue-green algae (68 %) of which the most common taxa were the nuisance blue-greens *Aphanizomenon flos-aquae* (19%) and *Microcystis aeruginosa* (26%). Both species reached their summer maximum on July 19, 2005 of 47,184 cells/ ml for *Microcystis* and 25,756 cells/ml for *Aphanizomenon*. While those densities are moderately high, they fall considerably below numbers reported during summer in a large group of other eutrophic lakes including Minnewasta Lake. The Amsden Dam blue-green algae population in the summer of 2005 considerably exceeded those reported in 1998 and 2002 (Table 10).

It is probable that development of spring and early summer algae populations in Amsden Dam was limited during 2005 by heavy rainfall and resulting tributary inflow. A 3.85 inch rainfall was recorded in the watershed on June 14 and a 4.25-inch downpour was recorded on June 29, 2005. Large tributary inflows may have exerted a diluting and flushing effect on developing algae populations from late May to early July (Figure 29). A decrease in rainfall subsequently allowed reservoir blue-green algae to take advantage of the abundant nutrients carried in earlier by the tributaries and increase to an annual maximum of 82,016 cells/ml on July 19 (Table 10).

Diatoms were noticeably sparse in Amsden Dam making up only about 5% of the reservoir algae population during this survey. A probable cause may have been the abundant rainfall noted above that may have hindered the development of a large spring diatom bloom. Massive spring diatom increases are fairly typical for eutrophic water bodies (Hutchinson, 1967). A single exception to this scenario was the large-sized colonial diatom *Asterionella formosa* which managed an increase to a density of 2053 cells/ml (2-site mean) on June 20, 2005. Some literature indicates that growth of *Asterionella* is particularly stimulated by runoff from eroding soils that provide a sudden influx of inorganic nutrients (ammonia, nitrates) that were in short supply in the reservoir. A rapid rate of reproduction was indicated on June 20 by the many-celled colonies of this diatom in the samples, many of which contained 16 to 27 cells (the usual number of cells in a colony is 8). At a water temperature of 20 degrees C, *Asterionella* is capable of increasing at a rate of two divisions per day (ibid.). It was noted, however, that most of the *Asterionella* frustules appeared weakly-developed and misshapen (bent) which suggests that the rapid increase may have depleted reservoir silica supplies which are the building blocks for diatom frustules. This is often cited as a cause leading to the termination of *Asterionella* blooms when other nutrients are still present in sufficient concentrations to promote further growth (ibid.) In Amsden Dam, *Asterionella* was no longer present in July 5 samples.

Non-motile green algae (Chlorophyta) comprised approximately 10% of the total reservoir plankton. Whereas green algae represented the most diverse group in terms of the number of species present, they were poorly-developed in biomass, bio-volume and size of population. Ninety percent of the green algae in Amsden Dam during the survey were small-sized species, *Characium* sp. and/or *Schroederia judayi*, many of which may be attached forms displaced from various substrates.

Planktonic green algae appear to be at a competitive disadvantage in alkaline water bodies with elevated pH such as Amsden Dam. Alkaline lakes tend to favor the growth of blue-green algae, including the nuisance varieties (Shapiro, 1973). In less mineralized eutrophic waters of near neutral pH, green algae can out-compete blue-greens due to the abundance of free dissolved CO_2. In alkaline waters like Amsden Dam (pH >8), free CO_2 is nearly absent (Reid, 1961).

Table 10 Amsden Dam Algae Abundance (cells/milliliter)

Date	Algae Group	Cells/ml	%
30 June'98	Flagellated (Motile) Algae	2230	10.0
	Blue-Green Algae	13885	61.9
	Diatoms	315	1.4
	Non-Motile Green Algae	232	1.0
	Unidentified Algae	5760	25.7
	Total	22422	
11 Aug'98	Flagellated (Motile) Algae	1049	5.6
	Blue-Green Algae	14006	74.4
	Diatoms	60	0.3
	Non-Motile Green Algae	194	1.0
	Unidentified Algae	3520	18.7
	Total	18829	
24 June'02	Flagellated (Motile) Algae	262	1.7
	Blue-Green Algae	12929	83.4
	Diatoms	14	0.1
	Non-Motile Green Algae	1257	8.1
	Unidentified Algae	1050	6.8
	Total	15512	
22 July'02	Flagellated (Motile) Algae	1718	9.9
	Blue-Green Algae	14518	83.7
	Diatoms	146	0.8
	Non-Motile Green Algae	377	2.2
	Unidentified Algae	580	3.4
	Total	17339	

Table 10 cont. Amsden Dam Algae Abundance (cells/milliliter)

Date	Algae Group	Cells/ml	%
19 May'05	Flagellated (Motile) Algae	28	5.5
	Blue-Green Algae	310	60.8
	Diatoms	33	6.5
	Non-Motile Green Algae	74	14.5
	Unidentified Algae	65	12.8
	Total	510	
6 June'05	Flagellated (Motile) Algae	41	5.8
	Blue-Green Algae	120	16.6
	Diatoms	24	3.4
	Non-Motile Green Algae	468	65.6
	Unidentified Algae	60	8.4
	Total	713	
20 June'05	Flagellated (Motile) Algae	2022	33.2
	Blue-Green Algae	870	14.3
	Diatoms	2119	34.8
	Non-Motile Green Algae	440	7.2
	Unidentified Algae	630	10.4
	Total	6081	
5 July'05	Flagellated (Motile) Algae	1618	31.5
	Blue-Green Algae	3111	60.6
	Diatoms	169	3.3
	Non-Motile Green Algae	135	2.6
	Unidentified Algae	105	2.0
	Total	5138	
19 July'05	Flagellated (Motile) Algae	339	0.4
	Blue-Green Algae	82016	99.0
	Diatoms	20	0.0
	Non-Motile Green Algae	290	0.4
	Unidentified Algae	190	0.2
	Total	82855	
8 Aug'05	Flagellated (Motile) Algae	372	1.4
	Blue-Green Algae	25124	97.6
	Diatoms	34	0.1
	Non-Motile Green Algae	152	0.6
	Unidentified Algae	60	0.2
	Total	25742	

Table 10 cont. Amsden Dam Algae Abundance (cells/milliliter)

Date	Algae Group	Cells/ml	%
22 Aug'05	Flagellated (Motile) Algae	784	1.2
	Blue-Green Algae	64114	98.1
	Diatoms	20	0.0
	Non-Motile Green Algae	310	0.5
	Unidentified Algae	135	0.2
	Total	65363	
14 Sept'05	Flagellated (Motile) Algae	218	1.6
	Blue-Green Algae	13233	97.6
	Diatoms	1	0.0
	Non-Motile Green Algae	30	0.2
	Unidentified Algae	73	0.5
	Total	13555	

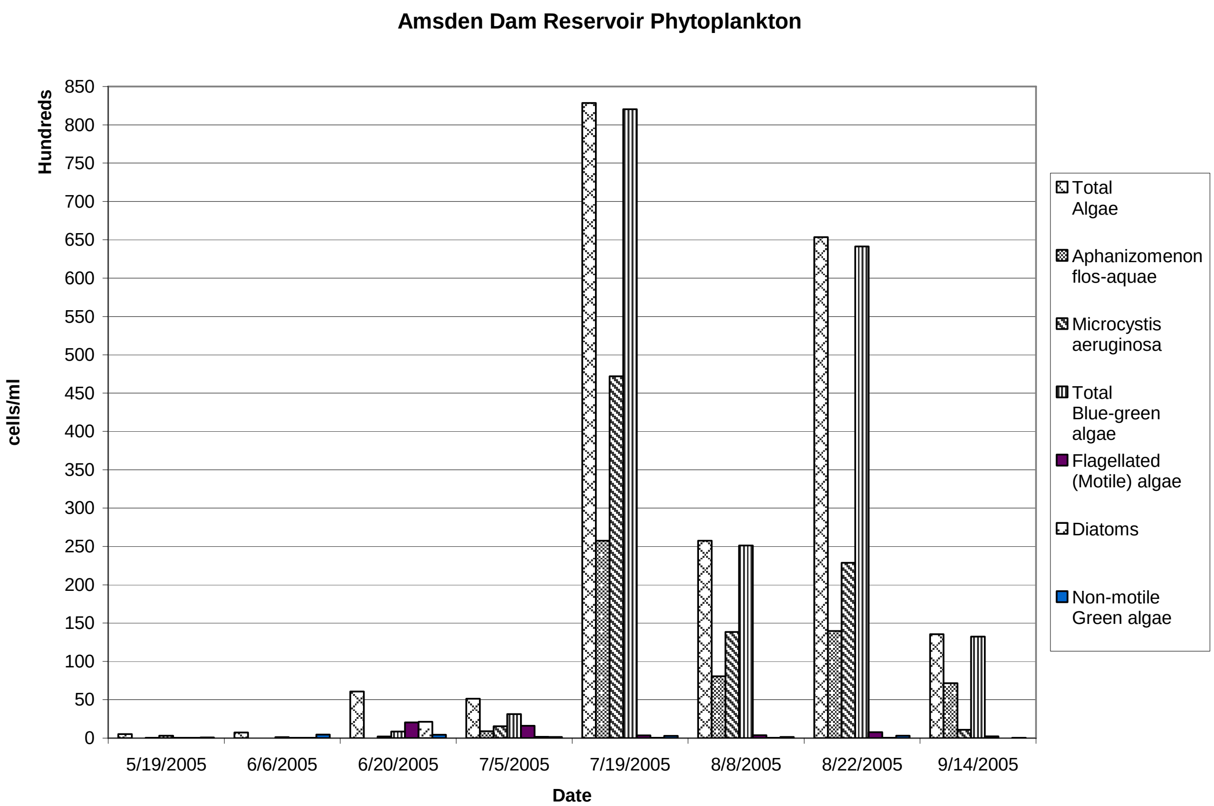

Figure 29. Amsden Dam Reservoir Phytoplankton Totals

Table 11. Algae Species and Densities in 20 samples for Amsden Dam, Day County, South Dakota, during 2005, 2002, and 1998.

#	Algae Species(61 taxa)	% Density	samples	Algae Type
1	Microcystis aeruginosa	25.8	20	Blue-Green Algae (colonial)
2	Aphanizomenon flos-aquae	19.0	13	Blue-Green Algae (filament)
3	Aphanocapsa sp.	11.2	15	Blue-Green Algae (colonial)
4	unidentified algae	7.4	20	Algae
5	Phormidium mucicola	6.4	12	Blue-Green Algae (filament)
6	Characium sp.	6.4	15	Green Algae (single cells)
7	Rhodomonas minuta	6.3	19	Flagellated Algae (crypto.)
8	Coelosphaerium naegelianum	4.8	6	Blue-Green Algae (colonial)
9	Asterionella formosa	3.4	3	Diatoms (colonial pennate)
10	unid. flagellated algae	3.4	17	Flagellated Algae
11	Schroederia judayi	2.6	14	Green Algae (single cells)
12	Stephanodiscus niagarae	1.3	11	Diatoms (centric)
13	Chlamydomonas sp.	0.8	10	Flagellated Algae (Green)
14	Phormidium sp.	0.8	8	Blue-Green Algae (filament)
15	Chlorella ellipsoidea?	0.5	11	Green Algae (single cells)
16	Anabaena flos-aquae	0.2	3	Blue-Green Algae (filament)
17	Anabaena sp.	0.2	3	Blue-Green Algae (filament)
18	Melosira granulata	0.3	5	Diatoms (filament centric)
19	Cryptomonas sp.	0.3	18	Flagellated Algae (crypto.)
20	Kirchneriella sp.	0.2	8	Green Algae (single cells)
21	Oocystis sp.	0.1	4	Green Algae (colonial)
22	Chrysochromulina parva	0.1	6	Flagellated Algae (golden-br)
23	Sphaerocystis schroeteri	0.1	4	Green Algae (colonial)
24	unidentified green algae	0.1	2	Green Algae (single cells)
25	Nitzschia sp.	0.0	12	Diatoms (pennate)
26	Nitzschia reversa	0.0	3	Diatoms (pennate)
27	Nitzschia acicularis	0.0	1	Diatoms (pennate)
28	Navicula cryptocephala	0.0	1	Diatoms (pennate)
29	Navicula sp.	0.0	2	Diatoms (pennate)
30	Cocconeis sp.	0.0	1	Diatoms (pennate)
31	Rhoicosphenia curvata	0.0	1	Diatoms (pennate)
32	Fragilaria capucina	0.0	4	Diatoms (pennate)
33	unidentified pennate diatoms	0.0	4	Diatoms (pennate)
34	Bacillaria paradoxa	0.0	1	Diatoms (pennate)
35	Gomphonema sp.	0.0	1	Diatoms (pennate)
36	Cyclotella meneghiniana	0.0	4	Diatoms (centric)
37	Stephanodiscus minutus	0.0	2	Diatoms (centric)
38	Stephanodiscus hantzschii	0.0	2	Diatoms (centric)
39	Pandorina morum	0.0	1	Flagellated Algae (Green col)
40	Kephyrion sp.	0.0	2	Flagellated Algae (golden-br)
41	Ceratium hirundinella	0.0	3	Dinoflagellates

Table 11 cont. Algae Species and Densities in 20 samples for Amsden Dam, Day County, South Dakota, during 2005, 2002, and 1998.

#	Algae Species(61 taxa)	% Density	samples	Algae Type
42	Phacus pseudonordstedtii	0.0	1	Flagellated Algae (euglenoid)
43	Phacus sp.	0.0	1	Flagellated Algae (euglenoid)
44	Euglena sp.	0.0	3	Flagellated Algae (euglenoid)
45	Lepocinclis sp.	0.0	1	Flagellated Algae (euglenoid)
46	Trachelomonas sp.	0.0	4	Flagellated Algae (euglenoid)
47	Ankistrodesmus sp.	0.0	2	Green Algae (single cells)
48	Oscillatoria sp.	0.0	1	Blue-Green Algae (filament)
49	Dactylococcopsis sp.	0.0	2	Blue-Green Algae (single c.)
50	Pediastrum duplex	0.0	2	Green Algae (colonial)
51	Spirogyra sp.	0.0	1	Green Algae (filament)
52	Closteriopsis longissima	0.0	2	Green Algae (single cells)
53	Tetraedron minimum	0.0	1	Green Algae (single cells)
54	Staurastrum sp.	0.0	1	Green Algae (Desmids)
55	Cosmarium sp.	0.0	1	Green Algae (Desmids)
56	Scenedesmus quadricauda	0.0	1	Green Algae (colonial)
57	Scenedesmus sp.	0.0	1	Green Algae (colonial)
58	Characium limneticum	0.0	5	Green Algae (single cells)
59	Micractinium pusillum	0.0	1	Green Algae (colonial)
60	Coelastrum sp.	0.0	1	Green Algae (colonial)
61	Actinastrum hantzschii	0.0	1	Green Algae (colonial)

Minnewasta Lake Phytoplankton

Surface samples of planktonic algae were collected at two widely separated lake water quality sites twice monthly from May 19 to Sept 14, 2005. In addition, two composite samples had been previously collected on July 18 and August 21, 2001, and the two sites sampled separately on Sept 28, 2004 (Table 12). On 6 of 9 sampling dates, samples from the smaller upper basin (site MW01) contained appreciably more algae than those from site MW02. It is not known if this represents a consistent trend or if the differences are statistically significant. A total of 23 samples were analyzed for this lake, including one replicate sample.

A total of 48 algal taxa, including two “unidentified algae” categories, were collected from this 601-acre natural lake (Table 13). Algae species richness (the number of algal species observed) and diversity for this survey was rated as “below average” when compared to 14 recently monitored smaller lakes of 200 acres or less, which had an average of 73 taxa.

Non-motile green algae (Chlorophyta) represented the most diverse algal group in Minnewasta Lake with 18 species, followed by diatoms with 14 taxa. A less varied algal group was blue-green algae (Cyanophyta) with 10 taxa, and the flagellated (motile) algae were represented by only 5 taxa. This was a fairly similar distribution to that found in Amsden Dam except the reservoir had more than twice as many taxa of flagellated algae (13). There appear to be a good number of similarities in the characteristics of the algae populations of these two otherwise dissimilar water bodies.

The planktonic algae community during this survey consisted mostly of blue-green algae (88.3%) of which the most common species were *Aphanizomenon flos-aquae* (61%), *Microcystis aeruginosa* (10%) and a minute (1micro meter) colonial taxon called *Aphanocapsa* (15%). A*phanizomenon* created a dense summer bloom as it increased to its annual maximum on July 19, 2005, of 377,632 cells/ml which was nearly 15 times larger than the yearly maximum for this species in Amsden Dam, also on July 19. *Microcystis* recorded a much smaller, poorly-defined peak on September 14, 2005, of 3866 cells/ml (Figure 30).

During late August 2001, *Microcystis* attained a density of nearly 24,000 cells/ml when the *Aphanizomenon* population was considerably smaller at 67,640 cells/ml. In Amsden Dam, *Microcystis* was more abundant than *Aphanizomenon* during this survey. It is probable that a competitive relationship exists between these two blue-green species. In general, limited data gathered in recent years suggest there has been an appreciable increase in the algae populations of this lake, notably in the abundance of blue-green algae.

Diatoms were very sparse in Minnewasta Lake making up only about 2% of total algae for the project. A moderate annual peak of 974 cells/ml was recorded on June 20, 2005, consisting almost entirely of a single species of *Melosira*, tentatively identified as *M. varians*. *Melosira* is a genus consisting of various species of filamentous centric diatoms. The most commonly distributed species in eutrophic state lakes and reservoirs was found to be *Melosira granulata* that usually reaches maximum annual abundance in summer. The *Melosira varians* in Minnewasta Lake was lightly-silicified with no ornamentation visible under a light microscope, unlike the relatively heavier frustules of *M. granulata* with readily visible ornamentation. Diatoms were present in somewhat higher numbers in Amsden Dam although not in any abundance, as previously noted. Unlike in the case of Amsden Dam, there was no heavy rainfall or watershed runoff in spring here to provide extra nutrients as an impetus for a large spring diatom or algae bloom. The only noticeable increase in the lake algae population came in early summer when warming water temperatures produced a favorable environment for a sharp increase in numbers of the blue-green *Aphanizomenon*.

Non-motile green algae (Chlorophyta) comprised only about 6% of the total lake algae during this survey. Similar to Amsden Dam, green algae represented the most diverse algal group in terms of the number of taxa, likewise, as in Amsden, they were poorly-developed in density and biovolume. Also similarly, most of the green algae were the small-sized forms of the *Characium*/*Schroederia* group.

Planktonic green algae may be at a severe competitive disadvantage in highly alkaline lakes with high pH such as Minnewasta Lake. Alkaline lakes tend to favor the growth of blue-green algae including the nuisance bloom-formers, provided there is an abundance of nutrients available (Shapiro, 1973). In less mineralized eutrophic waters of circumneutral pH, green algae can out-compete blue-greens due to the abundance of free dissolved CO_2. In alkaline waters like Minnewasta Lake and Amsden Dam (pH >8) free CO_2 is nearly absent (Reid, 1961).

Table 12. Minnewasta Lake Algae Abundance (cells/milliliter)

Date	Algae Group	Cells/ml	%
18 July'01	Flagellated (Motile) Algae	225	0.2
	Blue-Green Algae	88691	99.1
	Diatoms	18	0.0
	Non-Motile Green Algae	27	0.0
	Unidentified Algae	500	0.6
	Total	89461	
21 Aug'01	Flagellated (Motile) Algae	182	0.2
	Blue-Green Algae	94278	99.2
	Diatoms	18	0.0
	Non-Motile Green Algae	410	0.4
	Unidentified Algae	110	0.1
	Total	94998	
28 Sept'04	Flagellated (Motile) Algae	566	0.6
	Blue-Green Algae	102961	99.3
	Diatoms	35	0.0
	Non-Motile Green Algae	90	0.1
	Unidentified Algae	70	0.1
	Total	103722	
19 May'05	Flagellated (Motile) Algae	80	1.2
	Blue-Green Algae	4070	63.3
	Diatoms	22	0.3
	Non-Motile Green Algae	2101	32.7
	Unidentified Algae	160	2.5
	Total	6433	
6 June'05	Flagellated (Motile) Algae	525	4.3
	Blue-Green Algae	10784	88.8
	Diatoms	62	0.5
	Non-Motile Green Algae	601	5.0
	Unidentified Algae	170	1.4
	Total	12142	

Table 12 cont. Minnewasta Lake Algae Abundance (cells/milliliter)

Date	Algae Group	Cells/ml	%
20 June'05	Flagellated (Motile) Algae	255	2.9
	Blue-Green Algae	5840	67.1
	Diatoms	974	11.2
	Non-Motile Green Algae	1472	16.9
	Unidentified Algae	160	1.8
	Total	8701	
28 June'05	Flagellated (Motile) Algae	281	0.6
	Blue-Green Algae	50483	98.3
	Diatoms	225	0.4
	Non-Motile Green Algae	189	0.4
	Unidentified Algae	180	0.4
	Total	51358	
5 July'05	Flagellated (Motile) Algae	78	0.0
	Blue-Green Algae	313180	99.8
	Diatoms	155	0.1
	Non-Motile Green Algae	102	0.0
	Unidentified Algae	225	0.1
	Total	313740	
19 July'05	Flagellated (Motile) Algae	48	0.0
	Blue-Green Algae	381854	100.0
	Diatoms	3	0.0
	Non-Motile Green Algae	20	0.0
	Unidentified Algae	50	0.0
	Total	381975	
26 July'05	Flagellated (Motile) Algae	32	0.0
	Blue-Green Algae	328314	100.0
	Diatoms	5	0.0
	Non-Motile Green Algae	40	0.0
	Unidentified Algae	5	0.0
	Total	328396	
8 Aug'05	Flagellated (Motile) Algae	26	0.0
	Blue-Green Algae	303194	100.0
	Diatoms	7	0.0
	Non-Motile Green Algae	6	0.0
	Unidentified Algae	5	0.0
	Total	303238	

Table 12 cont. Minnewasta Lake Algae Abundance (cells/milliliter)

Date	Algae Group	Cells/ml	%
22 Aug'05	Flagellated (Motile) Algae	30	0.0
	Blue-Green Algae	149584	100.0
	Diatoms	12	0.0
	Non-Motile Green Algae	7	0.0
	Unidentified Algae	30	0.0
	Total	149663	
14 Sept'05	Flagellated (Motile) Algae	1277	22.4
	Blue-Green Algae	4119	72.3
	Diatoms	40	0.7
	Non-Motile Green Algae	174	3.1
	Unidentified Algae	85	1.5
	Total	5695	

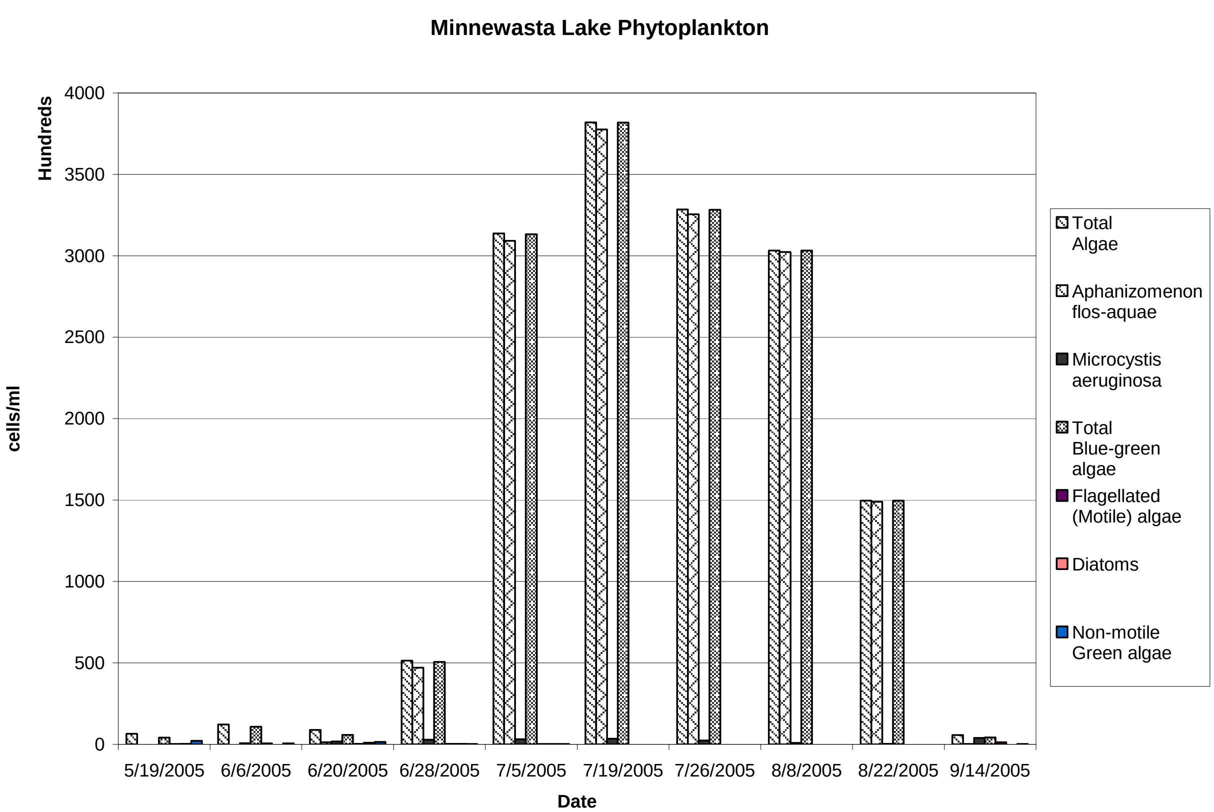

Figure 30. Minnewasta Lake Phytoplankton Totals

Table 13. Algae Species and Densities in 22 samples for Minnewasta Lake, Day County, South Dakota during 2005, 2004, and 2001.

#	Algae Species (48 taxa)	% Density	samples	Algal Type
1	Aphanizomenon flos-aquae	60.9	19	Blue-Green Algae (filament)
2	Aphanocapsa sp.	14.8	8	Blue-Green Algae (colonial)
3	Microcystis aeruginosa	10.0	20	Blue-Green Algae (colonial)
4	Rhodomonas minuta	3.2	21	Flagellated Algae (crypto.)
5	Schroederia sp. ?	3.0	5	Green Algae (single cells)
6	Characium sp.	1.7	13	Green Algae (single cells)
7	Melosira varians	1.5	10	Diatoms (filament centric)
8	Anabaena flos-aquae	1.0	3	Blue-Green Algae (filament)
9	Phormidium sp.	0.9	9	Blue-Green Algae (filament)
10	Phormidium mucicola	0.6	14	Blue-Green Algae (filament)
11	Schroederia judayi	0.6	17	Green Algae (single cells)
12	unidentified algae	0.7	20	Algae
13	unid. flagellated algae	0.2	20	Flagellated Algae
14	Cryptomonas sp.	0.1	8	Flagellated Algae (crypto.)
15	Anabaena sp.	0.1	6	Blue-Green Algae (filament)
16	Kirchneriella sp.	0.1	7	Green Algae (single cells)
17	Sphaerocystis schroeteri	0.1	4	Green Algae (colonial)
18	Stephanodiscus niagarae	0.0	4	Diatoms (centric)
19	Stephanodiscus minutus	0.0	3	Diatoms (centric)
20	Stephanodiscus sp.	0.0	1	Diatoms (centric)
21	Cyclotella atomus	0.0	1	Diatoms (centric)
22	Melosira granulata	0.0	2	Diatoms (centric)
23	Nitzschia paleacea	0.0	1	Diatoms (pennate)
24	Nitzschia sp.	0.0	11	Diatoms (pennate)
25	Navicula cryptocephala	0.0	1	Diatoms (pennate)
26	Synedra cyclopum	0.0	2	Diatoms (pennate)
27	Synedra sp.	0.0	1	Diatoms (pennate)
28	Navicula ventosa ?	0.0	3	Diatoms (pennate)
29	Navicula sp.	0.0	1	Diatoms (pennate)
30	Surirella ovalis	0.0	1	Diatoms (pennate)
31	Chlamydomonas sp.	0.0	7	Flagellated Algae(Green Alg)
32	Euglena sp.	0.0	1	Flagellated Algae(Euglenoid)
33	Oscillatoria sp.	0.0	2	Blue-Green Algae (filament)
34	Coelosphaerium sp.	0.0	4	Blue-Green Algae (filament)
35	Anabaena subcylindrica?	0.0	4	Blue-Green Algae (filament)
36	Oocystis sp.	0.0	8	Green Algae (colonial)
37	Characium limneticum	0.0	1	Green Algae (single cells)
38	unidentified green algae	0.0	2	Green Algae (single cells)
39	Coelastrum sp.	0.0	1	Green Algae (colonial)
40	Scenedesmus quadricauda	0.0	1	Green Algae (colonial)
41	Scenedesmus sp.	0.0	2	Green Algae (colonial)

Table 13 cont. Algae Species and Densities in 22 samples for Minnewasta Lake, Day County, South Dakota during 2005, 2004, and 2001.

#	Algae Species (48 taxa)	% Density	samples	Algal Type
42	Ankistrodesmus sp.	0.0	2	Green Algae (single cells)
43	Botryococcus braunii	0.0	1	Green Algae (colonial)
44	Chlorella ellipsoidea ?	0.0	3	Green Algae (single cells)
45	Spirogyra sp.	0.0	3	Green Algae (filament)
46	Pediastrum boryanum	0.0	1	Green Algae (colonial)
47	Closteriopsis longissima	0.0	1	Green Algae (single cells)
48	Dictyosphaerium pulchellum	0.0	1	Green Algae (colonial)

Other Monitoring

Annualized Agricultural Non-Point Source Modeling (AnnAGNPS)

Data was collected by the coordinator for the AnnAGNPS model. Since both lakes are meeting their assigned beneficial uses, the AnnAGNPS model was not run for figuring sediment and nutrient loading reductions. However, there are certain BMPs that should be implemented in both watersheds to help improve and maintain current water quality in the lakes.

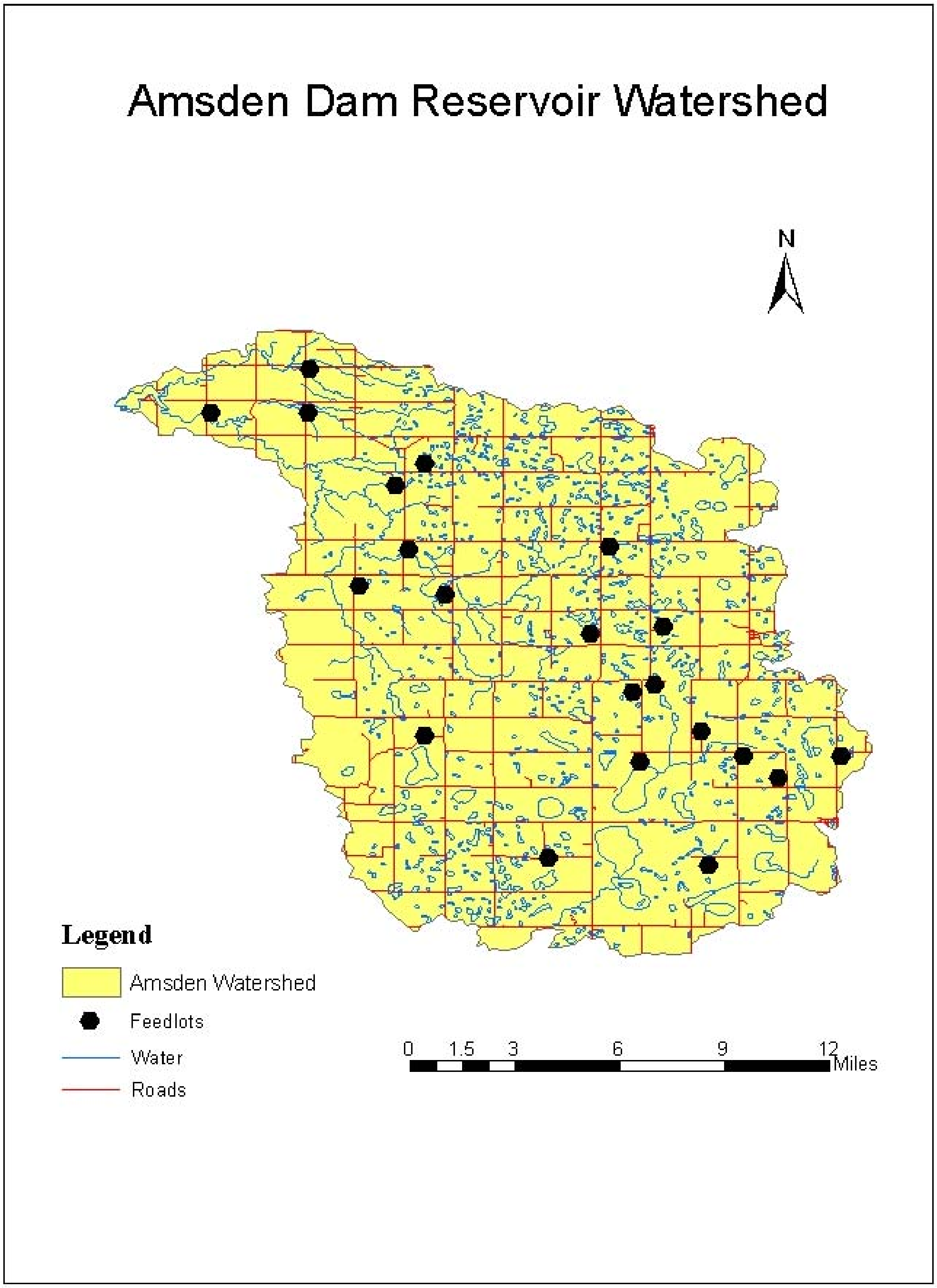

Figure 31. Amsden Watershed Feedlot Locations

Quality Assurance/Quality Control (QA/QC)

The project PIP called for one QA/QC set to be prepared for every 10 lake and 10 tributary samples collected in the field during the project. A QA/QC sample set consists of a field replicate and a blank sample of analyte-free de-ionized water. Field replicates are taken in the field with the same equipment, methods, and within as close in time as possible to the previous sample to which the replicate is matched for comparison.

In-Lake Sampling QA/QC

Three QA/QC sample sets were collected from Minnewasta Lake on October 19, 2004, April 19 2005, and August 8, 2005. This represented 9% of the 32 lake samples collected from Minnewasta Lake. No QA/QC samples were collected from Amsden Dam Reservoir due to a lack of local match required to capture Federal 319 dollars. Table 14 shows variations in chemical parameters between the sample and replicate set, and the chemical parameters detected in the blank sample.

Table 14. Lake Replicates and Blanks - Minnewasta Lake

Site	Date	Type	Depth	TALKA mg/L.	TSOL mg/L.	TDSOL mg/L.	TSSOL mg/L.	AMMO mg/L.	NIT mg/L.	TKN mg/L.	TPO4 mg/L.	TDPO4 mg/L.	FEC 100 ml.
MW-02	10/19/04	Blank	Surface	<6	<7	6	<1	<0.02	<0.1	<0.23	0.002	<0.002	<10
MW-02	10/19/04	Replicate	Surface	433	1600	1596	4	0.47	0.2	2.67	0.209	0.17	<10
MW-02	10/19/04	Sample	Surface	440	1605	1596	9	0.17	0.2	2.19	0.203	0.174	<10
				2%	0%	0%	56%	64%	0%	18%	3%	2%	0%
MW-02	4/19/05	Blank	Surface	<6	<7	6	<1	<0.02	<0.1	<0.5	0.004	<0.002	<10
MW-02	4/19/05	Replicate	Surface	425	1581	1577	4	<0.02	<0.1	1.98	0.1	0.088	<10
MW-02	4/19/05	Sample	Surface	424	1580	1572	8	<0.02	<0.1	1.76	0.1	0.079	<10
				0%	0%	0%	50%	0%	0%	11%	0%	12%	0%
MW-01	8/8/05	Blank	Surface	<6	<7	6	<1	<0.02	<0.1	<0.5	0.004	<0.002	<10
MW-01	8/8/05	Replicate	Surface	356	1549	1530	19	<0.02	<0.1	3.99	0.126	0.038	10
MW-01	8/8/05	Sample	Surface	355	1547	1530	17	<0.02	<0.1	3.83	0.125	0.039	<10
				0%	0%	0%	11%	0%	0%	4%	1%	3%	0%
	Average Percent Difference:			0.7%	0.0%	0.0%	39.0%	21.0%	0.0%	11.0%	1.3%	5.7%	0.0%

The October 19, 2004 QA/QC set showed a 56% difference in TSSOL and a 64% difference in ammonia between the replicate and sample sets.

The April 19, 2005 QA/QC set showed increases in TSSOL, TKN, and TDP04 between the samples and replicate sets.

The August 8, 2005 QA/QC set showed very little variation between sample and replicate sets.

Tributary Sampling QA/QC

Four QA/QC sample sets were collected from Amsden Dam Reservoir tributaries on September 22, 2004, October 1, 2004, November 1, 2004, and June 14, 2005. This represented only 7% of the 59 sample sets collected from tributary sites. Table 15 shows variations in chemical parameters between the sample and replicate set and the chemical parameters detected in the blank sample.

Table 15. Amsden Tributary Replicates and Blanks

Site	Date	Type	Depth	TALKA mg/L.	TSOL mg/L.	TDSOL mg/L.	TSSOL mg/L.	AMMO mg/L.	NIT mg/L.	TKN mg/L.	TPO4 mg/L.	TDPO4 mg/L.	FEC 100 ml.
ADT-04	9/22/04	Blank	Surface	<6	<7	6	<1	<0.02	<0.1	<0.23	<0.002	<0.002	<10
ADT-04	9/22/04	Replicate	Surface	273	1095	1088	7	0.14	0.2	0.46	0.124	0.087	460
ADT-04	9/22/04	Sample	Surface	274	1089	1084	5	0.14	0.2	0.45	0.124	0.084	530
				0%	0%	0%	29%	0%	0%	2%	0%	3%	12%
ADT-02	10/1/04	Blank	Surface	<6	<7	6	<1	<0.02	<0.1	<0.23	<0.002	<0.002	ND
ADT-02	10/1/04	Replicate	Surface	324	1618	1616	2	<.002	<0.1	0.65	0.192	0.17	ND
ADT-02	10/1/04	Sample	Surface	324	1611	1607	4	<0.02	<0.1	0.76	0.195	0.176	ND
				0%	0%	1%	50%	0%	0%	14%	2%	3%	
ADT-03	11/1/04	Blank	Surface	<6	<7	6	<1	<0.02	<0.1	<0.23	<0.002	<0.002	<10
ADT-03	11/1/04	Replicate	Surface	284	1084	1082	2	<0.02	0.2	0.83	0.127	0.099	260
ADT-03	11/1/04	Sample	Surface	291	1082	1080	2	<0.02	0.2	0.88	0.123	0.101	200
				2%	0%	0%	0%	0%	0%	6%	3%	2%	23%
ADT-03	6/14/05	Blank	Surface	<6	<7	6	<1	<0.02	<0.1	<0.5	<0.002	<0.002	<10
ADT-03	6/14/05	Replicate	Surface	171	611	578	33	<0.02	1.2	1.37	0.737	0.609	540
ADT-03	6/14/05	Sample	Surface	171	609	580	29	<0.02	1.2	1.46	0.666	0.646	410
				0%	0%	0%	12%	0%	0%	6%	10%	6%	24%
	Average Percent Difference:			0.5%	0.0%	0.3%	23.0%	0.0%	0.0%	7.0%	3.8%	3.5%	19.7%

The September 22, 2004 QA/QC sample set showed a 29% difference in TSSOL between the samples and replicate sets.

The October 1, 2004 QA/QC sample set showed a 50% difference in TSSOL levels and a 14% difference in TKN levels between the replicate and sample sets.

The November 1, 2004 and June 14, 2005 QA/QC sets detected little to no difference between the samples and replicate samples for all the chemical parameters tested.

The variations between sample and replicate sets do not indicate any significant problems with field collection techniques or laboratory procedures or errors. Sample contamination, contamination of distilled water, poorly-rinsed sample bottles, and poorly-rinsed filters may be some reasons for differences. Natural sample variation and the fact these QA/QC samples were replicate not duplicate more likely explains the variations between replicate and sample sets.

The levels of all chemical parameters in the blank samples were below the SD State Health Laboratory's minimum detectable limits except for the total phosphorus found in the Minnewasta Lake samples. The source of the total phosphorus detected in these samples is likely from over-the-counter distilled water used for the blank samples and for rinsing sampling equipment. The same brand of distilled water utilized for Minnewasta Lake's blank samples was used for Amsden tributary samples which had total phosphorus levels below detectable limits.

Discrete Sampling

Two discrete samples were taken during the assessment project. The samples were collected on June 29, 2005, following a 4.25 inch rainstorm event, downstream of a large AFO suspected of contributing non-point source pollutants to Amsden Dam Reservoir. The AFO is located on a small intermittent stream approximately two miles upstream of the tributary sampling site ADT03 (Figure 32). This AFO was the suspected source of high fecal coliform counts found in ADT03 samples after several storm events. The discrete sample taken immediately downstream of the AFO had a fecal coliform count of 34,000,000/100 ml and a total phosphorus count of 30.6 mg/L. All other parameters are given in Table 16 below.

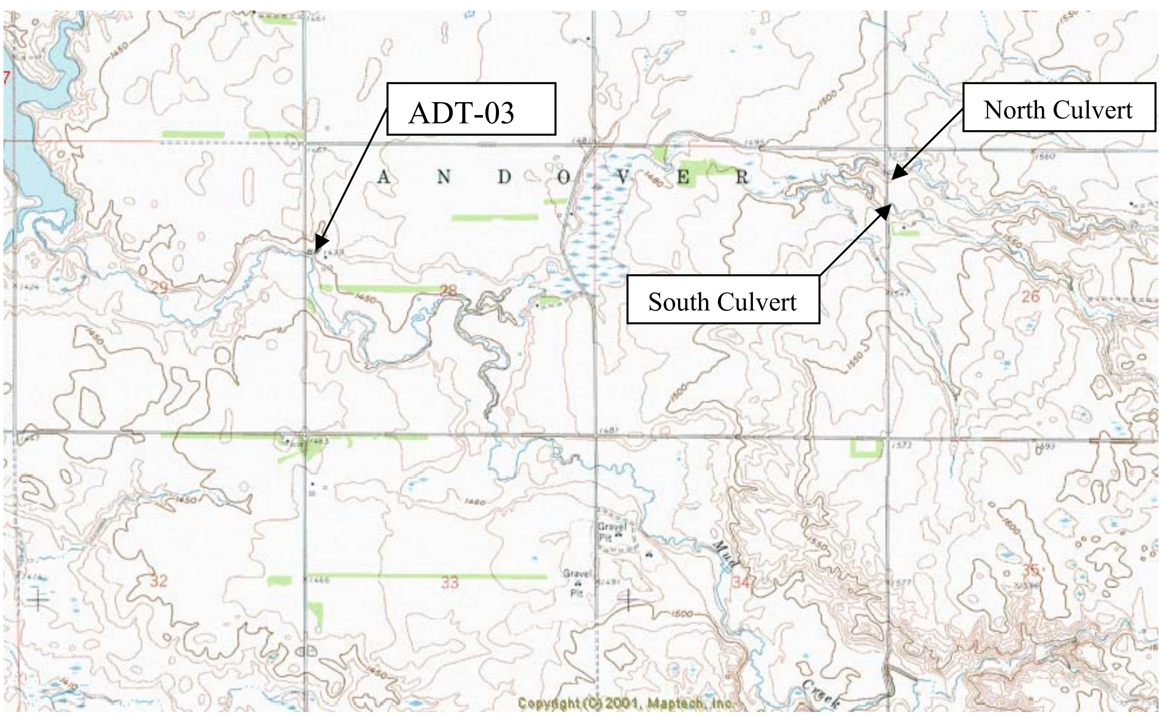

Figure 32. Amsden Dam Tributary Discrete Sample Site Location

Table 16. Amsden Dam Tributary Discrete Samples

Alkalinity M mg/L.	Total Solids mg/L.	Suspended Solids mg/L.	VTSS mg/L.	Ammonia	Nitrate	TKN	Total Phosphorus mg/L.	Total Dissolved Phosphorus mg/L.	Fecal Coliform	E.Coli
95	450	82	6	0.07	1.4	2.26	0.78	0.541	12000	>2420
(North Culvert)										
433	3424	2700	880	6.24	<0.1	77.5	30.6	NA	34000000	>2420
(South Culvert)										

Depositional Sampling

A depositional sampler was installed at the Webster USDA Service Center in Webster, South Dakota. The location of the sampler was located approximately mid-way between the two watersheds being assessed by this project. The purpose of this monitoring was to determine the amount of phosphorus carried in dust particulates deposited by wind or rain in a water body. The sampler consists of dry and wet collection buckets. The wet bucket is filled with approximately 1000 ml of distilled water and is left exposed to the atmosphere to collect dust. A second dry bucket is left covered with a lid until an electronic sensor detects precipitation. The electronically controlled lid opens exposing the dry bucket to the atmosphere allowing rainfall to be collected. The wet bucket is covered by the lid until precipitation ceases. Samples were collected after rainfall events. Chemical and field data collected from the sampler are shown in Table 17.

There were some problems noted with the depositional sampler. The sensor did not always move the bucket lid during rainfall events allowing rainwater to contaminate the wet bucket or left the dry bucket exposed to the atmosphere after rain events had ceased possibly contaminating the dry bucket sample water. A nearby resident flock of purple martins also utilized the wet bucket as a bird bath. Bird droppings were often seen in the mid-summer wet bucket samples that is the probable source of high phosphorous levels of some samples.

Table 17. Depositional Sampler Field and Chemical Parameters

Dates	Sample Type	Suspended Solids mg/lL	Ammonia mg/L.	Nitrate mg/L.	TKN mg/L.	Total Phosphorus mg/L.	pH su	Precipitation inches
4/6/05 to 4/13/05	wet	18	0.47	0.3	0.61	0.031	NA	NA
4/13/05 to 5/9/05	wet	24	0.63	0.3	1.02	0.132	NA	NA
5/13/05 to 5/26/05	wet	29	1.48	0.6	2.75	0.164	NA	NA
5/27/05 to 6/7/05	wet	23	0.91	0.3	2.9	0.435	NA	NA
6/8/05 to 6/13/05	wet	4	0.07	0.2	<0.5	0.009	NA	NA
6/24/05 to 6/30/05	wet	1	1.39	0.3	3.43	0.309	NA	NA
7/1/05 to 7/8/05	wet	6	0.33	0.2	0.54	0.024	NA	NA
7/9/05 to 7/27/05	wet	46	<0.2	<0.1	2.29	0.331	NA	NA
7/28/05 to 8/11/05	wet	13	0.25	0.4	0.79	0.09	NA	NA
8/12/05 to 9/12/05	wet	36	<0.02	<0.1	1.39	0.142	NA	NA
4/6/05 to 4/13/05	dry	7	0.49	0.3	<0.50	0.011	4.98	0.6
4/13/05 to 5/9/05	dry	17	1.2	0.3	1.4	0.041	5.98	1.93
5/9/05 to 5/13/05	dry	1	<0.02	0.1	<0.5	0.008	5.23	0.76
5/13/05 to 5/26/05	dry	3	0.27	0.3	<0.5	0.011	5.63	NA
5/27/05 to 6/7/05	dry	<1	0.31	0.2	<0.5	0.004	5.39	2.73
6/8/05 to 6/13/05	dry	3	0.27	0.3	<0.5	0.004	5.37	3.04
6/24/05 to 6/30/05	dry	5	0.21	0.1	<0.5	0.01	5.55	1.28
7/1/05 to 7/8/05	dry	<1	0.62	0.1	0.75	0.004	6.65	1.27
7/9/05 to 7/27/05	dry	2	0.8	0.3	1.05	0.7	6.59	1.57
7/28/05 to 8/11/05	dry	1	0.17	0.2	<0.5	0.004	NA	1.54
8/12/05 to 9/12/05	dry	1	0.82	0.4	0.82	0.018	6.18	1.2
7/27/2005	blank wet	3	<0.02	<0.1	<0.5	0.006	NA	NA
	blank dry	4	<0.02	<0.1	<0.5	0.003	NA	NA

Public Involvement and Coordination

State Agencies

The South Dakota Department of Environment and Natural Resources (SD DENR) was the lead state agency involved in the completion of this assessment. SD DENR provided a Natural Resources Fee Fund Grant to match the federal EPA grant, and also provided equipment as well as technical assistance throughout the entire project.

The South Dakota Department of Game, Fish and Parks (SDGF&P) aided in the completion of the assessment by providing a complete report on the condition of the fishery in Amsden Dam Reservoir and Minnewasta Lake.

Federal Agencies

The Environmental Protection Agency (EPA) provided a Section 319 grant to fund this assessment.

The Natural Resource Conservation Service (NRCS) provided office space and technical assistance for the assessment project coordinator.

The Farm Service Agency (FSA) provided land use information for the AnnAGNPS model used for watershed modeling.

Local Governments, Industry, Environmental and other Groups, General Public

The Day County Conservation District was the local sponsor providing cash and in-kind match that included water testing equipment, gas and transportation, boat and ATV for lake sampling, and bookkeeping by the District's business manager. The District hired a project coordinator to conduct assessment activities. The Day County Conservation District Board of Directors supervised the project.

No public meetings were held. Instead, information was provided to the public during the Day County Farm, Home and Sports Show. Monthly meetings of the Day County Conservation District's Board of Supervisors are also open to the public. Project information was distributed through the District's newsletters and news releases to local media.

The Water Resources Institute located on the campus of South Dakota State University, Brookings, SD, provided equipment, technical assistance, and personnel to help with lake sampling and macrophyte surveys.

There are no lake associations on either water body nor were there any sportsmen's groups interested in supporting the assessment project financially.

Aspects of the Project that Did Not Work Well

All of the objectives proposed for the project were met in an acceptable time frame. Due to a lack of snow accumulation, there was no spring runoff to sample. Several large rainstorm events provided sufficient tributary runoff to sample during the early summer months in 2005.

Due to a lack of financial support from local government and groups, some project activities were eliminated or changed due to a projected shortfall in local cash and in-kind match. Bottom samples were eliminated from the work plan for Minnewasta Lake. Although the lake's depth was over ten feet, the difference in chemical and field parameters between surface and bottom samples was deemed insignificant. Elutriate sampling was also eliminated from the work plan. Instead, a bottom sediment sample was taken from each water body.

Future Activity Recommendations

Amsden Dam Reservoir

There is a critical need for stabilization and improvement of riparian buffers around a majority of Amsden Dam Reservoir's shoreline. It was documented during the shoreline habitat assessment conducted that the habitat is in a suboptimal condition due to heavy grazing of cattle (Figure 33). Overgrazing has resulted in the degradation and removal of shoreline vegetation. There are several areas of severe shoreline erosion from cattle accessing the lake for water. Installation of fenced riparian buffer zones and alternate water sources to control access by livestock, and installation of both hard and soft methods of shoreline stabilization are needed to protect and reestablish the reservoir's shoreline.

Figure 33. Riparian Degradation – Amsden Dam Reservoir Shoreline

Contracts for several hundred acres of cropland currently enrolled in the NRCS Conservation Reserve Program (CRP) are set to expire in 2007 and 2008 (Figure 34). Fields not re-enrolled into CRP should be checked for riparian buffers and other Best Management practices that would protect Amsden Dam Reservoir's water quality.

Minnewasta Lake

Future development of this lake may require the installation of a closed sewer collection system for lake homes. Steps should also be taken to control runoff from two nearby AFOs. One feedlot operator adjacent to the lake has already contacted the Day County Conservation District about implementing an animal nutrient management system.

The Day County Conservation District will be applying for grants to fund a water quality improvement project for the Amsden and Minnewasta watersheds.

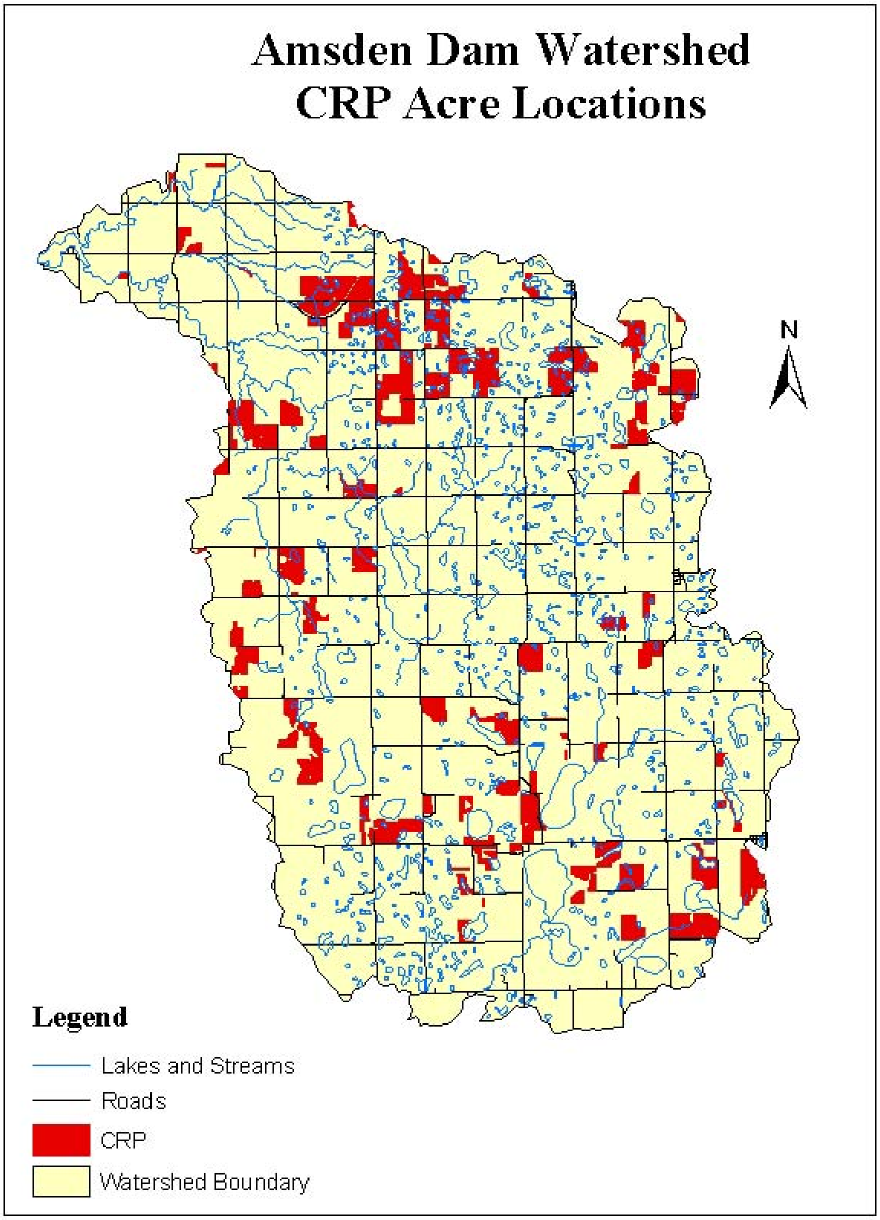

Figure 34. Location of expiring CRP acres in Amsden Watershed

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Appendix A.

Amsden Dam Reservoir Water Quality Data

Amsden Dam Reservoir Field Parameters								
Date Sampled	Sample Location	Depth	Air Temp °C	Water Temp °C	Secchi Disk (Meters)	Secchi Disk (Feet)	DO	pH
9/14/2004	AD06	Surface Bottom	18.3	20.8 20.3	2.29	7.5	7.3 7.0	8.67 8.68
	AD07	Surface Bottom	18.3	20.8 20.2	3.32	10.9	8.1 7.5	8.72 8.73
10/19/2004	AD06	Surface Bottom	12	9.0 8.8	1.49	4.9	9.9 9.6	8.79 8.82
	AD07	Surface Bottom	12	8.6 8.1	1.95	6.4	10.1 10.1	8.83 8.8
1/25/2005	AD06	Surface Bottom	1.7	2.1 3.7	7.32	24	12.4 5.3	8.52 NA
	AD07	Surface Bottom	1.7	1.6 1.7	3.66	12	12.7 13.0	8.59 NA
2/24/2005	AD06	Surface Bottom	-7	4.2 4.4	3.66	12	13.5 6.9	8.56 NA
	AD07	Surface Bottom	-7	1.5 4.8	1.22	4	16.1 13.2	8.69 NA
4/19/2005	AD06	Surface Bottom	13	14.3 14.3	2.13	7	9.9 9.9	8.6 8.61
	AD07	Surface Bottom	13	14.3 14.3	2.13	7	9.9 9.9	8.6 8.59
5/19/2005	AD06	Surface Bottom	22	13.9 13.2	3.26	10.7	11.3 11.3	8.66 8.64
	AD07	Surface Bottom	22	15.5 13.9	2.99	9.8	11.0 11.4	8.7 8.68
6/6/2005	AD06	Surface Bottom	21	19 16.5	4.57	15	8.8 7.2	8.43 8.34
	AD07	Surface Bottom	21	19 18	3.6	11.8	8.4 7.8	8.46 8.42
6/20/2005	AD06	Surface Bottom	16	23 19	1.25	4.1	8.6 4.3	8.31 8.22
	AD07	Surface Bottom	16	23.5 22.5	1.28	4.2	7.8 8	8.2 8.27
7/5/2004	AD06	Surface Bottom	16.7	22.9 20	1.92	6.3	7 2.4	8.14 7.88
	AD07	Surface Bottom	16.7	23 22	2.29	7.5	6.4 5.8	8.07 8.03
7/19/2005	AD06	Surface Bottom	25.5	24 20	1.83	6	6.1 2.4	8.35 8.04
	AD07	Surface Bottom	25.5	24.5 24	1.43	4.7	6.4 6.2	8.44 8.46
8/8/2005	AD06	Surface Bottom	27	24 22	3.23	10.6	5.9 1.4	8.6 8.48
	AD07	Surface Bottom	27	25.5 25	2.71	8.9	6.3 5.8	8.71 8.67
8/22/2005	AD06	Surface Bottom	16.7	22.6 22.5	3.08	10.1	7.3 6.3	8.5 8.5
	AD07	Surface Bottom	16.7	22.3 22.0	2.74	9	6.7 6	8.5 8.46
9/14/2005	AD06	Surface Bottom	15	20.1 19.9	1.37	4.5	4.9 4.8	8.52 8.54
	AD07	Surface Bottom	15	20 19.3	1.4	4.6	5.1 5.3	8.53 8.52

Amsden Dam Resevoir Chemical Parameters

Date Sampled	Sample Location	Depth	Alkalinity M mg/L.	Total Solids mg/L.	Suspended Solids mg/L.	VTSS mg/L.	Ammonia	Nitrate	TKN	Total Phosphorus mg/L.	Total Dissolved Phosphorus mg/L.	Fecal Coliform	E.Coli
9/14/04	AD06	Surface	261	1448	10	3	0.08	<0.1	1.0	0.253	0.223	<10/100	<1/100
		Bottom	262	1464	15	5	0.12	<0.1	1.0	0.268	0.227	NA	NA
	AD07	Surface	266	1454	8	2	0.06	<0.1	1.18	0.243	0.211	<10/100	<1/100
		Bottom	266	1456	10	4	0.08	<0.1	0.77	0.244	0.225	NA	NA
10/19/04	AD06	Surface	272	1466	17	8	<0.02	<0.1	0.68	0.191	0.147	<10/100	<1/100
		Bottom	272	1465	20	5	<0.02	<0.1	0.51	0.194	0.147	NA	NA
	AD07	Surface	273	1456	13	3	<0.02	<0.1	0.53	0.189	0.144	10/100	2.0/100
		Bottom	274	1466	15	6	<0.02	<0.1	0.62	0.193	0.145	NA	NA
1/25/05	AD06	Surface	307	1580	5	<1	<0.02	<0.1	0.57	0.061	0.056	<10/100	<1/100
		Bottom	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	AD07	Surface	309	1588	5	2	<0.02	<0.1	0.52	0.056	0.051	<10/100	<1/100
		Bottom	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2/24/05	AD06	Surface	295	1441	<1	<1	<0.02	0.1	<0.5	0.049	0.042	<10/100	<1/100
		Bottom	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	AD07	Surface	298	1488	4	1	<0.02	<0.1	<0.5	0.071	0.045	<10/100	<1/100
		Bottom	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4/19/05	AD06	Surface	276	1388	8	4	<0.02	<0.1	<0.5	0.08	0.049	<10/100	<1/100
		Bottom	275	1385	10	5	<0.02	<0.1	0.51	0.077	0.048	NA	NA
	AD07	Surface	276	1383	6	3	<0.02	<0.1	0.53	0.078	0.05	<10/100	1.0/100
		Bottom	276	1389	12	6	<0.02	<0.1	0.69	0.108	0.054	NA	NA
5/19/05	AD06	Surface	260	1393	11	4	<0.02	<0.1	<0.5	0.057	0.038	<10/100	<1/100
		Bottom	267	1402	14	4	<0.02	<0.1	<0.5	0.071	0.043	NA	NA
	AD07	Surface	261	1398	13	4	<0.02	<0.1	<0.5	0.061	0.042	10/100	2.0/100
		Bottom	268	1405	15	4	<0.02	<0.1	<0.5	0.068	0.042	NA	NA
6/6/05	AD06	Surface	268	1401	4	2	<0.02	<0.1	<0.5	0.064	0.046	<10/100	<1/100
		Bottom	278	1397	2	1	<0.02	<0.1	<0.5	0.146	0.074	NA	NA
	AD07	Surface	269	1398	4	4	<0.02	<0.1	<0.5	0.078	0.054	<10/100	<1/100
		Bottom	NA	NA	NA	NA	<0.02	<0.1	<0.5	0.086	0.077	NA	NA
6/20/05	AD06	Surface	227	1071	8	4	<0.02	0.4	0.88	0.268	0.217	<10/100	4.1/100
		Bottom	228	1080	10	4	0.02	0.3	0.65	0.22	0.227	NA	NA
	AD07	Surface	228	1009	8	2	0.11	0.3	1.21	0.408	0.356	<10/100	5.1/100
		Bottom	227	1023	13	3	<0.02	0.4	1.01	0.351	0.312	NA	NA

Date Sampled	Sample Location	Depth	Alkalinity M mg/L.	Total Solids mg/L.	Suspended Solids mg/L.	VTSS mg/L.	Ammonia	Nitrate	TKN	Total Phosphorus mg/L.	Total Dissolved Phosphorus mg/L.	Fecal Coliform	E.Coli
7/5/05	AD06	Surface	182	827	3	3	0.02	0.5	1.24	0.393	0.368	<10/100	3.0/100
		Bottom	199	900	3	3	0.2	0.5	1.42	0.464	0.434	NA	NA
	AD07	Surface	177	791	3	3	0.04	0.5	1.33	0.46	0.415	10/100	3.0/100
		Bottom	180	806	5	5	0.05	0.5	1.28	0.429	0.403	NA	NA
7/19/05	AD06	Surface	203	877	7	7	0.07	<0.1	1.43	0.489	0.45	<10/100	<1/100
		Bottom	216	915	5	5	0.77	<0.1	1.87	0.901	0.893	NA	NA
	AD07	Surface	207	894	8	8	<0.02	<0.1	1.36	0.496	0.433	<10/100	1.0/100
		Bottom	207	894	11	10	<0.02	<0.1	1.25	0.515	0.441	NA	NA
8/8/05	AD06	Surface	219	908	2	<1	<0.02	<0.1	0.97	0.533	0.525	<10/100	3.1/100
		Bottom	224	916	11	<1	0.24	<0.1	1.32	0.696	0.597	NA	NA
	AD07	Surface	222	931	5	3	<0.02	<0.1	2.62	0.532	0.48	10/100	1.0/100
		Bottom	222	928	5	3	<0.02	<0.1	1.16	0.516	0.509	NA	NA
8/22/05	AD06	Surface	228	943	6	3	0.11	<0.1	1.4	0.588	0.578	<10/100	<1/100
		Bottom	230	956	22	5	0.15	<0.1	1.37	0.595	0.566	NA	NA
	AD07	Surface	229	946	8	5	0.17	<0.1	1.37	0.592	0.575	<10/100	<1/100
		Bottom	231	954	11	4	0.22	<0.1	1.37	0.615	0.561	NA	NA
9/14/05	AD06	Surface	242	976	7	5	0.35	0.1	1.16	0.542	0.521	20/100	3.0/100
		Bottom	241	973	7	4	0.32	0.1	1.12	0.537	0.503	NA	NA
	AD07	Surface	242	987	6	3	0.35	0.1	1.04	0.548	0.495	20/100	<1/100
		Bottom	245	990	9	4	0.37	0.1	1.1	0.543	0.524	NA	NA

Appendix B.

Minnewasta Lake Water Quality Data

Minnewasta Lake Field Parameters

Date Sampled	Sample Location	Depth	Air Temp °C	Water Temp °C	Secchi Disk (Meters)	Secchi Disk (Feet)	DO	pH
9/28/2004	MW01	Surface Bottom	12	15.4 15.2	0.69	2.25	6.7 6.3	8.87 8.80
	MW02	Surface Bottom	12	15.3 15.3	1.83	6	7.7 7.5	8.93 8.94
10/19/2004	MW01	Surface Bottom	8	6.8 6.6	1.37	4.5	9.7 9.5	8.79 8.78
	MW02	Surface Bottom	8	6.6 6.5	2.13	7	9.7 9.6	8.87 8.92
1/25/2005	MW01	Surface Bottom	1.7	1.4 2.0	3.93	12.9	11.7 11.3	8.79 NA
	MW02	Surface Bottom	1.7	0.8 2.1	4.48	14.7	14.3 13.7	8.81 NA
2/24/2005	MW01	Surface Bottom	-7	1.8 4	3.14	10.3	11.4 9.9	8.62 NA
	MW02	Surface Bottom	-7	1.3 2.9	2.87	9.4	12.3 12.2	8.82 NA
3/23/2005	MW01	Surface Bottom	0.5	6.3 5.6	4.2	13.8	9.5 8.5	8.55 NA
	MW02	Surface Bottom	0.5	5.8 5	4.33	14.2	11.6 11.9	8.71 NA
4/19/2005	MW01	Surface Bottom	5.5	14.3 14.3	2.13	7	9.0 8.9	8.73 NA
	MW02	Surface Bottom	5.5	14.0 14.0	2.29	7.5	9.0 9.0	8.83 NA
5/19/2005	MW01	Surface Bottom	16	13.5 13.3	1.86	6.1	9.5 9.5	8.7 NA
	MW02	Surface Bottom	16	13.4 13.1	1.34	4.4	9.9 10	8.76 NA
6/6/2005	MW01	Surface Bottom	14	18 17.5	1.49	4.9	7.8 7.4	8.56 NA
	MW02	Surface Bottom	14	18 17.5	2.38	7.8	8.2 8.2	8.61 NA
6/20/2005	MW01	Surface Bottom	23	23 21	1.22	4	9.0 7.5	8.59 NA
	MW02	Surface Bottom	23	22.5 22	1.77	5.8	8.8 8.5	8.62 NA
7/5/2004	MW01	Surface Bottom	10.6	21.5 21.5	0.49	1.6	7.9 7.6	8.69 NA
	MW02	Surface Bottom	10.5	21.5 21.5	0.82	2.7	9.2 8.7	8.77 NA
7/19/2005	MW01	Surface Bottom	18.9	23.5 23.5	0.49	1.6	7.0 6.9	8.68 NA
	MW02	Surface Bottom	18.9	23.5 23.5	1.25	4.1	7.3 7.2	8.72 NA
8/8/2005	MW01	Surface Bottom	25.5	24 24	0.85	2.8	6.8 6.4	8.77 NA
	MW02	Surface Bottom	25.5	24 23.5	1.34	4.4	6.4 5.8	8.74 NA
8/22/2005	MW01	Surface Bottom	13.3	21.5 21.6	1.77	5.8	7.4 7.2	8.86 NA
	MW02	Surface Bottom	13.3	21.5 21.5	1.52	5	7.9 7.7	8.8 NA
9/14/2005	MW01	Surface Bottom	9.4	19.2 19.2	0.58	1.9	5.3 5.3	8.42 NA
	MW02	Surface Bottom	9.4	19.0 19.0	0.88	2.9	5.3 5.6	8.4 NA

Minnewasta Lake Chemical Parameters

Date Sampled	Sample Location	Depth	Alkalinity M mg/L.	Total Solids mg/L.	Suspended Solids mg/L.	VTSS mg/L.	Ammonia	Nitrate	TKN	Total Phosphorus mg/L.	Total Dissolved Phosphorus mg/L.	Fecal Coliform	E.Coli
9/28/04	MW01	Surface	437	1574	28	12	0.620	<0.1	3.11	0.251	0.174	<10/100	2.0/100
		Bottom	441	1574	24	5	0.600	<0.1	2.94	0.234	0.167	NA	NA
	MW02	Surface	431	1572	14	5	0.13	0.1	2.64	0.2	0.142	<10/100	<1/100
		Bottom	432	1576	15	3	0.14	0.1	2.29	0.18	0.141	NA	NA
10/19/04	MW01	Surface	NA	NA	NA	NA	0.18	0.2	2.39	0.204	0.188	10/100	1.0/100
		Bottom	NA	NA	NA	NA	0.51	0.2	2.39	0.223	0.189	NA	NA
	MW02	Surface	440	1605	9	5	0.17	0.2	2.19	0.203	0.174	<10/100	<1/100
		Bottom	437	1600	9	4	0.19	0.2	2.22	0.198	0.17	NA	NA
1/25/05	MW01	Surface	506	1839	4	3	0.03	0.2	2.38	0.204	0.198	<10/100	<1/100
	MW02	Surface	503	1838	1	1	0.03	0.2	2.37	0.19	0.188	<10/100	<1/100
2/24/05	MW01	Surface	505	1840	2	<1	<0.02	0.3	2.6	0.212	0.188	<10/100	<1/100
	MW02	Surface	509	1857	1	<1	0.03	0.3	2.02	0.195	0.187	<10/100	<1/100
3/23/05	MW01	Surface	480	1761	3	<1	<0.02	0.2	1.94	0.226	0.161	<10/100	<1/100
	MW02	Surface	482	1770	3	1	<0.02	0.2	2.14	0.189	0.16	<10/100	<1/100
4/19/05	MW01	Surface	435	1604	6	3	<0.02	<0.1	1.95	0.12	0.099	<10/100	1.0/100
	MW02	Surface	424	1580	8	6	<0.02	<0.1	1.76	0.1	0.079	<10/100	1.0/100
5/19/05	MW01	Surface	435	1619	13	5	<0.02	0.1	2.2	0.166	0.139	<10/100	<1/100
	MW02	Surface	432	1619	14	4	<0.02	<0.1	2.09	0.171	0.129	<10/100	<1/100
6/6/05	MW01	Surface	436	1625	4	2	<0.02	0.1	1.95	0.184	0.159	<10/100	4.1/100
	MW02	Surface	434	1621	4	3	<0.02	<0.1	1.91	0.176	0.145	10/100	8.6/100
6/20/05	MW01	Surface	430	1592	13	7	<0.02	0.1	2	0.156	0.112	<10/100	2.0/100
	MW02	Surface	427	1581	9	2	<0.02	0.1	2.28	0.142	0.091	<10/100	<1/100
7/5/04	MW01	Surface	428	1609	32	18	<0.02	<0.1	3.47	0.227	0.094	<10/100	<1/100
	MW02	Surface	414	1590	19	14	<0.02	0.2	3.38	0.176	0.065	<10/100	1.0/100
7/19/05	MW01	Surface	368	1584	35	17	0.05	<0.1	4.14	0.142	0.036	<10/100	<1/100
	MW02	Surface	357	1555	14	14	<0.02	<0.1	3.44	0.098	0.035	<10/100	<1/100
8/8/05	MW01	Surface	355	1547	17	14	<0.02	<0.1	3.83	0.125	0.039	<10/100	14.3/100
	MW02	Surface	355	1548	12	8	<0.02	<0.1	3.33	0.104	0.044	<10/100	2.0/100
8/22/05	MW01	Surface	362	1578	14	8	0.03	<0.1	3.37	0.111	0.055	<10/100	<1/100
	MW02	Surface	365	1569	13	7	<0.02	<0.1	3.71	0.14	0.054	<10/100	1.0/100
9/14/05	MW01	Surface	385	1618	20	10	0.78	0.2	3.26	0.212	0.168	30/100	33.1/100
	MW02	Surface	381	1629	10	5	0.37	0.3	2.6	0.175	0.144	140/100	101/100

Appendix C.

Amsden Dam Reservoir Tributary Water Quality Data

Amsden Dam Tributary Field Parameters

Date Sampled	Sample Location	Depth	Air Temp °C	Water Temp °C	Discharge (CFS)	Stage (Feet)	DO (mg/L)	pH (su)
9/7/04	ADT01	Surface	15.5	19.6	7	1.15	7.5	8.72
9/8/04	ADT02	Surface	NA	13.8	1	0.62	6.8	8.02
9/7/04	ADT03	Surface	15.6	16.5	2	0.722	9.5	8.25
9/8/04	ADT04	Surface	NA	15.8	1.5	0.1	5.6	7.85
9/16/04	ADT01	Surface	16	17.5	3.1	1.08	8.8	8.62
	ADT02	Surface	17	11.9	1.1	0.62	7.8	8.05
	ADT03	Surface	17	13	2.5	0.8	9.7	8.22
	ADT04	Surface	18	14.6	1	0.06	7.3	7.89
9/22/04	ADT01	Surface	15.6	17.8	5	1.14	8.2	8.73
	ADT02	Surface	15.6	13.8	0.4	0.49	6.5	7.96
	ADT03	Surface	15.6	14	3.6	0.812	7.7	8.14
	ADT04	Surface	15.6	13.2	1.3	0.11	6	7.79
9/27/04	ADT01	Surface	13.9	15.9	5.4	1.1	8.7	8.72
	ADT02	Surface	15.6	13.3	0.6	0.55	7.1	8.01
	ADT03	Surface	15.6	13.9	3	0.78	9.3	8.28
	ADT04	Surface	15.6	13.8	0.8	0.05	7.1	7.85
10/1/04	ADT01	Surface	8	15.4	7.3	1.11	8.8	8.77
	ADT02	Surface	8	10.8	1	0.65	7.6	7.91
	ADT03	Surface	6	12.1	13.3	1.32	9	8.13
	ADT04	Surface	6	10.7	1.1	0.13	8.3	7.83
10/25/04	ADT01	Surface	4	9.3	8.1	1.08	10.8	8.91
	ADT02	Surface	4	6	1.4	0.91	9.2	7.97
	ADT03	Surface	4	6	3	0.876	11	8.17
	ADT04	Surface	4	8	1	0.06	8.7	7.83
10/28/04	ADT01	Surface	10	10	6.2	1.15	10.9	8.9
	ADT02	Surface	10	9.7	1	0.66	8.1	8
	ADT03	Surface	10	11	6.1	0.976	9.2	8.1
	ADT04	Surface	10	11.2	1.3	0.09	7.3	7.78
11/1/04	ADT02	Surface	6	6.3	3.1	0.98	8.3	7.99
	ADT03	Surface	6	7.4	5.1	0.965	9.4	8.14
	ADT04	Surface	6	7.4	1.9	0.11	7	7.77
4/6/05	ADT02	Surface	10	0.9	1.9	0.78	9.1	7.82
4/12/05	ADT01	Surface	16	11.1	18.7	1.21	10.4	8.55
	ADT02	Surface	16	5.2	2.8	0.98	8.6	7.68
	ADT03	Surface	16	7	5.3	0.793	11.3	7.96
	ADT04	Surface	16	8.9	1.3	-0.15	9	7.8
4/15/05	ADT05	Surface	18	14.8	0.5	1.34	10.4	7.86

Date Sampled	Sample Location	Depth	Air Temp °C	Water Temp °C	Discharge (CFS)	Stage (Feet)	DO (mg/L)	pH (su)
5/9/05	ADT01	Surface	13	14	7.6	1.2	9.2	8.69
	ADT02	Surface	13	14.5	1	0.57	6.2	7.88
	ADT03	Surface	13	15	3.4	0.731	9.5	8.22
	ADT05	Surface	13	15	0.05	0.84	5.6	7.89
5/10/05	ADT05	Surface	16	13	0.1	0.98	9.3	7.96
5/13/05	ADT05	Surface	11	6.4	0.5	1.3	11.4	7.82
5/18/05	ADT05	Surface	16	17	0.4	1.44	7.5	7.77
5/26/05	ADT01	Surface	16	18	5.6	1.18	9	8.64
	ADT02	Surface	16	16	1.4	0.72	7	7.86
	ADT03	Surface	16	18	4.6	0.75	10.1	8.25
	ADT04	Surface	14	16	1	-0.06	8.2	7.97
	ADT05	Surface	14	15	0.2	1.13	6.8	7.78
6/8/05	ADT01	Surface	12.8	20.5	12.9	1.21	8.6	8.43
	ADT02	Surface	12.8	18	1.4	0.79	5.4	7.62
	ADT03	Surface	12.8	18	8	0.89	8.6	7.97
	ADT04	Surface	12.8	16	1.5	0.27	7.7	7.56
	ADT05	Surface	12.8	16	1.3	1.64	6.6	7.35
6/14/05	ADT01	Surface	12.8	19	NA	NA	8.7	8.33
	ADT02	Surface	12.8	16.5	39.3	1.81	4	7.26
	ADT03	Surface	12.1	16.5	112.3	2.86	6.8	7.55
	ADT04	Surface	12.8	16	73.5	1.86	8.4	7.69
	ADT05	Surface	12.8	15.5	27.2	3.71	3.6	7.11

Amsden Dam Tributary Chemical Parameters

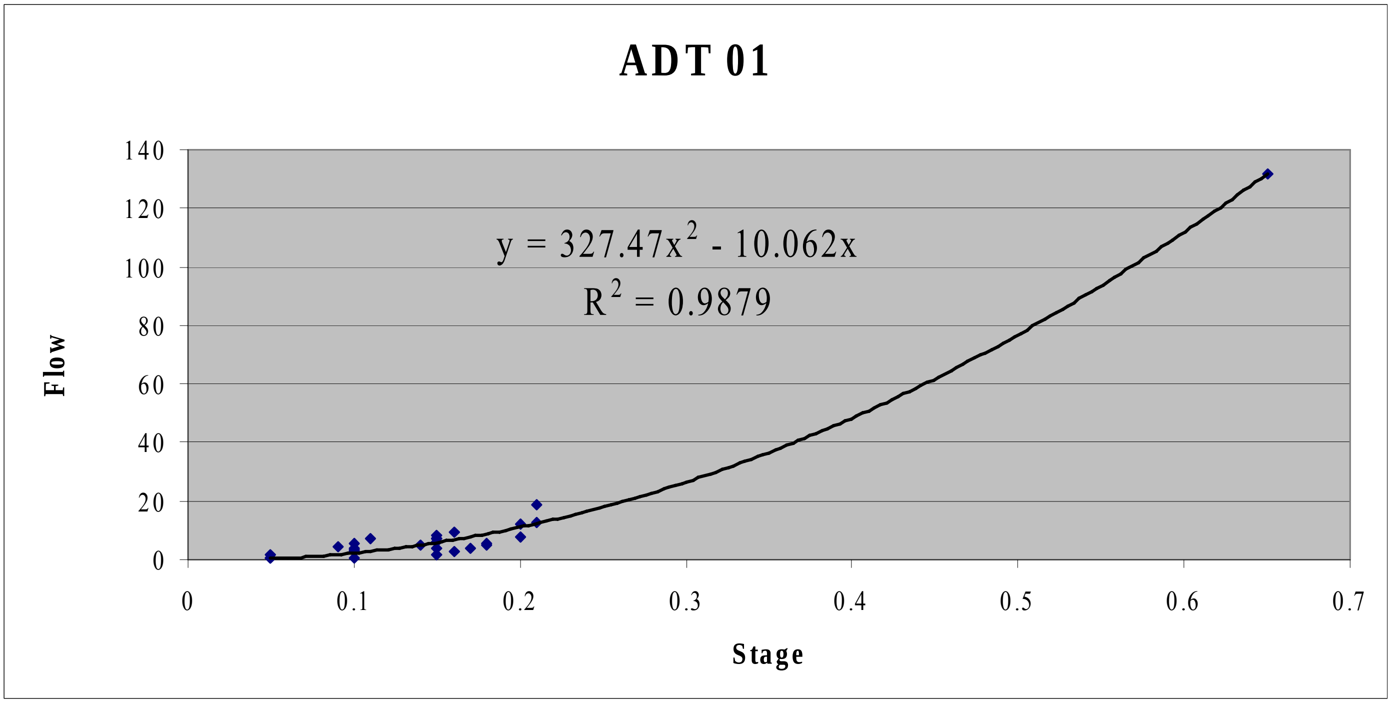
Date Sampled	Sample Location	Depth	Alkalinity M mg/L.	Total Solids mg/L.	Suspended Solids mg/L.	VTSS mg/L.	Ammonia	Nitrate	TKN	Total Phosphorus mg/L.	Total Dissolved Phosphorus mg/L.	Fecal Coliform	E.Coli
9/7/04	ADT01	Surface	264	1393	6	4	0.03	<0.1	0.78	0.241	0.215	10/100	6.3/100
9/8/04	ADT02	Surface	319	1602	8	1	<0.02	<0.1	0.89	0.18	0.166	310/100	345/100
9/7/04	ADT03	Surface	305	1273	7	5	<0.02	0.2	0.7	0.14	0.115	3300/100	2420/100
9/8/04	ADT04	Surface	266	1109	5	1	0.11	0.2	0.52	0.129	0.09	270/100	330/100
9/16/04	ADT01	Surface	258	1427	7	4	0.06	<0.1	0.88	0.267	0.221	50/100	179/100
	ADT02	Surface	389	1763	7	3	<0.02	<0.1	0.92	0.173	0.149	690/100	980/100
	ADT03	Surface	326	1234	6	2	<0.02	0.2	0.43	0.117	0.092	740/100	1300/100
	ADT04	Surface	316	1101	5	2	0.14	0.1	0.53	0.122	0.079	80/100	69.5/100
9/22/04	ADT01	Surface	254	1418	9	3	0.06	0.1	1.11	0.263	0.218	30/100	22.1/100
	ADT02	Surface	368	1563	7	1	<0.02	0.1	0.83	0.182	0.154	490/100	727/100
	ADT03	Surface	307	1195	31	6	0.07	0.3	1	0.264	0.146	600/100	>2420/100
	ADT04	Surface	274	1089	5	2	0.14	0.2	0.45	0.124	0.084	530/100	866/100
9/27/04	ADT01	Surface	266	1437	10	<1	0.05	<0.1	0.77	0.237	0.203	50/100	46.5/100
	ADT02	Surface	350	1694	6	<1	<0.02	<0.1	0.6	0.172	0.153	190/100	133/100
	ADT03	Surface	337	1297	8	1	0.02	0.2	0.35	0.121	0.097	1200/100	921/100
	ADT04	Surface	281	1184	7	1	0.2	0.2	0.34	0.102	0.064	80/100	115/100
10/1/04	ADT01	Surface	265	1451	8	4	0.02	<0.1	0.75	0.236	0.196	NA	NA
	ADT02	Surface	324	1611	4	3	<0.02	<0.1	0.76	0.195	0.176	NA	NA
	ADT03	Surface	306	1138	22	7	<0.02	0.2	0.59	0.17	0.108	NA	NA
	ADT04	Surface	255	1023	7	6	0.09	<0.1	0.37	0.118	0.063	NA	NA
10/25/04	ADT01	Surface	262	1443	20	4	<0.02	<0.1	0.78	0.159	0.103	<10/100	<1/100
	ADT02	Surface	300	1602	5	<1	<0.02	<0.1	0.65	0.136	0.12	140/100	101/100
	ADT03	Surface	325	1259	8	2	<0.02	0.2	0.52	0.088	0.069	200/100	344/100
	ADT04	Surface	276	1152	5	<1	0.21	0.2	0.54	0.084	0.048	60/100	105/100

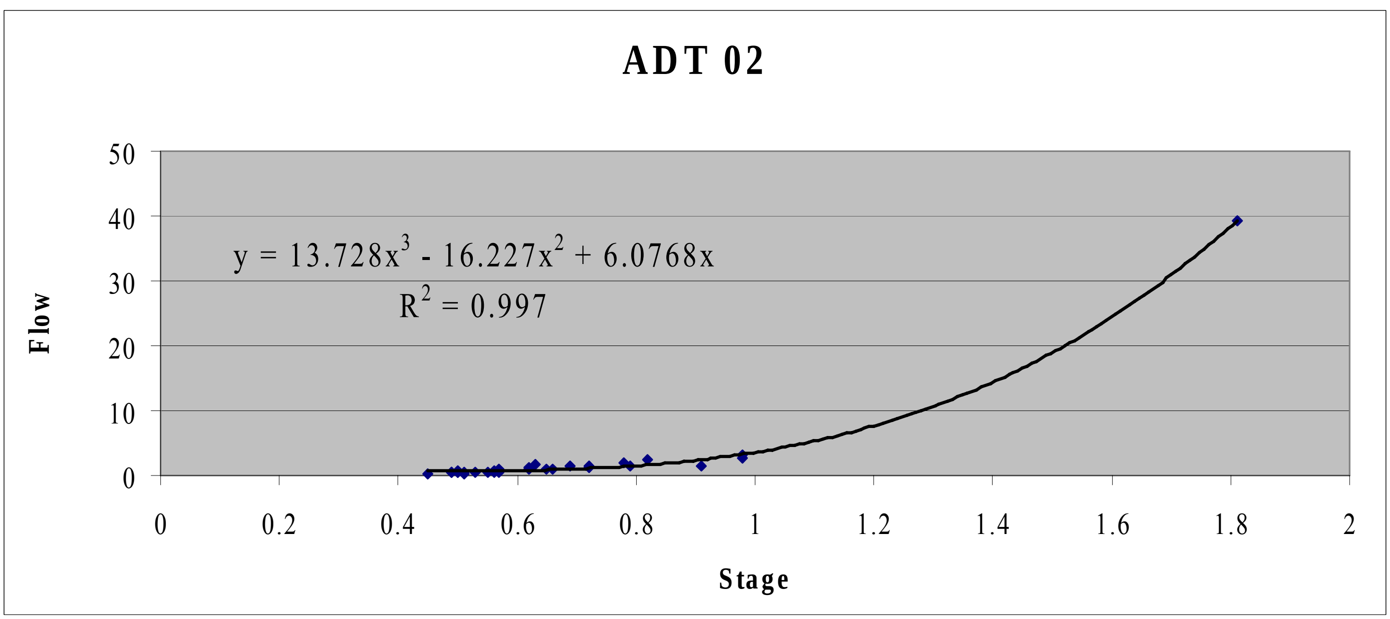
Date Sampled	Sample Location	Depth	Alkalinity M mg/L.	Total Solids mg/L.	Suspended Solids mg/L.	VTSS mg/L.	Ammonia	Nitrate	TKN	Total Phosphorus mg/L.	Total Dissolved Phosphorus mg/L.	Fecal Coliform	E.Coli
10/28/04	ADT01	Surface	269	1429	14	1	<0.02	<0.1	0.42	0.146	0.076	<10/100	1.0/100
	ADT02	Surface	326	1610	1	<1	<0.02	<0.1	0.32	0.122	0.105	30/100	38.8/100
	ADT03	Surface	320	1204	4	<1	<0.02	0.2	0.25	0.089	0.07	2000/100	2420/100
	ADT04	Surface	268	1071	2	<1	0.16	0.2	0.28	0.1	0.05	100/100	152/100
11/1/04	ADT02	Surface	302	1709	1	<1	<0.02	<0.1	0.7	0.136	0.127	40/100	52.1/100
	ADT03	Surface	291	1082	2	1	<0.02	0.2	0.88	0.123	0.101	200/100	361/100
	ADT04	Surface	232	823	6	4	0.13	0.2	1.12	0.304	0.25	220/100	365/100
4/6/05	ADT02	Surface	240	1014	1	<1	0.07	<0.1	0.55	0.102	0.075	<10/100	2.0/100
4/12/05	ADT01	Surface	271	1373	7	2	<0.02	<0.1	<0.5	0.081	0.053	<10/100	3.0/100
	ADT02	Surface	287	1413	5	2	<0.02	0.3	0.7	0.108	0.084	10/100	1.0/100
	ADT03	Surface	333	1356	12	5	0.06	0.3	0.87	0.106	0.07	130/100	143.9/100
	ADT04	Surface	277	1147	7	5	0.16	0.1	<0.5	0.094	0.044	110/100	66.3/100
4/15/05	ADT05	Surface	260	1028	6	3	<0.02	0.1	2.49	1.23	1.1	NA	NA
5/9/05	ADT01	Surface	273	1398	5	3	<0.02	<0.1	0.58	0.061	0.038	<10/100	5.1/100
	ADT02	Surface	380	2040	4	4	<0.02	<0.1	0.75	0.105	0.09	40/100	30.9/100
	ADT03	Surface	323	1251	10	5	<0.02	<0.1	<0.5	0.104	0.062	940/100	980/100
	ADT05	Surface	383	1742	15	12	<0.02	<0.1	3.91	1.6	1.35	14000/100	>2420/100
5/10/05	ADT05	Surface	412	1688	11	11	<0.02	<0.1	2.75	1.09	0.997	17000/100	>2420/100
5/13/05	ADT05	Surface	253	1319	10	3	<0.02	<0.1	1.84	0.633	0.574	NA	NA
5/18/05	ADT05	Surface	361	1903	4	1	<0.02	<0.1	2.22	0.904	0.854	2900/100	2420/100
5/26/05	ADT01	Surface	267	1413	5	<1	<0.02	<0.1	0.65	0.065	0.046	10/100	35.0/100
	ADT02	Surface	405	1950	2	<1	<0.02	<0.1	0.91	0.174	0.164	460/100	488/100
	ADT03	Surface	332	1198	3	<1	<0.02	0.1	0.6	0.168	0.144	950/100	1300/100
	ADT04	Surface	277	1167	4	<1	0.14	0.1	<0.5	0.113	0.079	340/100	272/100
	ADT05	Surface	392	2003	15	2	<0.02	<0.1	2.97	1.37	1.21	11000/100	>2420/100

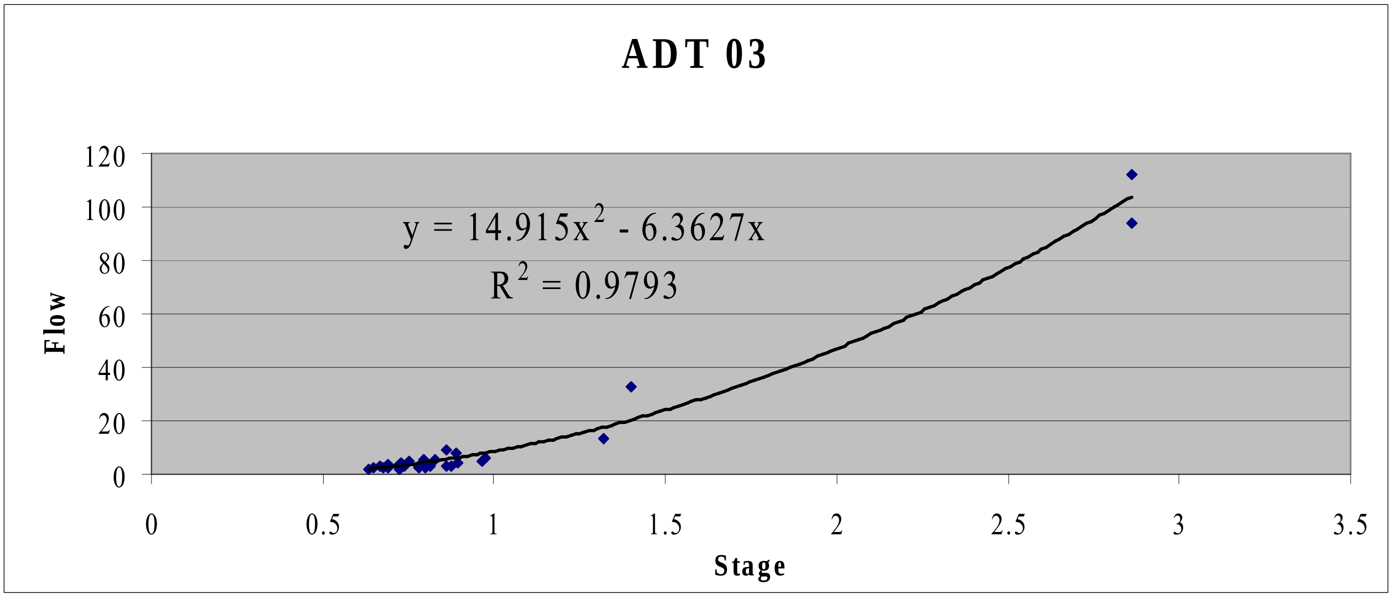
Date Sampled	Sample Location	Depth	Alkalinity M mg/L.	Total Solids mg/L.	Suspended Solids mg/L.	VTSS mg/L.	Ammonia	Nitrate	TKN	Total Phosphorus mg/L.	Total Dissolved Phosphorus mg/L.	Fecal Coliform	E.Coli
6/8/05	ADT01	Surface	264	1393	3	3	<0.02	<0.1	<0.5	0.075	0.055	60/100	124/100
	ADT02	Surface	364	2058	1	1	<0.02	<0.1	0.65	0.217	0.2	670/100	816/100
	ADT03	Surface	305	1041	1	1	<0.02	<0.1	0.58	0.158	0.139	3400/100	2420/100
	ADT04	Surface	256	1197	1	1	<0.02	<0.1	<0.5	0.132	0.113	450/100	649/100
	ADT05	Surface	237	927	28	6	0.05	4.4	2.58	1.6	1.45	14000/100	>2420/100
6/14/05	ADT01	Surface	251	1295	10	2	<0.02	0.2	0.6	0.131	0.097	230/100	248/100
	ADT02	Surface	214	1266	11	1	<0.02	0.5	1.19	0.4	0.344	260/100	326/100
	ADT03	Surface	171	609	29	4	<0.02	1.2	1.46	0.666	0.646	410/100	461/100
	ADT04	Surface	152	575	26	2	<0.02	1.1	1.47	0.917	0.842	700/100	579/100
	ADT05	Surface	147	553	4	<1	<0.02	1	1.37	0.988	1	110/100	152/100

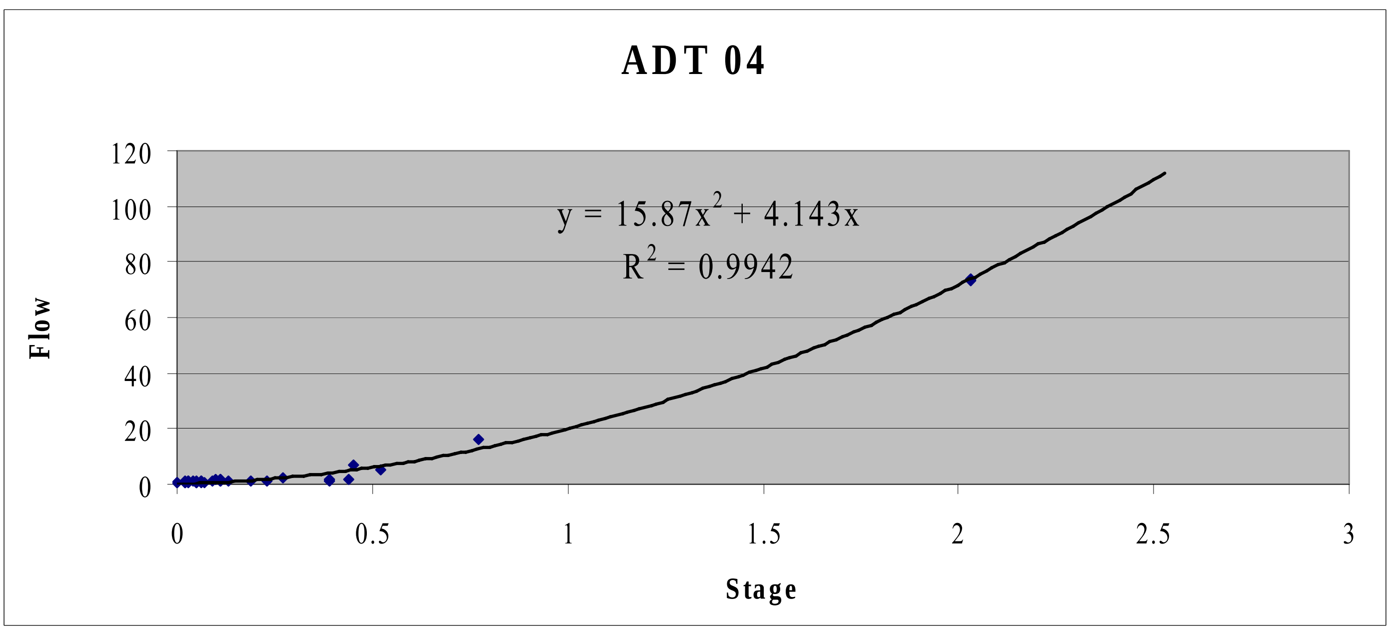
Appendix D.

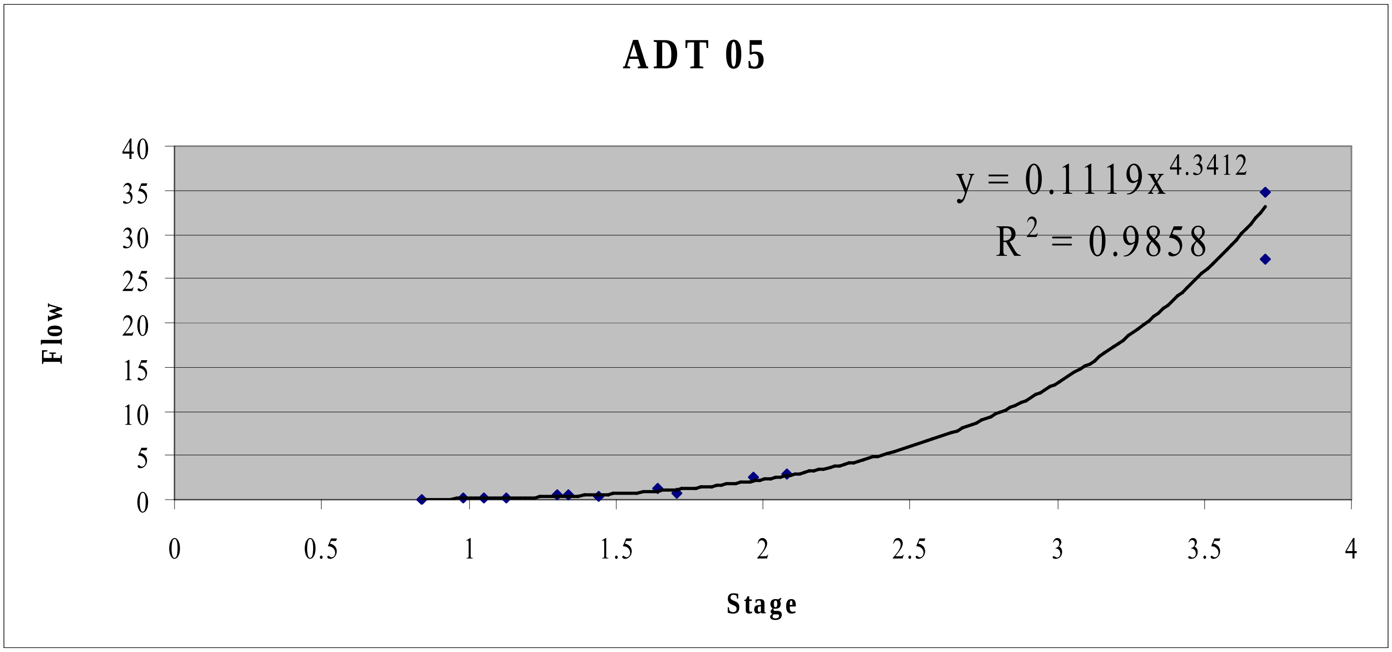
Amsden Dam Reservoir Stage to Discharge Tables


ADT 01
y = 327.47x2 - 10.062x
R2 = 0.9879
Flow
140
120
100
80
60
40
20
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Stage


ADT 02
y = 13.728x3 - 16.227x2 + 6.0768x
R2 = 0.997
Flow
50
40
30
20
10
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Stage


ADT 03
y = 14.915x2 - 6.3627x
R2 = 0.9793
Flow
Stage
120
100
80
60
40
20
0
0
0.5
1
1.5
2
2.5
3
3.5


ADT 04
y = 15.87x2 + 4.143x
R2 = 0.9942
Flow
Stage
120
100
80
60
40
20
0
0
0.5
1
1.5
2
2.5
3


ADT 05
y = 0.1119x^4.3412
R^2 = 0.9858
Flow
40
35
30
25
20
15
10
5
0
0
0.5
1
1.5
2
2.5
3
3.5
4
Stage

Appendix E.

Benthic Macroinvertebrate Identification and Metric Analysis
Amsden Dam Tributaries
Summary Report

Amsden Tributary Macroinvertebrate Sampling Field Data

Site #: ADT-03 Perennial Stream
Date: 9/6/04
Start Time: 2:08 pm
End Time: 3:30 pm
Collected by: Bob Smith, SD DENR

Transect spacing – 18 ft.
Total Transect Length from #1 to #11 = 198 ft.
Right bank (looking upstream) @ 0%
All sites depositional.

Bottle labeled A,B,C (collected from Transects 1,2,3)
Bottle Labeled D,E, F (collection from Transects 5,6,7)
Bottle Labeled G,H,I (collection from Transects 9,10,11)

Transect 1
75% periphyton
25% macroinvertebrate

Transect 2
50% macroinvertebrate
25% periphyton

Transect 3
75% macroinvertebrate
50% periphyton

Transect 4
75% periphyton

Transect 5
50% periphyton
25% macroinvertebrate

Transect 6
50% macroinvertebrate

Transect 7
75% macroinvertebrate
25% periphyton

Transect 8
50% periphyton

Transect 9
75% periphyton
25% macroinvertebrate

Transect 10
75% macroinvertebrate
50% periphyton

Transect 11
(collected from woody debris)
50% macroinvertebrate
25% periphyton

Site #: ADT-04 Perennial Stream
Date: 9/6/04
Start Time: 4:20 pm
End Time: 5:45 pm
Collected by: Bob Smith, SD DENR

Transect spacing – 13 ft.
Total Transect Length from #1 to #11 = 143 ft.
Right bank (looking upstream)@ 0%

Bottle Labeled A,B,C (collected from Transects 1,2,3) (note: collected in two bottles)
Bottle Labeled D,E, F (collection from Transects 5,6,7)
Bottle Labeled G,H,I (collection from Transects 9,10,11)

Transect 1 (depositional)
50% periphyton
25% macroinvertebrate

Transect 2 (depositional)
75% macroinvertebrate
25% periphyton

Transect 3 (erosional)
50% macroinvertebrate
75% periphyton

Transect 4 (erosional)
25% periphyton

Transect 5 (erosional)
50% periphyton
75% macroinvertebrate

Transect 6 (depositional)
25% macroinvertebrate
75% periphyton

Transect 7 (depositional)
50% macroinvertebrate
25% periphyton

Transect 8 (depositional)
50% periphyton

Transect 9 (depositional)
75% periphyton
50% macroinvertebrate

Transect 10 (depositional)
75% macroinvertebrate
25% periphyton

Transect 11 (depositional)
25% macroinvertebrate
50% periphyton

BENTHIC MACROINVERTEBRATE IDENTIFICATION AND METRIC ANALYSIS SUMMARY REPORT FOR THE AMSDEN DAM WATERSHED

Prepared for:

Day County Conservation District

Prepared by:

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September, 2005

INTRODUCTION

Benthic macroinvertebrate populations are known to be key indicators of stream ecosystem health. Life spans for some of these organisms can be as long as three years, and their complex life cycles and limited mobility provide ample time for the community to respond to cumulative effects of environmental perturbations. The analysis of benthic macroinvertebrate communities can thus be related to a stream's biological health, or integrity, defined by Karr and Dudley (1981) as "the capability of supporting and maintaining a balanced, integrated, adaptive community of organisms having a species composition, diversity and functional organization comparable to that of the natural habitat of the region."

The multimetric approach to bioassessment using benthic macroinvertebrates uses attributes of the assemblage in an integrated way to reflect overall biotic condition. Community attributes, which can contribute meaningfully to bioassessment, include assemblage structure, sensitivity of community members to stress or pollution, and functional feeding traits. Each metric component contributes an independent measure of the biotic integrity of a stream site.

METHODS

Benthic macroinvertebrate samples were collected from the Amsden Dam watershed in South Dakota. Samples were collected by personnel from the South Dakota Department of Environment and Natural Resources (SD-DENR) and the Day County Conservation District (DCCD). All samples for this project were collected in September of 2004.

Macroinvertebrate Sample Processing and Identification

Laboratory sample processing, benthic macroinvertebrate taxonomic identifications, data compilation, metrics computations and this report were contracted to Natural Resource Solutions, Inc. by the DCCD in Webster, SD. The benthic macroinvertebrate samples were processed and identified using the U.S. Environmental Protection Agency's (U.S. EPA) techniques outlined in their Rapid Bioassessment Protocols for Streams and Rivers (RBP III) (Plafkin et al.1989), and the Day County Conservation District's SOP, which was adopted from the SD-DENR SOP for Benthic Macroinvertebrate sample processing.

Sample processing consisted of obtaining approximately a 300-organism subsample. Organisms were then enumerated and identified whenever possible to the taxonomic level specified in the DCCD's (SD-DENR's) SOP. The requirements for subsampling and taxonomic resolution were deviated from only when the quality of the specimen was lacking due either to immaturity, or when body parts needed for identification were missing. In either case, when organisms could not be confidently taken to the taxonomic level outlined in the SOP, they were more conservatively identified. Taxonomic identification of the Chironomidae and Oligochaeta were subcontracted by Natural Resource Solutions, Inc. to McBride Benthic Consulting. Following is a description of the subsampling procedure: Each sample was rinsed in a 0.30 mm sieve to remove preservative. The washed sample was then transferred to an appropriately sized invertebrate sorting tray marked into square quadrants. Water was added to the tray to allow complete dispersion of the sample and even distribution of the organisms. Quadrants were randomly selected and organisms removed from each quadrant until the total number of organisms fell within the range of 270 to 330 (±10% of 300 organisms), or until there were no more invertebrates to remove, whichever occurred first. When a sample was very large (greater than 1 Liter of sand and/or sediment), the sample was split into halves or fourths before proceeding with processing. When a sample had an abundance of mineral, the organic portion was floated apart from the mineral portion using standard floatation methods.

DATA ANALYSIS

Community structure, function and sensitivity to impact were characterized for each sample, using whenever possible a specific battery of metrics requested by the DCCD. The data were entered into the "Ecological Data Analysis System (EDAS), a metrics analysis program designed by Tetra Tech, Inc. for the U.S. EPA, which functions within the Microsoft Access database.

Because reference conditions for streams in the Amsden Dam Watershed area were not available, the metrics could not be scored in order to determine a standardized impairment rating for each site. Thus, the overall biotic health and the final impairment rating reported for each site were determined based upon best professional judgment, after careful review of the entire suite of metrics results. The biotic health for each site was reported using the following scale, from worst to best: Poor, Fair, Good, Very Good, and Excellent. A general impairment rating for each site was reported as follows: Severe Impairment, Moderate Impairment, Minimum Impairment, and Slight Impairment. If results indicate biotic health and/or impairment that falls between the ratings, both ratings will be listed, for example, "Fair to Good," "Moderate to Minimum."

Tolerance values and Functional Feeding Group determinations used for this analysis were taken from the U.S. EPA's Rapid Bioassessment Protocols for Streams and Rivers, Appendix B (Plafkin et al.1989). Tolerance values are given on a 0 to 10 scale, with 0 representing an extremely sensitive, or intolerant organism, and 10 representing a highly tolerant organism. Please see Table 6, "Benthic Macroinvertebrates of the Amsden Dam Watershed, SD" for the raw data for each site.

METRIC	VALUE	Resp*	METRIC / TAXA	Tolerance Value	FFG[+]
Taxa Richness	21	(↓)	1st Dominant *Hyalella* sp. 48 %	6	Predator
EPT Taxa Richness	1	(↓)	2nd Dominant *Caenis* sp. 12 %	6	Collector
Ephemeroptera Taxa	1	(↓)	3rd Dominant Sphaeriidae 9 %	4	Collector
Plecoptera Taxa	0	(↓)	**METRIC**	**Value**	**Resp***
Trichoptera Taxa	0	(↓)	Hilsenhoff Biotic Index (HBI)	6.63	(↑)
Diptera Taxa	13	(↑)	Shannon-Weiner Diversity (Log 10)	0.833	(↓)
Chironomidae Taxa	11	(↑)	Biotic Index	1	(↓)
Predator Taxa	3	(↑)	% EPT	11.98	(↓)
Intolerant Taxa	0	(↓)	% Ephemeroptera	11.83	(↓)
Total Abundance	651	(↓)	% Plecoptera	0.00	(↓)
Extrapolated Abundance	16,275	(↓)	% Trichoptera	0.00	(↓)
EPT Abundance	78	(↓)	% Hydropsychidae/Trichoptera	0.00	(↑)
Chiro Abundance	107	(↑)	% Chironomidae	16.44	(↑)
EPT/Chiro Abundance	0.73	(↓)	% Odonata	0.00	(↑)
% Shredders	0.61	(↓)	% Diptera	17.82	(↑)
% Grazers+Scrapers	0.61	(↓)	% Non-Insects	69.12	(↑)
% Scrapers/Scrapers+Filterers	3.96	(↓)	% Oligochaeta	0.15	(↑)
% Scrapers/Filterers	0.04	(↓)	% Intolerant Organisms	0.00	(↓)
% Omnivores+Scavengers	88.33	(↑)	% Tolerant Organisms	43.0	(↑)
% Predators	0.46	(↑)	% Sediment Tolerant Organisms	23.81	(↑)
% Collector-Gatherers	72.81	(↓↑)	Biotic Health Assessment: Fair		
% Filterers	14.90	(↑)	Impairment Rating: Moderate		

* Arrows (↑↓) indicate each metric's expected response to environmental perturbation and/or impairment.

[+] FFG = Functional Feeding Group

Overall Assessment for ADT-03/A-C: Fair biotic condition, supporting a marginally tolerant benthic macroinvertebrate community. Cumulative metric data suggests moderate impairment is possible at this site.

METRIC	VALUE	Resp*	METRIC / TAXA	Tolerance Value	FFG+
Taxa Richness	22	(↓)	1st Dominant *Dicrotendipes* sp. 22 %	10	Collector
EPT Taxa Richness	1	(↓)	2nd Dominant *Tanytarsus* sp. 18 %	6	Filterer
Ephemeroptera Taxa	1	(↓)	3rd Dominant *Chironomus* sp. 13 %	10	Collector
Plecoptera Taxa	0	(↓)	**METRIC**	**Value**	**Resp***
Trichoptera Taxa	0	(↓)	Hilsenhoff Biotic Index (HBI)	7.79	(↑)
Diptera Taxa	15	(↑)	Shannon-Weiner Diversity (Log 10)	1.060	(↓)
Chironomidae Taxa	14	(↑)	Biotic Index	1	(↓)
Predator Taxa	4	(↑)	% EPT	10.0	(↓)
Intolerant Taxa	0	(↓)	% Ephemeroptera	10.0	(↓)
Total Abundance	360	(↓)	% Plecoptera	0.0	(↓)
Extrapolated Abundance	6,001	(↓)	% Trichoptera	0.0	(↓)
EPT Abundance	36	(↓)	% Hydropsychidae/Trichoptera	0.0	(↑)
Chiro Abundance	271	(↑)	% Chironomidae	75.3	(↑)
EPT/Chiro Abundance	0.13	(↓)	% Odonata	0.0	(↑)
% Shredders	0.0	(↓)	% Diptera	75.8	(↑)
% Grazers+Scrapers	0.0	(↓)	% Non-Insects	12.8	(↑)
% Scrapers/Scrapers+Filterers	0.0	(↓)	% Oligochaeta	0.8	(↑)
% Scrapers/Filterers	0.0	(↓)	% Intolerant Organisms	0.0	(↓)
% Omnivores+Scavengers	91.1	(↑)	% Tolerant Organisms	61.1	(↑)
% Predators	3.6	(↑)	% Sediment Tolerant Organisms	77.5	(↑)
% Collector-Gatherers	68.9	(↓↑)	Biotic Health Assessment: Poor		
% Filterers	22.2	(↑)	Impairment Rating: Moderate to Severe		

* Arrows (↑↓) indicate each metric's expected response to environmental perturbation and/or impairment.
+ FFG = Functional Feeding Group

Overall assessment for ADT-03/D-F: Poor biotic condition, supporting only a highly tolerant benthic macroinvertebrate community. Cumulative metric data suggests moderate to severe impairment likely exists at this site.

METRIC	VALUE	Resp*	METRIC / TAXA	Tolerance Value	FFG+
Taxa Richness	21	(↓)	1st Dominant *Caenis* sp. 16 %	7	Collector
EPT Taxa Richness	1	(↓)	2nd Dominant *Stictochironomus* sp. 15 %	9	Scavenger
Ephemeroptera Taxa	1	(↓)	3rd Dominant *Chironomus* sp. 13 %	10	Collector
Plecoptera Taxa	0	(↓)	**METRIC**	**Value**	**Resp***
Trichoptera Taxa	0	(↓)	Hilsenhoff Biotic Index (HBI)	7.82	(↑)
Diptera Taxa	14	(↑)	Shannon-Weiner Diversity (Log 10)	1.073	(↓)
Chironomidae Taxa	12	(↑)	Biotic Index	1	(↓)
Predator Taxa	4	(↑)	% EPT	16.5	(↓)
Intolerant Taxa	0	(↓)	% Ephemeroptera	16.5	(↓)
Total Abundance	357	(↓)	% Plecoptera	0.0	(↓)
Extrapolated Abundance	20,824	(↓)	% Trichoptera	0.0	(↓)
EPT Abundance	59	(↓)	% Hydropsychidae/Trichoptera	0.0	(↑)
Chiro Abundance	225	(↑)	% Chironomidae	63.0	(↑)
EPT/Chiro Abundance	0.26	(↓)	% Odonata	0.28	(↑)
% Shredders	0.0	(↓)	% Diptera	64.1	(↑)
% Grazers+Scrapers	0.0	(↓)	% Non-Insects	16.25	(↑)
% Scrapers/Scrapers+Filterers	0.0	(↓)	% Oligochaeta	2.8	(↑)
% Scrapers/Filterers	0.0	(↓)	% Intolerant Organisms	0.0	(↓)
% Omnivores+Scavengers	75.3	(↑)	% Tolerant Organisms	67.5	(↑)
% Predators	7.3	(↑)	% Sediment Tolerant Organisms	66.9	(↑)
% Collector-Gatherers	64.9	(↓↑)	Biotic Health Assessment: Poor		
% Filterers	10.4	(↑)	Impairment Rating: Moderate to Severe		

* Arrows (↑↓) indicate each metric's expected response to environmental perturbation and/or impairment.
+ FFG = Functional Feeding Group

Overall assessment for ADT-03/G-I: Poor biotic condition, able to support only a highly tolerant benthic macroinvertebrate community. Cumulative metric data suggests moderate to severe impairment is likely here.

METRIC	VALUE	Resp*	METRIC / TAXA	Tolerance Value	FFG+
Taxa Richness	26	(↓)	1st Dominant *Micropsectra* sp. 32 %	7	Collector
EPT Taxa Richness	1	(↓)	2nd Dominant *Hyalella* sp. 26 %	6	Collector
Ephemeroptera Taxa	1	(↓)	3rd Dominant *Caenis* sp. 12 %	7	Collector
Plecoptera Taxa	0	(↓)	**METRIC**	**Value**	**Resp***
Trichoptera Taxa	0	(↓)	Hilsenhoff Biotic Index (HBI)	7.11	(↑)
Diptera Taxa	16	(↑)	Shannon-Weiner Diversity (Log 10)	0.912	(↓)
Chironomidae Taxa	13	(↑)	Biotic Index	2	(↓)
Predator Taxa	5	(↑)	% EPT	12.3	(↓)
Intolerant Taxa	1	(↓)	% Ephemeroptera	12.3	(↓)
Total Abundance	381	(↓)	% Plecoptera	0.0	(↓)
Extrapolated Abundance	6,351	(↓)	% Trichoptera	0.0	(↓)
EPT Abundance	47	(↓)	% Hydropsychidae/Trichoptera	0.0	(↑)
Chiro Abundance	194	(↑)	% Chironomidae	50.9	(↑)
EPT/Chiro Abundance	0.24	(↓)	% Odonata	1.05	(↑)
% Shredders	4.2	(↓)	% Diptera	51.9	(↑)
% Grazers+Scrapers	4.2	(↓)	% Non-Insects	34.1	(↑)
% Scrapers/Scrapers+Filterers	69.6	(↓)	% Oligochaeta	5.5	(↑)
% Scrapers/Filterers	2.3	(↓)	% Intolerant Organisms	0.26	(↓)
% Omnivores+Scavengers	95.3	(↑)	% Tolerant Organisms	66.4	(↑)
% Predators	3.1	(↑)	% Sediment Tolerant Organisms	57.2	(↑)
% Collector-Gatherers	89.2	(↓↑)	Biotic Health Assessment: Fair		
% Filterers	1.8	(↑)	Impairment Rating: Moderate		

* Arrows (↑↓) indicate each metric's expected response to environmental perturbation and/or impairment.
+ FFG = Functional Feeding Group

Overall assessment for ADT-04/A-C, 1 of 2: Fair biotic condition, supporting a marginally tolerant benthic macroinvertebrate community overall. Cumulative metric data suggests moderate impairment at this site.

METRIC	VALUE	Resp*	METRIC / TAXA	Tolerance Value	FFG+
Taxa Richness	22	(↓)	1st Dominant *Micropsectra* sp. 34 %	7	Collector
EPT Taxa Richness	1	(↓)	2nd Dominant *Hyalella* sp. 24 %	6	Collector
Ephemeroptera Taxa	1	(↓)	3rd Dominant *Caenis* sp. 10 %	7	Collector
Plecoptera Taxa	0	(↓)	**METRIC**	**Value**	**Resp***
Trichoptera Taxa	0	(↓)	Hilsenhoff Biotic Index (HBI)	7.30	(↑)
Diptera Taxa	11	(↑)	Shannon-Weiner Diversity (Log 10)	0.908	(↓)
Chironomidae Taxa	10	(↑)	Biotic Index	1	(↓)
Predator Taxa	5	(↑)	% EPT	10.5	(↓)
Intolerant Taxa	0	(↓)	% Ephemeroptera	10.5	(↓)
Total Abundance	400	(↓)	% Plecoptera	0.0	(↓)
Extrapolated Abundance	8,400	(↓)	% Trichoptera	0.0	(↓)
EPT Abundance	42	(↓)	% Hydropsychidae/Trichoptera	0.0	(↑)
Chiro Abundance	204	(↑)	% Chironomidae	51.0	(↑)
EPT/Chiro Abundance	0.21	(↓)	% Odonata	1.2	(↑)
% Shredders	2.0	(↓)	% Diptera	51.5	(↑)
% Grazers+Scrapers	2.0	(↓)	% Non-Insects	35.5	(↑)
% Scrapers/Scrapers+Filterers	80.0	(↓)	% Oligochaeta	9.5	(↑)
% Scrapers/Filterers	4.0	(↓)	% Intolerant Organisms	0.0	(↓)
% Omnivores+Scavengers	93.7	(↑)	% Tolerant Organisms	71.0	(↑)
% Predators	2.7	(↑)	% Sediment Tolerant Organisms	62.0	(↑)
% Collector-Gatherers	91.2	(↓↑)	Biotic Health Assessment: Fair		
% Filterers	0.50	(↑)	Impairment Rating: Moderate		

* Arrows (↑↓) indicate each metric's expected response to environmental perturbation and/or impairment.
\+ FFG = Functional Feeding Group

Overall assessment for ADT-04/A-C, 2 of 2: Fair biotic condition, supporting a marginally tolerant benthic macroinvertebrate community. Cumulative metric data suggests moderate impairment.

METRIC	VALUE	Resp*	METRIC / TAXA	Tolerance Value	FFG[+]
Taxa Richness	22	(↓)	1st Dominant *Micropsectra* sp. 43 %	7	Collector
EPT Taxa Richness	2	(↓)	2nd Dominant *Hyalella* sp. 21 %	6	Collector
Ephemeroptera Taxa	2	(↓)	3rd Dominant *Caenis* sp. 15 %	7	Collector
Plecoptera Taxa	0	(↓)	**METRIC**	**Value**	**Resp***
Trichoptera Taxa	0	(↓)	Hilsenhoff Biotic Index (HBI)	7.02	(↑)
Diptera Taxa	10	(↑)	Shannon-Weiner Diversity (Log 10)	0.809	(↓)
Chironomidae Taxa	8	(↑)	Biotic Index	0	(↓)
Predator Taxa	6	(↑)	% EPT	15.2	(↓)
Intolerant Taxa	0	(↓)	% Ephemeroptera	15.2	(↓)
Total Abundance	414	(↓)	% Plecoptera	0.00	(↓)
Extrapolated Abundance	6,901	(↓)	% Trichoptera	0.00	(↓)
EPT Abundance	63	(↓)	% Hydropsychidae/Trichoptera	0.00	(↑)
Chiro Abundance	227	(↑)	% Chironomidae	54.8	(↑)
EPT/Chiro Abundance	0.28	(↓)	% Odonata	1.21	(↑)
% Shredders	0.00	(↓)	% Diptera	56.5	(↑)
% Grazers+Scrapers	0.00	(↓)	% Non-Insects	25.8	(↑)
% Scrapers/Scrapers+Filterers	0.00	(↓)	% Oligochaeta	3.14	(↑)
% Scrapers/Filterers	0.00	(↓)	% Intolerant Organisms	0.00	(↓)
% Omnivores+Scavengers	92.0	(↑)	% Tolerant Organisms	71.3	(↑)
% Predators	4.6	(↑)	% Sediment Tolerant Organisms	58.4	(↑)
% Collector-Gatherers	90.8	(↓↑)	Biotic Health Assessment: Fair		
% Filterers	1.21	(↑)	Impairment Rating: Moderate		

* Arrows (↑↓) indicate each metric's expected response to environmental perturbation and/or impairment.
[+] FFG = Functional Feeding Group

Overall assessment for ADT-04/D-F: Results indicate this site is in Fair biotic health, able to support a marginally tolerant benthic macroinvertebrate community. Cumulative metric data suggests this site may be moderately impaired.

METRIC	VALUE	Resp*	METRIC / TAXA	Tolerance Value	FFG+
Taxa Richness	17	(↓)	1st Dominant *Micropsectra* sp. 46 %	7	Collector
EPT Taxa Richness	1	(↓)	2nd Dominant *Dicrotendipes* sp. 30 %	10	Collector
Ephemeroptera Taxa	1	(↓)	3rd Dominant *Hyalella* sp. 8 %	6	Collector
Plecoptera Taxa	0	(↓)	**METRIC**	**Value**	**Resp***
Trichoptera Taxa	0	(↓)	Hilsenhoff Biotic Index (HBI)	7.87	(↑)
Diptera Taxa	7	(↑)	Shannon-Weiner Diversity (Log 10)	0.672	(↓)
Chironomidae Taxa	7	(↑)	Biotic Index	0	(↓)
Predator Taxa	3	(↑)	% EPT	5.8	(↓)
Intolerant Taxa	0	(↓)	% Ephemeroptera	5.8	(↓)
Total Abundance	347	(↓)	% Plecoptera	0.00	(↓)
Extrapolated Abundance	5,784	(↓)	% Trichoptera	0.00	(↓)
EPT Abundance	20	(↓)	% Hydropsychidae/Trichoptera	0.00	(↑)
Chiro Abundance	280	(↑)	% Chironomidae	80.7	(↑)
EPT/Chiro Abundance	0.07	(↓)	% Odonata	0.29	(↑)
% Shredders	0.29	(↓)	% Diptera	80.9	(↑)
% Grazers+Scrapers	0.29	(↓)	% Non-Insects	11.5	(↑)
% Scrapers/Scrapers+Filterers	33.3	(↓)	% Oligochaeta	1.7	(↑)
% Scrapers/Filterers	0.50	(↓)	% Intolerant Organisms	0.00	(↓)
% Omnivores+Scavengers	94.5	(↑)	% Tolerant Organisms	88.5	(↑)
% Predators	1.73	(↑)	% Sediment Tolerant Organisms	82.7	(↑)
% Collector-Gatherers	93.7	(↓↑)	Biotic Health Assessment: Poor		
% Filterers	0.58	(↑)	Impairment Rating: Severe		

* Arrows (↑↓) indicate each metric's expected response to environmental perturbation and/or impairment.
\+ FFG = Functional Feeding Group

Overall assessment for ADT-04/G-I: Results indicate poor biotic health, able to support only very highly tolerant benthic macroinvertebrates here. Cumulative metric data suggests severe impairment may exist at this site.

Appendix F.

Periphyton Identification Data Set
Amsden Dam Tributaries

Amsden Watershed Tributary Site ADT03 Periphyton

	A	B	C	D	E	F	G	H	I
1	**Genus/Species/Variety**	Author/Date	Reference	Synonym:	pH	Motility		Cells/0.1mL	Cells/1.0mL
2	*Achnanthes hauckiana v. rostrata*	Schulz 1926	Patrick & Reimer 1966	Planothidium delicatulum	5	N		16	160
3	*Achnanthes lanceolata*	(Brebisson) Grunow 1880	Krammer & Lange-Bertalot 1991b	Planothidium lanceolatum	4	N		28	280
4	*Achnanthes lanceolata v. dubia*	Grunow 1880	Krammer & Lange-Bertalot 1991b	Planothidium dubium	4	N		5	50
5	*Amphora ovalis*	(Kutzing) Kutzing 1844	Krammer & Lange-Bertalot 1986		4	M		13	130
6	*Amphora ovalis v. pediculus*	(Kutzing) Van Heurck 1880-1885	Patrick & Reimer 1975	Amphora pediculus	4	M		18	180
7	*Caloneis amphisbaena*	(Bory) Cleve 1894	Krammer & Lange-Bertalot 1986		4	M		23	230
8	*Caloneis silicula*	(Ehrenberg) Cleve 1894	Krammer & Lange-Bertalot 1986		4	M		1	10
9	*Caloneis ventricosa v. truncatula*	(Grunow) Meister 1912	Patrick & Reimer 1966	Caloneis silicula	4	M		4	40
10	*Cocconeis pediculus*	Ehrenberg 1838	Krammer & Lange-Bertalot 1991b		4	N		32	320
11	*Cocconeis placentula v. lineata*	(Ehrenberg) Van Heurck 1885	Krammer & Lange-Bertalot 1991b		4	N		101	1010
12	*Cyclotella meneghiniana*	Kutzing 1844	Krammer & Lange-Bertalot 1991a	Stephanocyclus meneghiniana	4	N		24	240
13	*Cymbella minuta*	Hilse ex Rabenhorst 1862	Patrick & Reimer 1975	Encyonema minutum	3	V		3	30
14	*Denticula elegans*	Kutzing 1844	Krammer & Lange-Bertalot 1988		.	M		2	20
15	*Fragilaria construens*	(Ehrenberg) Grunow 1862	Krammer & Lange-Bertalot 1991a	Staurosira construens	4	N		2	20
16	*Gomphonema angustatum v. intermedia*	Grunow 1880	Patrick & Reimer 1975		.	N		1	10
17	*Gomphonema olivaceum*	(Hornemann) Brebisson 1838	Krammer & Lange-Bertalot 1986		5	N		23	230
18	*Gomphonema parvulum*	(Kutzing) Kutzing 1849	Patrick & Reimer 1975		3	N		3	30
19	*Navicula capitata*	Ehrenberg 1838	Krammer & Lange-Bertalot 1986	Hippodonta capitata	4	M		4	40
20	*Navicula capitata v. hungarica*	(Grunow) Ross 1947	Krammer & Lange-Bertalot 1986	Hippodonta hungarica	4	M		8	80
21	*Navicula circumtexta*	Meister ex Hustedt 1934	Patrick & Reimer 1966	Biremis circumtexta	5	M		1	10
22	*Navicula cryptocephala*	Kutzing 1844	Krammer & Lange-Bertalot 1986		3	M		5	50
23	*Navicula gregaria*	Donkin 1861	Krammer & Lange-Bertalot 1986		4	M		6	60
24	*Navicula oblonga*	(Kutzing) Kutzing 1844	Krammer & Lange-Bertalot 1986		4	M		2	20
25	*Navicula peregrina*	(Ehrenberg) Kutzing 1844	Patrick & Reimer 1966		4	M		9	90
26	*Navicula pupula*	Kutzing 1844	Krammer & Lange-Bertalot 1986	Sellaphora pupula	3	M		5	50
27	*Navicula pygmaea*	Kutzing 1849	Krammer & Lange-Bertalot 1986	Fallacia pygmaea	5	M		2	20
28	*Navicula radiosa v. tenella*	(Brebisson ex Kutzing) Grunow 1	Patrick & Reimer 1966	Navicula cryptotenella	4	M		16	160
29	*Navicula rhynchocephala*	Kutzing 1844	Krammer & Lange-Bertalot 1986		4	M		1	10
30	*Navicula rhynchocephala v. germainii*	(Wallace) Patrick 1966	Patrick & Reimer 1966	Navicula germainii	4	M		1	10
31	*Navicula salinarum v. intermedia*	(Grunow) Cleve 1895	Patrick & Reimer 1966	Navicula capitatoradiata	4	M		18	180
32	*Navicula subrotundata*	Hustedt 1945	Krammer & Lange-Bertalot 1986		4	M		1	10
33	*Navicula tripunctata*	(O.F. Muller) Bory 1822	Krammer & Lange-Bertalot 1986		4	M		15	150
34	*Navicula viridula v. rostellata*	(Kutzing) Cleve 1895	Krammer & Lange-Bertalot 1986	Navicula rostellata	4	M		19	190
35	*Nitzschia acicularis*	(Kutzing) W. Smith 1853	Krammer & Lange-Bertalot 1988		4	H		1	10
36	*Nitzschia angustata v. acuta*	Grunow 1880	Hustedt 1930a	Nitzschia angustata	.	H		1	10
37	*Nitzschia dissipata*	(Kutzing) Grunow 1862	Krammer & Lange-Bertalot 1988		4	H		28	280
38	*Nitzschia dissipata v. media*	(Hantzsch) Grunow 1881	Krammer & Lange-Bertalot 1988		4	H		1	10
39	*Nitzschia frustulum v. subsalina*	Hustedt 1925	Hustedt 1930a	Nitzschia frustulum	4	H		19	190
40	*Nitzschia gracilis*	Hantzsch 1860	Krammer & Lange-Bertalot 1988		3	H		13	130
41	*Nitzschia hungarica*	Grunow 1862	Krammer & Lange-Bertalot 1988	Tryblionella hungarica	4	H		16	160
42	*Nitzschia lacuum*	Lange-Bertalot 1980	Krammer & Lange-Bertalot 1988		4	H		7	70
43	*Nitzschia recta*	Hantzsch 1861-1879	Krammer & Lange-Bertalot 1988		4	H		12	120
44	*Nitzschia subinflata*	Hustedt 1922	A. Schmidt 1874-1959		.	H		4	40
45	*Pleurosigma delicatulum*	W. Smith 1852	Patrick & Reimer 1966		.	H		14	140
46	*Rhoicosphenia curvata*	(Kutzing) Grunow 1864	Patrick & Reimer 1966	Rhoicosphenia abbreviata	4	N		19	190
47	*Rhopalodia musculus*	(Kutzing) O. Muller 1899	Krammer & Lange-Bertalot 1988		.	M		5	50
48	*Surirella linearis v. helvetica*	(Brun) Meister 1912	Krammer & Lange-Bertalot 1988		3	H		5	50
49	*Surirella minuta*	Brebisson in Kutzing 1849	Krammer & Lange-Bertalot 1988		4	H		9	90
50	*Surirella ovalis*	Brebisson 1838	Krammer & Lange-Bertalot 1988		4	H		21	210
51	*Surirella ovata*	Kutzing 1844	Hustedt 1930a	Surirella minuta	4	H		3	30
52	*Surirella robusta*	Ehrenberg 1841	Krammer & Lange-Bertalot 1988		3	H		1	10
53	*Synedra ulna*	(Nitzsch) Ehrenberg 1836	Patrick & Reimer 1966		4	N		7	70
54	*Stauroneis livingstonii*	Reimer 1961	Patrick & Reimer 1966		.	.		2	20
55									
56			Total					600	6000

Amsden Watershed Tributary Site ADT04 Periphyton

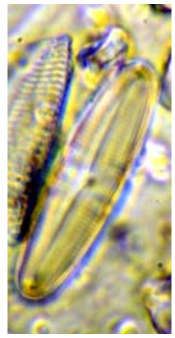
	A	B	C	D	E	F	G	H	I
1	**Genus/Species/Variety**	Author/Date	Reference	Synonym:	pH	Motility		Cells/0.1mL	Cells/1.0mL
2	*Achnanthes hauckiana v. rostrata*	Schulz 1926	Patrick & Reimer 1966	Planothidium delicatulum	5	N		24	240
3	*Achnanthes lanceolata*	(Brebisson) Grunow 1880	Krammer & Lange-Bertalot 1991b	Planothidium lanceolatum	4	N		17	170
4	*Achnanthes lanceolata v. dubia*	Grunow 1880	Krammer & Lange-Bertalot 1991b	Planothidium dubium	4	N		3	30
5	*Amphora ovalis*	(Kutzing) Kutzing 1844	Krammer & Lange-Bertalot 1986		4	M		4	40
6	*Amphora ovalis v. pediculus*	(Kutzing) Van Heurck 1880-1885	Patrick & Reimer 1975	Amphora pediculus	4	M		15	150
7	*Caloneis amphisbaena*	(Bory) Cleve 1894	Krammer & Lange-Bertalot 1986		4	M		31	310
8	*Caloneis silicula*	(Ehrenberg) Cleve 1894	Krammer & Lange-Bertalot 1986		4	M		7	70
9	*Caloneis ventricosa v. truncatula*	(Grunow) Meister 1912	Patrick & Reimer 1966	Caloneis silicula	4	M		13	130
10	*Cocconeis pediculus*	Ehrenberg 1838	Krammer & Lange-Bertalot 1991b		4	N		41	410
11	*Cocconeis placentula v. lineata*	(Ehrenberg) Van Heurck 1885	Krammer & Lange-Bertalot 1991b		4	N		98	980
12	*Cyclotella meneghiniana*	Kutzing 1844	Krammer & Lange-Bertalot 1991a	Stephanocyclus meneghiniana	4	N		49	490
13	*Cymbella minuta*	Hilse ex Rabenhorst 1862	Patrick & Reimer 1975	Encyonema minutum	3	V		2	20
14	*Denticula elegans*	Kutzing 1844	Krammer & Lange-Bertalot 1988		.	M		1	10
15	*Fragilaria construens*	(Ehrenberg) Grunow 1862	Krammer & Lange-Bertalot 1991a	Staurosira construens	4	N		2	20
16	*Gomphonema angustatum v. intermedia*	Grunow 1880	Patrick & Reimer 1975		.	N		2	20
17	*Gomphonema olivaceum*	(Hornemann) Brebisson 1838	Krammer & Lange-Bertalot 1986		5	N		26	260
18	*Gomphonema parvulum*	(Kutzing) Kutzing 1849	Patrick & Reimer 1975		3	N		2	20
19	*Gomphonema truncatum*	Ehrenberg 1838	Patrick & Reimer 1975		.	N		5	50
20	*Gyrosigma acuminatum*	(Kutzing) 1853	Patrick & Reimer 1966		5	H		2	20
21	*Navicula capitata*	Ehrenberg 1838	Krammer & Lange-Bertalot 1986	Hippodonta capitata	4	M		2	20
22	*Navicula capitata v. hungarica*	(Grunow) Ross 1947	Krammer & Lange-Bertalot 1986	Hippodonta hungarica	4	M		1	10
23	*Navicula circumtexta*	Meister ex Hustedt 1934	Patrick & Reimer 1966	Biremis circumtexta	5	M		9	90
24	*Navicula cryptocephala*	Kutzing 1844	Krammer & Lange-Bertalot 1986		3	M		7	70
25	*Navicula gregaria*	Donkin 1861	Krammer & Lange-Bertalot 1986		4	M		8	80
26	*Navicula oblonga*	(Kutzing) Kutzing 1844	Krammer & Lange-Bertalot 1986		4	M		3	30
27	*Navicula peregrina*	(Ehrenberg) Kutzing 1844	Patrick & Reimer 1966		4	M		14	140
28	*Navicula pupula*	Kutzing 1844	Krammer & Lange-Bertalot 1986	Sellaphora pupula	3	M		3	30
29	*Navicula pygmaea*	Kutzing 1849	Krammer & Lange-Bertalot 1986	Fallacia pygmaea	5	M		13	130
30	*Navicula radiosa v. tenella*	(Brebisson ex Kutzing) Grunow 1	Patrick & Reimer 1966	Navicula cryptotenella	4	M		10	100
31	*Navicula rhynchocephala*	Kutzing 1844	Krammer & Lange-Bertalot 1986		4	M		5	50
32	*Navicula salinarum v. intermedia*	(Grunow) Cleve 1895	Patrick & Reimer 1966	Navicula capitatoradiata	4	M		21	210
33	*Navicula subrotundata*	Hustedt 1945	Krammer & Lange-Bertalot 1986		4	M		2	20
34	*Navicula tripunctata*	(O.F. Muller) Bory 1822	Krammer & Lange-Bertalot 1986		4	M		17	170
35	*Navicula viridula v. rostellata*	(Kutzing) Cleve 1895	Krammer & Lange-Bertalot 1986	Navicula rostellata	4	M		12	120
36	*Nitzschia angustata*	Grunow 1880	Krammer & Lange-Bertalot 1988		.	H		6	60
37	*Nitzschia dissipata*	(Kutzing) Grunow 1862	Krammer & Lange-Bertalot 1988		4	H		19	190
38	*Nitzschia gracilis*	Hantzsch 1860	Krammer & Lange-Bertalot 1988		3	H		2	20
39	*Nitzschia hungarica*	Grunow 1862	Krammer & Lange-Bertalot 1988	Tryblionella hungarica	4	H		11	110
40	*Nitzschia lacuum*	Lange-Bertalot 1980	Krammer & Lange-Bertalot 1988		4	H		5	50
41	*Nitzschia recta*	Hantzsch 1861-1879	Krammer & Lange-Bertalot 1988		4	H		8	80
42	*Pleurosigma delicatulum*	W. Smith 1852	Patrick & Reimer 1966		.	H		12	120
43	*Surirella linearis v. helvetica*	(Brun) Meister 1912	Krammer & Lange-Bertalot 1988		3	H		1	10
44	*Surirella minuta*	Brebisson in Kutzing 1849	Krammer & Lange-Bertalot 1988		4	H		14	140
45	*Surirella ovalis*	Brebisson 1838	Krammer & Lange-Bertalot 1988		4	H		34	340
46	*Surirella robusta*	Ehrenberg 1841	Krammer & Lange-Bertalot 1988		3	H		1	10
47	*Synedra ulna*	(Nitzsch) Ehrenberg 1836	Patrick & Reimer 1966		4	N		15	150
48	*Stauroneis livingstonii*	Reimer 1961	Patrick & Reimer 1966		.	.		1	10
49									
50			Total					600	6000

Organisms of Interest

Diatoms of the Amsden Dam Watershed, SD

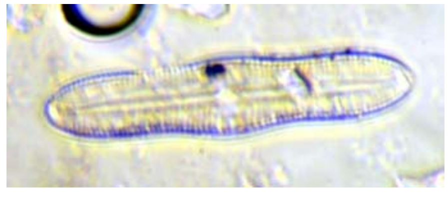
Collected in September, 2004

Caloneis silicula

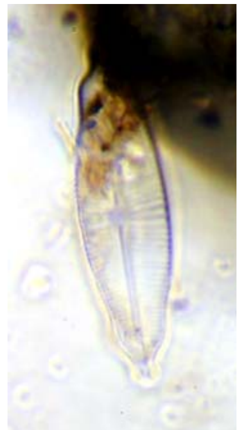


Synedra ulna

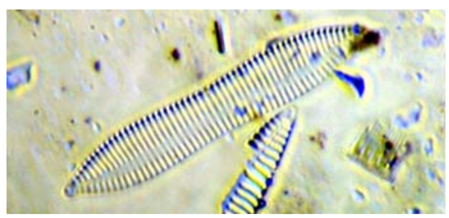
Caloneis ventricosa v. truncatula



Stauroneis livingstonii

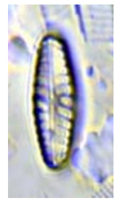


Nitzschia hungarica

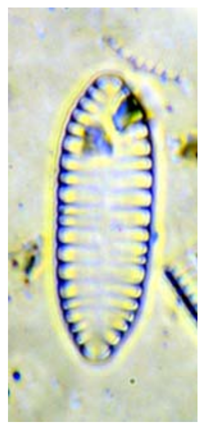


Cocconeis pediculus

Navicula capitata v. hungarica

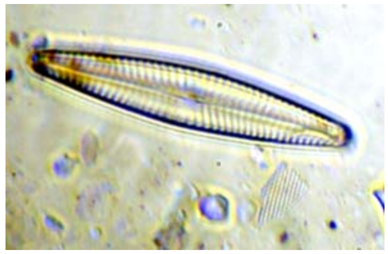


Surirella linearis v. helvetica

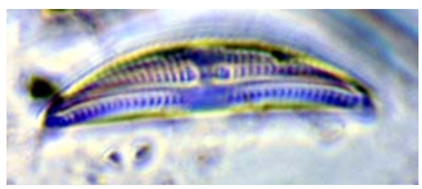


Surirella ovalis

Navicula tripunctata



Amphora ovali s v. pediculus

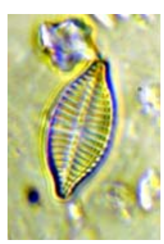


Navicula subrotundata

Pleurosigma delicatulum

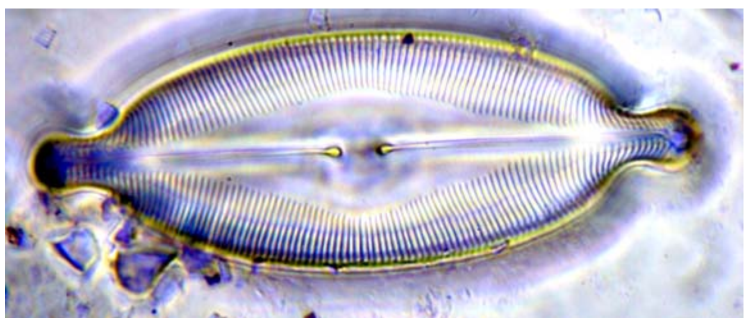
Navicula peregrina

Achnanthes hauckiana v. rostrata

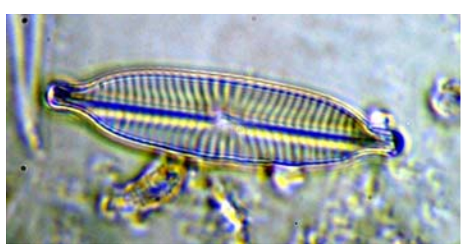


Gomphonema olivaceum

Caloneis amphisbaena



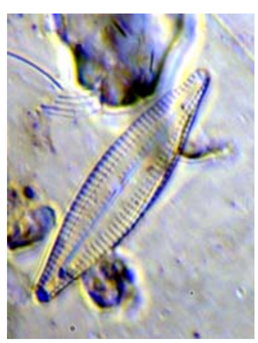
Navicula viridula v. rostellata



Rhopalodia musculus

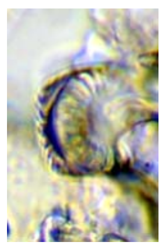
Navicula salinarum v. intermedia

Navicula circumtexta



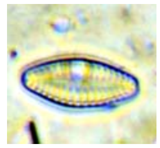
Nitzschia dissipata

Cyclotella meneghiniana



Gomphonema angustatum v. intermedia

Achnanthes lanceolata



Surirella robusta

Navicula pygmaea

Cymbella minuta

Navicula gregaria

Appendix G.

Amsden Dam Reservoir and Minnewasta Lake Macrophyte Survey Field Data

Amsden Lake Macrophyte Survey

Date:	8/3/05	8/2/05	8/2/05	8/2/05	8/2/05	8/3/05	8/3/05
Transect #:	AM1	AM2	AM3	AM4	AM5	AM6	AM7
Macrophyte Species Found							
Ceratophyllum demersum	X	X	X	X		X	X
Potamogeton friesii					X	X	
Potamogeton pectinatus	X	X	X	X	X	X	
Potamogeton richardsonii	X	X	X	X		X	X
Zosterella dubia						X	
Maximum Depth Of Plant Colonization (meters):	3.66	3.35	3.66	4.57	3.35	5.18	6.09
Shoreline Assessment							
Bank Stability Score	9	7	7	6	10	0	8
Vegetative Protection	9	9	5	3	9	1	10
Riparian Veg. Zone Width	3	7	6	2	4	4	7
Total Score:	**21**	**23**	**18**	**11**	**23**	**5**	**25**

Date:	8/2/05	8/3/05	8/3/05	8/3/05	8/2/05	8/2/05	8/2/05
Transect #:	AM8	AM9	AM10	AM11	AM12	AM13	AM14
Macrophyte Species Found							
Ceratophyllum demersum	X	X	X	X	X	X	X
Potamogeton friesii	X	X				X	
Potamogeton pectinatus	X	X	X	X	X		X
Potamogeton richardsonii	X	X	X	X	X	X	X
Zosterella dubia							
Maximum Depth Of Plant Colonization (meters):	2.74	2.74	1.37	3.35	3.35	3.35	1.22
Shoreline Assessment							
Bank Stability Score	9	9	8	10	3	0	3
Vegetative Protection	7	9	7	10	3	0	3
Riparian Veg. Zone Width	4	7	7	9	2	7	4
Total Score:	**20**	**25**	**22**	**29**	8	7	10

Amsden Lake Macrophyte Survey cont.

Date:	8/2/05	8/2/05	8/2/05	8/2/05	8/2/05	8/3/05
Transect #:	AM15	AM16	AM17	AM18	AM19	AM20
Macrophyte Species Found						
Ceratophyllum demersum	X	X	X	X	X	X
Potamogeton friesii				X	X	
Potamogeton pectinatus	X	X	X	X	X	X
Potamogeton richardsonii	X			X	X	X
Zosterella dubia						
Maximum Depth Of Plant Colonization (meters):	1.83	0.91	4.57	1.22	3.05	4.88
Shoreline Assessment						
Bank Stability Score	5	7	7	8	7	9
Vegetative Protection	8	6	8	8	9	10
Riparian Veg. Zone Width	4	4	4	4	10	10
Total Score:	17	17	19	20	26	29

Minnewasta Lake Macrophyte Survey

Date:	7/26/05	7/26/05	7/26/05	7/26/05	7/26/05	7/26/05	7/26/05
Transect #:	MM1	MM2	MM3	MM4	MM5	MM6	MM7
Macrophyte Species Found							
Potamogeton pectinatus	X				X	X	X
Potamogeton richardsonii							
Maximum Depth Of Plant Colonization (meters):	3.66				0.91	0.91	0.91
Shoreline Assessment							
Bank Stability Score	10	10	7	7	sandbar	sandbar	4
Vegetative Protection	10	10	10	10			8
Riparian Veg. Zone Width	10	10	10	10			10
Total Score:	**30**	**30**	**27**	**27**			**22**

Date:	7/26/05	7/26/05	7/26/05	7/26/05	7/28/05	7/28/05	7/28/05
Transect #:	MM8	MM8A	MM9	MM10	MM11	MM12	MM13
Macrophyte Species Found							
Potamogeton pectinatus		X	X	X		X	
Potamogeton richardsonii		X					
Maximum Depth Of Plant Colonization (meters):		1.52	0.91	1.52		1.22	
Shoreline Assessment							
Bank Stability Score	8	8	10	9	10	9	10
Vegetative Protection	10	10	10	9	8	9	10
Riparian Veg. Zone Width	10	10	8	8	5	5	9
Total Score:	**28**	**28**	**28**	**26**	**23**	**23**	**29**

Minnewasta Lake Macrophyte Survey cont.

Date:	7/28/05	7/28/05	7/28/05	7/28/05	7/28/05	7/28/05	7/28/05
Transect #:	MM14	MM15	MM16	MM17	MM18	MM19	MM20
Macrophyte Species Found							
Potamogeton pectinatus			X	X			X
Potamogeton richardsonii							
Maximum Depth Of Plant Colonization (meters):			1.22	0.91			2.13
Shoreline Assessment							
Bank Stability Score	9	9	sandbar	3	3	9	sandbar
Vegetative Protection	10	10		3	6	8	
Riparian Veg. Zone Width	10	10		3	7	10	
Total Score:	**29**	**29**		**9**	**16**	**27**	

Date:	7/28/05	7/29/05	7/29/05	7/29/05	7/29/05	7/29/05	7/29/05
Transect #:	MM21	MM22	MM23	MM24	MM25	MM26	MM27
Macrophyte Species Found							
Potamogeton pectinatus	X	X	X	X		X	X
Potamogeton richardsonii							
Maximum Depth Of Plant Colonization (meters):	1.52	1.52	0.91	3.05		2.74	2.44
Shoreline Assessment							
Bank Stability Score	10	9	10	8	9	9	6
Vegetative Protection	8	6	9	4	3	9	8
Riparian Veg. Zone Width	4	4	10	2	3	10	10
Total Score:	**22**	**19**	**29**	**14**	**15**	**28**	**24**

Minnewasta Lake Macrophyte Survey cont.

Date:	7/29/05	7/28/05	7/28/05
Transect #:	MM28	MM29	MM30
Macrophyte Species Found			
Potamogeton pectinatus	X	X	X
Potamogeton richardsonii			
Maximum Depth Of Plant Colonization (meters):	2.13	2.44	3.35
Shoreline Assessment			
Bank Stability Score	5	1	10
Vegetative Protection	5	5	10
Riparian Veg. Zone Width	4	4	10
Total Score:	14	10	30

Appendix H.

Total Maximum Daily Load Summaries (TMDL)

TOTAL MAXIMUM DAILY LOAD EVALUATION

For

Amsden Dam Reservoir

(HUC 10160005)

DAY COUNTY, SOUTH DAKOTA

SOUTH DAKOTA DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES

December, 2006

Amsden Dam Total Maximum Daily Load

Waterbody Type:	Lake (Impounded)
303(d) Listing Parameter:	TSI
Designated Uses:	Recreation, Warmwater permanent fish life
Size of Waterbody:	235 acres
Size of Watershed :	32,000 acres
Water Quality Standards:	Narrative and Numeric
Indicators:	Average TSI
Analytical Approach:	**FLUX**
Location:	HUC Code: 10160005
WaterbodyID:	SD-JA-L-Amsden_01
Target:	Maintain TSI of less than 58.4

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.

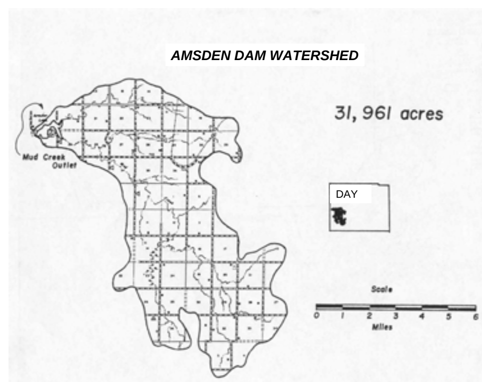


Figure 1. Amsden Dam Watershed

Introduction

Amsden Dam is a 235 acre (95 ha) man-made impoundment located in western Day County, South Dakota. The lake has a maximum depth of 27 feet (8.2 m) and a pool elevation capacity of 2,200 acre-feet of water. The outlet for the lake empties into Pickerel Creek, which eventually reaches the James River.

Problem Identification

The primary tributary to Amsden Dam drains through pasture, range land, Conservation Reserve Program (CRP acres), and some crop land. There are several animal feeding operations (AFO) in the watershed; however, the major contributor loading the lake is located three miles upstream of the reservoir. The stream carries nutrient loads, which appear to have a major impact on the water quality in the lake. Higher than normal run-off and high water levels in the lake may be contributing to the eutrophication of the lake.

Description of Applicable Water Quality Standards & Numeric Water Quality Targets

Amsden 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:

Warmwater permanent fish life propagation; Immersion recreation; Limited contact recreation; and Fish and wildlife propagation, recreation and stock watering.
Other indicators, including the lake's Trophic State Index (TSI) (Carlson, 1977) value, determine the support of beneficial uses and compliance with standards. A gradual increase in fertility of the water due to nutrients washing into the lake from external sources is a sign of the eutrophication process. Amsden Dam is identified in the 2006 South Dakota Integrated Report as non 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 assess the trophic status of a lake, SD DENR uses the mean TSI which incorporates Secchi depth, and chlorophyll *a* concentrations. SD DENR has developed a protocol that establishes desired TSI levels for lakes based on fishery classification. This protocol was used to assess impairment and determine a numeric target for Amsden Dam.

Amsden Dam currently has a mean TSI of 46.5, which places it in the eutrophic lakes category and is indicative of high levels of primary productivity. Assessment monitoring indicates that the primary cause of the high productivity is phosphorus loads from a combination of internal loading and the watershed. There does not appear to be a significant impact on nutrient concentrations as a result of sediment released phosphorus.

The numeric target, established for Amsden Dam in "Targeting Impaired Lakes in South Dakota" is a TSI of less than 58.4. This TSI has already been reached, likely due to the large amount of grass in the watershed, participation in the CRP program, and modern conservation tillage practices in the Amsden Dam watershed.

Pollutant Assessment

Point Sources

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

Nonpoint Sources/ Background Sources

Amsden Dam received a total loading of 5,742.2 Kg of total phosphorus during the assessment period. Tributaries in the watershed impacting the loading to Amsden Dam reservoir are as follows: ADT02 loaded 690.4 Kg (12.1%), ADT03 1537.8 Kg (26.7%), ADT04 1402.3 Kg (24.4%), and ADT05 loaded 2111.7 Kg (36.7%). The phosphorus load at ADT01 (below the outlet of Amsden Dam) was 614.8 Kg. Approximately 90% of the total phosphorus load (5127.4 Kg) remained in the reservoir. It should also be noted that approximately 90% of the total phosphorus load came during the summer months when rainfall intensity and hydrologic loading was greatest.

Linkage Analysis

Water quality data was collected from the upstream tributaries to Amsden Dam, below the outlet, and within the reservoir itself. 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 7% of the samples according to South Dakota's EPA approved Nonpoint Source Quality Assurance/Quality Control Plan. Details concerning water sampling techniques, analysis, and quality control are addressed on pages 16-23 of the assessment final report.

In addition to water quality monitoring, land use data was collected in anticipation of using a watershed landuse model. The Annualized Agriculture Nonpoint Pollution Source (AnnAGNPS) model was not completed due to the current landuse in the watershed and the fully supporting TSI measured during the study.

The impacts of phosphorus loadings on the condition of Amsden Dam were calculated using FLUX, an Army Corps of Engineers hydrologic loading model. The model predicted that most loading occurred during the summer months during high intensity rain events followed by hydrologic loading that delivered phosphorus to the reservoir from the watersheds. By reducing run-off from a few select feedlots, phosphorus reductions would be reduced and the lake will continue to meet its TSI value (58.4) and beneficial uses for years to come.

Maintaining current landuse practices may result in continued improvement in the water quality in Amsden Dam. Further protection to the lake may be achieved through using conservation tillage practices on tillable acres in the watershed, rotational grazing, refraining livestock from entering the creeks in the tributaries, and installing waste containment systems for feedlots in the watershed.

To identify a maximum daily limit, a method from EPA's "Technical Support Document For Water Quality-Based Toxics Control," referred to as the TSD method, was used. This method, which is based on a long-term average load that considers variation in a dataset, is a recommended method in EPA's technical guidance "Options for expressing Daily Loads in TMDLs"(USEPA 1991). The TSD method is represented by the following equation:

MDL=LTA×e[zσ−0.5σ2] where,
MDL = maximum daily limit
LTA = long-term average
z = z statistic of the probability of occurrence
σ2 = ln(CV2+1)
CV = coefficient of variation

The daily load expression is identified as a static daily maximum load. A static daily load expression was deemed suitable because of the small watershed size, relatively constant loadings from nonpoint sources (e.g., septics, roads, in-stream sources), and the fact that a steady-state analysis was used. Assuming a probability of occurrence of 95% and a CV of 0.38 (based on available data), the maximum daily load corresponding to an average annual load of 5742.2 kg/yr is 27.03 kg/day.

TMDL and Allocations

TMDL (Daily)

	0 kg/yr	(WLA)
+	27.03 kg/day	(LA)
	Implicit	(MOS)
	27.03 kg/day	(TMDL)

TMDL (Annual)

	0 kg/yr	(WLA)
+	5,742.2 kg/yr	(LA)
	Implicit	(MOS)
	5,742.2 kg/yr	(TMDL)

The South Dakota Department of Environment and Natural Resources believes that describing loadings as an annual load is more realistic and more protective of the waterbody. Seasonality and uncontrollable precipitation make meeting a daily load unrealistic. Implementation plans will most likely be planned off of annual loads. The daily load is simply expressed as the annual load divided by 365.

Wasteload Allocations (WLAs)

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

Load Allocations (LAs)

Shoreline stabilization, maintenance of current BMPs, fencing cattle out of stream segments, and installing waste containment systems on key feedlots in the watershed will insure that the reservoir continues to fully support its beneficial uses and may result in additional improvements in water quality.

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, Amsden Dam samples were separated into spring (March-May), summer (June-August), fall (September-November), and winter (December-February) collection periods. Seasonalized data may be found on page 23.

Margin of Safety

Conservative estimates were used throughout the modeling process. These estimates produced an implicit margin of safety. In addition to the implicit margin of safety, shoreline stabilization and installation of waste containment systems will increase the margin of safety that the lake will maintain its current state of full support of its beneficial uses.

Critical Conditions

The impairments to Amsden Dam were most severe during the summer. This is the result of high intensive rains and hydrologic loading carrying nutrients from the tributaries to the reservoir. Spring run-off is typically another critical condition.

Follow-Up Monitoring

Continued monitoring of Amsden Dam will be completed by the South Dakota Department of Environment and Natural Resources State Wide Lakes Assessment program.

Public Participation

Efforts taken to gain public education, review, and comment during development of the TMDL involved (numbers reflect contacts concerning both the Amsden Dam and Lake Minnewasta Assessments):

Meetings attended by the project coordinator include:

Day County Farm and Home Show 1

Day County Conservation District 12

And Over 40 contacts with individual land owners

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

Implementation Plan

The South Dakota DENR, working with the Day Conservation District, has taken the first steps to develop and initiate an implementation project to address water quality concerns for Amsden Dam. Products in the Project Implementation Plan will address these concerns through the implementation of animal nutrient management systems, riparian buffers, shoreline and stream bank stabilization and improved grazing land management for further providing protection to the lake and insuring it maintains full support of its beneficial uses.. The District has requested US EPA Section 319 funding for assistance with best management practice implementation.

TOTAL MAXIMUM DAILY LOAD EVALUATION

For

MINNEWASTA LAKE

(HUC 10160010)

DAY COUNTY, SOUTH DAKOTA

SOUTH DAKOTA DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES

December, 2006

Minnewasta Lake Total Maximum Daily Load

Waterbody Type:	Lake (Natural)
303(d) Listing Parameter:	TSI
Designated Uses:	Recreation, Warmwater Semi permanent aquatic life
Size of Waterbody:	601 acres
Size of Watershed :	8,275 acres
Water Quality Standards:	Narrative and Numeric
Indicators:	Average TSI
Analytical Approach:	**FLUX**
Location:	HUC Code: 10160010
WaterbodyID:	SD-BS-L-Minnewasta_01
Target:	Maintain TSI of less than 63.4

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.

Figure 2. Watershed Location in South Dakota

Introduction

Lake Minnewasta is a bowl-shaped 601 acre (247 ha) natural impoundment located in central eastern Day County, South Dakota. The lake has no tributaries and drains or fills Rush Lake. Depending upon water levels in the two lakes determines which direction the water will move. Lake Minnewasta can flow into Rush Lake, or Rush Lake can flow into Lake Minnewasta. The lake has a maximum depth of 14 feet (4.2 m) and a pool elevation capacity of approximately 6,700 acre-feet of water. The Lake Minnewasta watershed comprises a small portion of North Big Sioux Coteau hydrologic unit, which has a priority rank of 12 in the South Dakota Unified Watershed Assessment.

Problem Identification

Being there are no tributaries for Lake Minnewasta, it makes it hard to determine sources of pollution. There is one feedlot adjacent to the lake that does not have a waste containment system. Another problem appears to be the fact that Rush Lake, on occasion, will spill into Lake Minnewasta delivering sediment and nutrient loadings thus having a negative impact on Lake Minnewasta's TSI value and its ability to maintain its beneficial uses.

Description of Applicable Water Quality Standards & Numeric Water Quality Targets

Lake Minnewasta 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:

Warmwater semipermanent fish life propagation; Immersion recreation; Limited contact recreation; and Fish and wildlife propagation, recreation and stock watering.
Other indicators, including the lake's Trophic State Index (TSI) (Carlson, 1977) value, determine the support of beneficial uses and compliance with standards. A gradual increase in fertility of the water due to nutrients washing into the lake from external sources is a sign of the eutrophication process. Lake Minnewasta is identified in the 2006 South Dakota Integrated Report as non 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 assess the trophic status of a lake, SD DENR uses the mean TSI which incorporates Secchi depth, and chlorophyll *a* concentrations. SD DENR has developed a protocol that establishes desired TSI levels for lakes based on fishery classification. This protocol was used to assess impairment and determine a numeric target for Lake Minnewasta.

Lake Minnewasta currently has a mean TSI of 56.4, which places it in the eutrophic lakes category and is indicative of high levels of primary productivity. Assessment monitoring indicates that the primary cause of the high productivity is phosphorus loads from in-lake sediment containing nutrients and runoff from animal waste. There also appears to be a significant impact on nutrient concentrations as a result of sediment released phosphorus.

The numeric target, established for Lake Minnewasta in "Targeting Impaired Lakes in South Dakota" is a TSI of less than 63.4. This TSI has already been reached, likely due to a lack of tributaries in the watershed and their ability to transport nutrient and sediment loads to the lake.

Pollutant Assessment

Point Sources

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

Nonpoint Sources/ Background Sources

Nonpoint sources for pollution in the lake may be from a feedlot located near the lake that does not have an animal waste containment system. Both nonpoint and background sources can be loadings from Rush Lake as it empties in to Lake Minnewasta. Another source can be attributed to atmospheric loading. Atmospheric loading was not measured during the study.

Linkage Analysis

Water quality data was collected from two sites in Lake Minnewasta. 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 7% of the samples according to South Dakota's EPA approved Nonpoint Source Quality Assurance/Quality Control Plan. Details concerning water sampling techniques, analysis, and quality control are addressed on pages 16-23 of the assessment final report.

In addition to water quality monitoring, land use data was collected in anticipation of using a watershed landuse model. The Annualized Agriculture Nonpoint Pollution Source (AnnAGNPS) model was not completed due to the current landuse in the watershed and the fully supporting TSI measured during the study.

Maintaining current landuse practices may result in continued improvement in the water quality at Lake Minnewasta. Further protection to the lake may be achieved through the stabilization of failing banks, and installing a waste containment system for the feedlot along the lake.

TMDL and Allocations

TMDL

	0 kg/yr	(WLA)
+	0 kg/yr	(LA)
	Implicit	(MOS)
	0 kg/yr	(TMDL)

Wasteload Allocations (WLAs)

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

Load Allocations (LAs)

Maintenance of current BMPs in addition to bank stabilization will insure that the lake continues to fully support its beneficial uses and may result in additional improvements in water quality.

Seasonal Variation

Different seasons of the year can yield differences in water quality due to changes in precipitation, temperature, and agricultural practices. To determine seasonal differences, Lake Minnewasta's inlake samples were separated into spring (March-May), summer (June-August), fall (September-November), and winter (December-February) collection periods. Average seasonalized inlake phosphorus data may be found on page 23.

Margin of Safety

Conservative estimates were used throughout the modeling process. These estimates produced an implicit margin of safety. In addition to the implicit margin of safety, stabilization of the shoreline and installing a waste containment system in the nearby feedlot that is located adjacent to the lake will increase the margin of safety so the lake will maintain its current state of full support of its beneficial uses.

Critical Conditions

According to seasonal inlake average phosphorus concentrations, impairments to Lake Minnewasta are most severe during the fall and winter months. This is likely the result of decomposition of organic matter under the ice due to a lack of wind and wave action which mixes the water in the lake, thus elevating dissolved oxygen levels for less decomposition and phosphorus release.

Follow-Up Monitoring

Continued monitoring of Lake Minnewasta will be completed by the South Dakota Department of Environment and Natural Resources State Wide Lakes Assessment program.

Public Participation

Efforts taken to gain public education, review, and comment during development of the TMDL involved (numbers reflect contacts concerning both the Amsden Dam and Lake Minnewasta Assessments):

Meetings attended by the project coordinator include:

Day County Farm and Home Show 1

Day County Conservation District 12

And Over 40 contacts with individual land owners

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

Implementation Plan

The South Dakota DENR, working with the Day Conservation District, has taken the first steps to develop and initiate an implementation project to address water quality concerns for Lake Minnewasta. Products in the Project Implementation Plan will address these concerns through the implementation of animal nutrient management systems, shoreline stabilization for further providing protection to the lake and insuring it maintains full support of its beneficial uses.. The District has requested US EPA Section 319 funding for assistance with best management practice implementation.