WATERSHED POST-ASSESSMENT
FINAL REPORT

LAKE CAMPBELL, BROOKINGS COUNTY

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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Prepared By

East Dakota Water Development District

June 2009

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

EXECUTIVE SUMMARY

PROJECT TITLE: Lake Campbell Watershed Post-Assessment

START DATE: April 26, 2007 **COMPLETION DATE:** 12/31/2008

FUNDING: **TOTAL BUDGET:** $90,880.00

TOTAL EPA GRANT:	$56,583.00
TOTAL EXPENDITURES OF EPA FUNDS:	$34,193.97
TOTAL SECTION 319 MATCH ACCRUED:	$9,504.79
BUDGET REVISIONS:	None
TOTAL EXPENDITURES:	$43,698.76

SUMMARY ACCOMPLISHMENTS

The purpose of the post assessment is to determine the current ecological status of the lake, the influence of previously implemented Best Management Practices (BMPs), and to determine the effectiveness of those restoration activities that have taken place in the past. This project will take into account available historical water quality data and information from prior assessments and reports.

An initial water quality assessment was completed in 1985 by the South Dakota Department of Water and Natural Resources. A diagnostic and feasibility study was completed in 1993 by the South Dakota Department of Environment and Natural Resources. An EPA section 319 grant provided a majority of the funding for this post assessment project which was conducted by the East Dakota Water Development District, whom also provided matching funds.

During the diagnostic and feasibility study (Madison and Wax 1993), water quality monitoring and watershed modeling resulted in the identification of nutrient and sediment loadings to the lake. Nutrients and sediment were believed to be coming from the watershed through Battle Creek, from shoreline erosion, faulty septic systems, and in-lake sediment. This study recommended several restoration activities to be implemented that included an information/education program, feedlot runoff control, shoreline erosion control, establishment of a sanitary district, wetland evaluation, and dredging. The sources of impairment were addressed through BMPs including feedlot management, wetland restoration, shoreline buffers, and riparian management. As shown by the results of this post assessment project, previous efforts to improve the water quality of the lake were not as successful as hoped for. The post assessment does show the lake meeting all of its water quality standards. Results indicate that more improvements are needed in order for Lake Campbell to attain a TSI goal of
$\leq$ 68.4.

ACKNOWLEDGEMENTS

The cooperation of the following organizations and individuals is gratefully appreciated. The assessment of the Lake Campbell watershed could not have been completed without the cooperation of the landowners in the study area. Their cooperation is greatly appreciated.

South Dakota Department of Environment and Natural Resources
South Dakota Department of Game, Fish and Parks
South Dakota State Health Lab
United States Fish and Wildlife Service
United States Environmental Protection Agency

East Dakota Water Development staff that contributed to the development of this report:
Technical Staff: Deb Springman & Jeremy Hinke
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ABBREVIATIONS

AGNPS	Agricultural Non-Point Source – *an event-based, watershed-scale model developed to simulate runoff, sediment, chemical oxygen demand, and nutrient transport in surface runoff from ungaged agricultural watersheds*
AnnAGNPS	Annualized Agricultural Non-Point Source – *models the current condition of a watershed, simulating the transport of water, sediments, and nutrients and compares the effects of implementing various conservation practices over time*
BMP	Best Management Practice – *an agricultural practice that has been determined to be an effective, practical means of preventing or reducing nonpoint source pollution*
BSR	Big Sioux River
CFU	Colony Forming Units
CRP	Conservation Reserve Program
CV	Coefficient of Variance – *a statistical term used to describe the amount of variation within a set of measurements for a particular test*
DO	Dissolved Oxygen
EDWDD	East Dakota Water Development District
EPA	Environmental Protection Agency
NGP	Northern Glaciated Plains
NPDES	National Pollution Discharge Elimination System
NPS	Non-point Source
NTU	Nephelometric Turbidity Units – *measure of the concentration of the size of suspended particles (cloudiness) based on the scattering of light transmitted or reflected by the medium*
SD	South Dakota
SD DENR	South Dakota Department of Environment and Natural Resources
SD DWNR	South Dakota Department of Water and Natural Resources
SD GFP	South Dakota Department of Game Fish & Parks
SDGS	South Dakota Geologic Survey
SDSU	South Dakota State University
TKN	Total Kjeldahl Nitrogen
TSI	Trophic State Index – *a measure of the eutrophic state of a waterbody*
TSS	Total Suspended Solids
μmhos/cm	micromhos/centimeter – *unit of measurement for conductivity*
USFWS	United States Fish and Wildlife Service
USGS	United States Geologic Survey
WQ	Water Quality – *term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a* particular purpose
WRI	Water Resources Institute

INTRODUCTION

PURPOSE

The purpose of this post-assessment was to compare previous watershed conditions and present conditions of Lake Campbell in eastern South Dakota. Results of the Lake Campbell dredging project, Best Management Practices, and restoration activities that were implemented between the years of 1987 and 1999, were examined for their effectiveness in improving lake water quality.

According to the initial assessment (SD DWNR 1985), Lake Campbell was identified as being hypereutrophic due to high concentrations of total phosphorus and elevated total nitrogen levels from agriculture and other anthropogenic sources. In 1986 the Lake Campbell Association developed a plan to increase the water depth in selected public beach areas using dredging. The Association approached the East Dakota Water Development District (EDWDD) for financial and technical assistance. EDWDD was hesitant on financing the project until an analysis of the amount of sediment and nutrients entering the lake were completed.

In 1986 Water Resources Institute was contracted by East Dakota Water Development District to complete a study to determine the amount of sediment and nutrients coming from agricultural land and entering Lake Campbell (WRI 1986). That study revealed 1.19 million cubic feet of sediment had discharged from the watershed into Lake Campbell between 1966 and 1985. This volume was equal to 0.4 inch of deposition over the entire lake bottom. The dredging plan was to remove 470,000 cubic yards or 10 times the volume of sediment that entered between 1966 and 1985. The report also stated that "the lake is not being filled very rapidly with sediment". The next year (1987) the Lake Association started dredging the Lake Campbell. Dredging continued until 1989 when it was halted by the state and EPA. It was determined a more comprehensive watershed study was needed before pursuing further dredging.

In 1989, the Water Resources Institute completed another study identifying critical non-point source sediment and nutrient producing areas within the Lake Campbell watershed and recommended management options (WRI 1989). A diagnostic/feasibility study (Madison and Wax 1993) was completed between 1990 and 1992. The study evaluated water quality, shoreline erosion, septic systems, in-lake sediment, and the watershed. The study recommended an information/education program be established to help promote best management practices. It also recommended feedlot runoff control, shoreline erosion control, establishment of a sanitary district, evaluation of wetlands, and dredging.

In 1994 the Lake Campbell Sanitary Sewer District was incorporated. Between 1995 and 1999 the Brookings County Conservation District worked on implementing several of the BMPs recommended by the 1993 diagnostic/feasibility study (Brookings CCD 2002). In 1999 the outlet structure on the north end of the lake was replaced.

During the post-assessment water quality samples were collected from three in-lake sites and two tributary sites during 2007-2008. Results were analyzed for violations of water quality standards based on beneficial uses and water quality numeric criteria (Table 1). Historical data from the past 42 years were also utilized. Through water quality monitoring, stream gaging, and land use analysis, the restoration efforts conducted as a result of the 1993 diagnostic/feasibility study were measured for their effectiveness in improving the water quality of Lake Campbell.

Table 1. Designated Beneficial Uses for Lake Campbell and Water Quality Concerns

	Designated Beneficial Use	Concerned With:
(5)	Warmwater Marginal Fish Life Propagation	Total Ammonia Nitrogen as N, Dissolved Oxygen, pH, Water Temperature, Total Suspended Solids
(7)	Immersion Recreation	Dissolved Oxygen, Fecal Coliform Bacteria
(8)	Limited Contact Recreation	Dissolved Oxygen, Fecal Coliform Bacteria
(9)	Fish & Wildlife Propagation, Recreation, and Stock Watering	Alkalinity, Total Dissolved Solids, Conductivity, Nitrates, pH

GENERAL WATERSHED DESCRIPTION

Lake Campbell is an 800-acre (324 hectares) natural lake located in the Big Sioux River basin (Figure 1) with a sizable watershed encompassing approximately 118,161 acres (47,818 hectares). The watershed is located within four counties: south-central Brookings County, northwest Moody County, northeast Lake County, and a very small portion of southeast Kingsbury County (Figure 2). The lake is fed by Battle Creek from the south, with the north end of the lake draining intermittently to a tributary which joins the Big Sioux River a few miles downstream.

Figure 1. Location of Lake Campbell in the Big Sioux River Basin

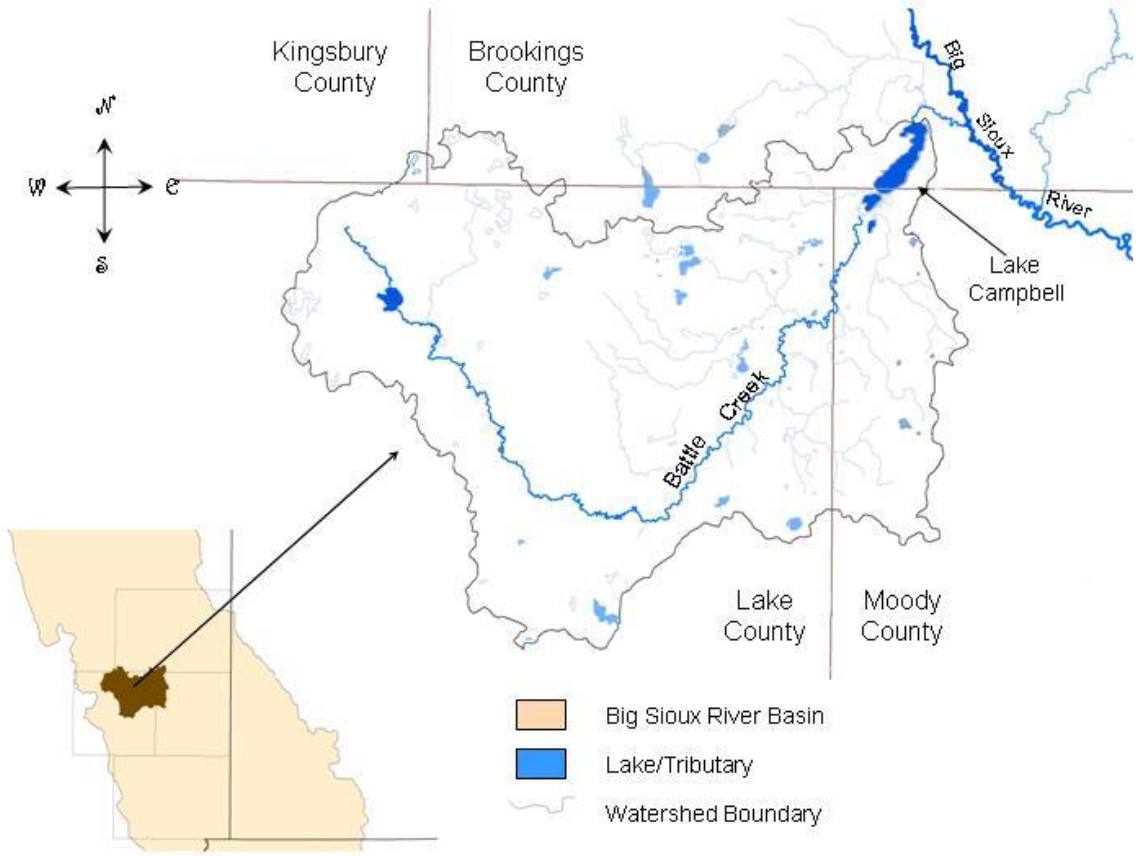


Figure 2. Location of the Lake Campbell Watershed

Geology and Soils

Lake Campbell is a glacial outwash lake that was formed during a sub-advance of the late Wisconsin glacial period. The lake and its watershed are located on what is known as the Coteau des Prairie. The prairie Coteau area is an erosion remnant, irregularly covered with glacial drift. The landscape of the area consists of a varied topography with numerous small depressions. Slopes in the end moraine areas range from six percent to more than ten percent. Slopes in the ground moraine areas are usually less than six percent. Generally, slopes range from zero to six percent.

Two shallow aquifers, the Battle Creek aquifer and the Big Sioux aquifer, merge just below Lake Campbell. Both aquifers are recharged by precipitation and snowmelt (Hansen 1986). Ground and surface water connections between Lake Campbell and the aquifers are moderate. Land elevation in the watershed ranges from 1,578 feet to 1,808 feet above mean sea level. The Lake Campbell ordinary high water mark elevation is 1,575.7 feet above mean sea level.

Soils within the watershed generally consist of well-drained silty clay loams that have developed over glacial till. The majority of the soils are categorized as Egan, Wentworth-Sinai, or Dempster series. The downstream end of the Battle Creek area consists of silty soils formed in alluvium over sand and gravel. The mid to upstream end of Battle Creek consists of silty soils formed in glacial drift (USDA 1973).

Climate

The average annual precipitation in the Lake Campbell watershed is approximately 23 inches (SDSU 2008), of which 75 percent typically falls during the growing season of April through September (Figures 3 and 4). The nearest weather station, located just northeast of Brookings (44°20'N / 96°46'W), recorded monthly rainfall and evaporation totals during the study years 2007-2008 (Tables 2 and 3). Tornadoes and severe thunderstorms strike occasionally. These storms are often of only local extent, short in duration, and occasionally produce heavy rainfall events.

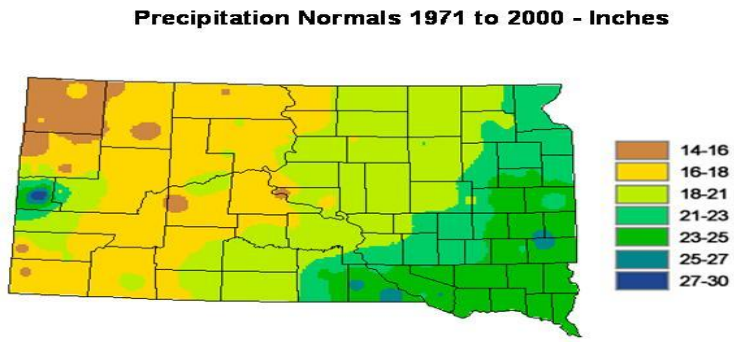


Figure 3. South Dakota Precipitation Normals in Inches (1971-2000)

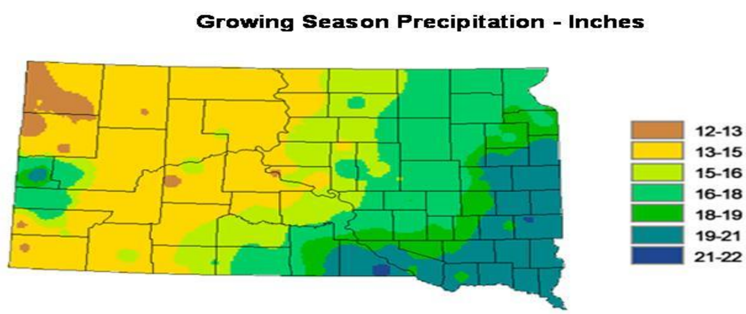


Figure 4. South Dakota Growing Season Precipitation in Inches (1971-2000)

Table 2. Monthly Rainfall Totals During the Study Period

BROOKINGS 2NE Coop Station - Total Monthly Precipitaton (inches)													
Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
2007	0.29	0.84	1.84	3.62	1.85	2.99	0.14	6.45	1.2	4.44	0.04	0.59	24.29
2008	0.11	0.04	1.25	1.36	3.04	5.96	1.89						

Table 3. Monthly Evaporation Totals During the Study Period

BROOKINGS 2NE Coop Station - Total Monthly Evaporation (inches)													
Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
2007				2.9	6.54	8.17	7.73	5.61	5.15	2.48			38.58
2008				1.44	7.55	7.91	9.04						

Land Use

Common land unit information from the Farm Service Agencies in Brookings County, Kingsbury County, Lake County, and Moody County shows that approximately 85 percent of the area is cropland, such as corn and soybeans, and 11 percent is grassland and pastureland (Figure 5). Approximately 37 animal feeding operations are located throughout the watershed. The majority are cow/calf operations. The Lake Campbell shoreline is privately owned except for the public access on the north side of the lake and a road right-of-way with access at the south end of the lake. Residential development in the watershed is limited to the surrounding lake area and the small towns of Nunda and Rutland.

Figure 5. Landuse in the Lake Campbell Watershed

Population

There are 150 shoreline homes on Lake Campbell, with approximately 65 percent of these being year-round residences. The watershed expands over 13 townships and across four counties. The majority of the watershed lies within the townships of Badus, Nunda, Leroy, Summit, and Rutland in Lake County; and Fremont, and Jefferson in Moody County. The population estimate of the watershed is 1,334 people (USCB 2000).

History

Lake Campbell is located six miles south and two miles west of the City of Brookings, South Dakota. It has been documented that the first homesteader (Nils Trygstad) settled the area 140 years ago. The lake was named after Albert H. Campbell of the Pacific Wagon Railroad. From the early 1900s and into the 1950s the Hagensick Resort on Lake Campbell was one of the most popular resorts in South Dakota. It offered a swimming beach, boat rentals, baseball diamonds, picnic grounds, roller skating rink, dance hall, gas station, restaurant, and a water slide. After the resort was sold in the 1950s it became known as Johnson's Park. The park was maintained until the 1980s and now the area is simply known as South Shore. Residents have speculated that declining water quality has been a factor in limited recreational use of the lake over the past few decades.

PROJECT DESCRIPTION

Shallow lakes in eastern South Dakota are vulnerable to accelerated sedimentation and nutrient enrichment due to agricultural practices, recreational activities, and developmental activities near and around the lakes.

In the early 1980s, citizens of Lake Campbell collected water quality samples because of their concerns about the declining water quality of the lake. A water quality assessment was conducted by the South Dakota Department of Water and Natural Resources in 1983. Results were published in the SD DWNR 1985 water quality report for Lake Campbell. The report stated, "The major problem of Lake Campbell is an excess of nitrogen and phosphorus." In 1984 the Lake Campbell Improvement Association put together a proposal for a restoration project, which was sent to the State Water Board for approval. The plan included constructing 17 silt impoundment dams in the watershed and removal of the sediment in the south slough. It was recognized at that time that the government would not pay for silt removal until sources of impairment were first dealt with (See Appendix A for notes from the Lake Campbell Improvement Association). Between 1983 and 1986 the Lake Campbell Improvement Association in coordination with the Madison Soil Conservation Service (SCS) installed six dugouts, cleaned out eight others, put in two miles of terraces, planted 32 acres of trees and enrolled 20 percent of the cropland into BMPs. However, the lake association was informed that at least 27 dugouts needed to be installed on the small streams entering Battle Creek before sediment removal in the lake should occur.

In 1986, the Lake Campbell Association approached the East Dakota Water Development District (EDWDD) with a dredging plan to improve the lake by increasing depths near selected public beach areas. It is unclear if any further work was completed in the watershed by the SCS, in regards to the earlier recommendations. However, EDWDD recommended an in-depth analysis of the sources and amounts of sediment and nutrients entering the lake before implementing a dredging project. Such an analysis could determine if adequate erosion controls were in place to prevent the lake from re-filling after dredging.

EDWDD contracted the Water Resources Institute (WRI) at South Dakota State University which completed a study that showed an estimated 1.19 million cubic feet of sediment had deposited from the watershed to Lake Campbell between 1966 and 1985. The report stated Battle Creek contributed nearly all the sediment and nutrients that entered the lake and the predominant source of sediment was upland erosion. The report also stated that the lake was not being filled very rapidly with sediment and the 470 thousand cubic yards to be removed by dredging would make up ten times the volume that entered the lake over the previous 20 years. Dredging efforts moved forward and began in the Spring of 1987.

At the same time, WRI began an evaluation of the watershed to identify critical areas contributing the most sediment and nutrient loads to the lake. WRI again mentioned sediment loadings to the lake were relatively low and those areas contributing high sediment loads needed to be identified and treated. The 1989 report recommended increasing conservation tillage, reducing rate of fertilizer application, converting cropland within 1.5 miles of the lake to permanent pasture, and implementing CRP in identified critical areas to control and decrease sediment and nutrients entering the lake.

Dredging continued until November of 1989 when the Lake Campbell Association and the State of South Dakota agreed to suspend all dredging activities until all federally funded studies were completed. By that time 220,000 cubic yards of sediment had been removed from Lake Campbell. Areas dredged included the southern end near the inlet and the northern end near the outlet.

In July of 1990, the South Dakota Department of Environment and Natural Resources in collaboration with EDWDD began a diagnostic/feasibility study of Lake Campbell. This was an EPA funded 314 project. The study included water quality monitoring of the lake and watershed, an analysis of land uses and non-point sources of pollution in the watershed, a socio-economic study, a shoreline erosion survey, a septic system survey, and a survey and analysis of the bottom sediments in the lake.

Professional engineers, Bernhard, Eisenbraun and Associates of Yankton, South Dakota, were hired in the fall of 1990 to complete a hydrographic survey of Lake Campbell. Topographic maps were drawn with the ranges in depth of the bottom sediment layer and ranges of depth of the water column. Survey results showed the average water depth was five feet, the average sediment depth six feet, and the estimated sediment volume 7,840,000 cubic yards (4,860 acre-feet).

The diagnostic/feasibility study concluded in May 1992. In-lake results showed high levels of nutrients and several exceedences of the water quality standards for dissolved oxygen, pH, and un-ionized ammonia. Sampling of Battle Creek indicated two specific areas of the watershed were contributing excessive nutrients and sediment to the stream. The shoreline survey found 4,155 feet of shoreline with minor to moderate/severe erosion. The septic survey of the shoreline homeowners revealed ten percent of the systems were not in compliance with construction requirements. Six recommendations were made to address the water quality problems:

1) information and education program to promote BMPs (to reduce sediment & nutrient loads)
2) feedlot runoff control (approximately 12 feedlots)
3) shoreline erosion control (1,365 ft)
4) sanitary district establishment (address failing systems)
5) wetland evaluation, restoration, and establishment (south slough, throughout watershed)
6) dredging (approximately 1,000,000 cubic yards)

The Lake Campbell Sanitary District was incorporated November 1, 1994. The first major effort of the district was contracting an engineering firm to construct a plan for a centralized sewer system.

In 1995, the Brookings County Conservation District took the lead in the Lake Campbell/Battle Creek Watershed Project. This was a four-year project funded with EPA 319 grant money as well as through the SD Conservation Commission. The goal of this project was to restore the lake from a hypereutrophic condition to a eutrophic condition. The following table (Table 4) outlines the restoration activities that took place during the Lake Campbell/Battle Creek Watershed Project (1995-1999). See Appendix B for maps of the shoreline stabilization project.

Table 4. Installed Best Management Practices (1995-1999)

Installed BMPs (1995-1999)	
BMP	**Number**
Animal Waste Storage Unit	1
Animal Waste Innovative Design (Diversion)	1
No-till enrollment	3,800 acres
Wetland creation	1
Conservation tillage	1,500 acres
Tree Planting	5 acres
Grazing systems with dugouts	3
Integragted crop management	480 acres
Critical Area Seeding	520 acres
Grassed Waterways	19,450 linear feet
Streambank stabilization (riparian buffer)	8,000 linear feet
Shorline stabilization	2,400 linear feet

In April 1996, an engineer and architect consulting agency (Banner Associates), drafted a facilities plan for a centralized collection and treatment facility for wastewater. The plan was presented to the Lake Campbell Sanitary District. The planning area included an area within 1,000 feet of the Lake Campbell shoreline, separated into two major service areas (west side and east side).

In January 1999, Banner Associates prepared a specification plan for Lake Campbell spillway repairs. The plan was prepared for the Lake Campbell Improvement Association and the SD Game, Fish and Parks. By November of 1999, Industrial Builders of North Dakota had completed construction of the new outlet structure on the north end of Lake Campbell. According to a newspaper article in the Brookings Register in 1999, the very first dam of the natural lake basin was built in 1913 to create what is known as Lake Campbell. Several years later, in 1929, the dam was replaced with a new one which lasted 70 years.

In 2007, the East Dakota Water Development District began a post-assessment of the Lake Campbell watershed. The purpose of this assessment was to check the condition of the lake and evaluate whether previous restoration activities positively impacted the water quality of the lake. The results of this second assessment are presented in the following pages.

The Lake Campbell watershed is a 118,161 acre area lies within the Northern Glaciated Plains (NGP), Level III ecoregion. Within the NGP, one of the 15-level IV ecoregions, the Prairie Coteau (46k), is represented in the assessment area. A description of the Prairie Coteau ecoregion is provided in Table 5. Of the five monitoring sites, three were located within the lake and the remaining two were set up to monitor the inlet and outlet (Figure 6).

Table 5. Description of the Level IV Ecoregion *Within* the Lake Campbell Watershed (Omernik et al. 1987)

Ecoregion	Physiography	Potential Natural Vegetation	Land Use and Land Cover	Climate	Soil Order
Northern Glaciated Plains					
Prairie Coteau (46k)	Surficial geology of glacial till. Hummocky, rolling landscape with high concentration of lakes and wetlands and poorly defined stream network.	Big bluestem, little bluestem, switch grass, Indian grass, and blue gramma.	Rolling portions of landscape primarily in pastureland. Flatter portions of landscape in row crop, primarily of corn and soybeans. Some small grain and alfalfa.	Mean annual rainfall of 20-22 inches. Frost-free from 110-140 free days.	Mollisols

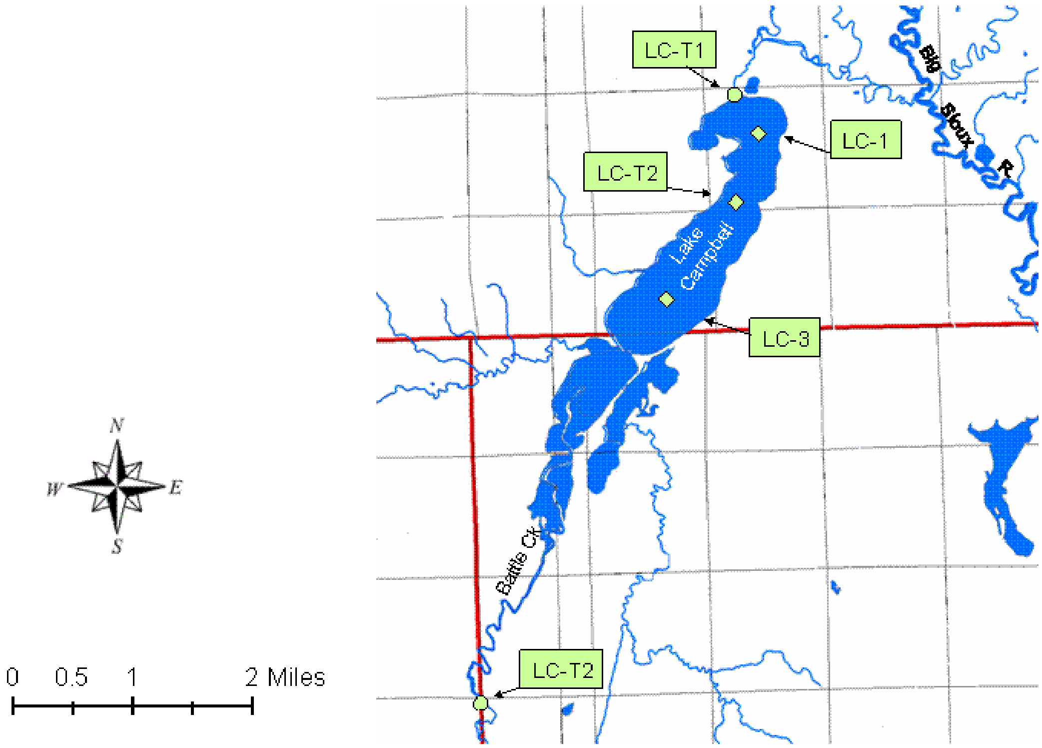


Figure 6. Location of the Monitoring Sites in the Lake Campbell Watershed

BENEFICIAL USES

The State of South Dakota has assigned all of the water bodies that are situated within its borders a set of beneficial uses. ‘Beneficial use’ refers to the purpose or benefit to be derived from a water body. Under state and federal law, the beneficial use of water is to be protected from degradation. One of the eleven beneficial uses, (9) fish and wildlife propagation, is assigned to all lakes in South Dakota, and two of the eleven beneficial uses, (9) fish and wildlife propagation and (10) irrigation, are assigned to all the streams in South Dakota. A set of standards is applied to the lakes and streams of South Dakota to maintain the beneficial uses of each waterbody. According to the 1992 diagnostic/feasibility study of Lake Campbell, in-lake results showed elevated levels of nutrients and several exceedences of the water quality standards for dissolved oxygen, pH, and un-ionized ammonia. Additionally, the sampling results from Battle Creek indicated two specific areas of the watershed were contributing excessive nutrients and sediment to the stream. Designated beneficial uses and numeric water quality standards not to be exceeded for the following uses are listed in Table 6 for the Lake Campbell watershed:

(6) Warmwater Marginal Fish Life Propagation
(7) Immersion Recreation
(8) Limited Contact Recreation
(9) Fish & Wildlife Propagation, Recreation, & Stock Watering
(10) Irrigation

Lake Campbell is assigned beneficial uses (6), (7), (8), and (9). The Lake Campbell outlet is assigned beneficial uses (9) and (10), and the Battle Creek inlet is assigned beneficial uses (6), (8), (9), and (10).

Table 6. Numeric Criteria and Beneficial Uses Applicable to the Lake Campbell Watershed

Parameters (mg/L) except where noted	**6** Warmwater marginal fish life propagation	**7** Immersion recreation	**8** Limited contact recreation	**9** Fish & wildlife propagation, recreation & stock watering	**10** Irrigation
Fecal Coliform (per 100 mL) May 1 - Sept. 30		$\leq$ 200 (mean[1]) $\leq$ 400 (single sample)	$\leq$ 1,000 (mean[1]) $\leq$ 2,000 (single sample)		
Specific Conductivity (µmhos/cm @ 25° C)				$\leq$ 4,000[1]/$\leq$ 7,000[2]	$\leq$ 2,500[1]/$\leq$ 4,375[2]
Nitrogen, total ammonia as N (mg/L)	Equation-based limit				
Nitrogen, Nitrate (mg/L) as N				$\leq$ 50[1]/$\leq$ 88[2]	
Dissolved oxygen (mg/L)	$\geq$ 4.0	$\geq$ 5.0	$\geq$ 5.0		
pH (standard units)	$\geq$ 6.0 - $\leq$ 9.0			$\geq$ 6.0 - $\leq$ 9.5	
Total alkalinity (mg/L)				$\leq$ 750[1]/$\leq$ 1,313[2]	
Suspended solids (mg/L)	$\leq$ 150[1]/$\leq$ 263[2]				
Total dissolved solids (mg/L)				$\leq$ 2,500[1]/$\leq$ 4,375[2]	
Temperature (°F)	$\leq$ 90				

Note: [1] 30-day average [2] daily maximum

RECREATIONAL USE

Recreational activities at Lake Campbell include fishing, swimming, boating, and picnicking. Lake Campbell is frequented by fisherpersons and recreational enthusiasts. The majority of the shoreline is privately owned with the exception of the access area on the north end of the lake which is owned by South Dakota Game, Fish and Parks, and a road right-of-way on the south end of the lake owned by Moody County and open for public access. Primary game fish include walleye and yellow perch. Other species of fish include black bullhead, northern pike, white bass, bluegill, white sucker, black crappie, carp, shorthead redhorse, channel catfish, and bigmouth buffalo. Lake Campbell partially winterkills about every four years. Lake Campbell is regularly stocked with fish (See Appendix C for a complete historical stocking table). The 2006 Fisheries Survey conducted by the South Dakota Department of Game, Fish and Parks can be found in Appendix D. There are state game production areas, state walk-in areas, as well as federal waterfowl production areas located within and adjacent to the watershed (Figure 7). These areas are frequently used by hunters (SD GFP 2008).

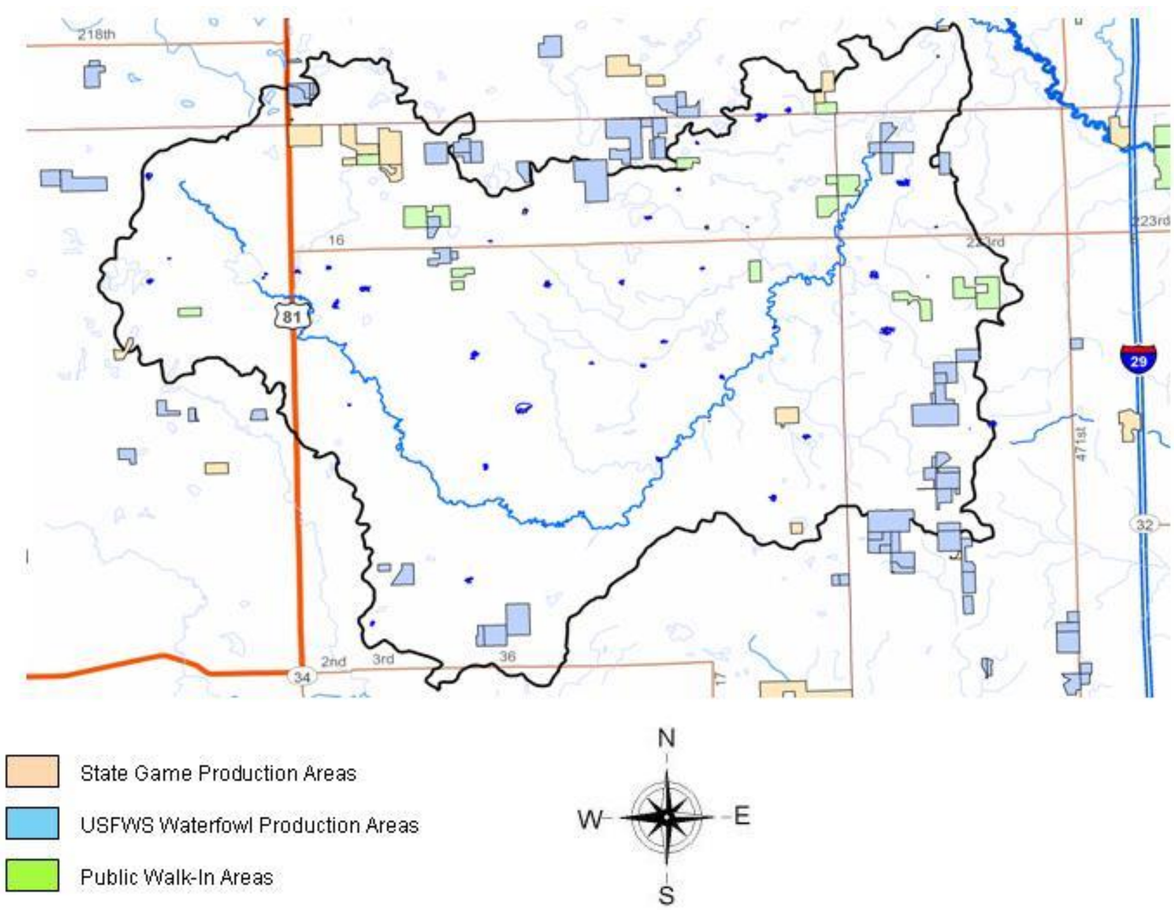


Figure 7. State and Federal Lands Located Within the Watershed

THREATENED AND ENDANGERED SPECIES

Information from South Dakota Natural Heritage Database (2008) located online at NatureServe (2008), the Fragile Legacy (Ashton and Dowd 2008) publication, and the USFWS (2008) were used to construct the following table (Table 7) of the rare, threatened and endangered species that may be found within the counties of Brookings, Moody, Lake, and Kingsbury, which includes the Lake Campbell watershed. Species status is identified as endangered, threatened, or rare. None of these species were encountered during the study.

Table 7. Rare, Threatened, and Endangered Species in the Lake Campbell Area

			STATUS		
NAME	**SCIENTIFIC NAME**	**CATEGORY**	**FEDERAL**	**STATE**	**OCCURRENCE**
Whooping Crane	*Grus americana*	Bird	FE	SE	Rare
Bald Eagle	*Haliaeetus leucocephalus*	Bird		ST	Known
Piping Plover	*Charadrius melodus*	Bird	FT	ST	Known
Topeka Shiner	*Notropis topeka*	Fish	FE		Known
Central Mudminnow	*Umbra limi*	Fish		SR	Known
Trout Perch	*Percopsis omiscomaycus*	Fish		SR	Known
Northern Redbelly Dace	*Phoxinus eos*	Fish		ST	Known
American Burying Beetle	*Nicrophorus americanus*	Insect	FE		Rare
Dakota Skipper	*Hesperia dacotae*	Insect	FC		Known
Western Prairie Fringed Orchid	*Platanthera praeclara*	Plant	FT		Rare
Northern Redbelly Snake	*Storeria occipitomaculata occipitomaculata*	Reptile		SR	Known
River Otter	*Lontra canadensis*	Mammal		ST	Known
Black-Footed Ferret	*Mustela nigripes*	Mammal	FE	SE	Rare

KEY TO CODES:

FE = Federal Endangered SE = State Endangered
FT = Federal Threatened ST = State Threatened
FC = Federal Candidate SR = State Rare

PROJECT GOALS, OBJECTIVES, AND MILESTONES

GOALS

The goals of this assessment project are to:

1) Determine present ecological status
2) Compare previous watershed conditions and present conditions as a result of installed BMPs
3) Determine the effectiveness of previous restoration efforts

Lake Campbell water quality was initially assessed in 1983 and showed excessive amounts of nitrogen and phosphorus in the lake. A diagnostic/feasibility study of the lake and its watershed was conducted between 1990 and 1992. In-lake results showed high level of nutrients and several exceedences of the water quality standards for dissolved oxygen, pH, and un-ionized ammonia. Sampling in the watershed indicated two specific areas were contributing excessive nutrients and sediment. In 1995, a four-year implementation project was initiated to address these problems. The post-assessment was necessary to determine if previous restoration efforts were effective and to complete a TMDL, if necessary.

Lake Campbell was identified in the 1996 South Dakota Report to Congress 305(b) Water Quality Assessment as hypereutrophic due to excessive nutrients, siltation, and noxious aquatic plants. Since that time, it has been listed as impaired in subsequent reports. Lake Campbell was most recently identified in the 2008 Integrated Waterbody List for TMDL development due to worsening TSI trend and non- support of its warmwater marginal fish life beneficial use. Since the 2008 Integrated Report, SD DENR and EPA have agreed to no longer consider TSI as a measure of impairment. However, the targets set in the 2005 DENR Targeting document can still be used as a guideline to provide direction to maintain or improve the condition of Lake Campbell.

Goals were attained through the collection of tributary and in-lake data and aided by the completion of the BATHTUB and Annualized Agricultural Non-Point Source (AnnAGNPS) watershed modeling tools. Data collected during previous studies and assessments were compared to the water quality data collected during this project to see if past restoration efforts were effective in improving water quality.

OBJECTIVES

Objective 1. Water Quality Assessment

Water samples were collected from April 2007 through June 2008 at three in-lake sites, one inlet site, and one outlet site. Water quality from past studies, citizen monitoring, and the SD DENR Statewide Lake Assessment Program were compiled and analyzed. Comparison of water quality data from pre-restoration and post-restoration assessments was completed.

A Thalimedes OTT stage recorder was installed at the inlet and two Solinst level loggers were installed at the outlet. Detailed level and flow data were entered into a database that was used to assess the nutrient and solids loadings.

Objective 2. Quality Assurance/ Quality Control (QA/QC)

Duplicate 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. QA/QC data collection began in May of 2007 and was completed in April of 2008.

Objective 3. Landuse Assessment

Three models were incorporated into this project to analyze and predict loadings. The FLUX model was used to calculate loadings and concentrations in monthly, yearly, and daily increments for the inlet to the lake from sample concentration data and continuous flow records. The BATHTUB model was used to predict changes in water quality parameters related to eutrophication (phosphorus, nitrogen, chlorophyll-*a*, and transparency). Reductions of phosphorus and nitrogen watershed loading were modeled to generate an in-lake reduction curve. The AnnAGNPS model was used to assess the pollution potential of feedlots in the area based on animal numbers, condition of the feedlot, proximity to water, soils, rainfall events, and topography during the pre-implementation period. Model outputs included a feedlot rating, chemical oxygen demand, and phosphorus loadings. The model was also used to simulate the transport of sediment, and nutrients through the watershed during various rainfall events. The current condition of the watershed was modeled and used to analyze the effectiveness of restoration efforts in comparison to the state of the watershed before implementation best management practices.

Objective 4. Information and Outreach

Project updates were provided to the project officer, at EDWDD monthly board meetings, and to the Lake Campbell Lake Association. The assessment of animal feeding operations located within the project area was conducted by contacting landowners individually via telephone.

Objective 5. Reporting

Water quality conditions were linked to potential sources of pollution. Based upon these linkages, restoration efforts were initiated to sustain pollution levels that would not reach beyond their maximum allowable loads (based on water quality standards) to improve the water quality of Lake Campbell. The hypereutrophic state of Lake Campbell caused by excess nutrients, siltation, and noxious aquatic plants, drove the dredging project and implementation of BMPs to restore the lake to a condition that could support its beneficial uses. Sources that exceeded the maximum allowable levels (or loadings) were addressed by an implementation plan that included the application of Best Management Practices during the years of 1995 to 1999. This report is an assessment of the present health of the watershed as well as a reassessment to evaluate the effectiveness of the restoration projects that were initiated as a result of the diagnostic/feasibility study of Lake Campbell in 1990.

MILESTONES

The Lake Campbell watershed post-assessment was scheduled to start in April 2007 and end December 2008. Table 8 shows the proposed completion dates versus the actual completion dates of the project goals, objectives, and activities.

Table 8. Project Milestones - Proposed and Actual Completion Dates

	2007												2008											
	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Objective 1				■	■	■	■	■	■	■	■	■	■	■	■									
Lake Sampling					▦	▦	▦	▦	▦	▦	▦	▦	▦	▦	▦	▦	▦	▦						
Objective 2				■	■	■	■	■	■	■	■				■									
Inflow/Outflow Monitoring				▦	▦	▦	▦	▦	▦	▦	▦				▦	▦	▦	▦						
Objective 3					■		■		■		■		■		■		■							
Quality Assurance/Control					▦	▦	▦	▦		▦			▦			▦								
Objective 4				■	■	■	■	■	■	■	■	■	■	■	■									
Landuse Evaluation											▦	▦	▦	▦	▦	▦	▦	▦	▦	▦	▦	▦	▦	
Objective 5						■			■			■												
Information and Outreach						▦	▦	▦	▦	▦	▦	▦	▦	▦	▦	▦	▦	▦	▦	▦	▦	▦	▦	▦
Objective 6									■						■	■	■	■	■	■	■	■	■	■
Reporting/TMDL																			▦	▦	▦	▦	▦	▦

Proposed Completion Dates ■
Actual Completion Dates ▦

METHODS

ENVIRONMENTAL INDICATORS

Water Quality Monitoring

Water samples were collected from three in-lake sites and two tributary sites. Collection of tributary samples was scheduled to coincide with spring runoff, storm events, and at base flow conditions. A total of 94 project samples were collected from April 2007 through June 2008. This included 77 standard samples, 8 blank samples, and 9 duplicate samples.

Field measurements included dissolved oxygen (DO), pH, air temperature, water temperature, stage, Secchi depth, and general climatic information. For most of the project a Hanna Instruments (HI) 9025 meter was used to measure pH. Salinity, DO, water temperature, and conductivity were measured using a YSI 85 meter and a mercury thermometer was used to measure air temperature. In 2008, a YSI 556 MPS multi-probe replaced the YSI 85 meter and the HI 9025 meter. Monitoring of the lake also included Secchi depth measurements.

The State Health Lab in Pierre, South Dakota performed analysis on all samples for alkalinity, total solids, total suspended solids (TSS), volatile total suspended solids, ammonia, nitrate-N, Total Kjeldahl Nitrogen (TKN), total phosphorus, total dissolved phosphorous, *E. coli*, and fecal coliform bacteria. Appendix E contains all grab sample data for each monitoring site.

Description of Parameters

Water quality was sampled according to the SD DENR protocols (SD DENR 2005a). Water quality analyses provided concentrations for a standard suite of parameters. The detection limits are set by the State Health Laboratory based on lab equipment sensitivity (Table 9).

Table 9. Water Quality Parameters Analyzed and Laboratory Detection Limits

Parameter	Units	Lower Detect Limit
Alkalinity-M	mg/L	< 6.0
Alkalinity-P	mg/L	0
Total suspended solids	mg/L	< 1.0
Total solids	mg/L	< 7.0
Volatile Total Suspended Solids	mg/L	< 1.0
Nitrates	mg/L	< 0.1
Ammonia-nitrogen	mg/L	< 0.02
TKN	mg/L	< 0.11
Total phosphorus	mg/L	< 0.002
Total dissolved phosphorus	mg/L	< 0.003
Fecal coliform bacteria	cfu/100 mL	< 10.0
E coli	mpn/100 mL	< 1.0

Alkalinity

Alkalinity is a measure of the buffering capacity of water, or the capacity of water to neutralize acid. Measuring alkalinity is important in determining a stream's or lake's ability to neutralize acidic pollution from rainfall or wastewater. Alkalinity does not refer to pH, but instead refers to the ability of water to resist change in pH. Waters with low alkalinity are very susceptible to changes in pH. Waters with high alkalinity are able to resist major changes in pH. The hardness of the water is usually determined by the amount of calcium and magnesium salts present in water and is associated with the presence of carbonates. Hardwater lakes are generally more productive than softwater lakes and can accept more input of salts, nutrients, and acids to their system without change than can softwater lakes. The range of pH values associated with M-alkalinity (Methyl orange indicator) is 4.2 to 4.5. The range of pH values associated with P-alkalinity (Phenolphthalein indicator) is 8.2 to 8.5.

Total Suspended Solids

Total Suspended Solids (TSS) is the portion of total solids that are suspended in solution, whereas dissolved solids make up the rest of the total. Suspended solids include silt and clay particles, plankton, algae, fine organic debris, and other particulate matter. Higher TSS can increase surface water temperature and decrease water clarity. Suspended solids are the materials that do not pass through a filter, e.g. sediment and algae. Subtracting suspended solids from total solids derives total dissolved solids concentrations. Suspended volatile solids are that portion of suspended solids that are organic (organic matter that burns in a 500^{o} C muffle furnace).

Total Solids

Total Solids are materials, suspended or dissolved, present in natural water. Sources of total solids include industrial discharges, sewage, fertilizers, road runoff, and soil erosion.

Volatile Total Suspended Solids

Volatile solids are those solids lost on ignition (heating to 500 degrees C.) They are useful because they give a rough approximation of the amount of organic matter present in the water sample. Volatile solids measure the sediments which are able to be burned off a dried sediment sample. ‘‘Fixed solids’’ is the term applied to the residue of total, suspended, or dissolved solids after heating to dryness for a specified time at a specified temperature. The weight loss on ignition is called ‘‘volatile solids.’’

Nitrate-Nitrite

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

Ammonia

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

Total Kjeldahl Nitrogen

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

Total Nitrogen

Total nitrogen is the sum of nitrate-nitrite and TKN concentrations. Total nitrogen is used mostly in determining the limiting nutrient, either nitrogen or phosphorus. Nitrogen was analyzed in four forms: nitrate/nitrite, ammonia, and Total Kjeldahl Nitrogen (TKN). From these four forms, total, organic, and inorganic nitrogen may be calculated. Nitrate and nitrite usually originate in fertilizer application runoff. High ammonia concentrations are directly related to sewage and fecal runoff. Nitrogen is difficult to manage because it is highly soluble and very mobile in water.

Total Phosphorus

Phosphorus differs from nitrogen in that it is not as water-soluble and will attach to fine sediments and other substrates. Once attached, it is less available for uptake and utilization. Phosphorus can be natural from geology and soil, from decaying organic matter, waste from septic tanks or agricultural runoff. Nutrients such as phosphorus and nitrogen tend to accumulate during low flows because they are associated with fine particles whose transport is dependent upon discharge (Allan 1995). These nutrients are also retained and released on stream banks and floodplains within the watershed. Phosphorus will remain in the sediments unless released by increased stage, discharge, or current.

Total Dissolved Phosphorus

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

Fecal Coliform Bacteria

Fecal coliform are bacteria that are found in the environment and are used as indicators of possible sewage contamination because they are commonly found in human and animal feces. They indicate the possible presence of pathogenic bacteria, viruses, and protozoan that also live in human and warm blooded animal digestive systems. These bacteria can enter lakes and tributaries by runoff from feedlots, wildlife deposits, pastures, sewage treatment plants, and seepage from septic tanks.

E. coli

Escherichia coli are a type of fecal coliform bacteria that is found in the intestines of humans and warm blooded animals. The presence of *E. coli* in water is a strong indication of recent sewage or animal waste contamination, which may contain disease causing organisms.

Dissolved Oxygen

Dissolved oxygen is important for the growth and reproduction of fish and other aquatic life. Solubility of oxygen generally increases as temperature decreases, and decreases with lowering atmospheric pressure. Stream morphology, turbulence, and flow can also have an affect on oxygen concentrations. Dissolved oxygen concentrations are not uniform within or between stream reaches. A stream with running water will contain more dissolved oxygen than still water. Cold water holds more oxygen than warm water. Dissolved oxygen levels of at least 4-5 mg/L are needed to support a wide variety of aquatic life. Very few species can exist at levels below 3 mg/L.

pH

pH is based on a scale from 0 to 14. On this scale, 0 is the most acidic value, 14 is the most alkaline value, and 7 represent neutral. A change of 1 pH unit represents a 10-fold change in acidity or alkalinity. The range of freshwater is 2-12. pH is a measure of hydrogen ion activity, the more free hydrogen ions (more acidic), the lower the pH in water. Values outside the standard (pH 6.0 – 9.5) do not meet water quality standards.

Water Temperature

Water temperature affects aquatic productivity and water chemistry, including the levels of dissolved oxygen and un-ionized ammonia. Temperature extremes are especially important in determining productivity of aquatic life from algae to fish.

Secchi Disk

A 20 cm Secchi disk is flat, with black and white alternating quadrants that is used to measure the transparency of water. The disk is lowered into water by a rope until the pattern on the disk is no longer visible and the depth is recorded. The deeper the measurement, the clearer the water.

Sampling

Tributary

Water quality samples were collected between the spring of 2007 and the summer of 2008, during base flows and storm events. Samples were collected using the State of South Dakota standard operating procedures for field sampling. Water samples were then filtered (when necessary), preserved (when necessary), and packed in ice for delivery to the State Health Laboratory in Pierre, South Dakota. Stream, climatic, and weather conditions were also recorded at the time of sampling.

In-lake

Water quality samples were scheduled to be collected for one year, once per month, except in June, July, and August when sampling occurred twice per month. Samples were collected using the State of South Dakota standard operating procedures for field sampling. Water samples were then filtered (when necessary), preserved (when necessary), and packed in ice for delivery to the State Health Laboratory in Pierre, South Dakota. Lake, climatic, and weather conditions were also recorded at the time of sampling.

Biological Monitoring

Algae Sampling

During the project period, algae were sampled twice in 2007 (June and August) and four times in 2008 (February, April, May, and June). A surface water sample was collected at three different locations on the lake at the established monitoring sites. Equal portions of the three samples were combined into one overall sample, and then preserved with Lugol's iodine. Algae were sampled according to the SD DENR protocols (SD DENR 2005b) and shipped to the SD DENR for analysis.

Chlorophyll-*a* Sampling

Chlorophyll-*a* was sampled at each in-lake monitoring location on Lake Campbell during the 2007-2008 study period by the project and by citizen monitors (Table 10). At each location, a surface grab sample was collected in a light impenetrable brown bottle. The sample was placed on ice, and shipped to the SD DENR in Pierre, South Dakota for analysis. Chlorophyll-*a* was sampled according to the SD DENR protocols (SD DENR 2005b).

Table 10. Chlorophyll-*a* Collection Months

2007	2008
May	Feb
Jun*	Apr
Jul*	May
Aug*	Jun
Sep	
Oct	

* sampled 3x during the month

Aquatic Plant Sampling

Aquatic plants were surveyed in Lake Campbell between August 13th and 15th, 2007. The shoreline was divided into 30 transects (Figure 8). A buoy attached to a 100 m floating rope, marked in 10 m increments, was used to sample each transect. One end of the rope was staked to the shoreline, and the other end attached to a buoy and an anchor which was positioned perpendicular to the shoreline. Lake depth was annotated at the buoy and also at each 10 m increment that was sampled. Starting at the 10 m increment closest to the shoreline, a vegetation rake was cast from the boat in four directions and dragged in to the boat. After each cast, vegetation caught in the tines was recorded. This process was repeated at successive 10 m increments until no vegetation in any of the four directions was documented. Other data recorded included GPS coordinates, identifying transect features on map, date, time, bank stability, shoreline vegetation, riparian zone width, and Secchi depth.

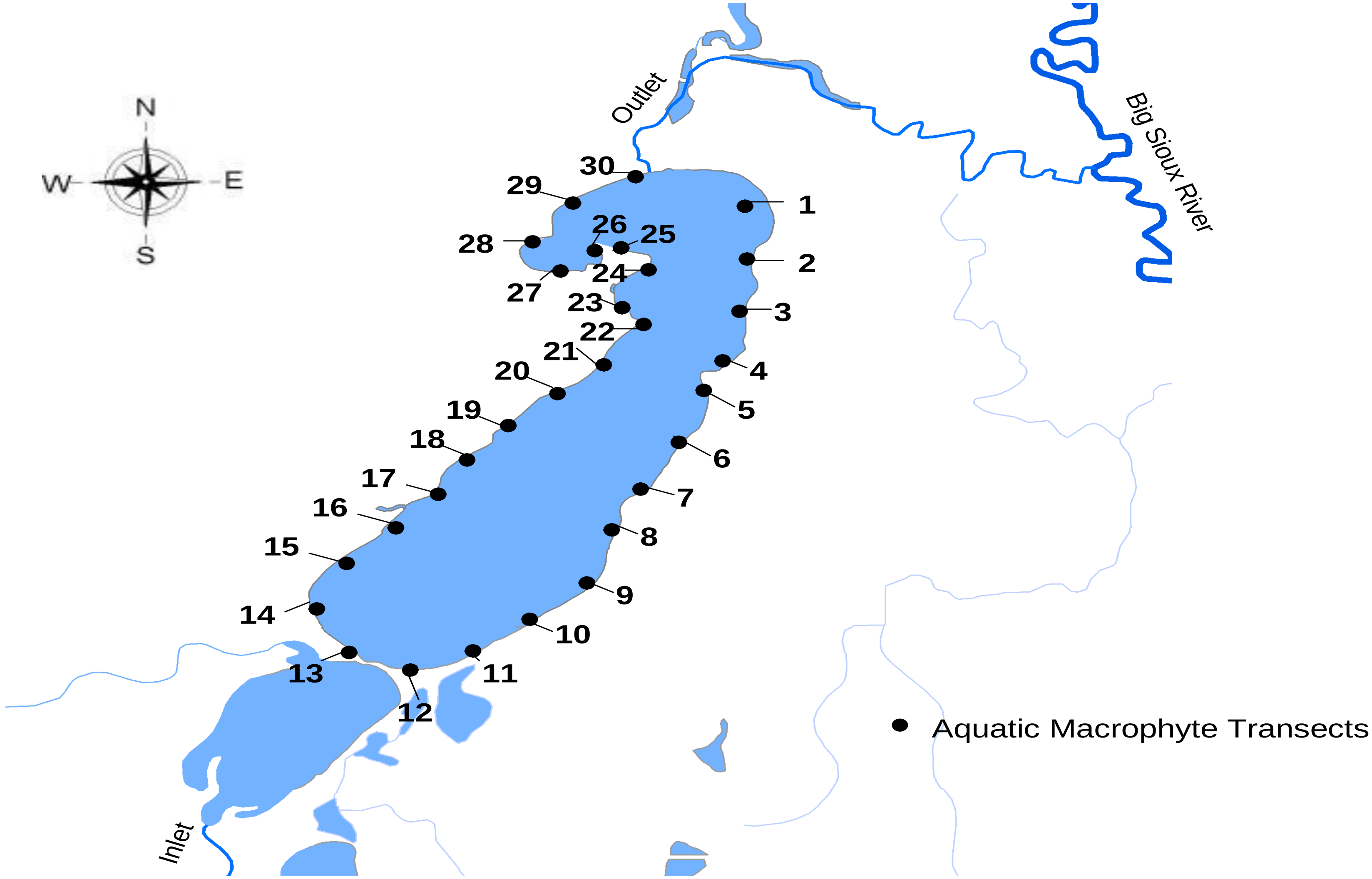


Figure 8. Diagram of the Lake Campbell Vegetation Sampling Transects

Hydrologic Monitoring

Tributary

Two tributary monitoring sites were selected, one at the inlet and one at the outlet of the lake. The inlet site was equipped with a Thalimedes OTT stage recorder that collected continuous stream flow records. The outlet was equipped with two Solinst level loggers, one recorded continuous atmospheric pressure while the other recorded continuous water pressure. Water stages were monitored and recorded to the nearest $1/100^{th}$ of a foot for each of the sites. A Marsh-McBirney 201D portable flow meter and a USGS top setting wading rod equipped with an electromagnetic sensor were used to determine flows at various stages. Each tributary site was also installed with USGS Style C staff gauge as a quality control check for the installed meters. Recorded stages and flows were used to create stage-discharge tables and curves for each site (Gordon et al. 1992). Stage-discharge tables, curves, and equations can be found in Appendix F.

In-lake

Hydrologic monitoring consisted of tracking lake levels using an existing benchmark established by the SD DENR, Water Rights Program. The benchmark used at Lake Campbell was an established ordinary high water mark (OHWM) benchmark (B6-6) located on the east side of the outlet structure, west of the boat ramp on the north side of the lake. Three other benchmarks on the south side of the lake were also used for measuring lake levels (MP_3, MP_2, and a location off the north side of the bridge).

Hydrologic Budgets

The hydrologic budget estimates how much water entered and left the lake during the study period. All inputs of water must equal all outputs of water in a hydrologic cycle. However, monitoring all possible inputs of water to a lake is very difficult. Thus, rough estimates of water loads to the lake were necessary to balance the equation.

Hydrologic inputs to Lake Campbell came from various sources including precipitation, tributary inflow, and groundwater. Tributary inflow was calculated using the FLUX model. Rainfall data was collected from the Brookings 2NE Co-op weather station near Brookings, South Dakota, and was used to calculate precipitation inputs. The following equations were used to calculate the inputs for the hydrologic budget:

Precipitation:

Amount of precipitation (feet) × Surface area of the lake = Precipitation input

Groundwater:

Outputs – Inputs = Groundwater input

Hydrologic outputs come from sources including evaporation, advective flow, out-flow, and change in storage. Advective flow was calculated by the BATHTUB model and tributary out-flow was calculated using the FLUX model. Evaporation data was measured from the nearest weather station with reliable data, located at the Brookings 2NE Co-op Station. The following equations were used to calculate the outputs for the hydrologic budget:

Evaporation:

Amount of evaporation (feet) × Surface area of the lake = Evaporation Volume

Change In Storage:

Benchmark reading (beginning of period) – Benchmark reading (end of period) = Change in storage

Change in storage × Surface area of the lake = Change in storage

TSI COMPUTATION

Carlson's (1977) Trophic State Index is a comparison index that uses total phosphorus, chlorophyll-*a*, and Secchi transparency to measure the relative eutrophic state of a waterbody. The concentrations and measurements of these parameters were adjusted to fit an index scale 0 to 100. In-lake data for three parameters was applied to Carlson's equations. The formulas used are below:

TSI (Total Phosphorus) = 10 (6- (LN (48/TP) / LN2)

TSI (Secchi Disk) = (6 – (LN SD / LN2))

TSI (Chlorophyll-*a*) = 10 × (6 – ((2.04 – (0.68 (LN (CHL))) / (LN (2)))

TP = Total phosphorus in μg/L
SD = Secchi depth in meters
CHL = Chlorophyll-*a* in mg/m^3

The mean TSI is usually calculated by averaging the TSI values for total phosphorus, Secchi depth, and chlorophyll-*a*. However, according to state requirements (SD DENR 2005c), the median TSI score of Secchi depth measurement in conjunction with the chlorophyll-*a* measurements are used to calculate the trophic state index of a lake.

QUALITY ASSURANCE AND DATA MANAGEMENT

Quality Assurance/Quality Control (QA/QC) samples are collected for at least 10% of the samples collected. A total of 94 water samples were collected from five monitoring sites. Seventeen QA/QC samples were taken; nine duplicate samples and eight blank samples.

The QA/QC results were entered into a computer database and screened for data errors. There was only one sample that showed a significant difference from the duplicate results for total dissolved phosphorus. The duplicate may have been grabbed from the wrong sample bottle as filtering of the sample was completed back at the office. It is suspected the sample water was taken from the wrong sample bottle before being filtered. Two of the blank samples detected ammonia and several of the blanks detected total phosphorus and total dissolved phosphorus. Total phosphorus and total dissolved phosphorus detects were likely due to the quality of rinsing water or the quality of the acid preserve. See Appendix G for field duplicates and blanks.

ASSESSMENT OF SOURCES

Point Sources

Wastewater Treatment Facilities (NPDES)

There are no NPDES facilities located within this watershed.

Non Point Sources

Urban Stormwater Runoff

Lake Campbell is located in a rural area about six miles southwest of the City of Brookings. Due to its rural location, it does not experience the effects of urban stormwater runoff.

Agricultural Runoff

Agricultural runoff was taken into account when the BATHTUB and AnnAGNPS models calculated land use scenarios for nutrient reductions, and when AnnAGNPS was used to perform ratings of the feedlots in the study area.

Background Wildlife Contribution

As part of the background contribution of fecal coliform bacteria, wildlife was considered. A general estimate of wildlife fecal coliform bacteria loading was derived from assessing total deer contributions. Deer are the largest of the wild animals potentially impacting the study area and factual information was readily available for this animal. Using the 2002 SD Game Report (Huxoll 2002), estimations of the number of deer per square mile were calculated for the watershed area in Lake, Brookings, Moody, and Kingsbury Counties. The following equations were used in the calculation.

The average number of deer per acre in each county was multiplied by the watershed acres within each of the counties:

$$\text{Sum of (deer/acre/county} \times \text{watershed acres in the county)} = \text{deer/watershed}$$

Then the number of deer per watershed was multiplied by the number of days monitored and then multiplied by the colony forming units (cfu) per deer per day to calculate total cfu's per watershed from deer.

$$\text{deer/watershed} \times \text{\# monitoring days} \times \text{cfu/deer/day} = \text{cfu's per watershed (from deer)}$$

Failing Septic Systems Contribution

During the 1990 to 1992 diagnostic/feasibility study of Lake Campbell, a sanitary survey was conducted of the lakeshore homes. This study identified several septic systems that were potentially affecting the water quality of the lake. In 1994 a Sanitary District was established, but a centralized wastewater collection and treatment facility has yet to be constructed. A similar septic survey was also conducted as part of this post-assessment.

As part of the background contribution of fecal coliform bacteria, rural households as well as shoreline homes should be considered for their contribution of the total fecal coliform bacteria in the watershed. To calculate a rough estimate of rural and shoreline household contribution of fecal coliform bacteria, information from the Census 2000 Housing Units (USCB 2000) was used to determine the number of occupied housing units in each of the townships located in the watershed.

According to the US EPA (2002) failure rates of onsite septic systems ranged from 10 to 20 percent, with the majority of these failures occurring with systems 30 or more years old. Therefore, 20 percent of the households in each township were used to figure septic contribution. Additionally, the number of occupied lakeshore homes was used to estimate the shoreline household contribution of fecal coliform bacteria. The average number of people per household (MPCA 2002) was multiplied by the number of households (20 percent) for each township and the lakeshore, giving a total number of people.

average number of people per household × # of households (20%) = total number of people

Then, the total number of people per township area or lake area was multiplied by the number of days monitored and then multiplied by the cfu/person/day to calculate total cfu's per monitored site.

total number of people per area × # monitoring days ×cfu/people/day = cfu's per area (from people)

Modeling

Modeling and assessment techniques are used to generate information about the health of a watershed. Modeling is a tool that can be used to evaluate the effectiveness of restoration efforts. It is also a tool that can indicate areas of the watershed still in need of restoration efforts. Three basic modeling and assessment techniques were used and are described below. Each technique generates an independent set of information (Table 11). This section will focus on the three models used to assess water quality in the study area.

Table 11. Modeling and Assessment Techniques and Outputs

Modeling Technique	Outputs
FLUX Model	WQ Parameter Loadings WQ Parameter Concentrations
BATHTUB Model	Trophic State Index (TSI) Values Reduction Response Model
AnnAGNPS	Phosphorus (attatched & soluble), Nitrogen (attached & soluble), Sediment Yield, & Feedlot Ratings

FLUX Model

Nutrient and sediment loads from the two tributary sites were calculated using the Army Corps of Engineers Eutrophication Model known as FLUX (Walker 1999). FLUX uses individual sample data in correlation with daily discharges to develop six loading calculations. Results for the outlet site (LC-T1) included the parameters of total suspended solids, total solids, dissolved solids, volatile total suspended solids, total Kjeldahl nitrogen, total phosphorus, total dissolved phosphorus, and fecal coliform bacteria. The inlet site (LC-T2) included all of these parameters plus nitrates/nitrites, ammonia, and *E. coli*. The FLUX model uses data obtained from 1) grab-sample water quality concentrations with an instantaneous flow and 2) continuous stage records. Loadings and concentrations were calculated by day, month, and year. Coefficients of variation (CV) were used to determine what method of calculation was appropriate for each parameter at each site.

BATHTUB Model

The BATHTUB model was used to predict in-lake responses to the tributary loadings. Input data for the model consists of general lake morphology, tributary loading data, and current in-lake water quality. Tributary loading data is calculated for the inlet to the lake using the average of water quality results.

The BATHTUB model is predictive in that it will assess impacts of changes in water and/or nutrient loadings. BATHTUB assumes if nutrient concentrations were reduced, the overall TSI values for total phosphorus, chlorophyll-*a*, and Secchi depth would be reduced, indicating improvement in water quality. Existing tributary nutrient concentrations were reduced by 10 percent successively (10 percent increments) and modeled to create an in-lake reduction curve.

AnnAGNPS Landuse Model

The AnnAGNPS model is intended to be used as a tool to evaluate non-point source pollution from agricultural watersheds ranging in size up to 740,000 acres. With this model the watershed is divided up into homogenous land areas or cells based on soil type, land use and land management. AnnAGNPS simulates the transport of surface water, sediment, nutrients, and pesticides through the watershed. The current condition of the watershed can be modeled and used to compare the effects of implementing various conservation alternatives over time within the watershed.

Watersheds dominated by agricultural land uses, pasturing cattle in stream drainages, runoff from manure application, and runoff from concentrated animal feeding operations can influence *E. coli* and fecal coliform bacteria concentrations. The AnnAGNPS feedlot assessment assumed the probable sources of fecal coliform bacteria loadings were related to agricultural land use (upland and riparian), use of streams for stock watering, and animal feeding operations. Feedlot ratings were generated by the model and were based on feedlot proximity to the receiving waters and the potential to pollute those waters. Ratings of 0 to 100 were assigned to each feedlot with higher numbers meaning a greater potential to pollute. ArcView GIS software was used to spatially analyze feedlots and their pollution potential.

RESULTS

WATER QUALITY MONITORING

The data was evaluated based on the specific criteria that the SD DENR developed for listing water bodies in the 1998 and 2002 South Dakota 303(d) Waterbody List, and in the 2004, 2006, and 2008 Integrated Report. The EPA-approved listing criteria used by the state of South Dakota during the assessment to determine if a waterbody is meeting its beneficial uses, is contained in the following paragraph. It should be noted that EPA guidance, in reference to TMDL targets, is based on the acute criteria of any one sample.

Use support was based on the frequency of exceedences of water quality standards (if applicable) for the following chemical and field parameters. A stream or lake with only a slight exceedence (10% or less violations for each parameter) is considered to meet water quality criteria for that parameter. The EPA established the following general criteria in the 1992 305(b) Report Guidelines (SD DENR 2000) suitable for determining use support of monitored surface waters.

Fully supporting	≤ 10 % of samples violate standards
Not supporting	> 10 % of samples violate standards

This general criteria is based on collecting 20 or more samples per monitoring location. Many of the monitoring sites were sampled less than 20 times. For those monitoring sites with less than 20 samples, the following criteria will apply:

Fully supporting	≤ 25 % samples violate standards
Not supporting	> 25 % of samples violate standards

Beneficial uses assigned to the three in-lake sites (Sites LC-1, LC-2, and LC-3) are (6), (7), (8), and (9). Beneficial uses assigned to the outlet include (9) and (10). Beneficial uses assigned to the inlet include (6), (8), (9), and (10).

(6) Warmwater Marginal Fish Life Propagation
(7) Immersion Recreation
(8) Limited Contact Recreation
(9) Fish, Wildlife Propagation, Recreation and Stock Watering
(10) Irrigation

Use support assessment for fishable use (fish life propagation) primarily involved monitoring levels of the following major parameters: dissolved oxygen, total ammonia nitrogen as N, water temperature, pH, and total suspended solids. Use support for swimmable uses and limited contact recreation involved monitoring the levels of fecal coliform bacteria (May 1 – September 30) and dissolved oxygen. If more than one beneficial use is assigned for the same parameter (i.e. fecal coliform bacteria) at a particular monitoring site, the more stringent criteria apply. The results for the following parameters are summarized below for the assessed tributaries (LC-T1 and LC-T2) and for Lake Campbell (LC-1, LC-2, and LC-3).

Tributary Seasonal Trends

Water quality parameters vary depending upon season due to changes in temperature, precipitation, and agricultural practices. Table 12 shows the average seasonal concentration of water quality parameters at Site LC-T1, an outlet of Lake Campbell which drains to the Big Sioux River. Table 13 shows the average seasonal contribution of water quality parameters at Site LC-T2 which is an inlet into Lake Campbell.

Table 12. Average Seasonal Concentrations (Lake Campbell outlet)

Lake Campbell Outlet - LC-T1 (mg/L)			
Parameter	**Spring (Mar-May)**	**Summer (Jun-Aug)**	**Fall (Sep-Nov)**
Diss. Oxygen	13.47	9.64	12.34
TSS	29	56	126
TotSol	1142	1374	1477
TDS	1137	1304	1319
Nitrates	0.01	0	0
Ammonia	0.09	0	0.02
TKN	1.56	2.76	2.23
TPO4	0.368	0.25	0.384
TDPO4	0.076	0.065	0.035
VTSS	12	29	42

Table 13. Average Seasonal Concentrations (Lake Campbell Inlet)

Battle Creek Inlet - LC-T2 (mg/L)			
Parameter	**Spring (Mar-May)**	**Summer (Jun-Aug)**	**Fall (Sep-Nov)**
Diss. Oxygen	11.47	8.87	10.79
TSS	32	35	30
TotSol	1157	1287	1285
TDS	1290	1174	1201
Nitrates	0.57	0.65	0.68
Ammonia	0.1	0.03	0.03
TKN	1.37	1.55	1.13
TPO4	0.268	0.245	0.204
TDPO4	0.14	0.114	0.135
VTSS	6	11	10

The tributaries exhibited the highest dissolved oxygen concentrations (averaged) in the spring. The cooler water temperatures and higher flows contributed to the higher dissolved oxygen concentrations. Throughout the sampling period, average dissolved oxygen levels for the tributaries did not fall below 8.87 mg/L.

Higher total and dissolved solids were observed during the spring at Site LC-T2 and in the fall at Site LC-T1. The higher concentrations can be attributed to rainfall events which cause erosion of soils and runoff from agricultural lands and harvested crops.

Higher average nitrate concentrations occurred at the inlet (Site LC-T2) throughout all the seasons. The highest average concentration of nitrates was 0.68 mg/L. Little to no nitrates were detected at the outlet.

The highest average concentrations of total Kjeldahl nitrogen (TKN) occurred at the outlet throughout all the seasons. The highest average concentration of TKN was 2.76 mg/L during the summer months.
Total phosphorus average concentrations were highest at the outlet (Site LC-T1) throughout all the seasons. However, average total dissolved phosphorus was higher at Site LC-T2 throughout all the seasons. Average total phosphorus entering Lake Campbell was highest in the spring with concentrations of 0.268 mg/L. Phosphorus contributions can increase the amount of algae growing in a lake, which in-turn causes reduced water clarity. Average total phosphorus leaving Lake Campbell was highest in the fall with concentrations of 0.384 mg/L.

Tributary Water Quality Results

Chemical Parameters

Fecal Coliform Bacteria

Fecal coliform bacteria ranged from no detection both at the Lake Campbell outlet (LC-T1) and the Battle Creek inlet (LC-T2), to a maximum of 2,600 cfu/100mL at the Battle Creek inlet. A single grab sample daily maximum of ≤ 2,000 cfu/100mL was used to determine the percent violations and assess for the beneficial use support of (8) Limited-Contact Recreation for Battle Creek. Using this criterion, Battle Creek is fully supporting of this parameter. There is no fecal coliform bacteria standard for the Lake Campbell outlet (Table 14).

Table 14. Tributary Sites Fecal Coliform Bacteria Results

Fecal Coliform Bacteria (counts/100mL)									
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
LC-T1	Lake Campbell Outlet	11	70.0	nd	580.0	10.0	------	------	------
LC-T2	Battle Creek (Inlet)	18	150.0	nd	2600.0	150.0	1	5%	Full

---- denotes no standard or beneficial use assigned

Note: For LC-T2, the standard is ≤ 2,000 cfu/100mL for beneficial use (8)

E. coli Bacteria

E. coli ranged from no detection both at the Lake Campbell outlet (LC-T1) and the Battle Creek inlet (LC-T2), to > 2,420 cfu/100mL at the Battle Creek inlet. The are no *E. coli* standards assigned to these tributary sites (Table 15).

Table 15. Tributary Sites *E. coli* Results

E. Coli (counts/100mL)									
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
LC-T1	Lake Campbell Outlet	11	129.4	nd	775.0	10.4	------	------	------
LC-T2	Battle Creek (Inlet)	18	518.6	nd	>2420	196.5	------	------	------

---- denotes no standard or beneficial use assigned

Total Solids

Total solids ranged from a minimum of 759 mg/L at the Battle Creek inlet (LC-T2), to a maximum of 1,914 mg/L also at the Battle Creek inlet. There are no total solids standards assigned to these tributary sites (Table 16).

Table 16. Tributary Sites Total Solids Results

Total Solids (mg/L)									
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
LC-T1	Lake Campbell Outlet	7	1223	789	1477	1271	------	------	------
LC-T2	Battle Creek (Inlet)	14	1240	759	1914	1194	------	------	------

---- denotes no standard or beneficial use assigned

Total Suspended Solids

Total suspended solids ranged from a minimum of 8 mg/L at the Lake Campbell outlet (LC-T1), to a maximum of 126 mg/L also at the Lake Campbell outlet. A single grab sample daily maximum of ≤ 263 cfu/100mL was used to determine the percent violations and assess for the beneficial use support of (6) Warmwater Marginal Fish Life Propagation. Using this criterion, Battle Creek is fully supporting of this parameter. There is no total suspended solids standard for the Lake Campbell outlet (Table 17).

Table 17. Tributary Sites Total Suspended Solids Results

Total Suspended Solids (mg/L)									
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
LC-T1	Lake Campbell Outlet	12	42	8	126	30	------	------	------
LC-T2	Battle Creek (Inlet)	19	32	12	62	31	0	0	Full

---- denotes no standard or beneficial use assigned

Note: For LC-T2, the standard is ≤ 263 mg/L for beneficial use (6)

Volatile Total Suspended Solids

Volatile total suspended solids ranged from no detection both at the Battle Creek inlet (LC-T2) and the Lake Campbell outlet (LC-T1), to a maximum of 42.0 at the Lake Campbell outlet (LC-T1). There are no volatile total suspended solids standards assigned to these tributaries (Table 18)

Table 18. Tributary Sites Volatile Total Suspended Solids

Volatile Total Suspended Solids (mg/L)									
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
LC-T1	Lake Campbell Outlet	12	17.4	nd	42.0	12.5	------	------	------
LC-T2	Battle Creek (Inlet)	19	8.3	nd	22.0	8.0	------	------	------

---- denotes no standard or beneficial use assigned

Total Dissolved Solids

Total dissolved solids ranged from a minimum of 684 mg/L at the Battle Creek inlet (LC-T2), to a maximum of 1,831 mg/L also at the Battle Creek inlet. A single grab sample daily maximum of ≤ 4,375 mg/L was used to determine the percent violations and assess for the beneficial use support of (9) Fish and Wildlife Propagation, Recreation, and Stock Watering for all tributary sites. Using this criterion, both tributary sites are fully supporting of this parameter (Table 19).

Table 19. Tributary Sites Total Dissolved Solids Results

Total Dissolved Solids (mg/L)									
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
LC-T1	Lake Campbell Outlet	12	1180	713	1399	1190	0	0	Full
LC-T2	Battle Creek (Inlet)	19	1235	684	1831	1129	0	0	Full

Note: The standard is ≤ 4,375 mg/L for beneficial use (9)

Total Ammonia Nitrogen as N

Total ammonia nitrogen as N ranged from no detection both at the Lake Campbell outlet (LC-T1) and the Battle Creek inlet (LC-T2) to a maximum of 0.85 mg/L at the Battle Creek inlet. The water quality standard for Battle Creek is less than or equal to the result of the equation: $(0.411 \div (1+10^{7.204\text{-pH}}) + (58.4 \div 1+10^{\text{pH-}7.204}))$ for beneficial use support of (6) Warmwater Marginal Fish Life Propagation. Using this criterion, the Battle Creek inlet is fully supporting of this parameter. There is no ammonia standard for the Lake Campbell outlet (Table 20).

Table 20. Tributary Sites Total Ammonia Nitrogen as N Results

Nitrogen, Total Ammonia as N (mg/L)									
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
LC-T1	Lake Campbell Outlet	12	0.07	nd	0.76	0.00	------	------	------
LC-T2	Battle Creek (Inlet)	20	0.06	nd	0.85	0.00	0	0	Full

---- denotes no standard or beneficial use assigned

NOTE: For LC-T2, the standard is ≤ result of equation: $(0.411 \div (1+10^{7.204\text{-pH}}) + (58.4 \div 1+10^{\text{pH-}7.204}))$ for beneficial use (6)

Nitrogen, Nitrates as N

Nitrogen, Nitrates as N ranged from no detection both at the Lake Campbell outlet (LC-T1) and the Battle Creek inlet (LC-T2) to a maximum of 3.40 mg/L at the Battle Creek inlet. A single grab sample daily maximum of ≤ 88 mg/L was used to determine the percent violations and assess for the beneficial use support of (9) Fish and Wildlife Propagation, Recreation, and Stock Watering for all tributary sites. Using this criterion, both sites are fully supporting of this parameter (Table 21).

Table 21. Tributary Sites Nitrogen, Nitrates as N Results

Nitrogen, Nitrates as N (mg/L)									
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
LC-T1	Lake Campbell Outlet	12	0.01	nd	0.10	0.00	0	0	Full
LC-T2	Battle Creek (Inlet)	20	0.62	nd	3.40	0.25	0	0	Full

Note: The standard is ≤ 88 mg/L for beneficial use (9)

Total Kjeldahl Nitrogen (TKN)

Total Kjeldahl nitrogen ranged from a minimum of 0.79 mg/L at the Battle Creek inlet (LC-T2), to a maximum of 2.90 mg/L at the Lake Campbell outlet (LC-T1). There are no total Kjeldahl nitrogen standards assigned to these tributary sites (Table 22).

Table 22. Tributary Sites Total Kjeldahl Nitrogen (TKN) Results

Total Kjeldahl Nitrogen (mg/L)									
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
LC-T1	Lake Campbell Outlet	12	1.82	1.04	2.90	1.77	------	------	------
LC-T2	Battle Creek (Inlet)	20	1.36	0.79	2.63	1.34	------	------	------

---- denotes no standard or beneficial use assigned

Total Phosphorus

Total phosphorus ranged from a minimum of 0.120 mg/L at the Lake Campbell outlet (LC-T1), to a maximum of 1.990 mg/L also at the Lake Campbell outlet. There are no total phosphorus standards assigned to these tributary sites (Table 23).

Table 23. Tributary Sites Total Phosphorus Results

Total Phosphorus (mg/L)									
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
LC-T1	Lake Campbell Outlet	12	0.349	0.120	1.990	0.182	------	------	------
LC-T2	Battle Creek (Inlet)	20	0.245	0.121	0.507	0.232	------	------	------

---- denotes no standard or beneficial use assigned

Total Dissolved Phosphorus

Total dissolved phosphorus ranged from a minimum of 0.022 mg/L at the Lake Campbell outlet (LC-T1), to a maximum of 0.300 mg/L also at the Lake Campbell outlet. There are no total dissolved phosphorus standards assigned to these tributary sites (Table 24).

Table 24. Tributary Sites Total Dissolved Phosphorus Results

Total Dissolved Phosphorus (mg/L)									
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
LC-T1	Lake Campbell Outlet	12	0.071	0.022	0.300	0.000	------	------	------
LC-T2	Battle Creek (Inlet)	19	0.131	0.041	0.264	0.112	------	------	------

---- denotes no standard or beneficial use assigned

Alkalinity-M

Alkalinity-M ranged from a minimum of 146 mg/L at the Battle Creek inlet (LC-T2), to a maximum of 291 mg/L also at the Battle Creek inlet. A single grab sample daily maximum of ≤ 1,313 mg/L was used to determine the percent violations and assess for the beneficial use support of (9) Fish and Wildlife Propagation, Recreation and Stock Watering for all tributary sites. Using this criterion, both sites are fully supporting of this parameter (Table 25).

Table 25. Tributary Sites Alkalinity-M Results

Alkalinity-M (mg/L)									
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
LC-T1	Lake Campbell Outlet	12	189	153	231	180	0	0	Full
LC-T2	Battle Creek (Inlet)	19	229	146	291	234	0	0	Full

Note: The standard is ≤ 1,313 mg/L for beneficial use (9)

Alkalinity-P

Alkalinity-P ranged from no detection at the Lake Campbell outlet (LC-T1) and the Battle Creek inlet (LC-T2), to a maximum of 18 at Lake Campbell outlet. There are no Alkalinity-P standards assigned to these tributary sites (Table 26)

Table 26. Tributary Sites Alkalinity-P

Alkalinity-P (mg/L)									
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
LC-T1	Lake Campbell Outlet	12	6	nd	18	5	------	------	------
LC-T2	Battle Creek (Inlet)	19	1	nd	8	0	------	------	------

---- denotes no standard or beneficial use assigned

Field Parameters

Dissolved Oxygen

Dissolved oxygen ranged from a minimum of 5.74 mg/L at the Battle Creek inlet (LC-T2), to a maximum of 16.66 mg/L at the Lake Campbell outlet (LC-T1). A single grab sample daily maximum of the most restrictive standard, ≥ 5.0 mg/L, was used to determine the percent violations and assess for the beneficial use support of (8) Limited Contact Recreation and (6) Warmwater Marginal Fish Life Propagation. Using this criterion, the Battle Creek inlet is fully supporting of this parameter (Table 27). There is no dissolved oxygen standard for the Lake Campbell outlet.

Table 27. Tributary Sites Dissolved Oxygen Results

Dissolved Oxygen (mg/L)									
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
LC-T1	Lake Campbell Outlet	12	12.74	8.38	16.66	11.70	------	------	------
LC-T2	Battle Creek (Inlet)	20	10.52	5.74	15.36	10.57	0	0	Full

---- denotes no standard or beneficial use assigned

Note: For LC-T2, the more restrictive standard of ≥ 5.0 mg/L is applied for beneficial uses of (6) and (8)

pH

pH ranged from a minimum of 7.76 units at the Battle Creek inlet (LC-T2), to a maximum of 8.99 units at the Lake Campbell outlet (LC-T1). For the Battle Creek inlet, a single grab sample daily maximum of the most restrictive standard, ≥ 6.0 to ≤ 9.0 units, was used to determine the percent violations and assess for the beneficial use support of (6) Warmwater Marginal Fish Life Propagation and (9) Fish and Wildlife Propagation, Recreation and Stock Watering. For the Lake Campbell outlet, a single grab sample daily maximum of the most restrictive standard, ≥ 6.0 to ≤ 9.5 units, was used to determine the percent violations and assess for the beneficial use support of (9). Using these criteria, both tributary sites are fully supporting of this parameter (Table 28).

Table 28. Tributary Sites pH Results

		pH (units)							
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
LC-T1	Lake Campbell Outlet	12	8.65	8.08	8.99	8.71	0	0	Full
LC-T2	Battle Creek (Inlet)	19	8.24	7.76	8.69	8.23	0	0	Full

NOTE: For LC-T2, the more restrictive standard of ≥ 6.0 to ≤ 9.0 units is applied for beneficial uses of (6) and (9)
For LC-T1, the standard is ≥ 6.0 to ≤ 9.5 units for beneficial use (9)

Air Temperature

Air temperature ranged from a minimum of 2.7º C at the Battle Creek inlet (LC-T2), to a maximum of 35.0º C both at the Battle Creek inlet and the Lake Campbell outlet (LC-T1). There are no air temperature standards assigned to these tributary sites (Table 29).

Table 29. Tributary Sites Air Temperature Results

		Air Temperature (C˚)							
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
LC-T1	Lake Campbell Outlet	11	20.8	3.9	35.0	23.8	------	------	------
LC-T2	Battle Creek (Inlet)	19	22.9	2.7	35.0	25.3	------	------	------

---- denotes no standard or beneficial use assigned

Water Temperature

Water temperature ranged from a minimum of 1.9º C at the Battle Creek inlet (LC-T2), to a maximum of 29.1º C at the Lake Campbell outlet (LC-T1). A single grab sample daily maximum of ≤ 32.2º C was used to determine the percent violations and assess for the beneficial use support of (6) Warmwater Marginal Fish Life Propagation. Using this criterion, Battle Creek is fully supporting of this parameter (Table 30). There is no water temperature standard assigned to the Lake Campbell outlet.

Table 30. Tributary Sites Water Temperature Results

		Water Temperature (C˚)							
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
LC-T1	Lake Campbell Outlet	12	15.9	9.8	23.8	16.6	------	------	------
LC-T2	Battle Creek (Inlet)	20	16.4	1.9	29.1	16.6	0	0	Full

---- denotes no standard or beneficial use assigned
Note: For LC-T2, the standard is ≤ 32.2˚ C for beneficial use (6)

Conductivity

Conductivity ranged from a minimum of 619 µS/cm at the Battle Creek inlet (LC-T2), to a maximum of 1,748 µS/cm also at the Battle Creek inlet. There are no conductivity standards assigned to these tributary sites (Table 31).

Table 31. Tributary Sites Conductivity Results

Conductivity (µS/cm)									
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
LC-T1	Lake Campbell Outlet	7	1201	822	1440	1238	------	------	------
LC-T2	Battle Creek (Inlet)	15	1266	619	1748	1305	------	------	------

---- denotes no standard or beneficial use assigned

Specific Conductivity

Specific conductivity ranged from a minimum of 955 µS/cm at the Battle Creek inlet (LC-T2), to a maximum of 2,874 µS/cm also at the Battle Creek inlet. A single grab sample daily maximum of the most restrictive standard, ≤ 4,375 µS/cm, was used to determine the percent violations and assess for the beneficial use support of (9) Fish and Wildlife Propagation, Recreation and Stock Watering and (10) Irrigation. Using this criterion both tributary sites are fully supporting of this parameter (Table 32).

Table 32. Tributary Sites Specific Conductivity Results

Specific Conductivity (µS/cm)									
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
LC-T1	Lake Campbell Outlet	12	1571	1033	2263	1474	0	0	Full
LC-T2	Battle Creek (Inlet)	19	1635	955	2874	1405	0	0	Full

NOTE: The more restrictive standard of ≤ 4,375 umhos/cm is applied for beneficial uses of (9) and (10)

Salinity

Salinity ranged from a minimum of 0.5 ppt both at the Lake Campbell outlet (LC-T1) and the Battle Creek inlet (LC-T2), to a maximum of 1.5 ppt at the Battle Creek inlet. There are no salinity standards assigned to these tributary sites (Table 33).

Table 33. Tributary Sites Salinity Results

Salinity (ppt)									
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
LC-T1	Lake Campbell Outlet	12	0.79	0.50	1.16	0.74	------	------	------
LC-T2	Battle Creek (Inlet)	20	0.84	0.50	1.50	0.75	------	------	------

---- denotes no standard or beneficial use assigned

Turbidity – NTU

Turbidity ranged from a minimum of 3.6 NTU at the Battle Creek inlet (LC-T2), to a maximum of 90.0 NTU at the Lake Campbell outlet (LC-T1). There are no turbidity standards assigned to these tributary sites (Table 34).

Table 34. Tributary Sites Turbidity (NTU) Results

Turbidity (NTU)									
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
LC-T1	Lake Campbell Outlet	11	30.7	5.5	90.0	21.0	------	------	------
LC-T2	Battle Creek (Inlet)	19	16.5	3.6	40.0	16.0	------	------	------

---- denotes no standard or beneficial use assigned

In-Lake Seasonal Trends

Lake Campbell

Typically, water quality parameters will vary with season due to changes in temperature, precipitation, and agricultural practices. Table 35 shows the average seasonal concentrations (Spring, Summer, and Fall) for several of the water quality parameters sampled at Lake Campbell.

Average concentrations for total suspended solids, total solids, total dissolved solids, total Kjeldahl nitrogen, total phosphorus, and volatile total suspended solids show an increase from the spring season to the fall season. The majority of the highest average concentrations occurred during the summer months. Average total phosphorus concentrations were highest in during the summer months. Phosphorus levels can contribute to algae density and in some cases algal blooms. Phosphorus is present in all aquatic systems. Phosphorus-bearing rocks and organic matter decomposition are natural sources. Other potential sources include manmade fertilizers, domestic sewage, and agricultural sources (SD DENR 2000). Total solids and total dissolved solids were also higher in the summer and fall, causing increases in turbidity.

Table 35. Average Seasonal Concentrations from Lake Campbell

Lake Campbell (mg/L)			
Parameter	Spring (Mar-May)	Summer (Jun-Aug)	Fall (Sep-Nov)
Diss. Oxygen	12.65	8.41	8.47
TSS	18	47	38
TotSol	1137	1428	1429
TDS	1211	1310	1310
Nitrates	0.13	0.18	0
Ammonia	0.07	0	0
TKN	1.69	3.16	2.94
TPO4	0.17	0.386	0.225
TDPO4	0.051	0.153	0.037
VTSS	11	34	27

In-Lake Water Quality Results

Chemical Parameters

Fecal Coliform Bacteria

Fecal coliform bacteria ranged from no detection at all three Lake Campbell monitoring sites (LC-1, LC-2, LC-3), to a maximum of 120 cfu/100mL at the Lake Campbell South Site (LC-3). A single grab sample daily maximum of the most restrictive standard, ≤ 400 cfu/100mL, was used to determine the percent violations and assess for the beneficial use support of (7) Immersion Recreation and (8) Limited-Contact Recreation for Lake Campbell. Using this criterion, Lake Campbell is fully supporting of this parameter (Table 36).

Table 36. Lake Campbell Fecal Coliform Bacteria Results

		Fecal Coliform Bacteria (counts/100mL)							
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
LC-1	Lake Campbell (north site)	13	6	nd	40	0	0	0	Full
LC-2	Lake Campbell (central site)	13	7	nd	80	0	0	0	Full
LC-3	Lake Campbell (south site)	13	15	nd	120	0	0	0	Full

NOTE: The more restrictive standard of ≤ 400 cfu/100mL is applied for beneficial uses of (7) and (8)

E. coli

E. coli ranged from no detection at all three Lake Campbell monitoring sites (LC-1, LC-2, LC-3), to 260 cfu/100mL at the Lake Campbell South Site. The are no *E. coli* standards assigned to these in-lake sites (Table 37).

Table 37. Lake Campbell *E. coli* Results

		E. coli (cfu/100mL)							
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
LC-1	Lake Campbell (north site)	13	6.3	nd	35.0	3.0	------	------	------
LC-2	Lake Campbell (central site)	13	11.8	nd	74.9	1.0	------	------	------
LC-3	Lake Campbell (south site)	13	33.7	nd	260.0	10.8	------	------	------

---- denotes no standard or beneficial use assigned

Total Solids

Total solids ranged from a minimum of 1,071 mg/L at the Lake Campbell South Site (LC-3), to a maximum of 2,045 mg/L at the Lake Campbell North Site (LC-1). There are no total solids standards assigned to these in-lake sites (Table 38).

Table 38. Lake Campbell Total Solids Results

		Total Solids (mg/L)							
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
LC-1	Lake Campbell (north site)	11	1505	1244	2045	1450	------	------	------
LC-2	Lake Campbell (central site)	11	1477	1096	2024	1438	------	------	------
LC-3	Lake Campbell (south site)	11	1473	1071	2005	1448	------	------	------

---- denotes no standard or beneficial use assigned

Total Suspended Solids

Total suspended solids ranged from 3 mg/L at the Lake Campbell North Site (LC-1), to a maximum of 82 mg/L also at the Lake Campbell North Site. A single grab sample daily maximum of ≤ 263 cfu/100mL was used to determine the percent violations and assess for the beneficial use support of (6) Warmwater Marginal Fish Life Propagation. Using this criterion, Lake Campbell is fully supporting of this parameter (Table 39).

Table 39. Lake Campbell Total Suspended Solids Results

Total Suspended Solids (mg/L)									
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
LC-1	Lake Campbell (north site)	14	40	3	82	45	0	0	Full
LC-2	Lake Campbell (central site)	14	33	8	58	37	0	0	Full
LC-3	Lake Campbell (south site)	14	34	7	50	36	0	0	Full

Note: The standard is ≤ 263 mg/L for beneficial use (6)

Volatile Total Suspended Solids (mg/L)

Volatile total suspended solids ranged from no detection at the Lake Campbell North Site (LC-1), to a maximum of 44.0 at the Lake Campbell South Site (LC-3). There are no volatile total suspended solids standards assigned to these in-lake sites (Table 40).

Table 40. Lake Campbell Volatile Total Suspended Solids

Volatile Total Suspended Solids (mg/L)									
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
LC-1	Lake Campbell (north site)	14	22.6	nd	38.0	27.0	------	------	------
LC-2	Lake Campbell (central site)	14	25.0	4.0	42.0	26.5	------	------	------
LC-3	Lake Campbell (south site)	14	23.8	5.0	44.0	24.5	------	------	------

---- denotes no standard or beneficial use assigned

Total Dissolved Solids

Total dissolved solids ranged from a minimum of 982 mg/L at the Lake Campbell South Site (LC-3), to a maximum of 1,945 mg/L at the Lake Campbell North Site (LC-3). A single grab sample daily maximum of ≤ 4,375 mg/L was used to determine the percent violations and assess for the beneficial use support of (9) Fish and Wildlife, Propagation, Recreation and Stock Watering for all in-lake sites. Using this criterion, Lake Campbell is fully supporting of this parameter (Table 41).

Table 41. Lake Campbell Total Dissolved Solids Results

Total Dissolved Solids (mg/L)									
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
LC-1	Lake Campbell (north site)	14	1366	1146	1945	1323	0	0	Full
LC-2	Lake Campbell (central site)	14	1358	996	1924	1324	0	0	Full
LC-3	Lake Campbell (south site)	14	1351	982	1914	1330	0	0	Full

Note: The standard is ≤ 4,375 mg/L for beneficial use (9)

Total Ammonia Nitrogen as N

Total ammonia nitrogen as N ranged from no detection at all three Lake Campbell monitoring sites (LC-1, LC-2, LC-3), to a maximum of 1.04 mg/L at the Lake Campbell North Site. A single grab sample daily maximum of less than or equal to the result of equation $(0.411 \div (1+10^{7.204-pH}) + (58.4 \div 1+10^{pH-7.204}))$ was used to determine the beneficial use support of (6) Warmwater Marginal Fish Life Propagation. Using this criterion, Lake Campbell is fully supporting of this parameter (Table 42).

Table 42. Lake Campbell Total Ammonia Nitrogen as N Results

Nitrogen, Total Ammonia as N (mg/L)									
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
LC-1	Lake Campbell (north site)	14	0.12	nd	1.04	0.00	0	0	Full
LC-2	Lake Campbell (central site)	14	0.14	nd	1.01	0.00	0	0	Full
LC-3	Lake Campbell (south site)	14	0.15	nd	0.82	0.00	0	0	Full

NOTE: The standard is ≤ result of equation: $(0.411 \div (1+10^{7.204-pH}) + (58.4 \div 1+10^{pH-7.204}))$ for beneficial use (6)

Nitrogen, Nitrates as N

Nitrogen, nitrates as N ranged from no detection at all three Lake Campbell monitoring sites (LC-1, LC-2, LC-3), to a maximum of 1.60 mg/L at the Lake Campbell South Site. A single grab sample daily maximum of ≤ 88 mg/L was used to determine the percent violations and assess for the beneficial use support of (9) Fish and Wildlife Propagation, Recreation and Stock Watering for all in-lake sites. Using this criterion, Lake Campbell is fully supporting of this parameter (Table 43).

Table 43. Lake Campbell Nitrogen, Nitrates as N Results

Nitrogen, Nitrates as N (mg/L)									
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
LC-1	Lake Campbell (north site)	14	0.07	nd	0.80	0.00	0	0	Full
LC-2	Lake Campbell (central site)	14	0.10	nd	0.90	0.00	0	0	Full
LC-3	Lake Campbell (south site)	14	0.16	nd	1.60	0.00	0	0	Full

Note: The standard is ≤ 88 mg/L for beneficial use (9)

Total Kjeldahl Nitrogen (TKN)

Total Kjeldahl nitrogen ranged from no detection at the Lake Campbell South Site (LC-3), to a maximum of 4.140 mg/L at the Lake Campbell Central Site (LC-2). There are no total Kjeldahl nitrogen standards assigned to these lake sites (Table 44).

Table 44. Lake Campbell Total Kjeldahl Nitrogen (TKN) Results

Total Kjeldahl Nitrogen (mg/L)									
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
LC-1	Lake Campbell (north site)	14	2.680	1.350	3.750	2.780	------	------	------
LC-2	Lake Campbell (central site)	14	2.860	1.340	4.140	2.780	------	------	------
LC-3	Lake Campbell (south site)	14	2.700	nd	3.730	2.820	------	------	------

---- denotes no standard or beneficial use assigned

Total Phosphorus

Total phosphorus ranged from a minimum of 0.109 mg/L at the Lake Campbell Central Site (LC-2), to a maximum of 0.596 mg/L also at the Lake Campbell Central Site. There are no total phosphorus standards assigned to these in-lake sites (Table 45 and Figure 9).

Table 45. Lake Campbell Total Phosphorus Results

		Total Phosphorus (mg/L)							
Site	**Name**	**# of Samples**	**Mean**	**Min**	**Max**	**Median**	**Violations of WQ Standards**	**Percent Violating**	**Use Support**
LC-1	Lake Campbell (north site)	15	0.292	0.122	0.561	0.281	------	------	------
LC-2	Lake Campbell (central site)	20	0.307	0.109	0.596	0.279	------	------	------
LC-3	Lake Campbell (south site)	15	0.304	0.110	0.564	0.287	------	------	------

---- denotes no standard or beneficial use assigned

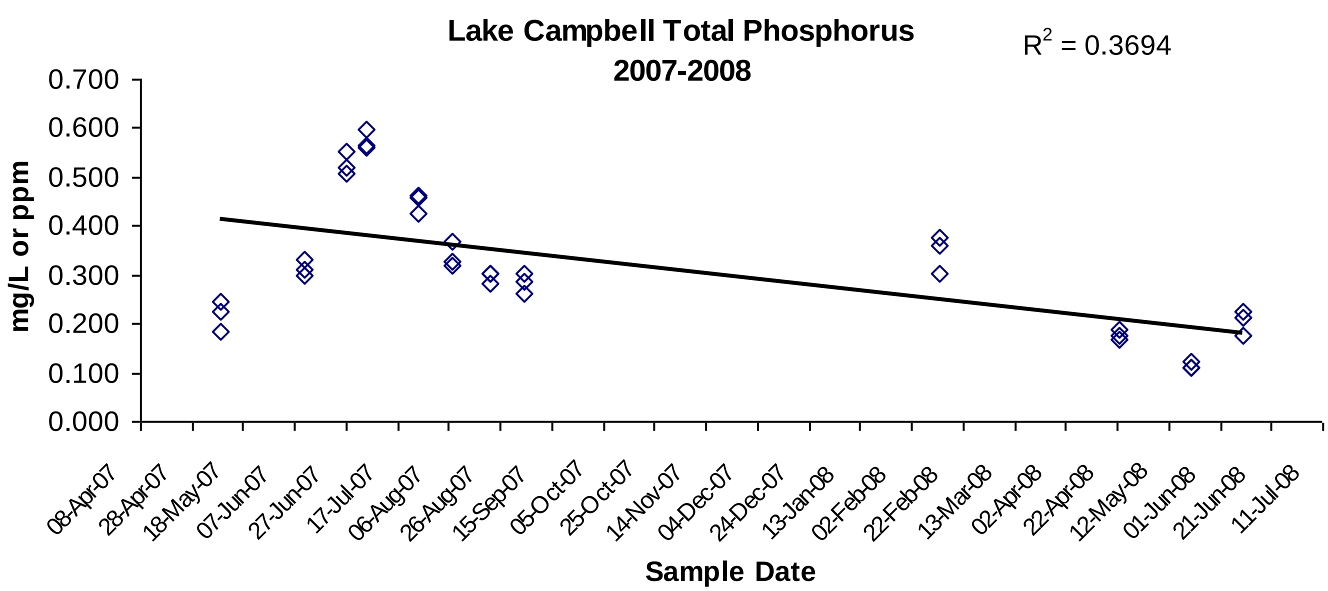


Figure 9. Plot of Total Phosphorus Samples

Total Dissolved Phosphorus

Total dissolved phosphorus ranged from a minimum of 0.018 mg/L at the Lake Campbell South Site (LC-3), to a maximum of 0.340 mg/L also at the Lake Campbell South Site. There are no total dissolved phosphorus standards assigned to these in-lake sites (Table 46).

Table 46. Lake Campbell Total Dissolved Phosphorus Results

Total Dissolved Phosphorus (mg/L)										
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
LC-1	Lake Campbell (north site)	15	0.110	0.022	0.302	0.070	------	------	------
LC-2	Lake Campbell (central site)	15	0.115	0.022	0.332	0.068	------	------	------
LC-3	Lake Campbell (south site)	15	0.118	0.018	0.340	0.096	------	------	------

---- denotes no standard or beneficial use assigned

Alkalinity-M

Alkalinity-M ranged from a minimum of 157 mg/L at the Lake Campbell North Site (LC-1), to a maximum of 268 mg/L also at the Lake Campbell North Site. A single grab sample daily maximum of ≤ 1,313 mg/L was used to determine the percent violations and assess for the beneficial use support of (9) Fish and Wildlife Propagation, Recreation and Stock Watering. Using this criterion, all in-lake sites are fully supporting of this parameter (Table 47).

Table 47. Lake Campbell Alkalinity-M Results

Alkalinity-M (mg/L)									
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
LC-1	Lake Campbell (north site)	14	202	157	268	188	0	0	Full
LC-2	Lake Campbell (central site)	14	199	158	266	184	0	0	Full
LC-3	Lake Campbell (south site)	14	199	158	262	185	0	0	Full

Note: The standard is ≤ 1,313 mg/L for beneficial use (9)

Alkalinity-P

Alkalinity-P ranged from a minimum of 0 mg/L at all three Lake Campbell monitoring sites (LC-1, LC-2, LC-3), to a maximum of 20 mg/L at the Lake Campbell South Site. There are no Alkalinity-P standards assigned to these in-lake sites (Table 48)

Table 48. Lake Campbell Alkalinity-P Results

Alkalinity-P (mg/L)									
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
LC-1	Lake Campbell (north site)	14	7	0	17	7	------	------	------
LC-2	Lake Campbell (central site)	14	7	0	19	4	------	------	------
LC-3	Lake Campbell (south site)	14	6	0	20	4	------	------	------

---- denotes no standard or beneficial use assigned

Field Parameters

Secchi Depth

Secchi depth ranged from a minimum of 0.1 m at all three Lake Campbell monitoring sites (LC-1, LC-2, LC-3), to a maximum of 1.3 m at the Lake Campbell North Site. There are no Secchi depth standards assigned to these in-lake sites (Table 49).

Table 49. Lake Campbell Secchi Depth Results

		Secchi Depth (m)							
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
LC-1	Lake Campbell (north site)	15	0.3	0.1	1.3	0.2	------	------	------
LC-2	Lake Campbell (central site)	20	0.3	0.1	0.7	0.2	------	------	------
LC-3	Lake Campbell (south site)	15	0.3	0.1	0.8	0.3	------	------	------

---- denotes no standard or beneficial use assigned

Dissolved Oxygen

Dissolved oxygen ranged from a minimum of 0.80 mg/L at the Lake Campbell South Site (LC-3), to a maximum of 19.60 mg/L at the Lake Campbell Central Site (LC-2). A single grab sample daily maximum of the most restrictive standard, ≥ 5.0 mg/L, was used to determine the percent violations and assess for the beneficial use support of (8) Limited Contact Recreation, (7) Immersion Recreation, and (6) Warmwater Marginal Fish Life Propagation. Using this criterion, Lake Campbell is fully supporting of this parameter (Table 50). Figures 10, 11, and 12 show the dissolved oxygen profiles at each of the in-lake sampling sites.

Table 50. Lake Campbell Dissolved Oxygen Results

		Dissolved Oxygen (mg/L)							
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
LC-1	Lake Campbell (north site)	15	8.45	1.80	15.00	7.25	1	7%	Full
LC-2	Lake Campbell (central site)	15	9.61	1.36	19.60	7.67	1	7%	Full
LC-3	Lake Campbell (south site)	15	8.49	0.80	15.80	8.45	1	7%	Full

Note: The more restrictive standard of ≥ 5.0 mg/L is applied for beneficial uses of (6), (7), and (8)

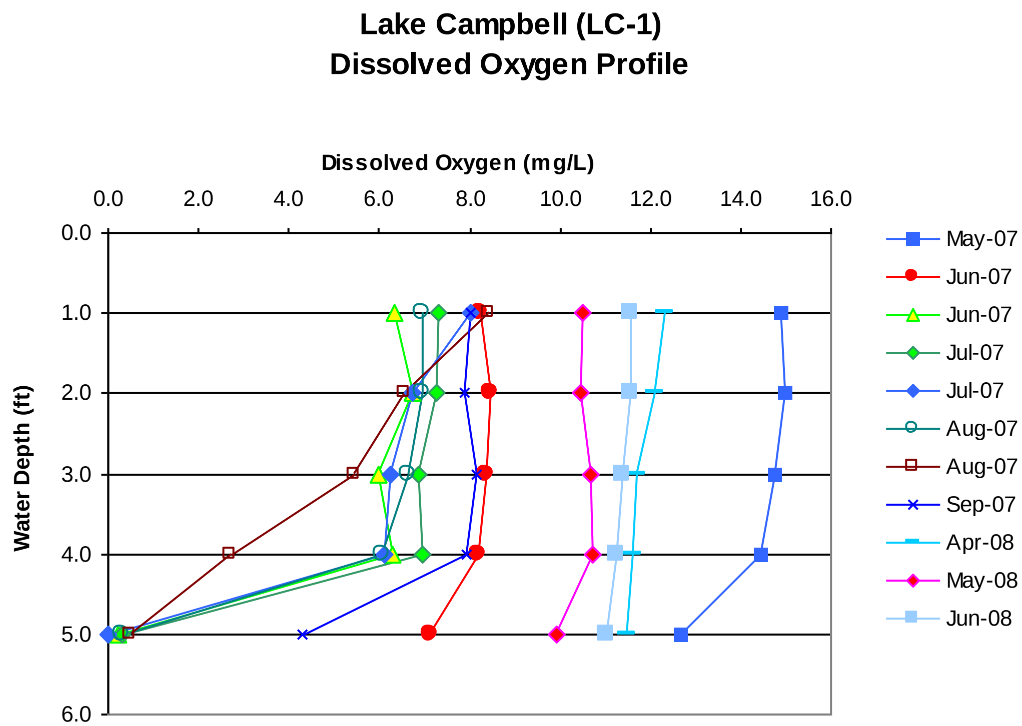


Figure 10. Dissolved Oxygen Profile at Site LC-1

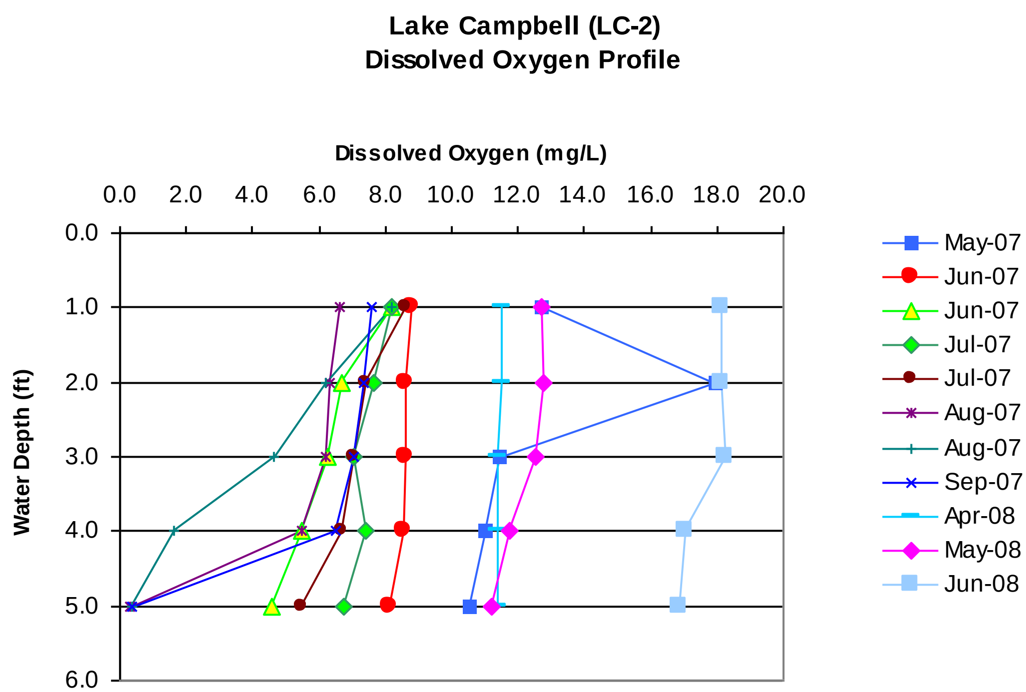


Figure 11. Dissolved Oxygen Profile at Site LC-2

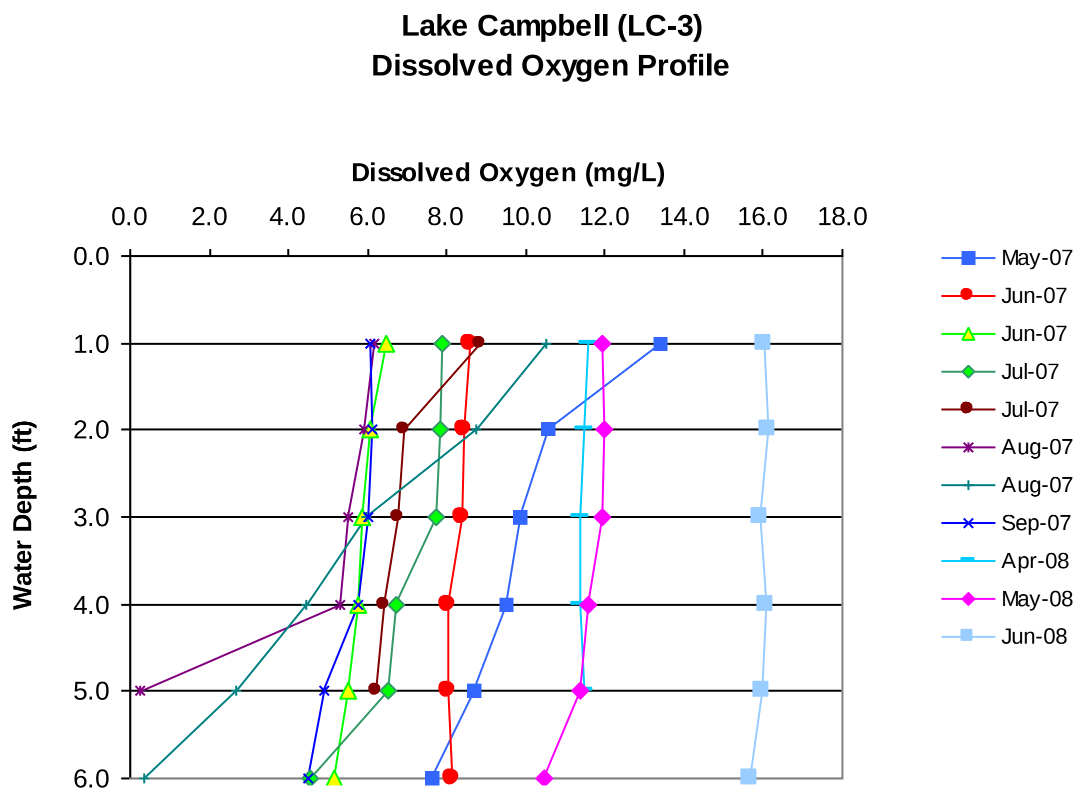


Figure 12. Dissolved Oxygen Profile at Site LC-3

pH

pH ranged from a minimum of 7.92 units at the Lake Campbell South Site (LC-3), to a maximum of 9.18 units also at the Lake Campbell South Site. A single grab sample daily maximum of the most restrictive standard, ≥ 6.0 to ≤ 9.0 units, was used to determine the percent violations and assess for the beneficial use support of
(6) Warmwater Marginal Fish Life Propagation and (9) Fish and Wildlife Propagation, Recreation and Stock Watering. Using this criterion, Lake Campbell is fully supporting of this parameter (Table 51).

Table 51. Lake Campbell pH Results

Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
		pH (units)							
LC-1	Lake Campbell (north site)	15	8.71	8.14	9.10	8.77	2	13%	Full
LC-2	Lake Campbell (central site)	15	8.73	8.39	9.06	8.74	1	7%	Full
LC-3	Lake Campbell (south site)	15	8.62	7.92	9.18	8.65	0	0	Full

NOTE: The more restrictive standard of ≥ 6.0 to ≤ 9.0 units is applied for beneficial uses of (6) and (9)

Air Temperature

Air temperature ranged from a minimum of -14.0º C at all three Lake Campbell monitoring sites (LC-1, LC-2, LC-3), to a maximum of 38.0º C at the Lake Campbell South Site. There are no air temperature standards assigned to these in-lake sites (Table 52).

Table 52. Lake Campbell Air Temperature Results

Air Temperature (C˚)									
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
LC-1	Lake Campbell (north site)	15	18.6	-14.0	37.0	23.0	------	------	------
LC-2	Lake Campbell (central site)	20	21.0	-14.0	37.0	23.5	------	------	------
LC-3	Lake Campbell (south site)	15	20.6	-14.0	38.0	24.0	------	------	------

---- denotes no standard or beneficial use assigned

Water Temperature

Water temperature ranged from a minimum of 0.0º C at the Lake Campbell Central Site (LC-2), to a maximum of 28.0º C also at the Lake Campbell Central Site. A single grab sample daily maximum of ≤ 32.2º C was used to determine the percent violations and assess for the beneficial use support of (6) Warmwater Marginal Fish Life Propagation. Using this criterion, Lake Campbell is fully supporting of this parameter (Table 53). Figures 13, 14, and 15 show the water temperature profiles at each of the in-lake sampling sites.

Table 53. Lake Campbell Water Temperature Results

Water Temperature (C˚)									
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
LC-1	Lake Campbell (north site)	15	17.0	0.4	26.9	20.5	0	0	Full
LC-2	Lake Campbell (central site)	20	18.2	0.0	28.0	21.7	0	0	Full
LC-3	Lake Campbell (south site)	15	17.3	0.1	27.2	21.4	0	0	Full

Note: The standard is ≤ 32.2˚ C for beneficial use (6)

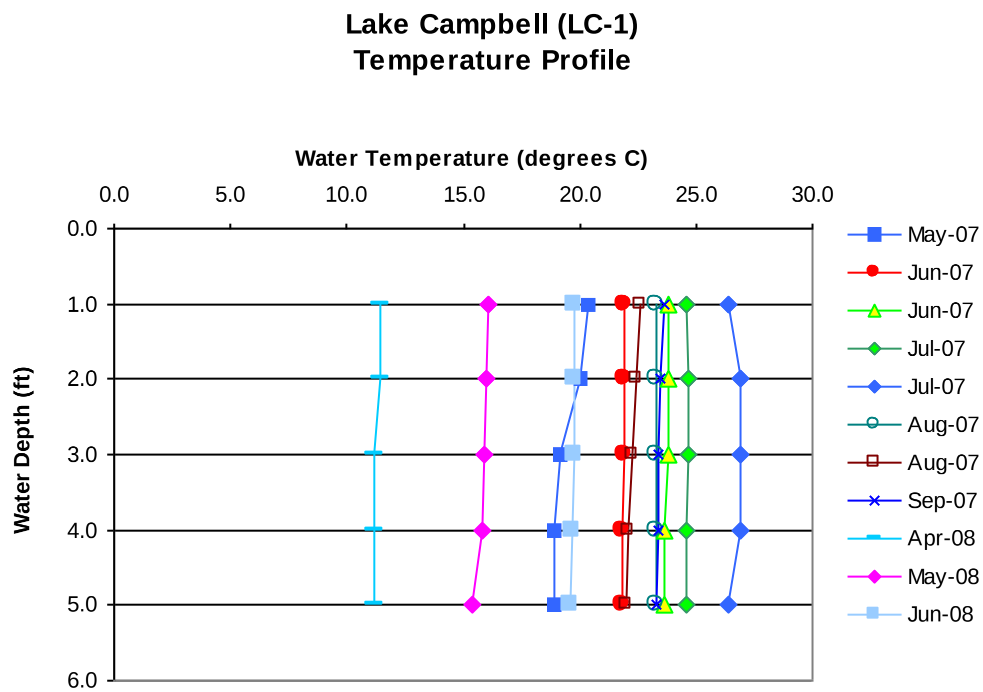


Figure 13. Water Temperature Profile at Site LC-1

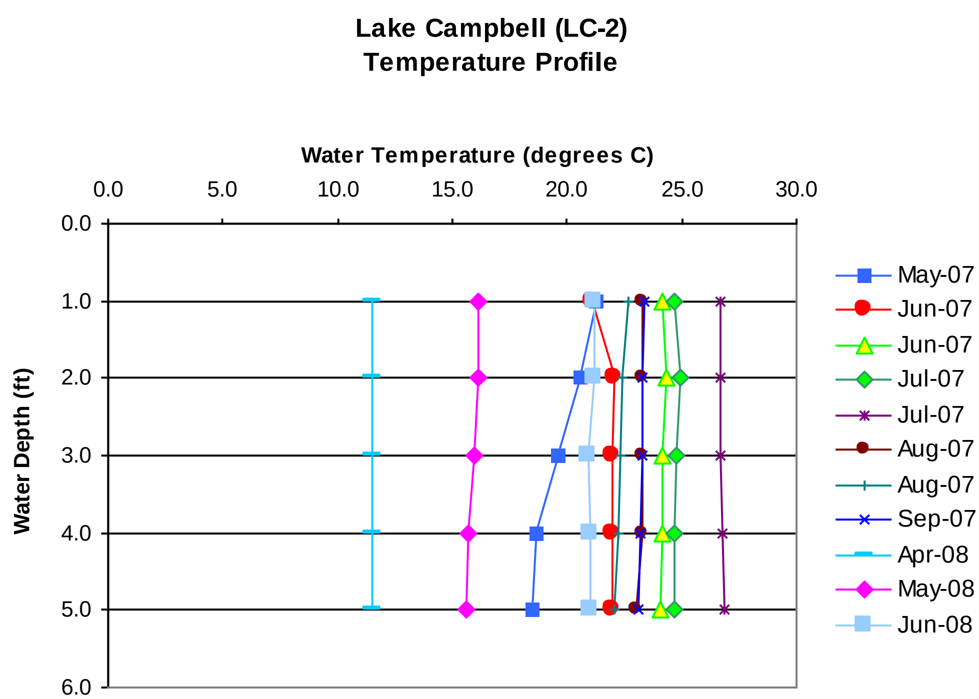


Figure 14. Water Temperature Profile at Site LC-2

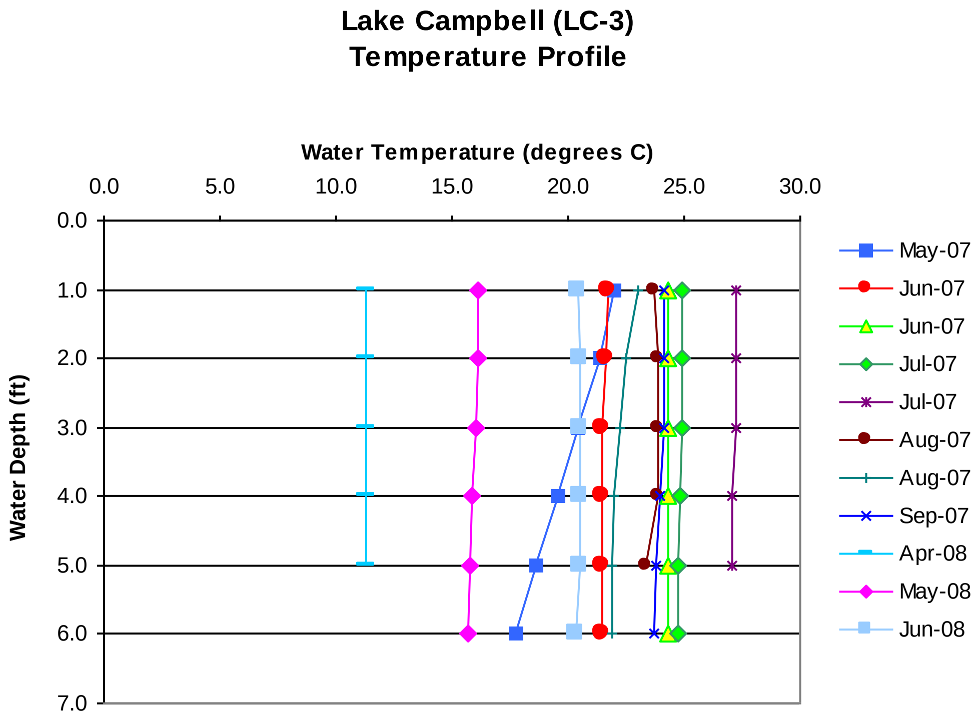


Figure 15. Water Temperature Profile at Site LC-3

Conductivity

Conductivity ranged from a minimum of 21 µS/cm at the Lake Campbell South Site (LC-3), to a maximum of 1,716 µS/cm also at the Lake Campbell South Site. There are no conductivity standards assigned to these in-lake sites (Table 54).

Table 54. Lake Campbell Conductivity Results

			Conductivity (µS/cm)						
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
LC-1	Lake Campbell (north site)	12	1390	938	1698	1437	------	------	------
LC-2	Lake Campbell (central site)	12	1377	932	1710	1446	------	------	------
LC-3	Lake Campbell (south site)	12	1291	21	1716	1445	------	------	------

---- denotes no standard or beneficial use assigned

Specific Conductivity

Specific conductivity ranged from a minimum of 1,254 µS/cm at the Lake Campbell South Site (LC-3), to a maximum of 2,265 µS/cm at the Lake Campbell Central Site (LC-2). A single grab sample daily maximum of ≤ 7,000 µS/cm was used to determine the percent violations and assess for the beneficial use support of (9) Fish and Wildlife Propagation, Recreation and Stock Watering. Using this criterion Lake Campbell is fully supporting of this parameter (Table 55).

Table 55. Lake Campbell Specific Conductivity Results

		Specific Conductivity (µS/cm)							
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
LC-1	Lake Campbell (north site)	13	1623	1465	2209	1584	0	0	Full
LC-2	Lake Campbell (central site)	14	1643	1289	2265	1603	0	0	Full
LC-3	Lake Campbell (south site)	14	1675	1254	2255	1601	0	0	Full

Note: The standard is ≤ 7,000 mg/L for beneficial use (9)

Salinity

Salinity ranged from a minimum of 0.00 ppt at the Lake Campbell South Site (LC-3), to a maximum of 1.2 ppt at all three Lake Campbell monitoring sites (LC-1, LC-2, LC-3). There are no salinity standards assigned to these in-lake sites (Table 56).

Table 56. Lake Campbell Salinity Results

		Salinity (ppt)							
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
LC-1	Lake Campbell (north site)	15	0.83	0.60	1.10	0.80	------	------	------
LC-2	Lake Campbell (central site)	15	0.83	0.60	1.20	0.80	------	------	------
LC-3	Lake Campbell (south site)	15	0.77	0.00	1.20	0.80	------	------	------

---- denotes no standard or beneficial use assigned

Turbidity – NTU

Turbidity ranged from a minimum of 3.1 NTU at the Lake Campbell North Site (LC-1), to a maximum of 60.0 NTU also at the Lake Campbell North Site. There are no turbidity standards assigned to these in-lake sites (Table 57).

Table 57. Lake Campbell Turbidity (NTU) Results

		Turbidity (NTU)							
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
LC-1	Lake Campbell (north site)	15	32.3	3.1	60.0	38.0	------	------	------
LC-2	Lake Campbell (central site)	15	30.9	4.0	50.0	37.0	------	------	------
LC-3	Lake Campbell (south site)	15	31.9	4.1	55.0	40.0	------	------	------

---- denotes no standard or beneficial use assigned

HYDROLOGIC MONITORING

The bathymetric map of Lake Campbell was created by SD Department of Game, Fish, and Parks (Figure 16). This map shows the water depths of the lake in 1995 and 1996. The average depth calculated by the South Dakota Game, Fish and Parks Department at that time was 3.1 feet.

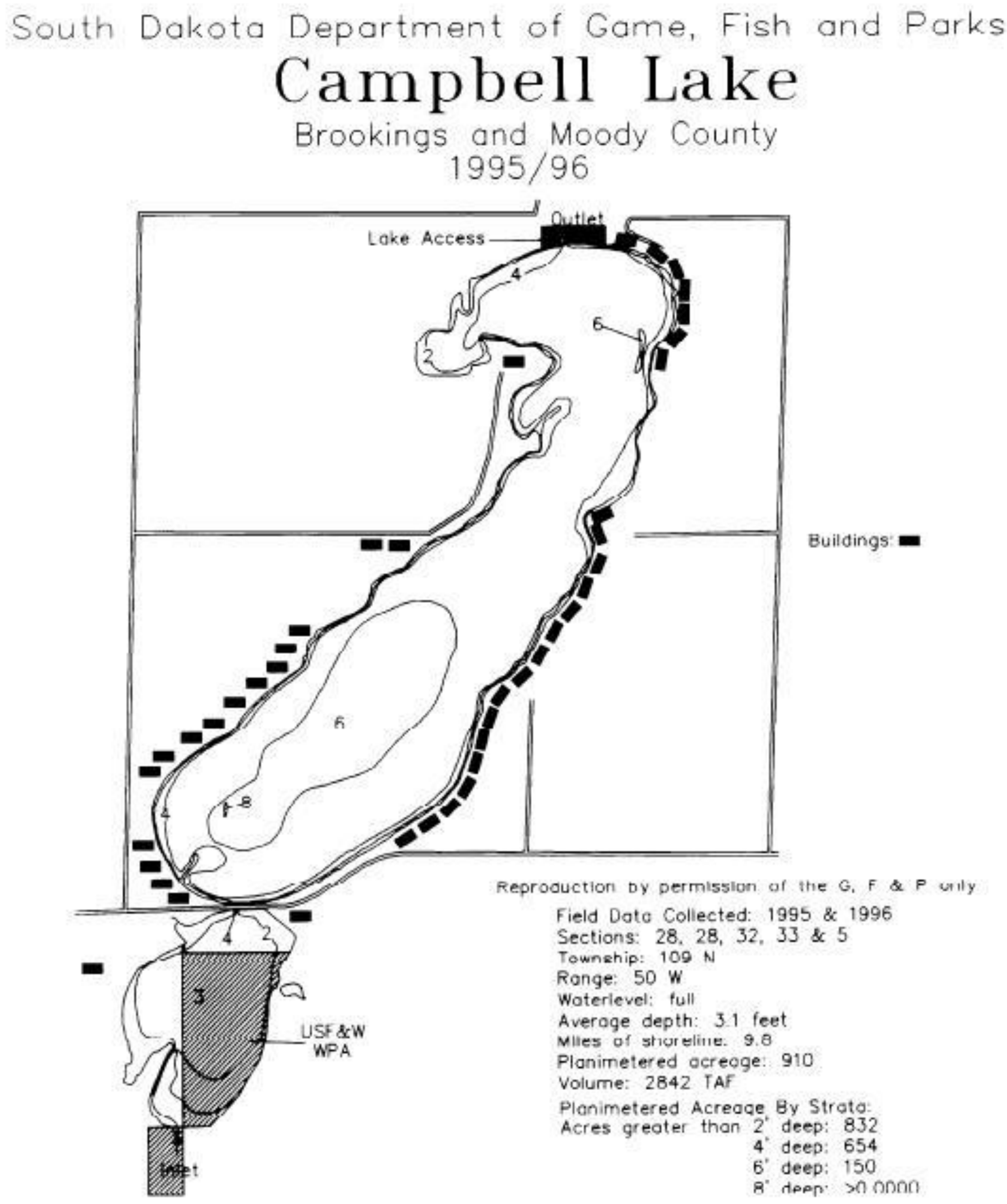


Figure 16. 1995-1996 Bathymetric Map of Lake Campbell

Annual Hydrologic Budget

Inflow and outflow sources were monitored from April 2007 through June 2008. One inflow source and one outflow source were monitored at Lake Campbell. A total of 291 flow days were used in the calculations (Table 58).

Table 58. Lake Campbell Hydrologic Balance

Lake Campbell - 2007/2008 (1 yr averaging period) Surface Area = 800 acres			
Inflow Sources	**Load (acre-feet)**	**Outflow Sources**	**Load (acre-feet)**
Precipitation	1622.06	Evaporation	2057.60
Tributaries (LC-T2 Battle Creek)	23600.97	Advective Outflow	5758.31
Ground Water	1230.02	Gaged Outflow (LC-T1)	17437.15
		Change in Storage	1200.00
Totals	**26453.05**		**26453.06**

Inflow Sources

In order to calculate the precipitation inputs, 2007 rainfall data was taken from the weather station located at the Brookings 2NE Coop Station (station # 391076) approximately eight miles northeast of the study site. The amount of precipitation in inches was converted to feet and multiplied by the surface area of Lake Campbell.

Tributary input was derived from stage and flow data collected during the study period. This data was entered into the FLUX model which estimated the yearly cubic hectometers of inflow from the tributary and was then converted into acre-feet.

After all of the hydrologic outputs were subtracted from the inputs, 1,230.02 acre-feet were unaccounted for. The only source not yet included was groundwater; therefore the remaining hydrologic load was attributed to groundwater input.

Outflow Sources

The nearest weather station that collected land evaporation data was the Brookings 2NE Co-op Station (#391076), located approximately eight miles northeast of the study site. In order to adjust the land data to surface water evaporation, monthly evaporation amounts were multiplied by the Class A monthly land pan coefficient (0.8) for the Midwestern United States (Fetter 1988). The monthly evaporation amounts were added, converted to feet, and multiplied by the surface area of Lake Campbell.

Tributary output was derived from stage and flow data collected during the study period. This data was entered into the FLUX model which estimated the yearly cubic hectometers of outflow and converted into acre-feet.

The storage of the lake decreased from its original measurements in the spring (May) of 2007 to the final measurements in the fall (September) of 2007. The difference between these measurements was a 1.5 foot gain (1,200 acre-feet).

Advective outflow was calculated using the BATHTUB model (Walker 1999). This outflow was in addition to the calculated tributary outflow. Advective flow is the movement of water by gravity and in this case likely moving out of the lake and into the groundwater.

Results

Lake Campbell inflow sources included precipitation, one inlet, and groundwater (Figure 17). Gaged inflow (Site LC-T2) contributed 23,601 acre-feet (89 percent). Precipitation contributed 1,622 acre-feet (6 percent). Groundwater contributed an estimated 1,230 acre-feet (5 percent).

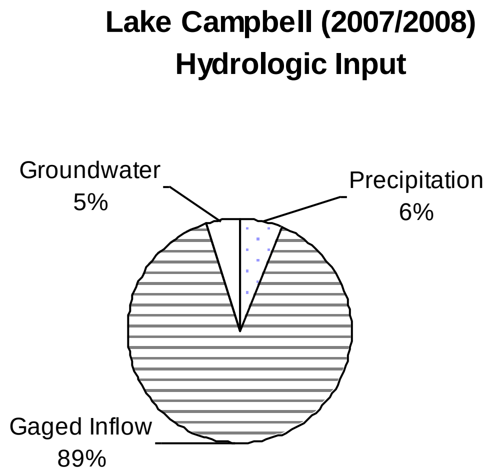


Figure 17. Lake Campbell Hydrologic Inputs

Lake Campbell outflow sources included evaporation, one outlet, advective flow (movement of water by gravity) and change in storage (Figure 18). Evaporation loss is estimated at 2,058 acre-feet (8 percent). Advective outflow loss is estimated at 5,758 acre-feet (22 percent). Gaged outflow loss is estimated at 17,437 acre-feet (65 percent). Change in storage loss is estimated at 1,200 acre-feet (5 percent).

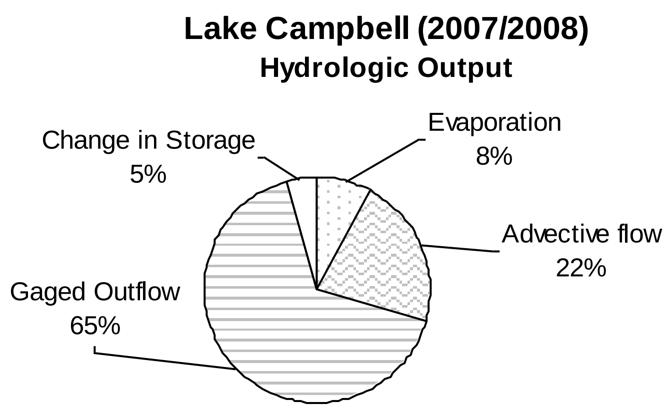


Figure 18. Lake Campbell Hydrologic Outputs

Sediment Loading and Nutrient Budgets

Suspended Solids Loading

The estimated percentage of total suspended solids loading into Lake Campbell was derived from the FLUX results for Site LC-T2 (Battle Creek inlet). It is estimated that Site LC-T2 contributed 919,556 kg of total suspended solids to Lake Campbell. After subtracting the outflow load (774,335 kg) at Site LC-T1, total yearly load of sediment remaining in the lake was estimated at 145,221 kg.

Nitrogen Budget

Sources contributing to the nitrogen load of Lake Campbell included tributary inflow, precipitation, and groundwater. Atmospheric nitrogen was not included in the inflow estimates. As atmospheric nitrogen enters a lake, it is utilized by different species of algae; therefore, making it impossible to calculate. Total nitrogen concentrations are derived from adding TKN concentration to nitrate-nitrite concentrations. The amount of total nitrogen loading into Lake Campbell was 67,097 kg. Of the 67,097 kg, the Battle Creek inlet (LC-T2) contributed 86 percent. Precipitation contributed an estimated 3,240 kg (5 percent) and groundwater contributed an estimated 5,880 kg (9 percent) of nitrogen to the lake (Figure 19). Nitrogen leaving the lake through the outlet (LC-T1) measured 45,939 kg and advective outflow measured 15,279 kg. After the outflow was subtracted from the inflow, an estimated 5,879 kg of nitrogen was retained within Lake Campbell.

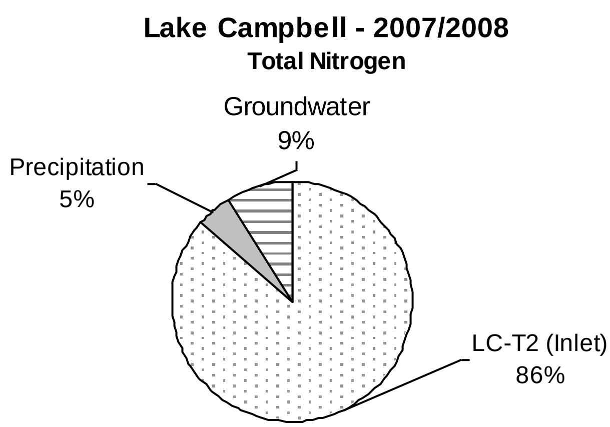


Figure 19. Lake Campbell Total Nitrogen Load

Since nitrogen is water soluble it is very difficult to estimate its contribution from groundwater. For the purpose of this study, a total nitrogen average concentration of 3.72 mg/L was used for groundwater inflow. The concentration was averaged from the South Dakota Geological Survey (SDGS 2008 and Rich 2001) monitored wells which included Big Sioux Aquifer wells R20-94-06, R20-94-07, R20-89-47, and R20-89-48 and data ranging from 1990 through 2007. Groundwater contribution was estimated to be nine percent of the nitrogen loading. The following calculations were used to find the groundwater contribution of nitrogen.

Hydrologic load converted to m^3:

$$1{,}281 \text{ acre-ft} \times 1{,}234 = 1{,}580{,}754 \text{ m}^3$$

Convert m^3 to liters:

$$1{,}580{,}754 \text{ m}^3 \times 1{,}000 = 1{,}580{,}754{,}000 \text{ L}$$

Groundwater nitrogen average concentration multiplied by hydrologic load (L):

$$3.72 \text{ mg/L} \times 1{,}580{,}754{,}000 \text{ L} = 5{,}880{,}404{,}880 \text{ mg}$$

Total groundwater nitrogen load converted to kg:

$$5{,}880{,}404{,}880 \text{ mg} \div 1{,}000{,}000 = 5{,}880 \text{ kg}$$

Phosphorus Budget

Sources of phosphorus loads into Lake Campbell included tributary inflow, groundwater, and precipitation (Figure 20). Total phosphorus inflow to Lake Campbell during the sampling period was approximately 6,955 kg. Of the 6,955 kg, the Battle Creek inlet (LC-T2) contributed 98 percent (6,763 kg) of the total loading. Groundwater contributed an estimated 95 kg (1 percent) of phosphorus and precipitation contributed an estimated 97 kg (1 percent) of phosphorus to the lake. Phosphorus leaving the lake through the outlet (LC-T1) measured 4,624 kg and advective outflow measured 1,538 kg. After the outflow was subtracted from the inflow, an estimated 793 kg of phosphorus was retained within Lake Campbell; enough to raise the lake 0.259 mg/L.

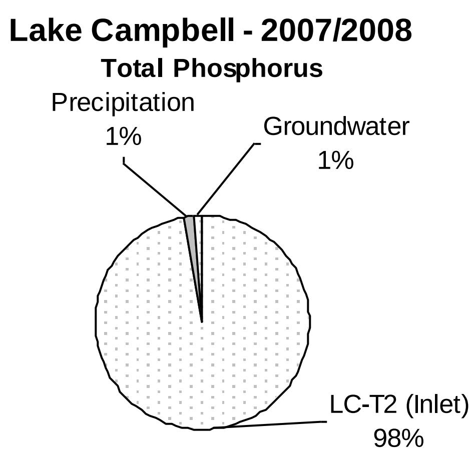


Figure 20. Lake Campbell Total Phosphorus Load

Groundwater was responsible for approximately one percent of the total phosphorus delivered to the lake. Groundwater contribution was estimated by multiplying the mean total phosphorus concentration (0.06 mg/L) from groundwater samples collected (by SDGS), by the amount of groundwater discharged into the lake (1,281 acre-feet). The following calculations were used to find the groundwater contribution of total phosphorus.

Hydrologic load converted to m^3:

$$1{,}281 \text{ acre-ft} \times 1{,}234 = 1{,}580{,}754 \text{ m}^3$$

Convert m^3 to liters:

$$1{,}580{,}754 \text{ m}^3 \times 1{,}000 = 1{,}580{,}754{,}000 \text{ L}$$

Groundwater phosphorus average concentration multiplied by hydrologic load (L):

$$0.06 \text{ mg/L} \times 1{,}580{,}754{,}000 \text{ L} = 94{,}845{,}240 \text{ mg}$$

Total groundwater phosphorus load converted to kg:

$$94{,}845{,}240 \text{ mg} \div 1{,}000{,}000 = 95 \text{ kg}$$

Total Dissolved Phosphorus

The estimated total dissolved phosphorus loading from Lake Campbell watershed runoff was derived using the FLUX model. The total dissolved phosphorus loading from the Battle Creek inlet (LC-T2) is 6,164 kg/year. The estimated total dissolved phosphorus loading through the outlet is 1,491 kg/year. After the load through the outlet was subtracted off the inlet load, the remainder became the estimated total yearly load of total dissolved phosphorus (4,673 kg/year) retained within the lake.

BIOLOGICAL MONITORING

In-Lake Biological Results

Phytoplankton (Algae) Data Summary

Algae were sampled by the East Dakota Water Development District in June and August 2007 and in February, April, May, and June 2008. Table 59 represents the algal density by date and year. Table 60 represents the algal biovolume by date and year. A complete list of algal species can be found in Appendix H.

Table 59. Algal Density by Date Sampled

Lake Campbell Algal Density (cells/mL)

2007			2008		
11-Jun-07			**13-Feb-08**		
	cells/mL	Percent		cells/mL	Percent
Flagellated Algae	636	0.03	Flagellated Algae	6,098	6.29
Blue-Green Algae	1,867,602	99.86	Blue-Green Algae	89,189	91.98
Diatoms	756	0.04	Diatoms	3	0.00
Non Motile Green Algae	973	0.05	Non Motile Green Algae	1,404	1.45
Unidentified Algae	270	0.01	Unidentified Algae	270	0.28
Total Algal Density	**1,870,237**		**Total Algal Density**	**96,964**	
7-Aug-07			**23-Apr-08**		
	cells/mL	Percent		cells/mL	Percent
Flagellated Algae	3,357	0.19	Flagellated Algae	18,384	5.56
Blue-Green Algae	1,765,852	99.12	Blue-Green Algae	275,072	83.27
Diatoms	4,284	0.24	Diatoms	25,024	7.57
Non Motile Green Algae	7,431	0.42	Non Motile Green Algae	9,222	2.79
Unidentified Algae	610	0.03	Unidentified Algae	2,650	0.80
Total Algal Density	**1,781,534**		**Total Algal Density**	**330,352**	
			21-May-08		
				cells/mL	Percent
			Flagellated Algae	59,517	30.37
			Blue-Green Algae	132,753	67.73
			Diatoms	1,687	0.86
			Non Motile Green Algae	844	0.43
			Unidentified Algae	1,200	0.61
			Total Algal Density	**196,001**	
			10-Jun-08		
				cells/mL	Percent
			Flagellated Algae	9,482	1.48
			Blue-Green Algae	620,526	96.76
			Diatoms	7,222	1.13
			Non Motile Green Algae	2,718	0.42
			Unidentified Algae	1,360	0.21
			Total Algal Density	**641,308**	

Lake Campbell total phytoplankton density ranged from 96,964 cells/mL (February 2008) to 1,870,237 cells/mL (June 2007). A comparison of phytoplankton density in June 2008 and the previous year in June showed a 65 percent decrease in algal density. Blue-green algae showed the highest density in all the samplings with the *Oscillatoria agardhii* species being the most dense in every sample. This species persisted with the highest density throughout the summer.

Table 60. Algal Biovolume by Date and Year Sampled

Lake Campbell Algal Biovolume (μm^3/mL)

11-Jun-07	µm3/mL	Percent
Flagellated Algae	266,672	0.30
Blue-Green Algae	89,596,622	99.19
Diatoms	287,130	0.32
Non Motile Green Algae	171,735	0.19
Unidentified Algae	8,100	0.01
Total Algal Biovolume	**90,330,259**	

7-Aug-07	µm3/mL	Percent
Flagellated Algae	1,625,676	1.71
Blue-Green Algae	91,338,460	95.91
Diatoms	1,154,100	1.21
Non Motile Green Algae	1,093,338	1.15
Unidentified Algae	18,300	0.02
Total Algal Biovolume	**95,229,874**	

13-Feb-08	µm3/mL	Percent
Flagellated Algae	6,835,656	62.20
Blue-Green Algae	4,083,285	37.15
Diatoms	820	0.01
Non Motile Green Algae	34,240	0.31
Unidentified Algae	36,000	0.33
Total Algal Biovolume	**10,990,001**	

23-Apr-08	µm3/mL	Percent
Flagellated Algae	2,756,950	13.34
Blue-Green Algae	12,915,770	62.49
Diatoms	4,639,970	22.45
Non Motile Green Algae	277,850	1.34
Unidentified Algae	79,500	0.38
Total Algal Biovolume	**20,670,040**	

21-May-08	µm3/mL	Percent
Flagellated Algae	10,094,608	59.26
Blue-Green Algae	6,354,029	37.30
Diatoms	502,350	2.95
Non Motile Green Algae	46,125	0.27
Unidentified Algae	36,000	0.21
Total Algal Biovolume	**17,033,112**	

10-Jun-08	µm3/mL	Percent
Flagellated Algae	3,996,928	11.50
Blue-Green Algae	29,367,763	84.46
Diatoms	1,137,450	3.27
Non Motile Green Algae	227,662	0.65
Unidentified Algae	40,800	0.12
Total Algal Biovolume	**34,770,603**	

Lake Campbell total phytoplankton biovolume ranged from 10,990,001 μm^3/mL (February 2008) to 95,229,874 μm^3/mL (August 2007). A comparison of phytoplankton biovolume in June 2008 and in June the previous year showed a 62 percent decrease in algal biovolume. Blue-green algae dominated the biovolume in the June and August samples. The species of blue-green algae with the most biovolume during these months was *Oscillatoria agarhii*, a nuisance species. Other nuisance species found in the lake included *Anabaena* sp., *Anabaenopsis* sp., *Aphanizomenon* sp., *Aphanocapsa* sp., and *Microcystis* sp.

All algae samples were incorporated into the following graphs (Figures 21 through 26). By far, blue-green algae dominated. Flagellated algae, blue-green algae, non-motile green algae, diatoms, and unidentified algae were compared by month.

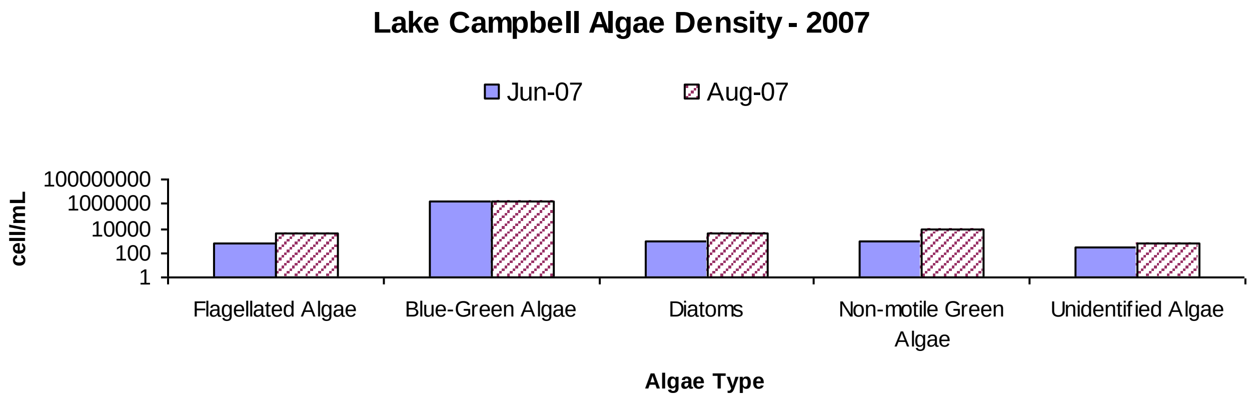


Figure 21. Total Algae Cells per Milliliter by Algae Type for Lake Campbell (2007)

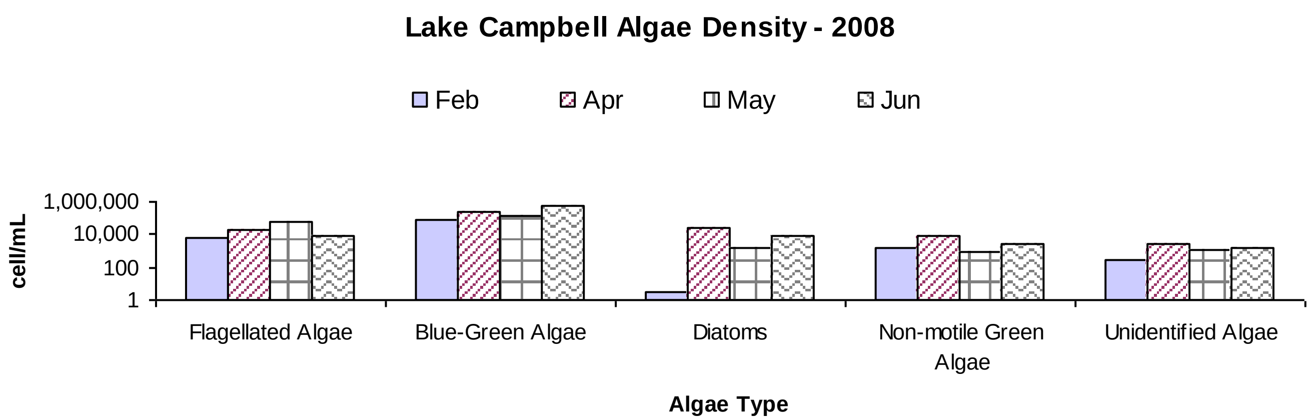


Figure 22. Total Algae Cells per Milliliter by Algae Type for Lake Campbell (2008)

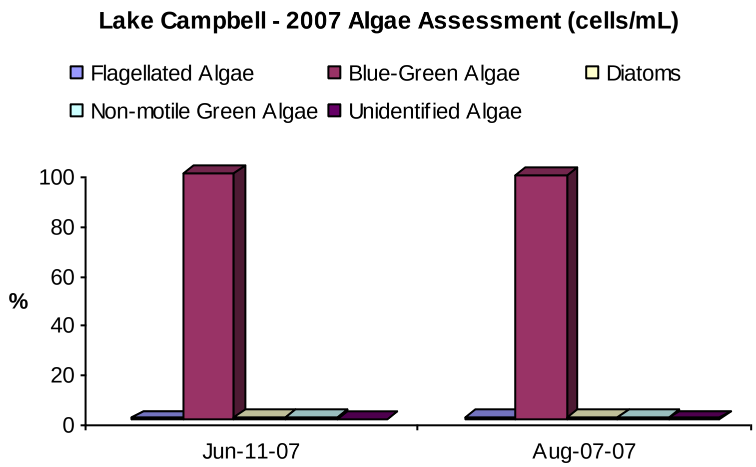


Figure 23. Percent Algal Type in Cells per Milliliter (2007)

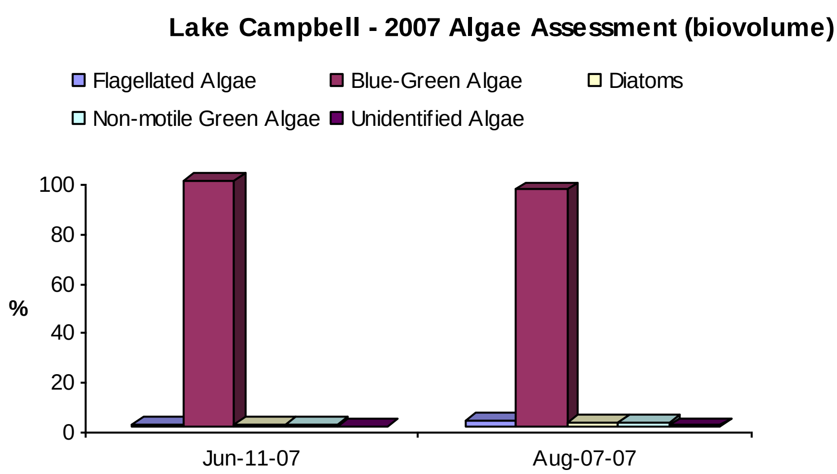


Figure 24. Percent Algal Type by Biovolume (2007)

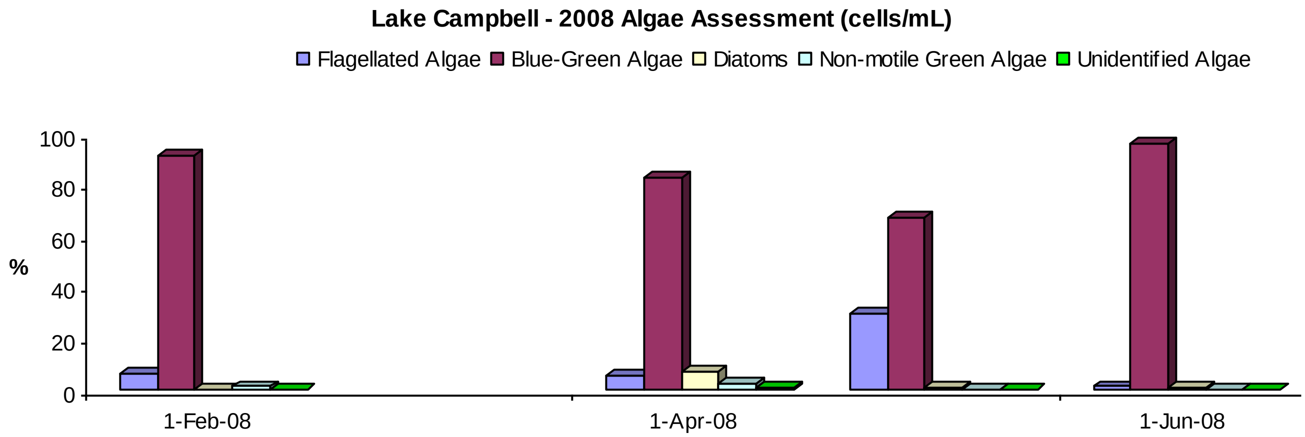


Figure 25. Percent Algal Type in Cells per Milliliter (2008)

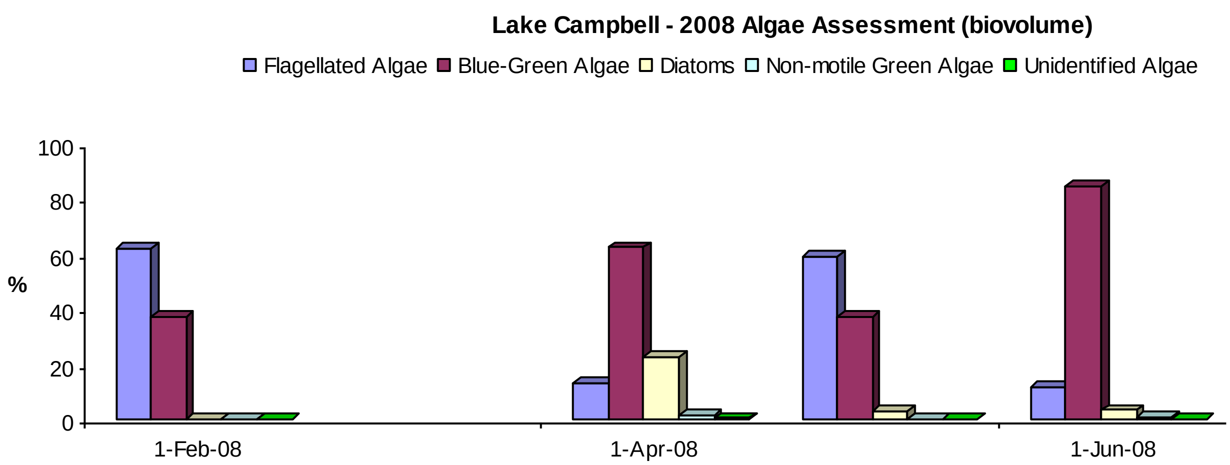


Figure 26. Percent Algal Type by Biovolume (2008)

Chlorophyll-*a* Sampling

Chlorophyll-*a* samples (n=39) were collected at all in-lake sampling sites (LC-1, LC-2, and LC-3) during the project period – April 2007 though June 2008 (Figure 27). Citizen monitoring samples are also included in this figure. Chlorophyll is the green pigment in plants that allows them to create energy from light. Chlorophyll-*a* concentrations can be used to help determine the trophic status of a lake. The trophic status is not related to water quality standards, but it is a tool for rating the amount of productivity of a lake. Overall, the chlorophyll-*a* concentrations for Lake Campbell were fairly high. The maximum chlorophyll-*a* concentration (195.43 mg/m^3) was collected at Site LC-1 (north site) on August 7, 2007. The average concentration during the study period was 96.57 mg/m^3. Of the 23 samples collected during the summer months (June, July, and August) the average chlorophyll-*a* concentration was 117.36 mg/m^3 and the median concentration was 113.26 mg/m^3.

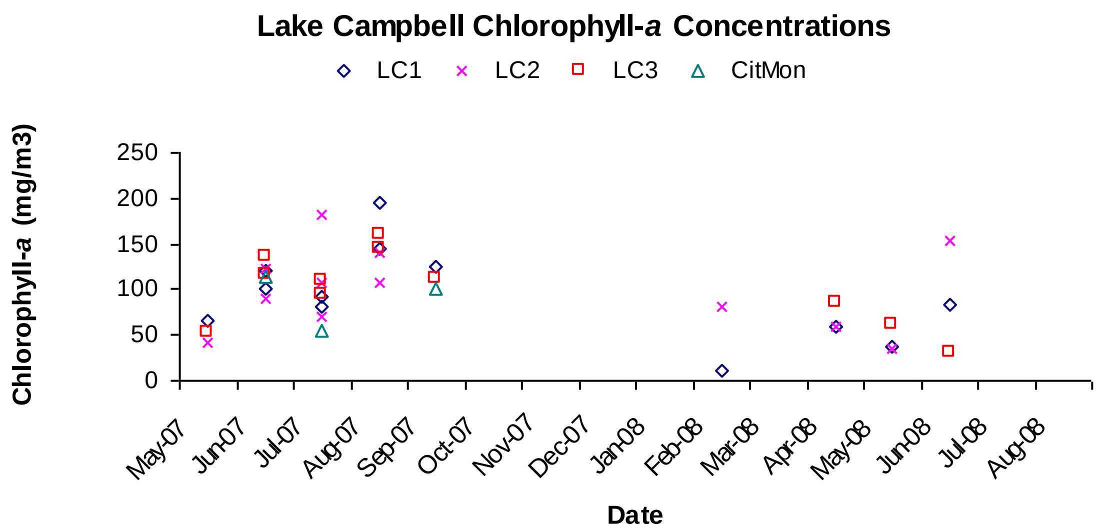


Figure 27. Monthly In-Lake Chlorophyll-*a* Concentrations by Date and Sampling Site

Chlorophyll-*a* is the photosynthetic pigment in all green plants and can be a measure of the amount of algae present in a lake. Phosphorus is the primary nutrient algae use for growth. Plots of total phosphorus and chlorophyll-*a* collected between May and September of 2007 were constructed (Figure 28) to show the relationship between the amount of phosphorus present versus the amount of algal growth. Phosphorus is usually the limiting nutrient in the growth of algae. Therefore, increase in phosphorus should yield increases in algae mass. However, Figure 28 indicates there is not a correlation between chlorophyll-*a* and total phosphorus in Lake Campbell during 2007. When comparing total nitrogen with chlorophyll-*a* during the same time period there is a strong correlation between the two (Figure 29). In some instances, nitrogen can become the limiting nutrient in the growth of algae. This seems to be the case in Lake Campbell. Figure 29 indicates increases in total nitrogen are yielding increases in algae mass in Lake Campbell (R^2 = 0.3918 at Site LC-1, R^2 = 0.6541 at Site LC-2, and R^2 = 0.8302 at Site LC-3).

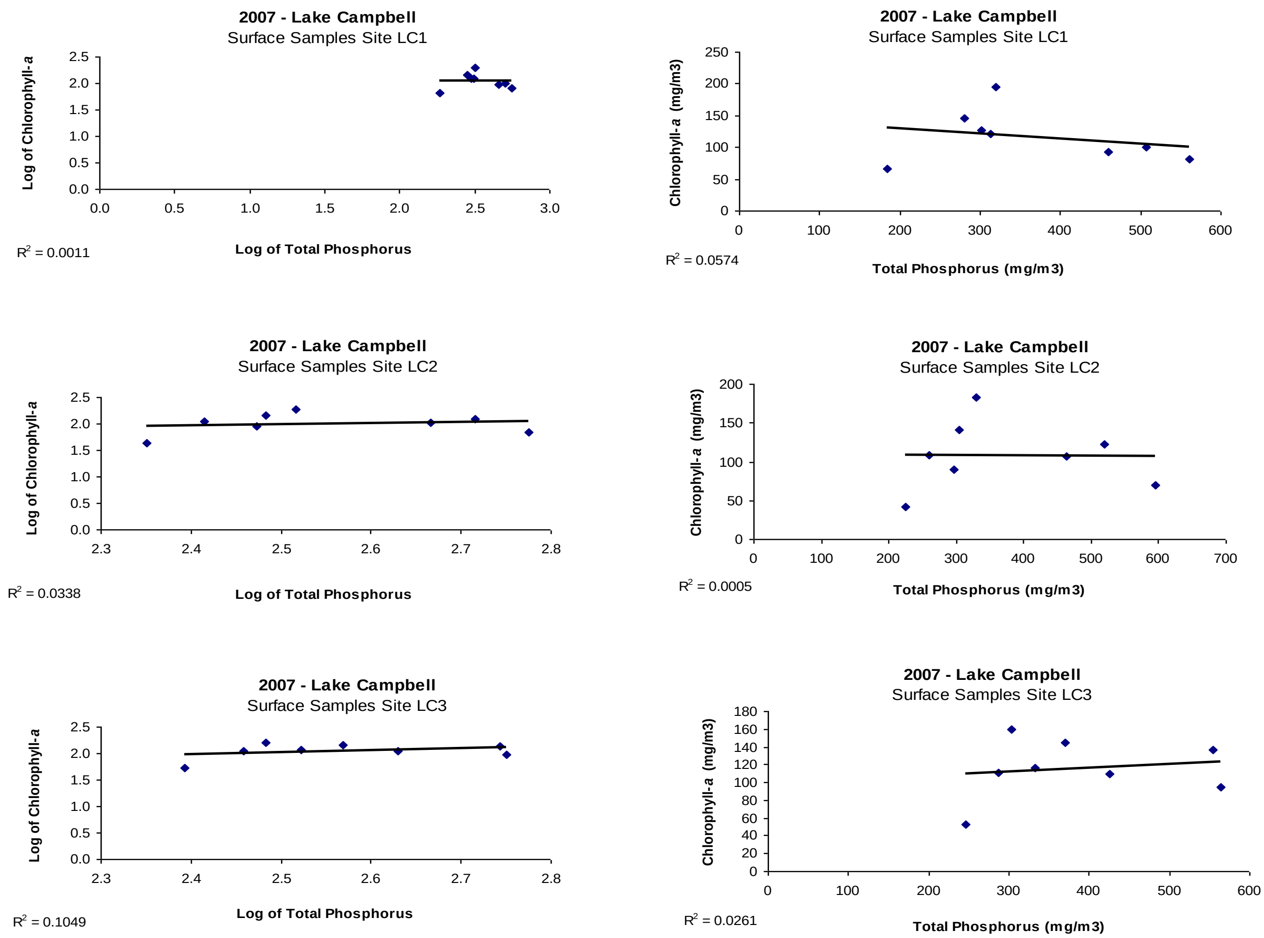


Figure 28. Total Phosphorus to Chlorophyll-*a* Relationship (Sites LC-1, LC-2, & LC-3)

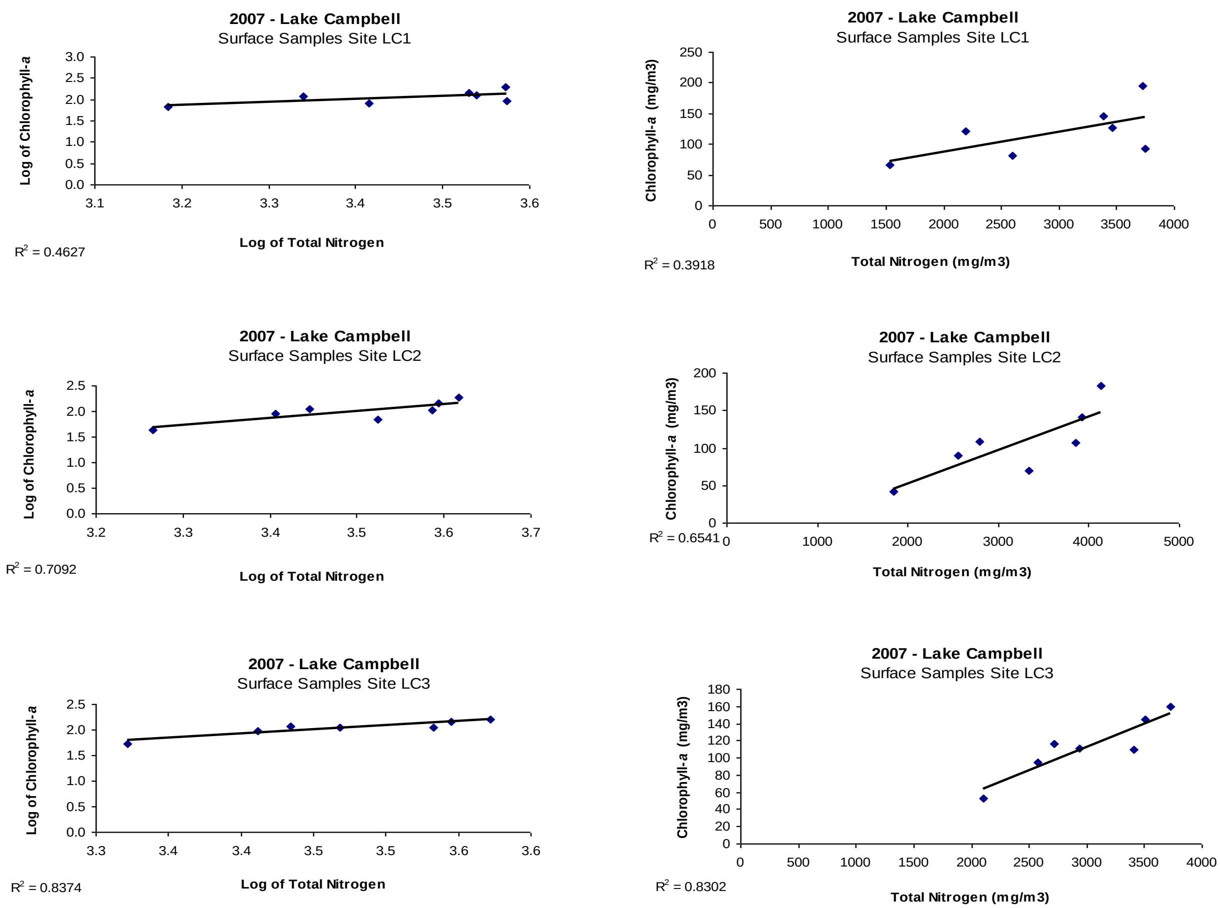


Figure 29. Total Nitrogen to Chlorophyll-*a* Relationship (Sites LC-1, LC-2, & LC-3)

Water clarity is measured using a Secchi disk. These measurements are also used to help determine the trophic status of a lake. The deeper the Secchi disk can be seen, the clearer the water. Indicatively, water clarity decreases as the amount of chlorophyll-*a* increases. For this reason, chlorophyll-*a* and Secchi depth measurements collected during the sampling period were compared (Figure 30).

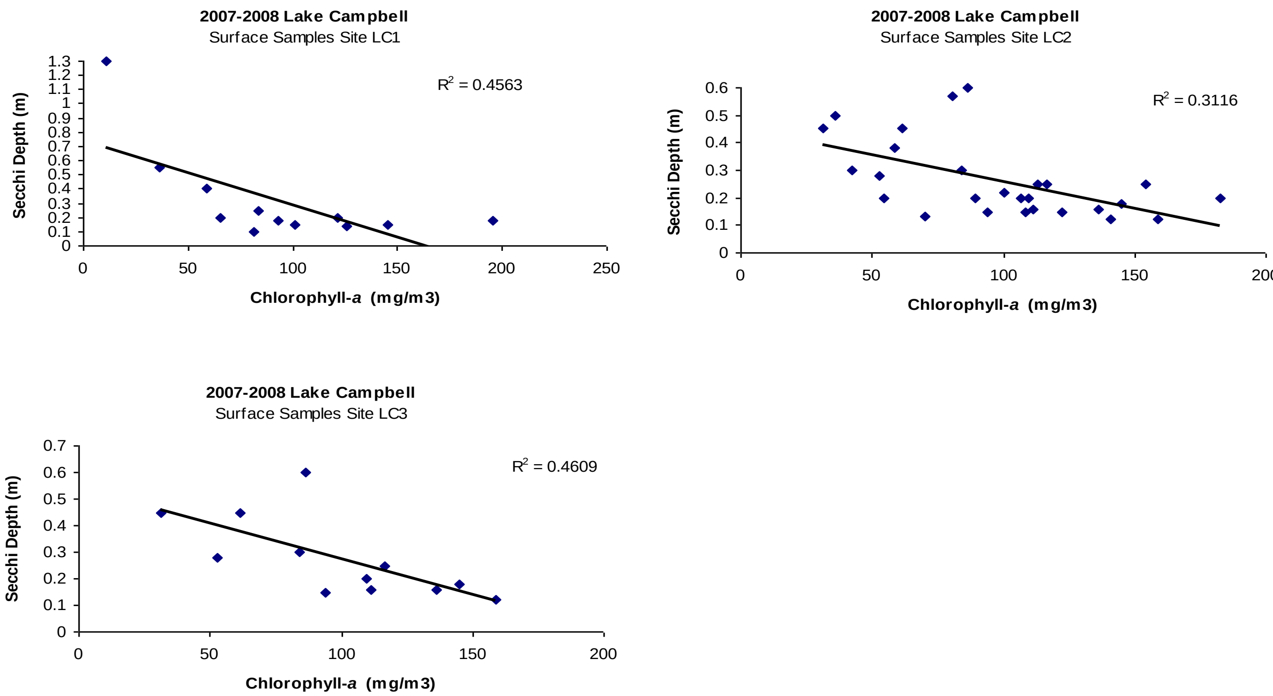


Figure 30. Secchi Depth to Chlorophyll-*a* Relationship (Sites LC-1, LC-2, & LC-3)

N : P Ratios

To compare the availability of nitrogen and phosphorus, a ratio of total nitrogen to total phosphorus can be calculated. Typically ratios ≤ 10:1 indicate a nitrogen-limited situation. Those ratios that fall between 10:1 to 15:1 usually indicate enough nutrients (both total nitrogen and total phosphorus) are present to facilitate excess algae and plant growth. For an organism, such as algae, to survive in a given environment, it must have the necessary nutrients and environment to maintain life and successfully reproduce. If an essential life component approaches a critical minimum, this component will become the limiting factor (Odum 1959). Nutrients such as phosphorus and nitrogen are most often the limiting factors in highly eutrophic lakes. Typically, phosphorus is the limiting nutrient for algal growth. However, in many highly eutrophic lakes with an overabundance of phosphorus, nitrogen can become the limiting factor. Lake Campbell seems to have a tendency toward being a nitrogen-limited lake as shown by Figure 31. The overall total N:P ratio for the study period is 9.45 : 1. The 1985 water quality report also indicated Lake Campbell tends to be nitrogen limited. The report stated, "The nutrient ratios of in-lake water samples ranged from 3.36 to 12.10 and the mean values (at two sites were 7.76 and 7.48)." Several studies have shown that a total nitrogen to total phosphorus ratio of 10 : 1 appears to favor algal blooms, especially blue-green algae, which are capable of fixing atmospheric nitrogen (Sigua et al. 2006).

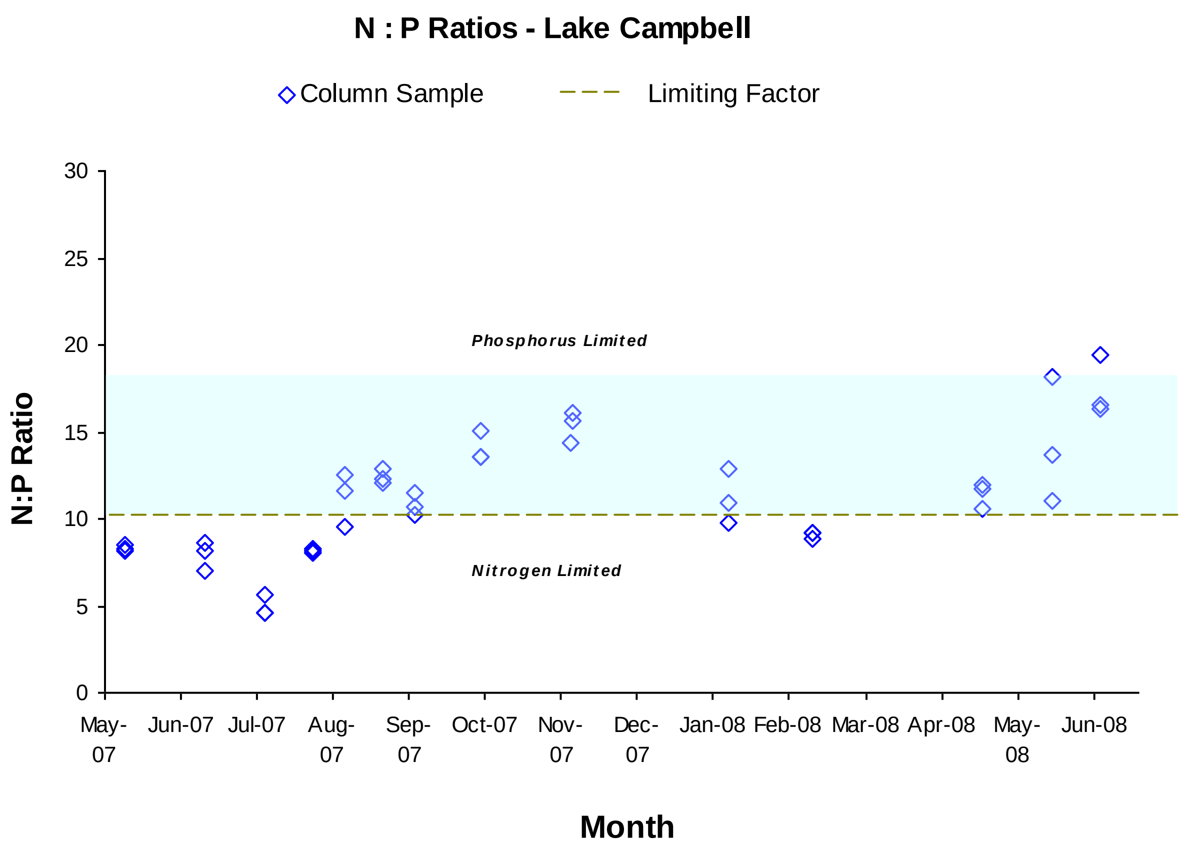


Figure 31. Lake Campbell Total Nitrogen to Total Phosphorus Ratio

Aquatic Plant Sampling

An aquatic macrophyte survey was conducted on Lake Campbell. A shoreline survey, along 30 transects, identified only three emergent aquatic plants – prairie bulrush, bulrushes, and cattails. Only one submergent plant was identified - sago pondweed (*Potamogeton pectinatus*). Sago pondweed was identified at eight of the 30 transect sampling locations (Table 61 and Figure 32).

Table 61. Aquatic Plant Species Identified in Lake Campbell

Lake Campbell Aquatic Macrophytes			
Common Name	**Genus**	**Species**	**Habitat**
Sago Pondweed	*Potamogeton*	*pectinatus*	Submergent
Prairie Bulrush	*Scirpus*	*maritimus*	Emergent
Bulrushes	*Scirpus*	*spp.*	Emergent
Cattails	*Typha*	*spp.*	Emergent

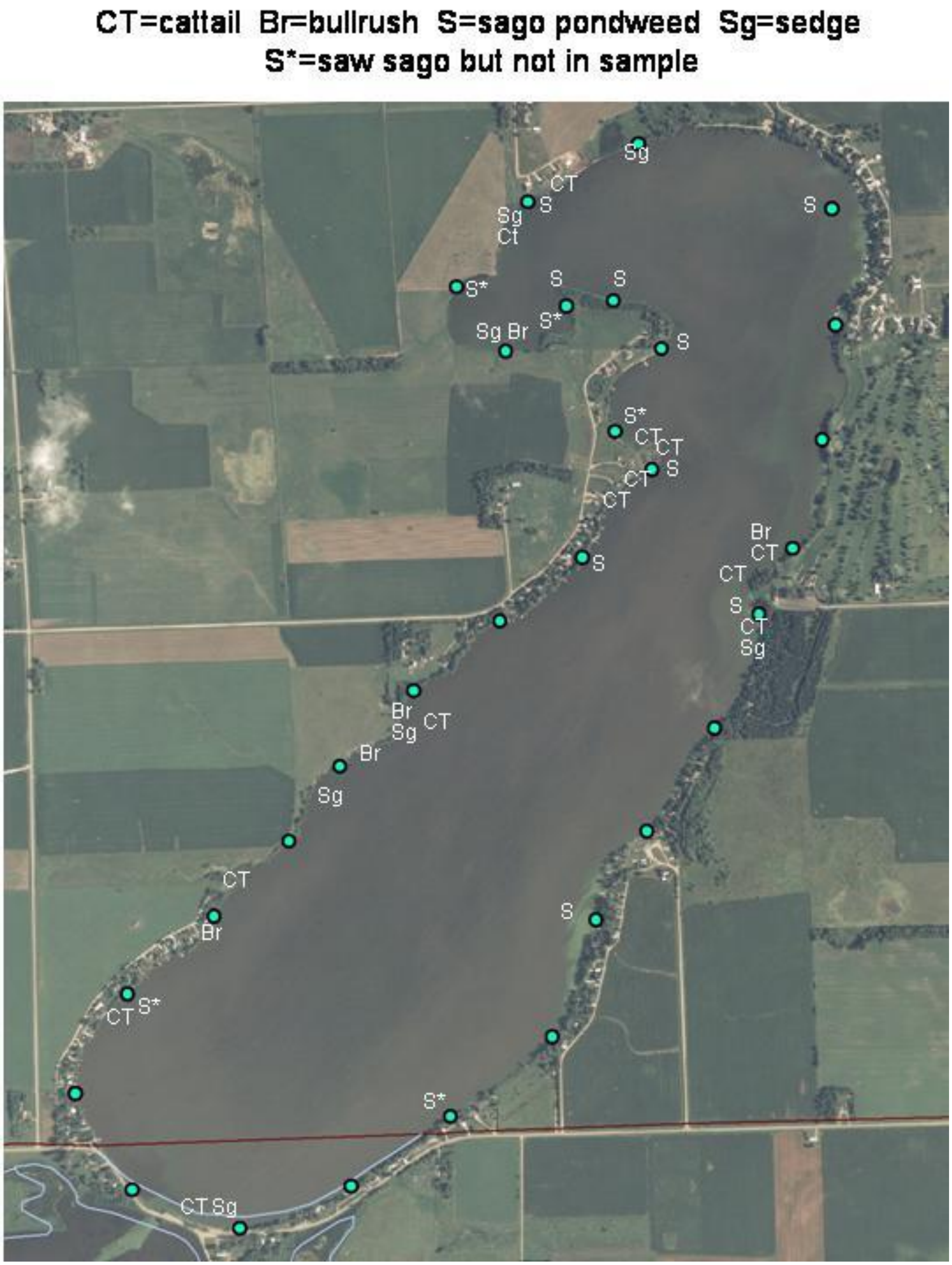


Figure 32. Location of Aquatic Plant Species (Lake Campbell)

SEPTIC SYSTEM SURVEY

In 1991 a septic survey was conducted of the lakeshore residents. A total of 87 surveys were collected with 68 (or 78 percent) documenting the date of septic construction. These surveys indicated 41 percent of the septic systems were 10 years old or older and 29 percent were 15 years old or older (Figure 33). According to the returned surveys with documented distances of drain fields to the lake (84 percent), 10 percent of the septic systems were less than 100 feet from the lake. The state requires at least 100 feet between a septic drain field and a body of water. The 1993 report stated, "The survey of septic wastewater systems around the lake found that at least 10 percent of the systems were out of compliance with current construction requirements. Because of their age and location, many more septic systems may be failing and contributing to the degradation of water quality in Lake Campbell."

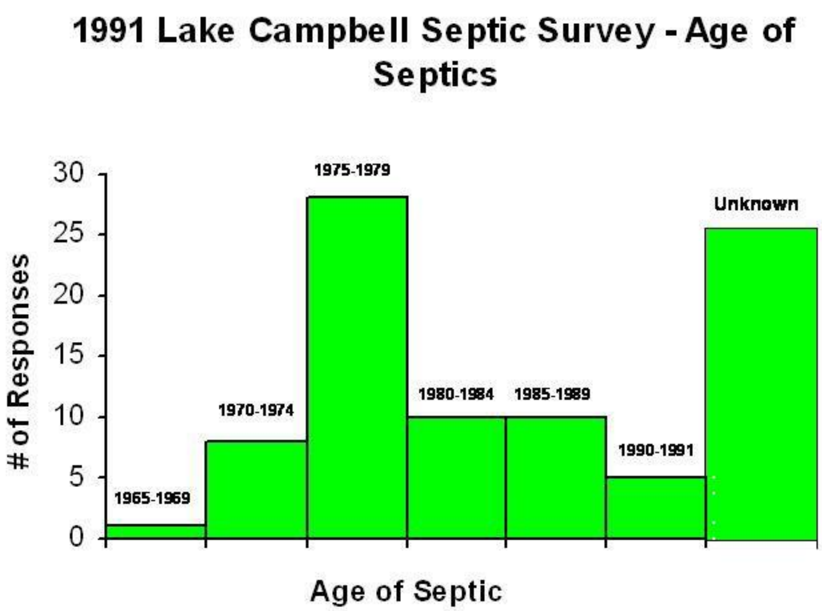


Figure 33. 1991 Lake Campbell Septic Survey – Age of Septics

In 2008 another septic survey was conducted of the lakeshore residents (See Appendix I for data sheet example). A total of 77 surveys were collected with 62 (or 81 percent) documenting the date of septic construction. These surveys indicated 53 percent of the septic systems were 15 years old or older and 21 percent were 30 years old or older (Figure 34). According to the returned surveys with documented distances of drain fields to the lake (58 percent of the surveys), 33 percent indicated septic systems were less than 100 feet from the lake. A comparison with the 1993 report suggests that septic systems are getting older and many of the tanks and fields are still in need of being moved. The 1993 report recommended a sanitary district be formed and the need for a wastewater treatment systems be assessed. Thus far, the sanitary district has been formed (in 1994) and a preliminary wastewater treatment system was designed (in 1996) but funding has yet to be acquired for its construction.

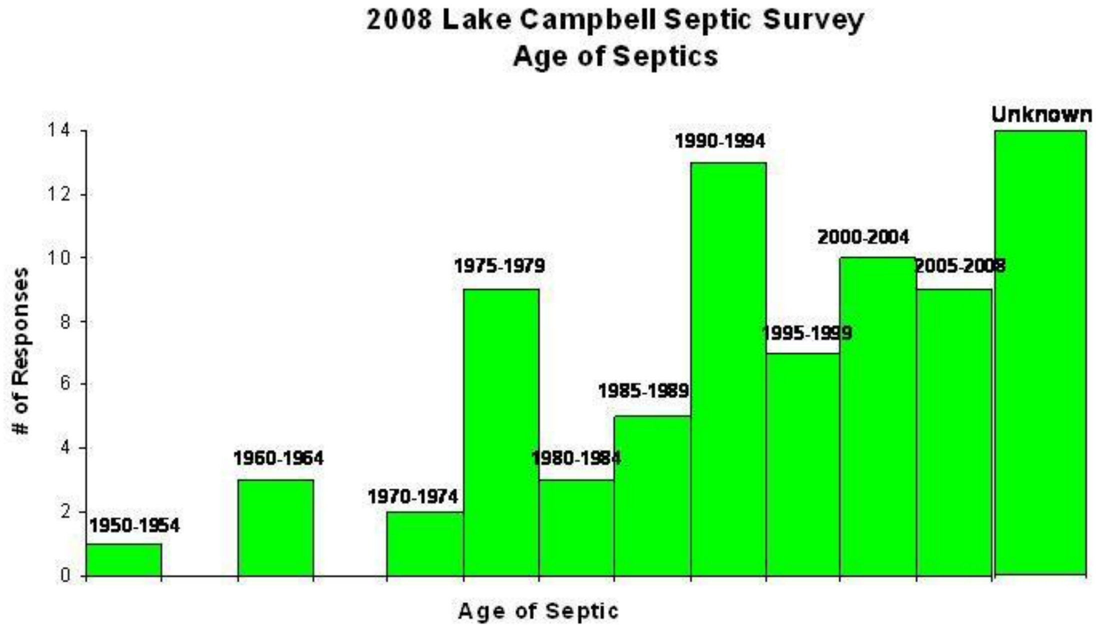


Figure 34. 2008 Lake Campbell Septic Survey – Age of Septics

SEDIMENT SAMPLING

On January 9, 2008, a sediment survey of Lake Campbell was performed by the South Dakota Department of Environment and Natural Resources. A total of 143 holes were drilled in the ice and water and sediment depths were measured at each hole. The procedure was to drill a hole in the ice with an auger, GPS the water surface, GPS the top of the mud, and GPS the bottom of the mud. To find the sediment depth, the elevation of the top of the mud was subtracted from the elevation of the bottom of the mud. To find the water depth, the water surface elevation was subtracted from the elevation at the top of the mud. The average water depth was calculated at 5.6 feet, and the maximum water depth was calculated at 7.6 feet. The average sediment depth was calculated at 0.8 foot, and the maximum sediment depth was calculated at 2.8 feet. The estimated volume of sediment currently in Lake Campbell is 1.3 million cubic yards. The south slough was also surveyed, but very little sediment was found (Figure 35).

During the sediment sampling, it was also noted that there were several places near the east shoreline and near the southern end of the lake that had soft spots. These soft spots could be caused by springs or by other inflowing water from along the shoreline. These soft spots were also observed by assessment personnel during water quality sampling.

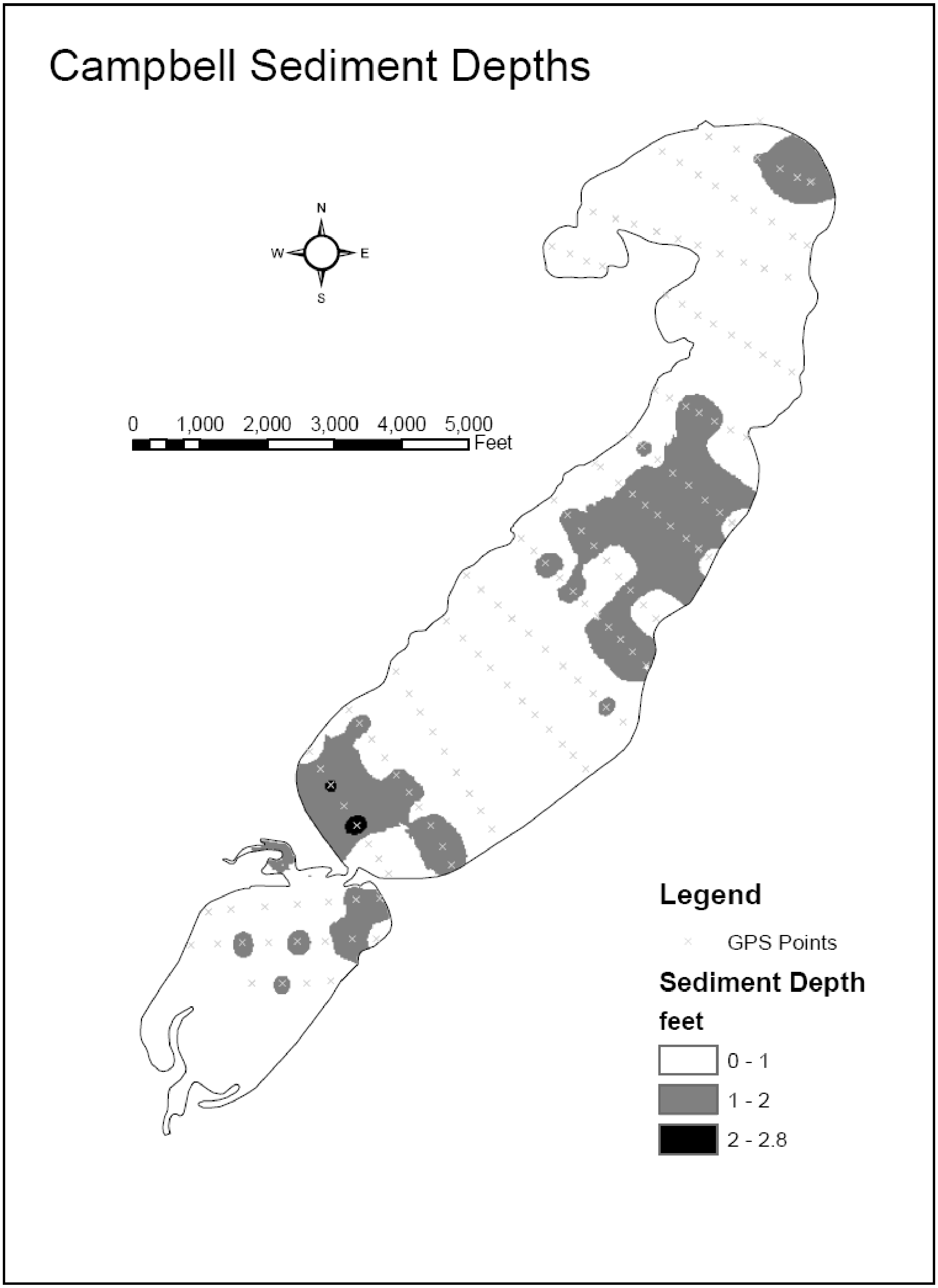


Figure 35. 2008 Sediment Survey Results Map

BENCHMARKS

Several benchmarks were tracked around Lake Campbell during the sampling season. There is one officially established benchmark that has been in place since April 14, 1983. This benchmark is located at the outlet structure of Lake Campbell at 1,575.7 feet above mean sea level (fmsl) and is named B6-6. The MP_3 benchmark (1,580.21 fmsl) is located on the south side of the lake on the northeast wing wall of the new concrete bridge. The MP_2 benchmark (1,578.86 fmsl) is located on the south side of the lake on the southeast wing wall of the old concrete bridge. Measurements were also taken from atop the south bridge 13 posts from the northeast side of the new bridge going from east to west. Using the B6-6 established benchmark, between May and September of 2007 there was a 1.5 foot drop in lake elevation (loss in storage). Between April and November of 2007 was a 1.2 foot drop in elevation, but there were heavy rains in October and November that contributed to an increase in storage in the fall. As shown by Figure 36, lake level dropped for most of the 2007 sampling season. Due to heavy rains during the fall of 2007 and heavy snow during the 2007-2008 winter months, the lake showed a gain in storage through the end of the sampling year. Benchmarks and elevation data at each of the locations can be found in Appendix J.

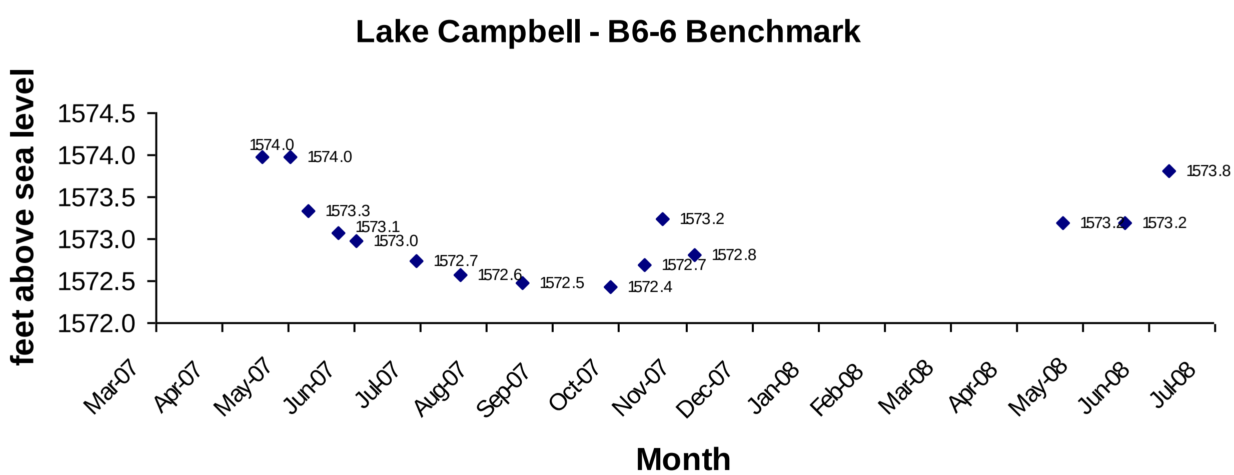


Figure 36. Lake Level Readings at Benchmark B6-6 on Lake Campbell (2007-2008)

TSI COMPUTATION

Trophic State Index

The trophic state index (TSI) of a lake is a numerical value that ranks its relative productivity. Developed by Carlson (1977), the Trophic State Index allows a lake's productivity to be easily quantified and compared to other lakes. Low TSI values correlate with low nutrient concentrations, while higher TSI values correlate with higher nutrient concentrations. TSI values range from 0 (oligotrophic) to 100 (hypereutrophic). Table 62 describes the TSI trophic levels and numeric ranges applicable to Lake Campbell. Each increase of 10 units represents a doubling of algal biomass.

Table 62. Carlson's Trophic Levels and Numeric Ranges

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

Carlson's (1977) Trophic State Index (TSI) for phosphorus, chlorophyll-*a* and Secchi depth was calculated for Lake Campbell and are plotted by sampling date (Figure 37 and 38). The state of South Dakota uses the median value of the chlorophyll-*a* and Secchi depth measurements to determine the status of a lake based on its fishery classification (SD DENR 2005c). Lake Campbell is designated as a warmwater marginal fishery and needs to maintain a TSI value of ≤ 68.4 to meet its fishery target. Data shows the majority of the samples do not meet the TSI criteria to meet the goals of a warmwater marginal fishery. Using all sample data from 2007 and 2008, Lake Campbell median TSI values (Secchi depth plus chlorophyll-*a* TSI daily values) ranged from 55.1 to 85.4 with and overall median value of 77.7. Secchi depth TSI values ranged from 56.2 to 93.2 and chlorophyll-*a* TSI values ranged from 53.9 to 83.1. The overall median TSI value of Lake Campbell indicates a hypereutrophic condition (Figure 38).

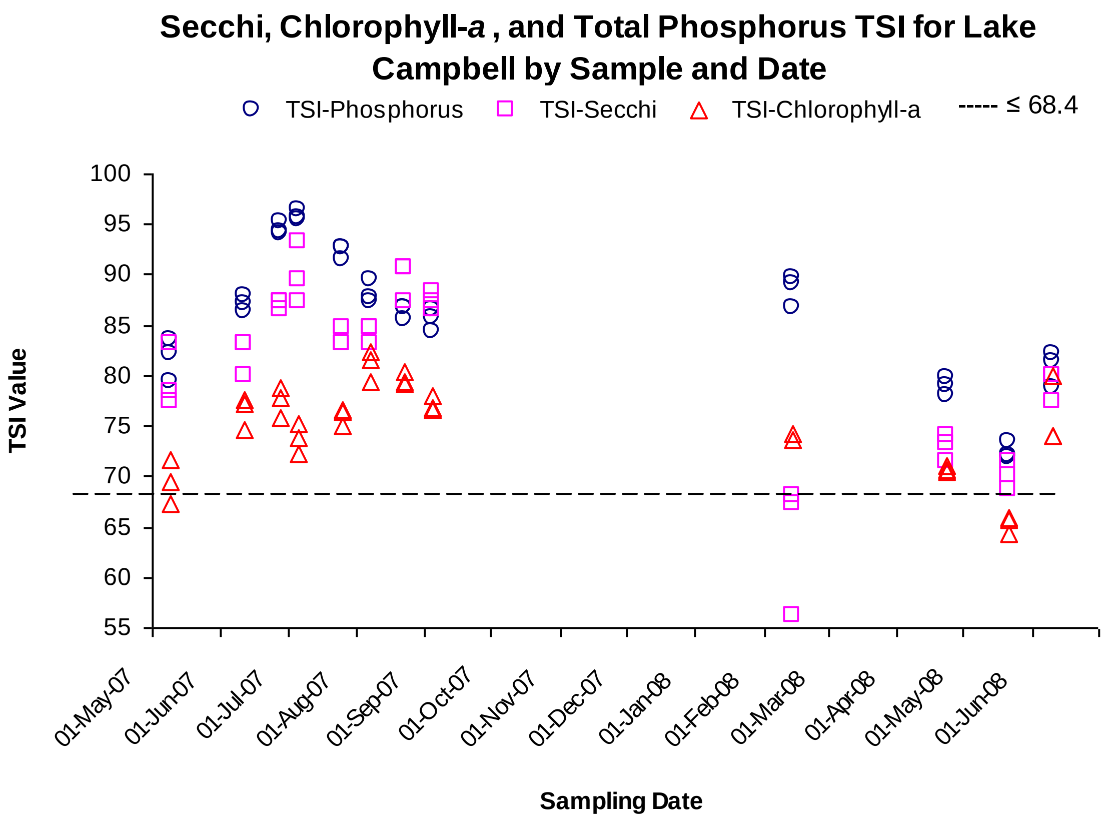


Figure 37. Lake Campbell TSI Values

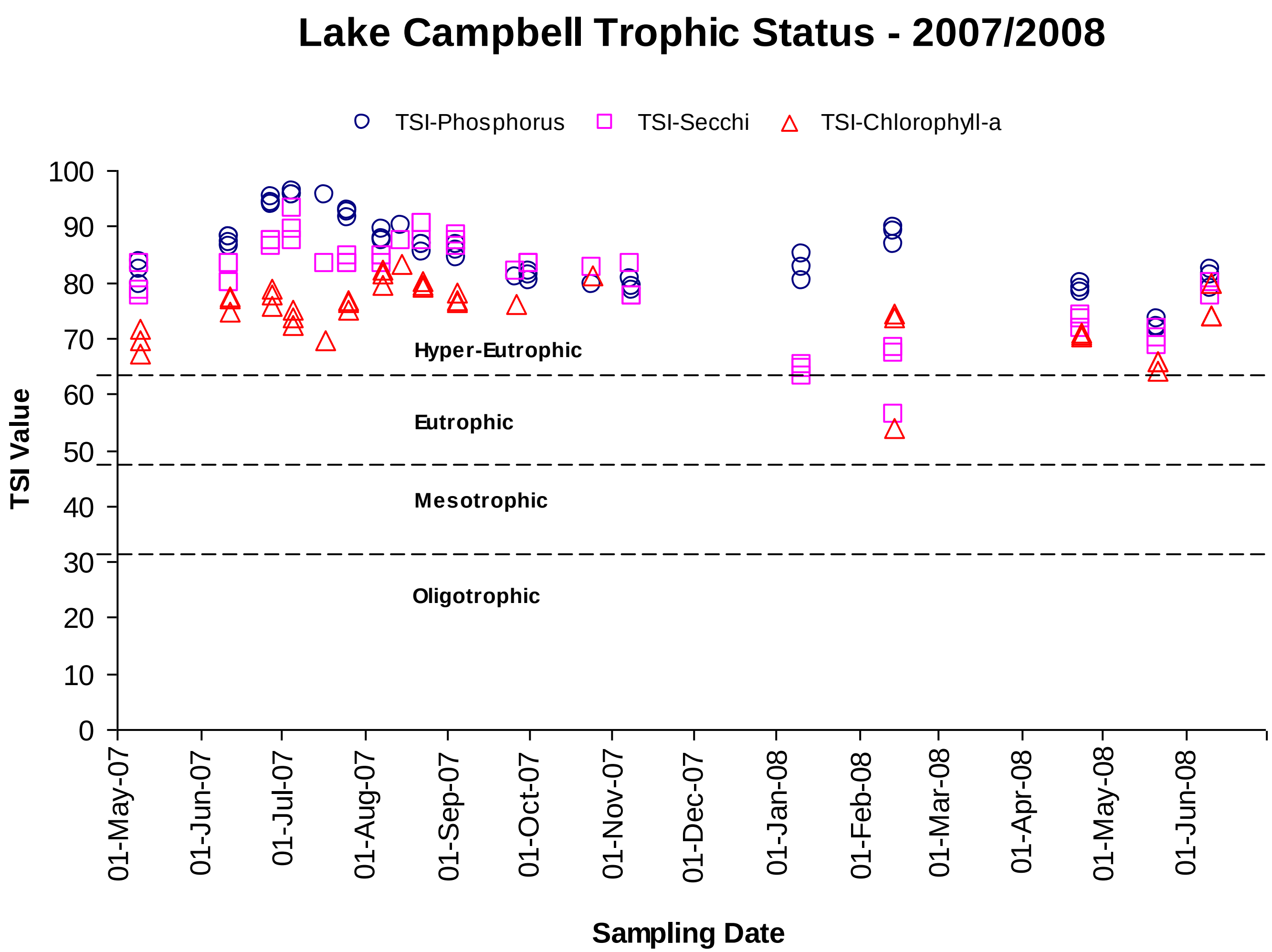


Figure 38. Lake Campbell Trophic Status

MODELING

BATHTUB Modeling

The BATHTUB model calculated the median observed and predicted TSI values (chlorophyll-*a* and Secchi depth) for Lake Campbell. Water quality data collected between May 1st and September 30th were used to populate the model. The observed TSI values are based on in-lake data. The predicted TSI values are based on in-lake data and watershed nutrient loading calculating the interaction between the lake and watershed area. The observed median TSI value for Lake Campbell (May 1st through September 30th) is 79.1 and the predicted median TSI value for Lake Campbell (May 1st through September 30th) is 78.1. The BATHTUB model also calculated the response of each lake to reductions in watershed loading. Watershed nutrient loading concentrations were reduced by 10 percent increments and modeled to create an in-lake reduction curve (Figure 39 and Table 63). A 52 percent reduction in nutrients is recommended for Lake Campbell to meet an acceptable target trophic state (≤ 68.4 TSI) in order to meet the target set for a warmwater marginal fishery.

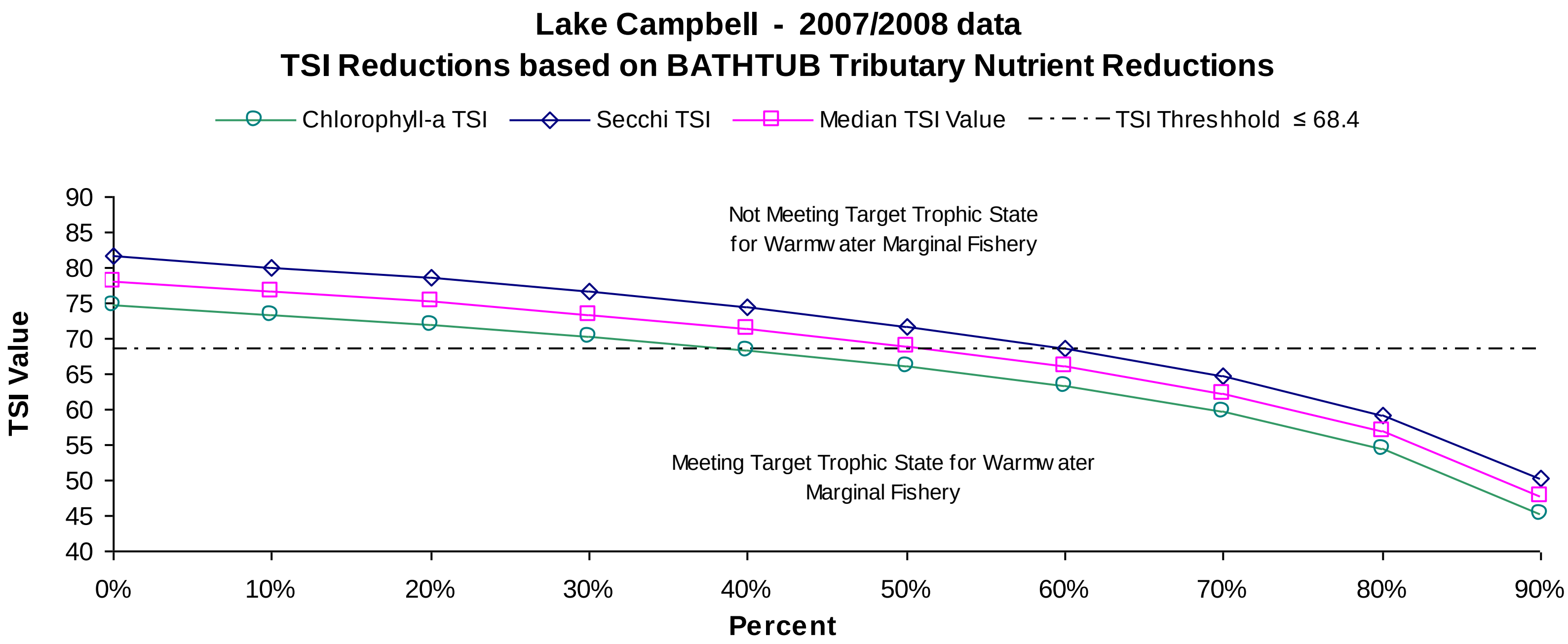


Figure 39. BATHTUB Predicted Median TSI Reductions and Target Trophic State of Lake Campbell

Table 63. 2007-2008 Lake Campbell Observed and Predicted Values with Watershed Reductions

Lake Campbell 2007/2008	Mean Values Calculated using the BATHTUB Model		Percent reductions for total lake load based on PREDICTED model								
			10%	20%	30%	40%	50%	60%	70%	80%	90%
Variable	OBSERVED	PREDICTED	Est	Est	Est	Est	Est	Est	Est	Est	Est
Total P	337.0	215.2	194.0	172.8	151.6	130.4	109.1	87.9	66.7	45.5	24.3
Total N	2948.0	2138.2	1935.7	1733.2	1530.7	1328.2	1125.7	923.2	720.7	518.2	315.7
CHL-A	106.4	88.9	77.8	67.1	56.7	46.7	37.1	27.9	19.3	11.4	4.5
SECCHI	0.2	0.2	0.2	0.3	0.3	0.4	0.4	0.5	0.7	1.1	2.0
ORGANIC N	2759.0	2384.9	2133.2	1888.5	1651.4	1422.6	1203.2	994.7	798.8	618.8	460.2
ANTILOG PC-1	10015.1	6854.6	5476.1	4264.7	3216.4	2327.0	1591.5	1004.6	559.7	249.2	63.8
ANTILOG PC-2	11.0	10.4	10.2	10.0	9.8	9.5	9.3	9.0	8.6	8.1	7.2
(N-150)/P	8.3	9.2	9.2	9.2	9.1	9.0	8.9	8.8	8.6	8.1	6.8
INORGANIC N/P	1.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
FREQ (CHL-a>10)%	100.0	99.9	99.9	99.7	99.4	98.5	96.4	91.1	77.4	46.2	5.4
FREQ (CHL-a>20)%	99.1	98.2	97.0	95.0	91.5	85.5	75.3	59.0	35.7	11.2	0.3
FREQ (CHL-a>30)%	95.8	92.5	89.0	83.9	76.3	65.7	51.2	33.5	15.4	3.1	0.0
FREQ (CHL-a>40)%	89.8	83.6	77.8	70.0	60.0	47.6	33.2	18.7	6.9	1.0	0.0
FREQ (CHL-a>50)%	81.8	73.2	65.7	56.6	45.7	33.7	21.4	10.6	3.3	0.4	0.0
FREQ (CHL-a>60)%	73.0	62.7	54.4	44.8	34.4	23.7	13.8	6.1	1.6	0.1	0.0
TSI-P	88.1	81.6	80.1	78.4	76.6	74.4	71.8	68.7	64.7	59.2	50.1
*TSI-CHLA	76.4	74.6	73.3	71.9	70.2	68.3	66.0	63.3	59.6	54.5	45.3
*TSI-SEC	81.8	81.6	80.1	78.5	76.6	74.4	71.8	68.7	64.7	59.2	50.2
Median TSI (of Chl-a & Secchi)	79.1	78.1	76.7	75.2	73.4	71.4	68.9	66.0	62.2	56.9	47.8

* these variables used to calculate the median TSI

FLUX Modeling

The FLUX model (Army Corps of Engineers Loading Model) was used to estimate the nutrient loadings for the inlet and the outlet sites. These loads and their standard errors (CV) were calculated (Table 64). Sample data (discharge and water quality) collected during this project were utilized in the calculation of the loads and concentrations. For each site sampled, monthly loadings and concentrations for each sampled parameter is detailed in Appendix K.

Table 64. FLUX Yearly Loads and Concentrations

LC-T1 (Lake Campbell Outlet)

Parameter	Concentration (ppb)	FLUX Load Kg/Yr	CV
SuspSol	36041	774335	0.163
TotSol	1241147	26665890	0.119
DisSol	1182409	25403910	0.047
NO2NO3	----- only one sample - the rest were no-detects -----		
NH3N	--- only two samples - the rest were no-detects ---		
VTSS	17923	385073	0.181
TKN	1725	37058	0.141
TotPO4	309	6643	0.353
TotDisPO4	69	1491	0.231
Fecal	165686	3559752	0.654

LC-T2 (Battle Creek - Inlet)

Parameter	Concentration (ppb)	FLUX Load Kg/Yr	CV
SuspSol	31547	919556	0.074
TotSol	1123191	32739680	0.044
DisSol	1131575	32984080	0.052
NO2NO3	1149	33500	0.307
NH3N	943	27476	0.524
VTSS	5421	158008	0.116
TKN	1321	38490	0.137
TotPO4	307	8941	0.060
TotDisPO4	212	6164	0.075
Fecal	279247	8139723	0.697

AnnAGNPS Modeling

The AnnAGNPS model was used to compare sediment, nitrogen, and phosphorus loadings within the watershed during 1-year, 10-year, and 25-year simulated rainfall periods. Several landuse scenarios were modeled including 1) present watershed condition, 2) changing cropland (corn and soybeans) to grass, 3) removing the feedlots, 4) removing any impoundments, and 5) changing cropping practices to no-tillage. Critical phosphorus cells (≥ 2 lbs/acre/year) and critical nitrogen cells (> 3 lbs/acre/year) during a 10-year simulated period were identified. Cells ranged from zero pounds per acre per year of phosphorus to 8.5 pounds per acre per year. Cells ranged from zero pounds per acre per year of nitrogen to 14.2 pounds per acre per year. Maps and a detailed listing of the critical nitrogen and phosphorus cells can be found in Appendix L. Best management practices (BMPs) were applied to determine the amount of reduction that would be possible. Figure 40 shows the cells where the most achievable nutrient reductions in phosphorus and nitrogen may be possible. These areas need to be ground truthed before implementation can take place

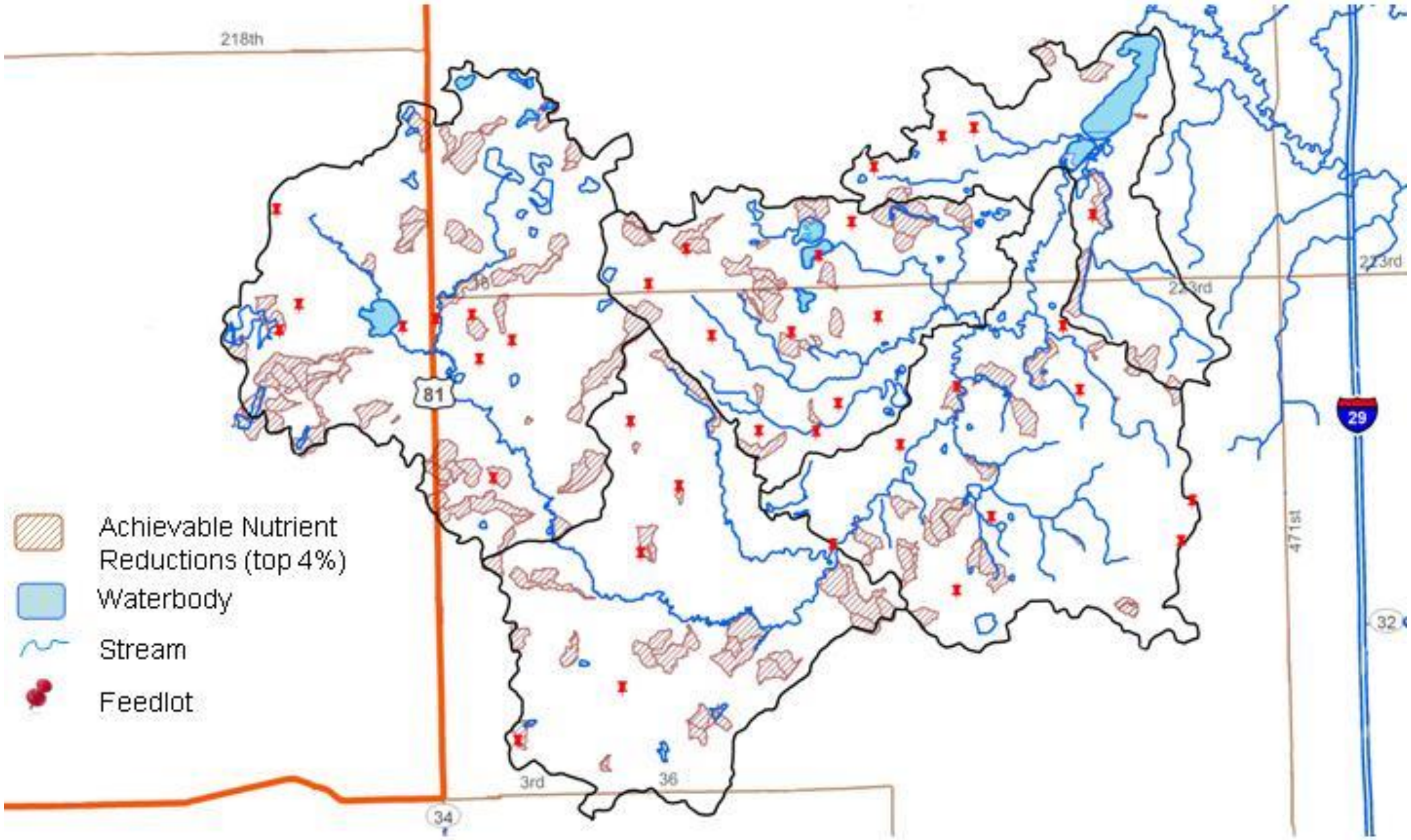


Figure 40. AnnAGNPS Cells with the Highest Achievable Nutrient Reductions

Table 65 shows overall watershed results of sediment, nitrogen, and phosphorus for a 10-year simulated period. Feedlot removal and no-tillage application were scenarios applied watershed-wide. As indicated, feedlots in the watershed are not contributing as much to nutrient problems as compared to agricultural practices. The 1-year and 25-year simulations can be found in Appendix M.

Table 65. Modeled Percent Reductions in Nutrients and Sediment After BMP Application

Lake Campbell Watershed - 10 Year Simulation Period							
Scenerio	Sediment Load (tons/acre/year)	Nitrogen Load (unit area) (lbs/acre/yr)	Attached Nitrogen Load (lbs/acre/yr)	Dissolved Nitrogen Load (lbs/acre/yr)	Total Phosphorus Load (unit area) (lbs/acre/yr)	Attached Phosphorus Load (lbs/acre/yr)	Dissolved Phosphorus Load (lbs/acre/yr)
Present Condition	0.0000	1.061	0.328	0.733	0.404	0.026	0.377
All Grass	0.0000	0.515	0.020	0.496	0.110	0.001	0.110
No Feedlots	0.0000	1.052	0.323	0.729	0.403	0.026	0.377
No Impoundments	0.0186	1.688	0.736	0.952	0.542	0.038	0.503
No Tillage	0.0000	0.977	0.164	0.813	0.272	0.009	0.264

	Percent Difference from Present Condition						
All Grass	0	51 ↓	94 ↓	32 ↓	73 ↓	96 ↓	71 ↓
No Feedlots	0	1 ↓	2 ↓	1 ↓	0 ↓	0	0
No Impoundments	100 ↑	37 ↑	55 ↑	23 ↑	25 ↑	32 ↑	25 ↑
No Tillage	0	8 ↓	50 ↓	10 ↑	33 ↓	65 ↓	30 ↓

Feedlot Modeling

The feedlot model portion of AnnAGNPS simulates a 25-year period, 24-hour rainstorm event which is a model of the current requirement for the general permitting of waste storage facility construction. The model calculates the loading potential of phosphorus, nitrogen, and chemical oxygen demand of each animal feeding operation and ranks them from 0 to 100 based on their potential to pollute nearby surface waters. The East Dakota Water Development District evaluated 37 feedlots within the Lake Campbell watershed. Sixteen of the 37 operations rated 50 or greater by the feedlot model (Table 66).

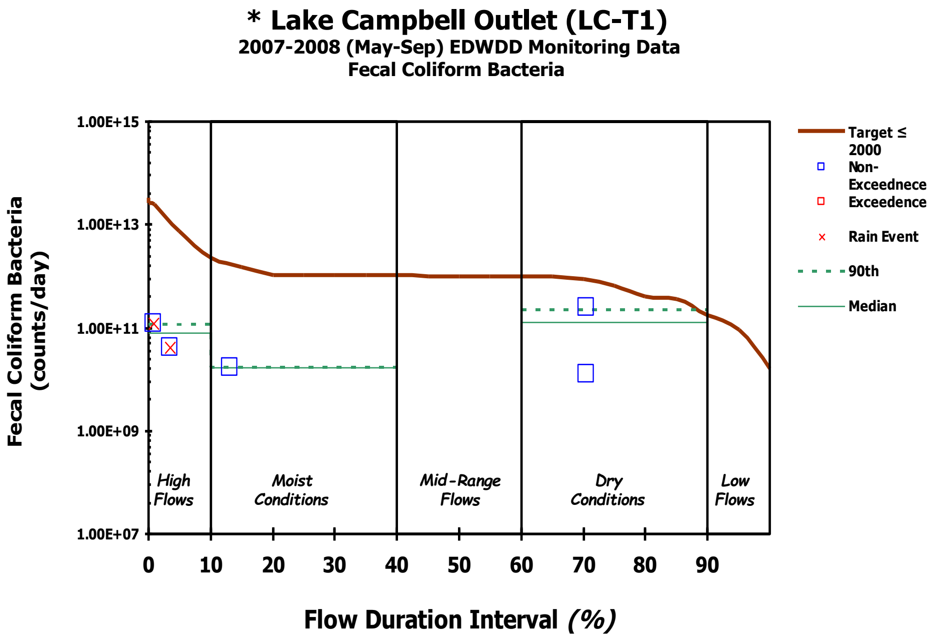
Table 66. AnnAGNPS Feedlot Ratings ≥ 50

Feedlot	Watershed	Rating
35	Lake Campbell	51
52	Lake Campbell	51
72	Lake Campbell	51
87	Lake Campbell	53
82	Lake Campbell	54
70	Lake Campbell	55
22	Lake Campbell	56
88	Lake Campbell	58
14	Lake Campbell	61
61	Lake Campbell	61
31	Lake Campbell	65
56	Lake Campbell	65
64	Lake Campbell	66
78	Lake Campbell	66
51	Lake Campbell	73
23	Lake Campbell	79

Flow Duration Intervals

Flow duration intervals were constructed for the monitored inlet and outlet to assess that status of fecal coliform bacteria and total suspended solids entering and leaving the lake. Lake Campbell is assigned beneficial uses which are associated with numeric standards for fecal coliform bacteria and total suspended solids. These flow duration intervals could be used to assess the amount of bacteria and sediment loading the inlet and outlet are carrying in comparison to the numeric standard that is applicable for the lake. Sample data collected during this project were used in the calculation of the loadings.

The outlet of Lake Campbell (Site LC-T1) is not assigned water quality standards for fecal coliform bacteria or total suspended solids. The target line on the flow duration interval graphs for LC-T1 are based on the numeric criteria related to the Big Sioux River. Because this stream drains into the Big Sioux River a few miles downstream it must meet the criteria assigned to the river which is ≤ 2,000 cfu/100mL for fecal coliform bacteria and ≤ 158 mg/L for total suspended solids (Figure 41 and 42). The Battle Creek inlet (Site LC-T2) is assigned water quality standards for fecal coliform bacteria (≤ 2,000 cfu/100mL) and for total suspended solids (≤ 263 mg/L). The target line on the flow duration interval graphs for LC-T2 are based on the numeric criteria related to Lake Campbell which is ≤ 400 cfu/100mL of fecal coliform bacteria and ≤ 263 mg/L for total suspended solids (Figure 43 and 44). According to **South Dakota Administrative Rule 74:51:01:04,** when a waterbody enters into another waterbody with a more stringent water quality standard, the more stringent standard must be used to assess the contiguous waterbodies. Thus, Battle Creek must meet the more stringent water quality criteria assigned to Lake Campbell for fecal coliform bacteria.



* Numeric standard does not apply

Figure 41. Fecal Coliform Bacteria Flow Duration Interval (Site LC-T1)

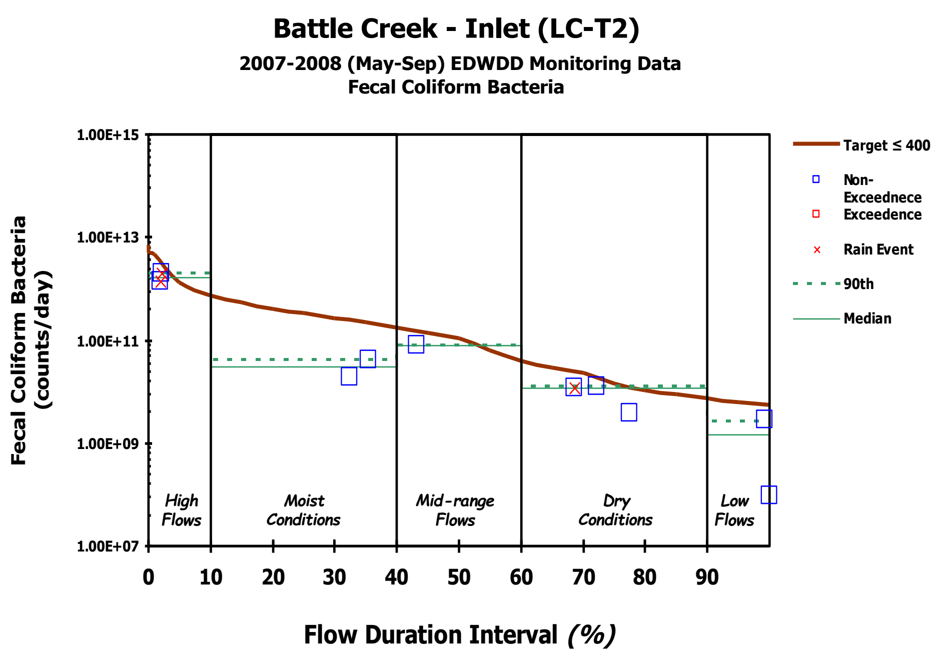
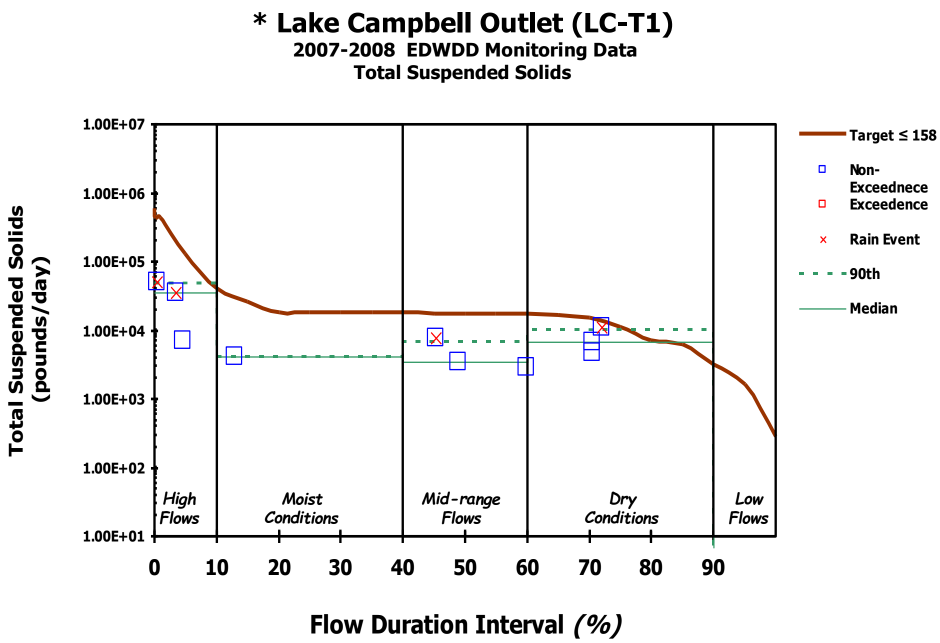


Figure 42. Fecal Coliform Bacteria Flow Duration Interval (Site LC-T2)



* Numeric standard does not apply

Figure 43. Total Suspended Solids Flow Duration Interval (Site LC-T1)

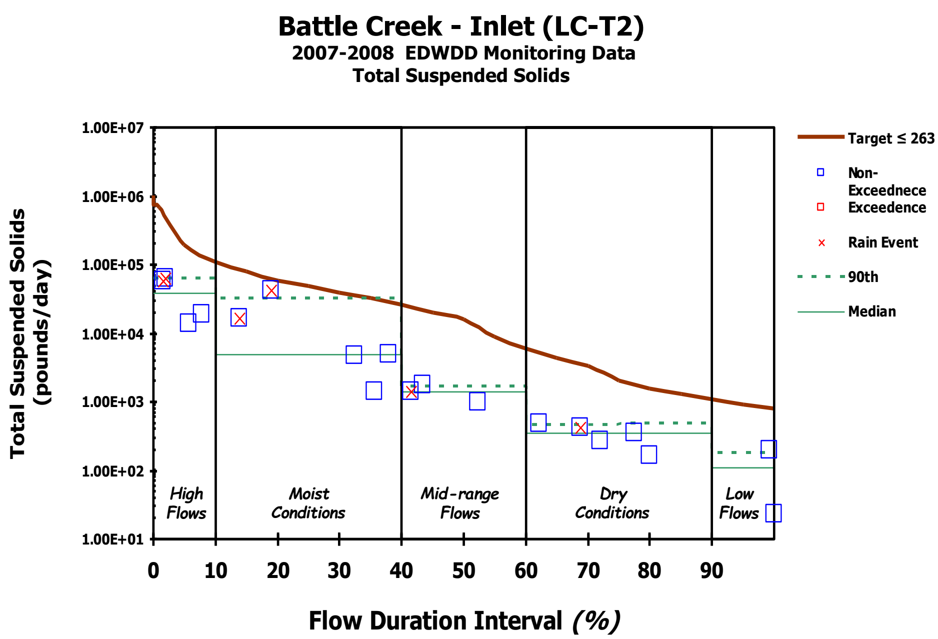


Figure 44. Total Suspended Solids Flow Duration Interval (Site LC-T2)

ASSESSMENT OF SOURCES

Point Sources

There are no municipalities or known point sources located within this watershed.

Non-Point Sources

Agricultural Runoff

Agricultural runoff was taken into account when the AnnAGNPS model calculated sediment and nutrient loadings using different landuse scenarios. Agricultural runoff was also taken into account when AnnAGNPS was used to perform ratings of the feedlots in the study area. This information was then incorporated in the process of prioritizing watershed areas for reduction in nutrients.

Background Wildlife Contribution

The average contribution of fecal coliform bacteria from deer (white tail and mule) is estimated at 1.06×10^{14} colony forming units, watershed wide, during approximately eight months of open (unfrozen) surface water (Table 67). This number assumes 100 percent of the fecal coliform bacteria from deer are delivered into the receiving waters. Therefore, due to its unrealistic 100 percent delivery only for deer, it will represent all wildlife contributions in this watershed for this project.

Wildlife Background - Fecal Coliform Contibution						
County	Deer per Acre	# Acres in Watershed	# of Deer	# Days	CFU per Deer per Day	Total CFUs
Lake	0.008	93090	745	153	5.00E+08	5.70E+13
Brookings	0.005	5553	28	153	5.00E+08	2.12E+12
Moody	0.006	18290	110	153	5.00E+08	8.40E+12
Kingsbury	0.007	322	2	153	5.00E+08	1.72E+11
TOTAL	.					6.77E+13

Table 67. Fecal Coliform Bacteria Contributions From Wildlife May Through September

Failing Septic Systems Contribution

The calculated average contribution of fecal coliform bacteria from failing rural septic systems is 8.54×10^{13} colony forming units, watershed-wide, between May 1 and September 30 (Table 68). This table takes into account occupied "rural" households and occupied "lake residential" households. According to the US EPA (2002), failure rates of onsite septic systems range from 10 to 20 percent, with a majority of these failures occurring with systems 30 or more years old. This percentage assumes 20 percent of the estimated rural septic systems are failing and reaching the receiving waters. The exact number of onsite septic systems in the study area is unknown. There are approximately 150 homes located along the shoreline of Lake Campbell, of which 65 percent are year-round residents.

Table 68. Fecal Coliform Bacteria Contribution From Failing Septic Systems

Failing Septic Estimations - Lake Campbell Watershed							
Area	Avg People per Household	# of Households	20% Failure	Total People	# Days in Season	CFUs per person per day	Total CFU's from Septics
Rural	2.5	453	90.6	227	153	2.00E+09	6.93E+13
Lake Residential	2.5	105	21	53	153	2.00E+09	1.61E+13
TOTAL							8.54E+13

HISTORICAL REVIEW

ACTIVITIES SINCE 1993

Activities in and around the watershed since the 1993 Diagnostic/Feasibility study:

- A Lake Campbell Sanitary Sewer District was incorporated in 1994.
- A preliminary design of a centralized sewer system was completed in 1996.
- Between 1995 and 1999 the following BMPs were implemented:
  - Creating one wetland
  - Constructing one animal waste storage unit
  - Constructing one animal waste diversion
  - Enrolling 3,800 acres of no-tillage
  - Enrolling 1,500 acres of conservation tillage
  - Planting five acres in trees
  - Installing three grazing systems with dugouts
  - Applying Integrated Crop Management to 480 acres
  - Constructing 19,450 linear feet of grassed waterways
  - Stabilizing 8,000 linear feet stream bank with riparian buffer and riprap
  - Stabilizing 2,400 linear feet of shoreline
  - Mass mailing of brochures and fact sheets for information & education
- In 1999 the concrete dam (built in 1929) at the outlet of Lake Campbell was replaced.

HISTORICAL LAKE LEVELS AND PRECIPITATION

Long-term Lake Levels and Precipitation

The following two figures (Figure 45 and 46) show lake levels over the past 42 years as well as the historical precipitation totals.

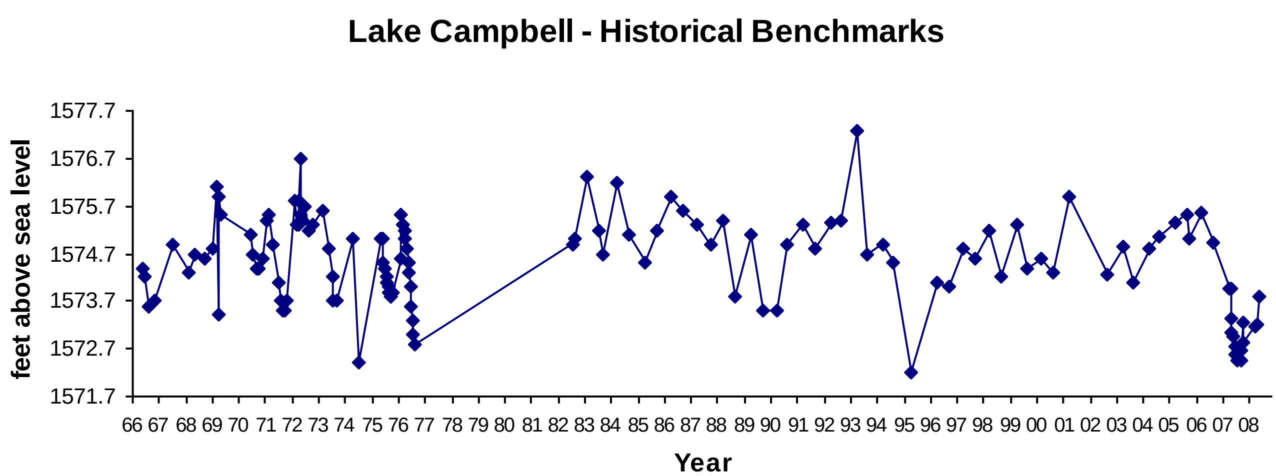


Figure 45. Historical Benchmarks (1966-2008)

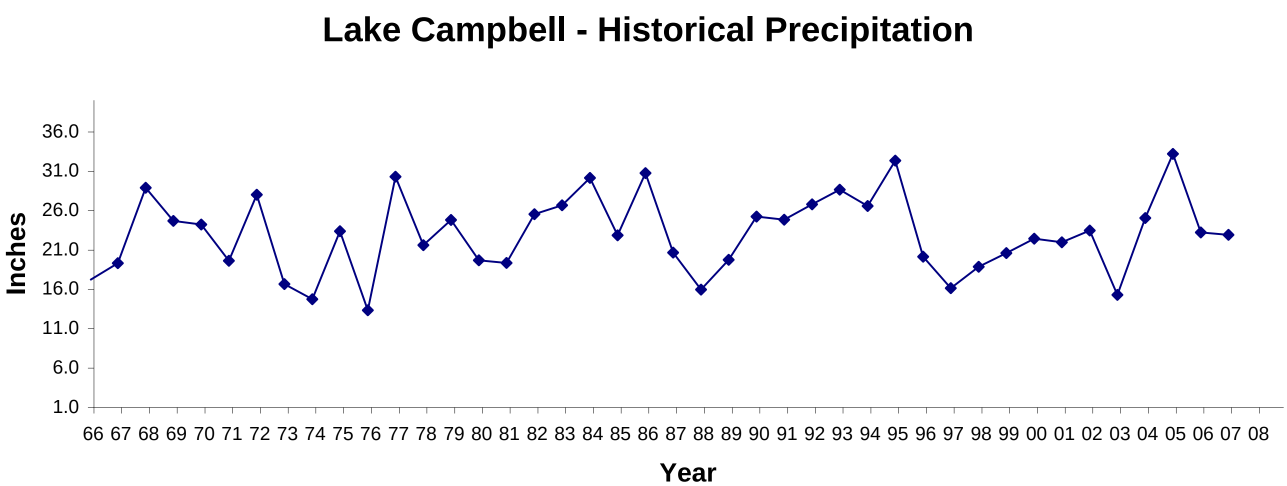


Figure 46. Historical Precipitation Totals (1966-2007)

WATER QUALITY HISTORY

Water Quality Comparisons

Over the past 32 years, during four specific periods of time, sampling of water quality has occurred at Lake Campbell. The first record of sampling of the lake for water quality was in 1976 by the East Dakota Conservancy Sub-District, now known as the East Dakota Water Development District. Water sampling was also completed during the 1983 Water Quality Assessment (SD DWNR 1985). A third set of samples were collected during the diagnostic/feasibility study in 1991 and 1992 and then most recently during the post-assessment project from 2007-2008. It should be noted that water quality samples were also collected during the dredging project (1987-1989). However the dredging report could not be located and therefore the sampling locations are unknown making the data unusable.

Table 69 compares water quality averages during these four periods of time. The only water quality parameters that were comparable among all the years were dissolved oxygen, total phosphorus, ammonia, total dissolved phosphorus, and fecal coliform bacteria. Sites LC-1, LC-2, and LC-3 are the in-lake sites, LC-T1 is the lake outlet and LC-T2 is the inlet on Battle Creek. The comparison does not show much deviation in averages among the years and in-lake sites. The only noticeable improvement since the initial assessment period is with ammonia. The tributaries both seem to show improvements, based on average water quality, in dissolved oxygen, nutrients (total phosphorus and total dissolved phosphorus), and ammonia.

In the 1985 assessment report, fecal coliform observations at Site LC-T2 (inlet) ranged from 10 cfu/100 mL to 1,800 cfu/100 mL (Table 70). Recent water quality results exceed these numbers, with ranges from 'no detect' to 2,600 cfu/100 mL. Comparison of the medians from these two periods shows 10 cfu/100mL in 1983 and 150 cfu/100mL in 2007-2008.

Ranges in ammonia have significantly decreased over the past 30 years in the lake and at the outlet. In the 1980's the range was 0.02 mg/L to 7.2 mg/L and in 2007-2008 ammonia ranged from "no detect" to 1.04 mg/L.

Table 69. Historical Water Quality Averages

Lake Campbell - Historical WQ Averages						
Site LC-1 (north in-lake)						
	DO	**TPO4**	**NH3N**	**TDPO4**	**Fecal**	**Comments**
1983	10.20	0.334	0.995	0.113	63	aka site 46CA05
1991-1992	9.28	0.228	------	0.098	15	aka CAMPB96CL01
2007-2008	8.45	0.292	0.116	0.110	6	
Site LC-2 (middle in-lake)						
	DO	**TPO4**	**NH3N**	**TDPO4**	**Fecal**	**Comments**
1976-1977	9.66	0.185	3.318	0.060	7	aka site 46BG01
1983	------	0.230	0.040	0.021	10	aka site 46CA06
1991-1992	8.76	0.251	------	0.116	21	aka CAMPB96CL02
2007-2008	9.61	0.307	0.139	0.115	7	
Site LC-3 (south in-lake)						
	DO	**TPO4**	**NH3N**	**TDPO4**	**Fecal**	**Comments**
1983	10.14	0.305	0.973	0.112	121	aka site 46CA04
1991-1992	9.70	0.283	------	0.090	19	aka CAMPB96CL03
2007-2008	8.49	0.304	0.149	0.118	15	
Site LC-T1 (outlet)						
	DO	**TPO4**	**NH3N**	**TDPO4**	**Fecal**	**Comments**
1983	9.59	0.506	1.078	0.210	375	aka site 46CA03
1991	11.40	------	------	------	------	aka CAMPB96CT01
2007-2008	12.74	0.207	0.070	0.071	70	
Site LC-T2 (Battle Creek inlet)						
	DO	**TPO4**	**NH3N**	**TDPO4**	**Fecal**	**Comments**
1983	9.39	0.416	0.216	0.281	288	aka site 46CA01
1989	8.97	0.318	0.367	0.031	------	46CAT1 (1/2 mi upstream)
1991-1992	10.91	0.348	0.057	0.217	207.43	aka CAMPB96CT03
2007-2008	10.52	0.245	0.061	0.131	325	

Table 70. Historical Water Quality Ranges

Lake Campbell - Historical WQ Ranges											
Site LC-1 (north in-lake)											
	DO	*n =*	**TPO4**	*n =*	**NH3N**	*n =*	**TDPO4**	*n =*	**Fecal**	*n =*	**Comments**
1983	3.5 - 15.6	*10*	0.166 - 0.644	*10*	0.02 - 3.64	*10*	0.006 - 0.369	*10*	10 - 170	*7*	aka site 46CA05
1991-1992	3.4 -15	*16*	0.115 - 0.369	*16*	------	*0*	0.034 - 0.325	*15*	2 - 60	*16*	aka CAMPB96CL01
2007-2008	1.8 - 15	*15*	0.122 - 0.561	*15*	nd - 1.04	*14*	0.022 - 0.302	*15*	nd - 40	*13*	
Site LC-2 (middle in-lake)											
	DO	*n =*	**TPO4**	*n =*	**NH3N**	*n =*	**TDPO4**	*n =*	**Fecal**	*n =*	**Comments**
1976-1977	5.4 -14.7	*5*	0.121 - 0.275	*5*	0.02 - 7.2	*5*	0.004 - 0.175	*5*	3 - 13	*5*	aka site 46BG01
1983	------	*0*	0.230	*1*	0.040	*1*	0.021	*1*	10	*1*	aka site 46CA06
1991-1992	3.8 - 17	*16*	0.136 - 0.400	*16*	------	*0*	0.047 - 0.318	*14*	2 - 114	*16*	aka CAMPB96CL02
2007-2008	1.36 - 19.6	*15*	0.109 - 0.596	*20*	nd - 1.01	*14*	0.022 - 0.332	*15*	nd - 80	*13*	
Site LC-3 (south in-lake)											
	DO	*n =*	**TPO4**	*n =*	**NH3N**	*n =*	**TDPO4**	*n =*	**Fecal**	*n =*	**Comments**
1983	4.6 - 15.6	*9*	0.173 - 0.417	*10*	0.02 - 3.53	*10*	0.009 - 0.35	*10*	10 - 480	*7*	aka site 46CA04
1991-1992	5.2 - 16.5	*15*	0.075 - 0.827	*16*	------	*0*	0.02 - 0.224	*14*	2 - 92	*16*	aka CAMPB96CL03
2007-2008	0.80 - 15.8	*15*	0.110 - 0.564	*15*	nd - 0.82	*14*	0.018 - 0.340	*15*	nd - 120	*13*	
Site LC-T1 (outlet)											
	DO	*n =*	**TPO4**	*n =*	**NH3N**	*n =*	**TDPO4**	*n =*	**Fecal**	*n =*	**Comments**
1983	4.7 - 15	*12*	0.115 - 2.21	*16*	0.04 - 3.86	*16*	0.005 - 0.342	*16*	10 - 3500	*10*	aka site 46CA03
1991	9.6 - 13.2	*4*	------	*0*	------	*0*	------	*0*	------	*0*	aka CAMPB96CT01
2007-2008	8.38 - 26.66	*12*	0.12 - 0.384	*12*	nd - 0.76	*12*	0.022 - 0.277	*12*	nd - 580	*11*	
Site LC-T2 (Battle Creek inlet)											
	DO	*n =*	**TPO4**	*n =*	**NH3N**	*n =*	**TDPO4**	*n =*	**Fecal**	*n =*	**Comments**
1983	4.4 - 15.4	*15*	0.139 - 0.798	*18*	0.02 - 0.81	*18*	0.015 - 0.669	*18*	10 - 1800	*11*	aka site 46CA01
1989	4.7 - 13.6	*9*	0.115 - 0.475	*9*	0.02 - 1.62	*9*	0.005 - 0.133	*9*	------	*0*	46CAT1 (1/2 mi upstream)
1991-1992	6.5 - 16	*21*	0.122 - 0.83	*21*	0.02 - 0.220	*13*	0.136 - 0.305	*6*	2 - 1400	*21*	aka CAMPB96CT03
2007-2008	5.74 - 15.36	*20*	0.121 - 0.507	*20*	nd - 0.85	*20*	0.041 - 0.264	*19*	nd - 2600	*18*	

Several graphs were constructed from water quality samples collected in-lake between 1976 and 2008 for trend analysis (Figures 47 through 50). The in-lake monitoring sites do not indicate any trends (increase or decreases) in phosphorus, fecal coliform bacteria, or dissolved oxygen over the past 32 years.

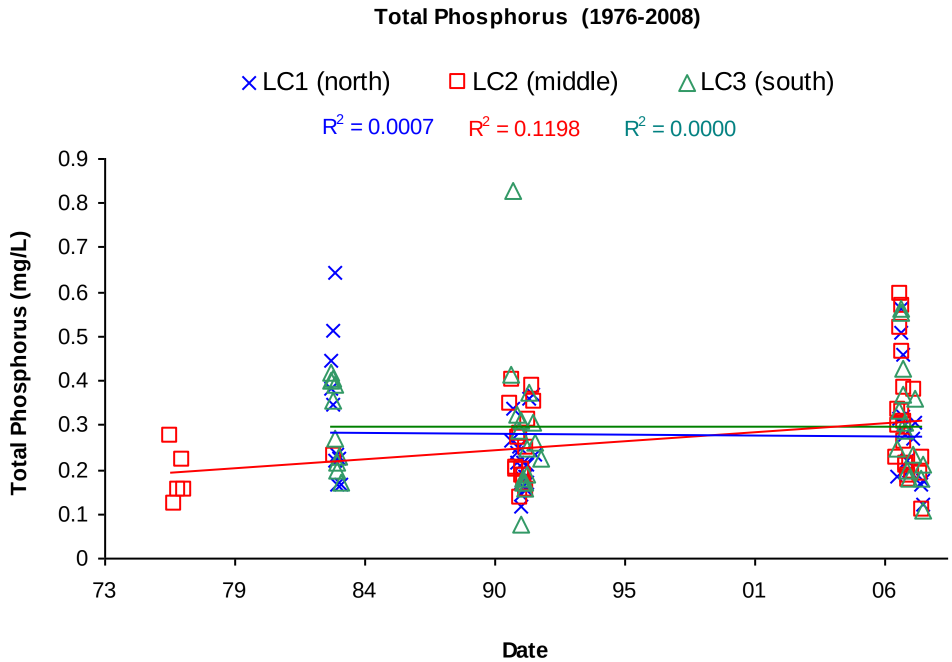


Figure 47. Total Phosphorus Trends of the In-Lake Sites (1976-2008)

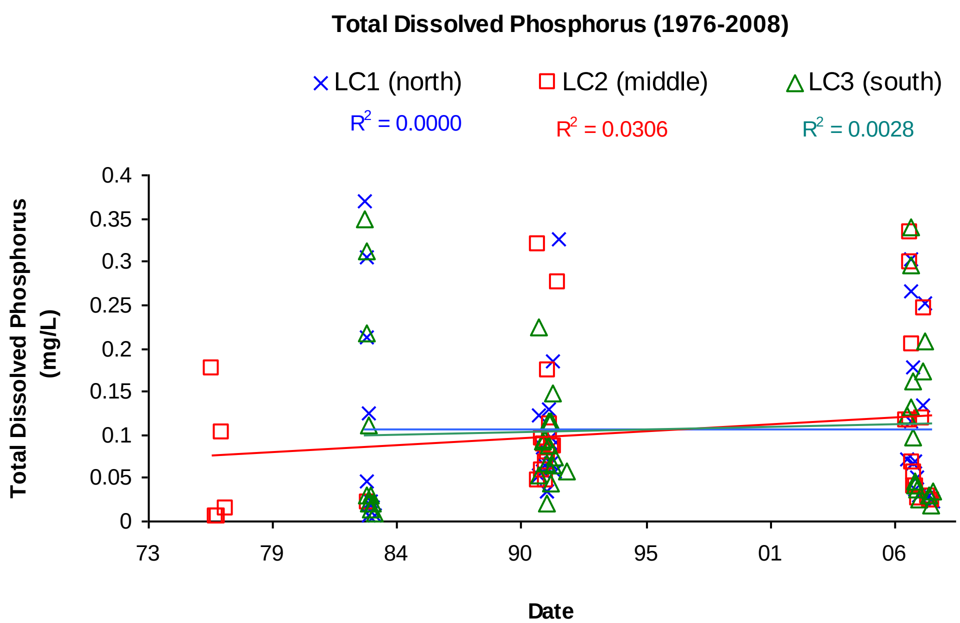


Figure 48. Total Dissolved Phosphorus Trends of the In-Lake Sites (1976-2008)

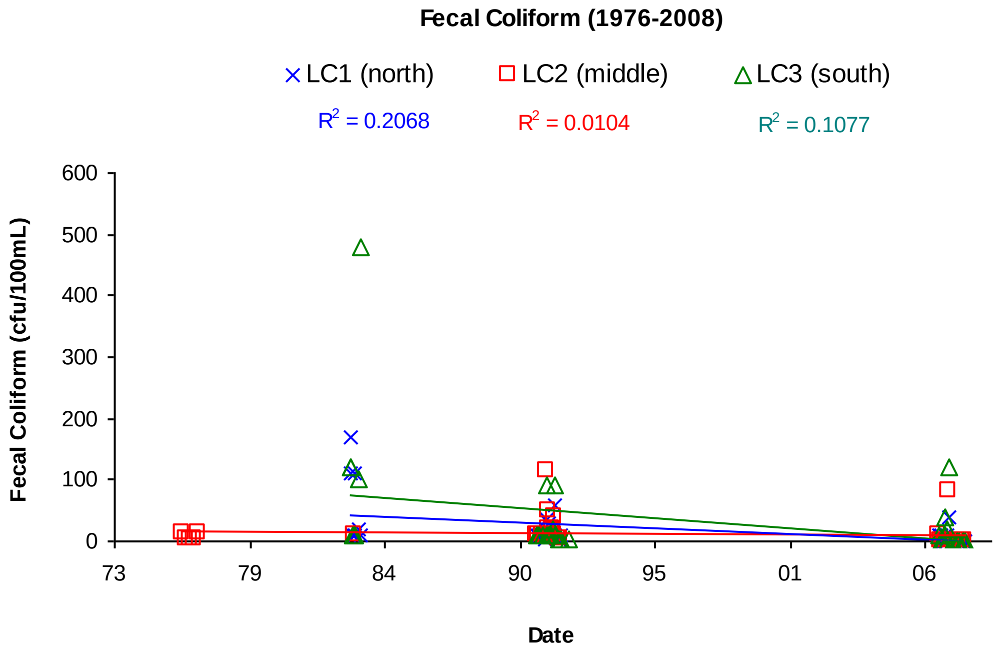


Figure 49. Fecal Coliform Bacteria Trends of the In-Lake Sites (1976-2008)

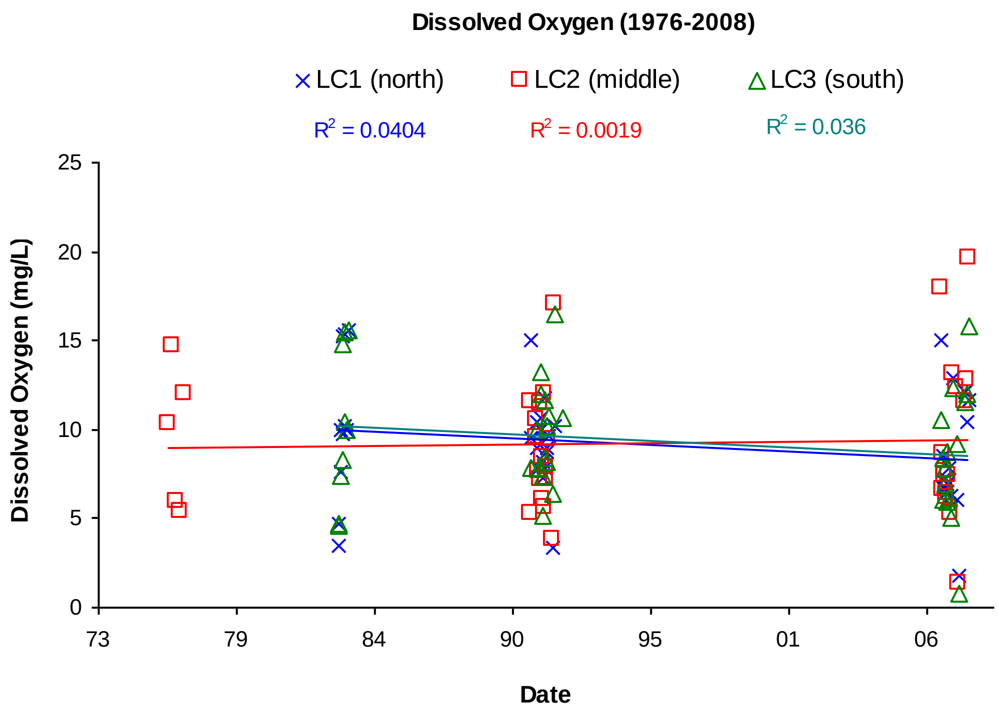


Figure 50. Dissolved Oxygen Trends of the In-Lake Sites (1976-2008)

Median surface water quality data for fecal coliform bacteria, total phosphorus, and total dissolved phosphorus were compiled (Table 71). The data does not show conclusive evidence of reductions in the lake for any of the parameters. Total phosphorus and total dissolved phosphorus concentrations remain elevated within the lake and decreasing in the outlet since the 1970s, possibly indicating more being retained within the lake. The 1993 Diagnostic/Feasibility study stated, "Significantly higher loadings of total phosphorus and total dissolved phosphorus are entering the lake than are leaving the lake". Fecal coliform bacteria remain relatively high within the inlet, probably due to cattle being allowed access to the stream in the immediate area. Median data of total phosphorus and total dissolved phosphorus at the inlet does indicate decreases in concentrations since the 1970s, possibly due to more conservative agricultural practices. It is unknown if decreases in nutrients has resulted from established BMPs, or from seasonal differences.

Table 71. Historical Water Quality Medians

	Fecal Coliform Bacteria			Total Phosphorus			Total Dissolved Phosphorus		
Lake	Median	Average	Sample #	Median	Average	Sample #	Median	Average	Sample #
1976-1977	3	7	5	0.155	0.185	5	0.015	0.060	5
1983	20	87	15	0.271	0.316	21	0.030	0.108	21
1991-1992	10	19	48	0.232	0.254	48	0.085	0.101	42
2007-2008	nd	10	39	0.284	0.302	50	0.070	0.114	45

	Fecal Coliform Bacteria			Total Phosphorus			Total Dissolved Phosphorus		
Outlet	Median	Average	Sample #	Median	Average	Sample #	Median	Average	Sample #
1983	25	375	10	0.377	0.506	16	0.250	0.210	16
1991	-----	-----	0	-----	-----	0	-----	-----	0
2007-2008	10	70	11	0.182	0.207	12	0.043	0.071	12

	Fecal Coliform Bacteria			Total Phosphorus			Total Dissolved Phosphorus		
Inlet	Median	Average	Sample #	Median	Average	Sample #	Median	Average	Sample #
1983	10	288	11	0.412	0.416	18	0.292	0.281	18
1989	-----	-----	0	0.319	0.318	9	0.010	0.031	9
1991-1992	28	207	21	0.302	0.348	21	0.209	0.217	6
2007-2008	150	325	18	0.232	0.245	20	0.112	0.131	19

Graphs of the grab samples from the outlet (Site LC-T1) and the inlet (Site LC-T2) are shown in Figures 51, 52 and 53. The only data that was historically comparable over the years 1983-2008 were total phosphorus, total dissolved phosphorus, dissolved oxygen, fecal coliform bacteria, and ammonia (nitrogen as N). At the outlet (Site LC-T1) there were noticeable decreasing trends in total dissolved phosphorus and ammonia (nitrogen as N).

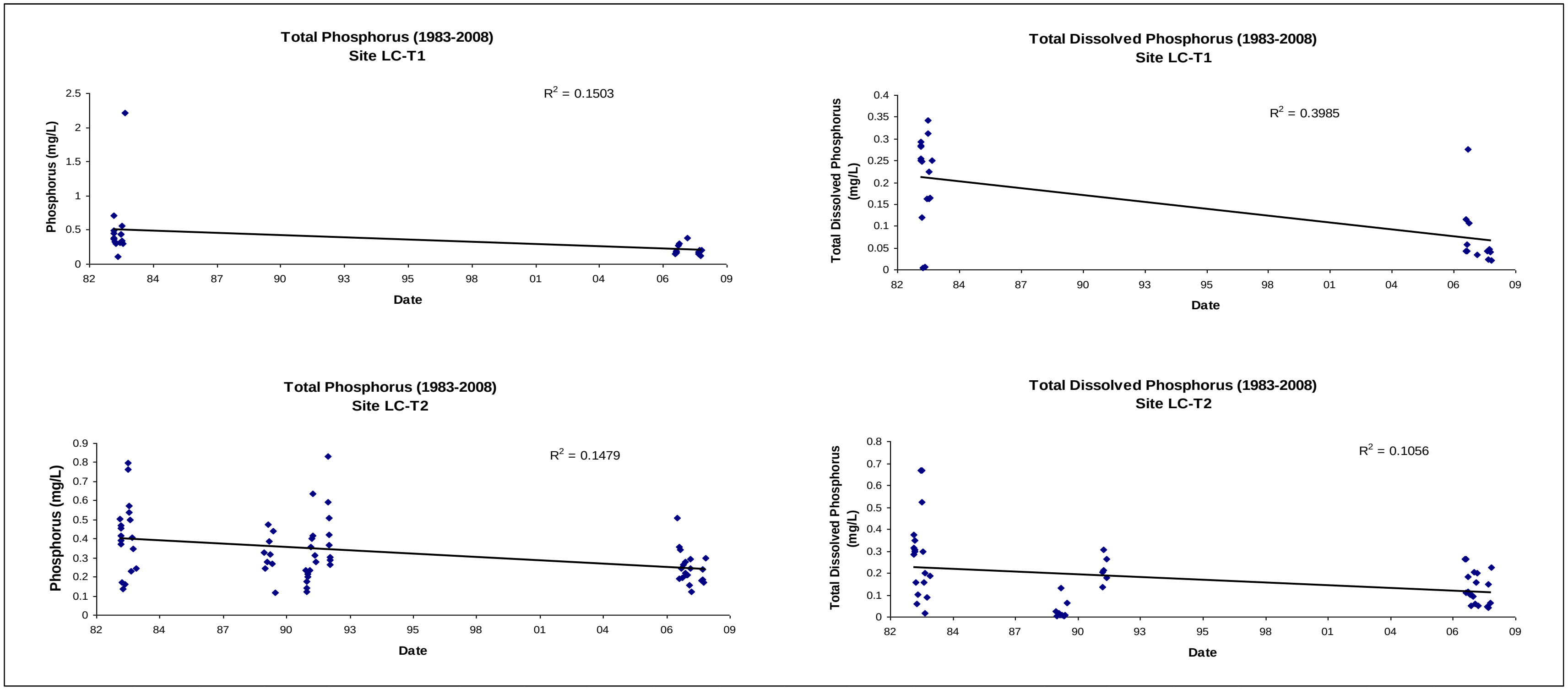


Figure 51. Total Phosphorus and Total Dissolved Phosphorus Trends - Tributaries (1983-2008)

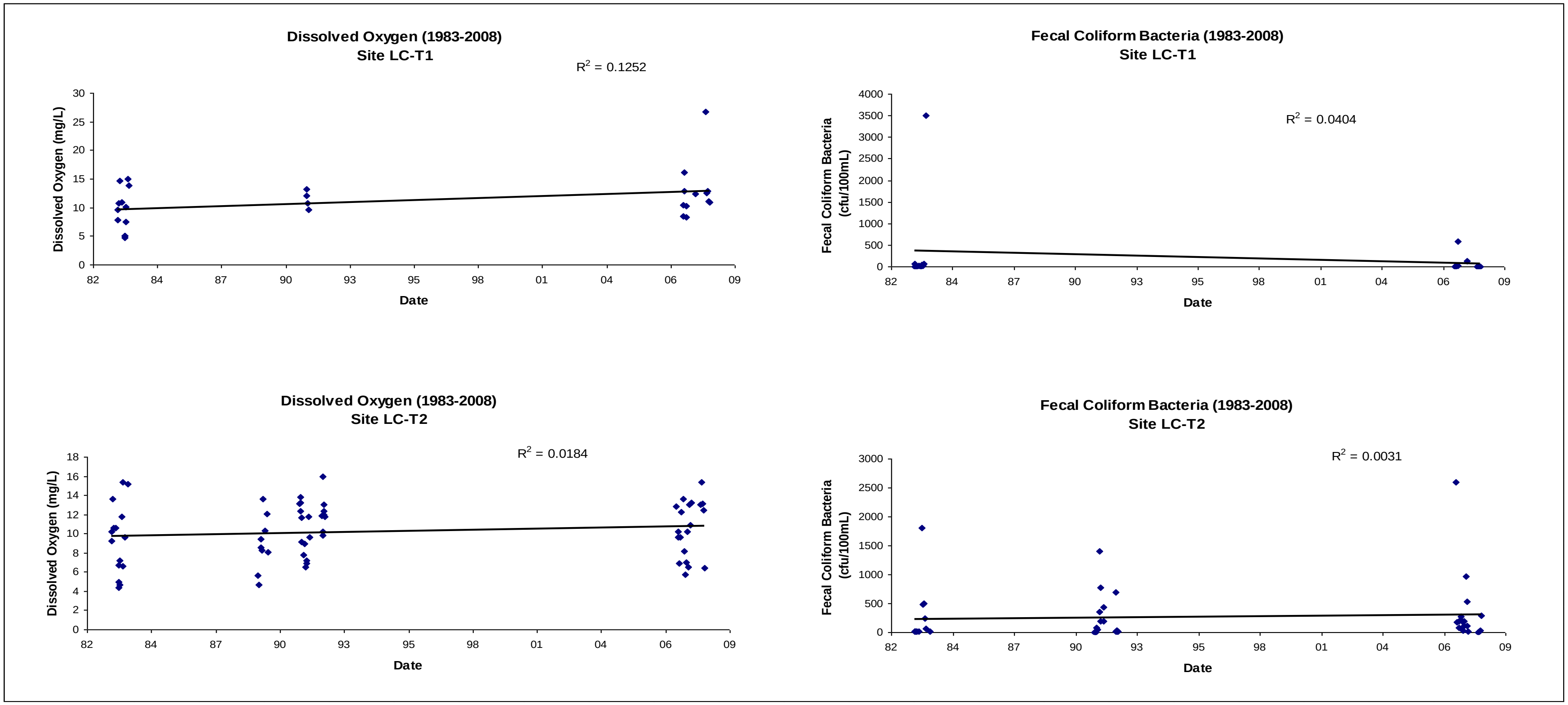


Figure 52. Dissolved Oxygen and Fecal Coliform Bacteria Trends - Tributaries (1983-2008)

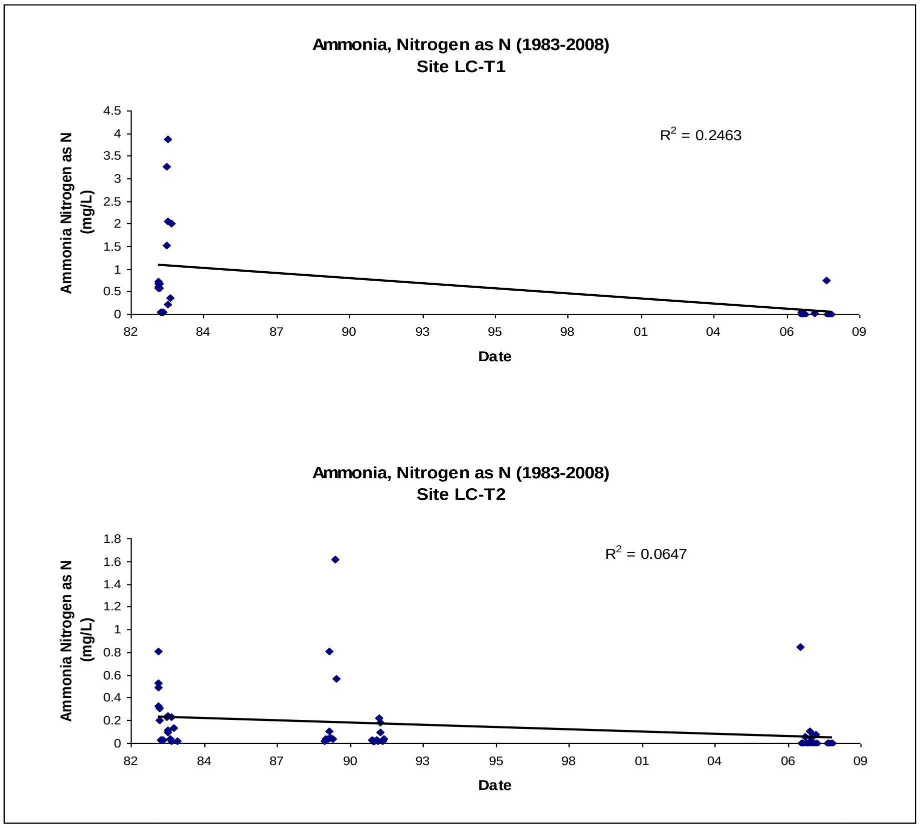


Figure 53. Ammonia, Nitrogen as N Trends of Tributary Sites (1983-2008)

NUTRIENT AND SEDIMENT HISTORY

Nutrient and Sediment Comparisons

Estimates of the amount of sediment and nutrients coming from the Lake Campbell watershed were calculated in the 1980s and again in 2007-2008. Tables 72 and 73 show the 1986 and 1987 AGNPS results reported in the 1989 Water Resource Institute report. The results are based on a 25-year simulation, using a 24-hour precipitation event (4.6 inches). AGNPS is an agricultural non-point source model used for predicting sediment and nutrient loads based on agricultural practices and precipitation events.

Table 72. 1986 AGNPS Results

1986 AGNPS Results for Nutrients

	Original Nitrogen (pounds/acre)	Original Phosphorus (pounds/acre)
Sediment	0.29	0.15
Soluble	2.78	0.56
Total	**3.07**	**0.71**

Table 73. 1987 AGNPS Results

1987 AGNPS Results for Nutrients & Achievable Reductions				
	Original Nitrogen (pounds/acre)	Conservation Tillage Applied	Original Phosphorus (pounds/acre)	Conservation Tillage Applied
Sediment	0.29	0.25	0.15	0.12
Soluble	1.35	1.23	0.23	0.21
Total	**1.64**	**1.48 (10% redux)**	**0.38**	**0.33 (13% redux)**

The results of the 1989 study showed that "increasing the acreage of land treated with conservation tillage significantly reduced sediment and nutrient discharges from Battle Creek". Also "reducing fertilizer rate on cropland by a factor of one have decreased the discharge of both total nitrogen and total phosphorus by 27 percent. Combining this with a conversion to fertilizer injection reduced total nitrogen and phosphorus discharges by 40 and 42 percent, respectively". The study also found that "implementation of the Conservation Reserve Program (CRP) significantly reduced the sediment and nutrient discharges entering Lake Campbell" especially in the northeast quarter of the watershed.

The AnnAGNPS results from the 2007-2008 assessment showed similar results to that of the 1989 study. The AnnAGNPS model expands the capabilities of the AGNPS model. It models the watershed based on homogenous land areas or cells. Table 74 shows the results of a 25-year simulation period, during a 24-hour precipitation event.

Table 74. 2007-2008 AnnAGNPS Results

2007-2008 AnnAGNPS Results for Nutrients & Achievable Reductions				
	Original Nitrogen (pounds/acre)	Conservation Tillage Applied	Original Phosphorus (pounds/acre)	Conservation Tillage Applied
Sediment	0.259	0.132	0.023	0.008
Soluble	0.644	0.733	0.477	0.395
Total	**0.903**	**0.865 (4% redux)**	**0.500**	**0.404 (19% redux)**

The 2007-2008 results also showed the greatest reductions in nutrients when no-till practices were used and even a greater reduction when cropland was converted to grassland. The 2007-2008 modeled scenarios showed no significant loadings in sediment to the lake.

Sediment Survey Comparisons

In 1986 the Water Resource Institute was contracted by the East Dakota Water Development District to complete a study to determine the amount of sediment and nutrients coming from agricultural land and entering Lake Campbell. That study revealed 1.19 million cubic feet of sediment had discharged from the watershed into Lake Campbell between 1966 and 1985. This volume was equal to 0.4 inches of deposition over the entire lake bottom. Between 1987 and 1989, 220,000 cubic yards of sediment were removed from two locations in Lake Campbell.

Professional engineers, Bernhard, Eisenbraun and Associates of Yankton, South Dakota, were hired in the fall of 1990 to complete a hydrographic survey of Lake Campbell (See Appendix N for methodology). Topographic maps were drawn with the ranges in depth of the bottom sediment layer and ranges of depth of the water column. Survey results showed the average water column depth at five feet, the average sediment depth at six feet, and the estimated sediment volume at 7,840,000 cubic yards (4,860 acre-feet).

The 1993 Diagnostic/Feasibility study recommended that approximately 1 million cubic yards be removed by dredging to improve the fisheries habitat. The recommendation was to dredge an average sediment depth of 6 feet so that 100 surface acres of the lake would have a water column depth of 10-11 feet. At that time it was estimated that could be accomplished in two years at a cost of $1,000,000. The study also stated, "…it is recommended that dredging not be undertaken right away. This would provide an opportunity to reduce sediment loadings into the lake through shoreline and watershed work. It will also provide the Lake Campbell Association and other local entities the time required to secure the resources necessary for a major dredging project".

Dredging efforts have not recurred since 1989.

The SD DENR completed another sediment survey in 2008. The survey estimated the volume of sediment to be 1.3 million cubic yards (See Appendix N for methodology). As can be seen by the different estimates in sediment surveys, the methodologies used to determine sediment volume can make a big difference.

Long-Term TSI Trends

Phosphorus, Secchi depth, and chlorophyll-*a* TSI was plotted using available data from 1976-2008 (Figure 54). There has been no noticeable change in total phosphorus in Lake Campbell. Chlorophyll-*a* amounts seems to be increasing and water clarity seems to be decreasing. However, the data does not indicate a significant trend of either parameter at this time. The 1985 water quality report stated, "The major problem of Lake Campbell is an excess of nitrogen and phosphorus". The 1993 Diagnostic/Feasibility study stated, "Levels of total phosphorus were found in Lake Campbell that may be leading to impairment of the beneficial uses of the lake". See Appendix P for the historic TSI data.

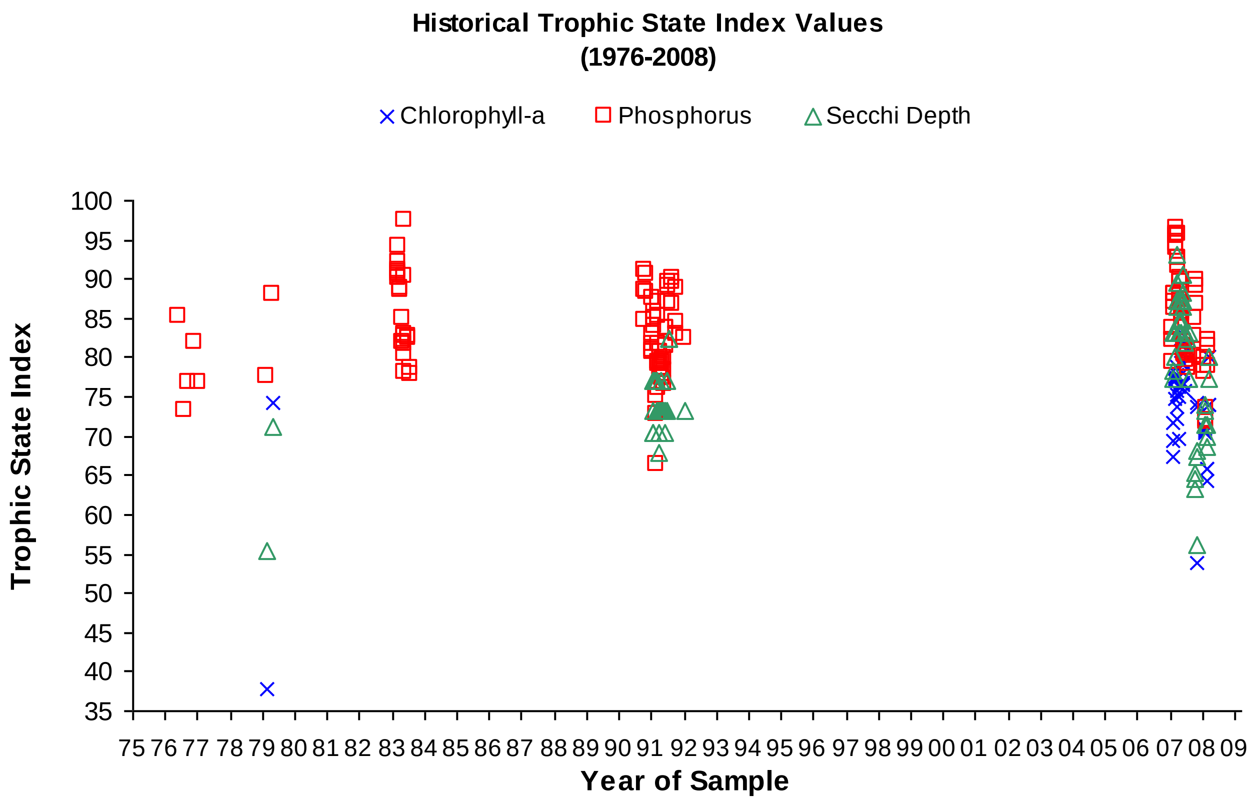


Figure 54. Lake Campbell Historical Trophic State Index Values (1976-2008)

Algae History (1998-2008)

Algae species in Lake Campbell have been documented since 1998. From June 1998 to July 2006 the most abundant algae species was *Aphanizomenon flos-aquae*, with the exception of August 1998 when *Glenodinium gymnodinium* was the most abundant species (Table 75). The sampling in 2007 showed the dominance in blue-green algae switched to *Oscillatoria agardhii*. Both *Aphanizomenon flos-aquae* and *Oscillatoria agardhii* are blue-green algae species. Both can form algae blooms and become toxic if conditions are right. *Oscillatoria* sp. is a strong competitor with the *Aphanizomenon* sp., especially under high phosphorus and ammonia concentrations. High levels of different organic forms of nitrogen may enhance the development of *Oscillatoria*. This is one of the differences between the two species; *Aphanizomeno*n fixes atmospheric nitrogen, whereas *Oscillatoria* needs organic nitrogen to thrive. The change in dominance was likely due to the mixing of bottom sediments and/or strong winds and heavy rains. For more information about algae species and their abundance since 1998 see Appendix P.

Table 75. Most Abundant Algae (1998-2008)

Most Abundant Algae Species (1998-2008)		
Jun-98	**Biovolume (µm3/mL)**	**Algae Type**
Aphanizomenon flos-aquae	15,841,800	Blue-Green
Aug-98		
Glenodinium gymnodinium	48,691,080	Flagellated
Jul-02		
Aphanizomenon flos-aquae	5,692,050	Blue-Green
Aug-02		
Aphanizomenon flos-aquae	2,846,376	Blue-Green
Jun-06		
Aphanizomenon flos-aquae	218,790	Blue-Green
Jul-06		
Aphanizomenon flos-aquae	71,161,740	Blue-Green
Jun-07		
Oscillatoria agardhii	89,559,792	Blue-Green
Aug-07		
Oscillatoria agardhii	76,434,720	Blue-Green
Feb-08		
Oscillatoria agardhii	3,594,240	Blue-Green
Apr-08		
Oscillatoria agardhii	12,060,000	Blue-Green
May-08		
Oscillatoria agardhii	6,330,240	Blue-Green
Jun-08		
Oscillatoria agardhii	27,020,400	Blue-Green

WATER QUALITY GOALS

Water quality goals are based on beneficial uses and the numeric standards assigned to meet those uses. Based on water quality monitoring results, Lake Campbell was found to be fully supporting of its assigned beneficial uses. However, modeled TSI levels indicate Lake Campbell carries excessively high nutrient levels and is in a hypereutrophic condition. These high nutrient levels can adversely affect aquatic life as well as discourage recreational use of the lake. The recommended TSI level for a warm-water marginal fishery is ≤ 68.4. Currently, Lake Campbell is showing a modeled TSI of 78. A 52 percent reduction in nutrient inputs is recommended for Lake Campbell to meet an acceptable target trophic state (≤ 68.4 TSI) in order to properly maintain and/or sustain its warmwater marginal fishery target.

Excessive Nutrients
Phosphorus is the main nutrient that contributes to excessive algae and weed growth in lakes. Sources of phosphorus include human and animal waste, soil erosion, fertilizer runoff, and detergents. It is estimated that phosphorus levels should be maintained below 0.03 mg/L to prevent nuisance algae blooms. During the study period, average total phosphorus was 0.302 mg/L and average total dissolved phosphorus was 0.114 mg/L.

Nitrogen is the second main nutrient contributing to plant growth. Sources of nitrogen are fertilizers, animal wastes, and septic systems. According to the water quality results, Lake Campbell tends toward nitrogen-limited conditions. During the study period average total nitrogen was 2.86 mg/L and average organic nitrogen was 2.61 mg/L. Seasonal average (May 1 to Sept 30) was 2.95 mg/L for total nitrogen and 2.76 mg/L for organic nitrogen.

Using the predicted modeling data this lake is considered hypereutrophic. This means Lake Campbell has high levels of nutrients which are contributing to algae growth. Increasing productivity is a natural lake process. However, human induced conditions (i.e. agricultural practices and lakeshore activities) can speed up these processes, becoming detrimental to the aquatic life living there. Total phosphorus levels should be kept below 0.1 mg/L if possible. Phosphorus is the limiting factor for algae growth in lakes with high nitrogen and low phosphorus.

Siltation
Silt is composed of mineral (soils) or organic (algae) particulates. Excessive siltation can cause an overabundance of phosphorus, due to the sediment releasing phosphorus during periods of anoxia. Phosphorus can also be released after the sediment is re-suspended due to wave action, benthic fish foraging, or recreational activities. Bottom sediments in the shallower areas of the lake can contain phosphorus which is stirred up during recreational activities. Dredging efforts during 1987-1989 removed less than half of siltation that was recommended for removal to help improve water quality. Siltation is a normal aging process for any lake, but when a lake has little to no flushing during dry years and high levels of organic matter like that in Lake Campbell, efforts are needed to minimize additional nutrient and sediment particles coming into the lake from the watershed.

Macrrophytes
Lake Campbell exhibited the presence algae and macrophytes during the entire summer period. N:P ratios indicate a trend toward nitrogen limitation. Noxious plant growth can be prevented or at least reduced by lowering the nutrient loading to the lake (both phosphorus and nitrogen). Chlorophyll-*a* concentrations above 40 ug/L are representative of excessive biomass and would be considered "nuisance bloom" levels. Concentrations in excess of 55 ug/L usually indicate hypereutrophic conditions. Chlorophyll-*a*, during 2007-2008 sampling, averaged 101 ug/L with a median of 98 ug/L.

ADDITIONAL MANAGEMENT OPTIONS AND RECOMMENDATIONS

Over the course of the past 32 years, conservation management activities have taken place in and around Lake Campbell. The first initiative was the dredging of two small portions of the lake, which began in 1987 and lasted approximately two years. Reduction of external sources of nutrients and sediment were addressed through BMPs implemented between 1995 and 1999. The concern with this is the external sources of the nutrient and sediment loadings were not reduced before the implementation of the in-lake alternative (dredging). It is imperative to attempt to reduce external loading of sediment and nutrients before tackling in-lake restoration. After assessing the recent water quality data, it appears the inlet is still contributing a fair amount of nutrients to the lake. As of 2008, the modeled TSI for this lake is 78, which warrants a continuation of best management applications by revisiting the areas that were identified for BMP application but not implemented 10 years ago.

BEST MANAGEMENT PRACTICES

External Management of Sediment and Nutrient Sources

Best Management Practices (BMPs) suggested to control external nutrient loads and sediment transport to the lake are shown in Table 76. These BMPs are options for reducing or eliminating external sources of both sediment and nutrients within the watershed. Since this lake does not experience regular flushing, it is important to control as much of the external sources of nutrients as possible. As indicated by the AnnAGNPS model, the loading of nutrients seems to be the biggest issue.

Table 76. Best Management Practices for Reducing Sediment and Nutrient Loads

BMP	TSS	Nutrients	Potential Reduction
(1) Feedlot Runoff Containment		X	High
(2) Manure Management		X	High
(3) Grazing Management	X	X	Moderate
(4) Alternative Livestock Watering	X	X	Moderate
(5) Conservation Tillage (30% residue)	X	X	Moderate
(6) No Till	X	X	High
(7) Grassed Waterways	X	X	Moderate
(8) Buffer/Filter Strips	X	X	Moderate
(9) Commercial Fertilizer Management	X	X	Moderate
(10) Wetland Restoration or Creation	X	X	High
(11) Riparian Vegetation Restoration	X	X	High
(12) Conservation Easements	X	X	High
(13) Livestock Exclusion	X	X	High

Note: approximate range of reductions:
Low = 0-25% Moderate = 25-75% High = 75-100%

Most of these BMPs are further explained in Table 77, with descriptions of the benefits of using a particular BMP and the reduction in sediment and nutrients that can be achieved when put to use. This table was adapted from Minnesota Pollution Control Agency sources (MPCA 1990).

Table 77. Percent Reduction Achievable by Best Management Practice

BMP	Benefits	Achievable Reduction
Manure Management	• Reduces Nutrient Runoff • Significant Source of Fertilizer	50-100% reduction of nutrient runoff
Buffer/Filter Strips	• Controls sediment, phosphorus, nitrogen, organic matter, and pathogens	50% sediment and nutrient delivery reduction
Conservation Tillage	• Reduces runoff • Reduces wind erosion • More efficient in use of labor, time, fuel, and equipment	30-70% pollutant reduction 50% nutrient loss reduction (depends on residue and direction of rows and contours)
Fencing	• Reduces erosion • Increases vegetation • Stabilized banks • Improves aquatic habitat	Up to 70% erosion reduction
Grassed Waterways	• Reduces gulleys and channel erosion • Reduces sediment associated nutrient runoff • Increases wildlife habitat	10-50% sediment delivery reduction (broad) 0-10% sediment deliver reduction (narrow)
Strip Cropping	• Reduces erosion and sediment loss • Reduces field loss of sediment associated nutrients	High quality sod strips filter out 75% of eroded soil from cultivated strips

Improved landuse practices can greatly reduce the amount of nutrients and sediment entering Lake Campbell. In addition to the effects of the watershed on water quality, there are also effects from shoreline development. Most of Lake Campbell's shoreline is developed. Lakeshore homeowners can also help reduce lake pollution and protect water quality by preventing nutrients and sediment from entering the lake. The following lakeshore BMPs should be implemented by lakeshore owners:

- Maintaining appropriate landscaping
- Reducing the use of fertilizers on lawns/gardens or using phosphorus free fertilizers
- Reduce the use of pesticides
- Consider planting native vegetation near shoreline
- Use organic fertilizers and pesticides
- Properly maintaining septic systems

Fertilizers and weed killers contribute greatly to nutrients in the lake as they run off lakeshore property during heavy rains.

Internal (In-Lake) Management of Sediment and Nutrient Sources

Alternatives for in-lake management of sediment and nutrients are shown in Table 78 (USEPA 1990). Parts of Lake Campbell were dredged from 1987-1989, which removed approximately 220,000 cubic yards of sediment. The amount removed was quite minimal, considering the hydrographic survey completed in 1990 showed there to be 7.8 million cubic yards of sediment remaining in the lake. Nonetheless, algae blooms are still a nuisance and the lake is hypereutrophic based on the predicted TSI value calculated in 2008. Unfortunately, Lake Campbell will probably always be hypereutrophic as it would take an enormous amount of funding and voluntary agreement to apply all the necessary BMPs throughout the 118,161-acre watershed. To consider dredging again would cost millions of dollars due to the size of the lake and the amount of sediment already deposited in the basin. Therefore, it is recommended that once external BMP applications are exhausted, a more holistic approach to maintaining water quality in the lake could be considered. This would include activities to reduce/remove biological nutrients by using aeration, microbial augmentation, or physical removal.

Table78. In-Lake Management Options with Effectiveness and Longevity

Management Option	Effectiveness	Longevity
Aluminum Sulfate	High	Moderate
Dredging (entire lake)	Low	High
Dredging (inlets)	High	high
Aeration	Moderate	Moderate
Sediment Oxidation	Moderate	Moderate
Algicides	Moderate	Poor
Food Chain Manipulation	Moderate	Unknown
Herbicides	Moderate	Low
Weed Harvesting	Moderate	Low
Biological Control (weeds)	Moderate	Moderate

Note: approximate range
High = Excellent (75-100%) Low = Poor (0-25%)
Moderate = Fair to Good (25-75%)

A chemical alternative like sediment sealing (aluminum sulfate treatment) is highly effective in reducing in-lake nutrients but is extremely expensive and will not work on shallower lakes with an extraordinary amount of recreational use and turbidity. Hundreds of thousands of dollars have already been spent on dredging this lake in the late 1980s and it is recommended that a more aggressive management plan be implemented within the watershed, especially near the main inlet to the lake. All shoreline residents need to take an active role in helping reduce nutrient and sediment runoff into the lake. It is recommended that landowners be contacted and provided with educational materials on how to prevent contaminated runoff from entering the lake from their properties. A consolidated sewer system was recommended 15 years ago and has yet to be installed. Water quality data indicates the lake does receive plenty of nutrients from the watershed, but the lake itself contributes partially to its own problems. Due to its shallowness, sediment retention, and high nutrients that keep re-suspending themselves, the lake will continue to cycle through winterkills and algae blooms.

Increased nutrient levels have been shown to decrease plant community diversity with an increase in dominance of species such as sago pondweed (Moss et. al 1996). Sago pondweed was the only submergent macrophyte identified during the aquatic plant survey of Lake Campbell (See Appendix Q for location of the surveyed macrophytes and the shoreline evaluation).

The reduction of nutrients in this lake should reduce noxious blue-green algae problems. Algaecides can be used, which are effective, but do not maintain their effectiveness for long periods of time. With the amount of recreational activity on this lake, nutrients will constantly be stirred up which will accelerate algae growth. The most sensible option to reduce nutrients would be to eliminate the obvious, manageable, inputs from the watershed. A reduction of nutrients from this lake's watershed will positively impact the reduction of nutrients and sediment loadings that also carry nutrients.

PUBLIC INVOLVEMENT AND COORDINATION

STATE AGENCIES

SD DENR was the primary state agency involved in the development and completion of this assessment. They provided equipment and field assistance as well as technical guidance to East Dakota Water Development District throughout the project. They also provided ambient surface water quality data.

SD Game, Fish and Parks provided the fish survey and stocking information.

FEDERAL AGENCIES

The US EPA provided the primary source of funds for the completion of the assessment of the Lake Campbell watershed.

The United States Geological Survey (USGS) provided maps of the area.

LOCAL GOVERNMENTS, OTHER GROUPS, AND GENERAL PUBLIC

Public involvement consisted of telephone conversations about landuse with operators in the watershed and distributing information at two Lake Campbell Lake Association meetings. The Lake Campbell Lake Association, Brookings County Conservation District, South Dakota Department of Environment and Natural Resources, and the Brookings County Historical Society all provided historical information for Lake Campbell and its watershed.

OTHER SOURCES OF FUNDS

In addition to funds supplied by the US EPA. additional financial support was provided by the East Dakota Water Development District (EDWDD).

ASPECTS OF THE PROJECT THAT DID NOT WORK WELL

Most of the objectives proposed for the project were met with acceptable methods and in a reasonable amount of time. Data that was gathered during this project was sufficient enough to make a reasonable determination on the condition of this lake and to make realistic suggestions for management options.

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Appendix A.
Notes from the Lake Campbell Improvement Association

LAKE CAMPBELL IMPROVEMENT ASSOCIATION, INC.
P. O. Box 664
Brookings, S.D. 57006

MAY 1984

To the Members

Since our last spring Annual Meeting a lot of things have taken place in regard to our Lake Campbell Restoration Project. From February of 83 to this February Merle Plucker and I have taken the water Quality samples. The results of these tests gave the reasons for the Algae and sediment buildup. These tests were required before our project could be submitted to the Water Board. In late August and September with the help of Jerry Siegel and Dennis Nelson of the East Dakota Conservancy Subdistrict and Tim Bjork of the Dept. of Water and Natural Resources I made out the application for the Lake Campbell Restoration Project.

The application was presented to the East Dakota Conservancy Subdistrict Board of Directors. They passed it with approval and sent it to the Dept. of Water and Natural Resources. That Department sent it to the State Water Board where it was recognized and put on inventory as there were insufficient funds to do lake projects. Since that time Tim Bjork and I have had several conferences to determine other sources of funds. Tim suggested there might be funds in the Dept of Agriculture for the Impoundment Dams. I wrote Senator James Abdnor and he received a reply from J. W. Haas in the SCS Washington Officethat our State Conservationist Robert Swenson would help. Recently Clair Welbon of the Madison SCS office and I met and prepared some preliminary strategy.

Perhaps a brief outline of the Project is in order. There are two phases. Phase 1 is the construction of 17 silt Impoundment Dams. These are to be constructed on farmer owned land and are applied for by the land owner. Phase 2 is the removal of the sediment in the bay south of the bridge.Phase 1 must be completed and tested before Phase 2 starts.This is natural as the government will not spend money for silt removal until the sources are eliminated.

Last Week Clair designated on his U.S.Geological maps the sites of the dams and the land owner of the site.Our first step now is to get the permission of the land owner to make a survey of the site and the estimated cost of the dam. If everything is favorable then the land owner makes a request of the ASCS office for funds to build it. As these are on a 50-50 cost sharing basis with a cost share limit of $3,500.00 I have no doubts that the land owners share will have to be made up locally. Local cost share may come from county funds, City of Brookings, East Dakota Conservancy Subdistrict. our Association and private donations. These dams are a three year project. Five dams in 1984, 6 in 85 and 6 in 86.

Now about the work and funding. When I was talking to Clair Welbon he gave me a copy of the Lake Herman Model Implementation Program MIP. It is a portfolio of 96 pages of information graphs and data. Recently Tim Bjork sent me a portfolio of Standardized Implementation Stratedgy for Lake Restoration. Quite frankly if I had had these in 82 I would not have undertaken the job of Lake Campbell restoration alone. I have had support from Merle, Dennis and Tim Bjork but if we are to succeed in saving the Lake we are going to do things differently.

Appendix B.
Shoreline Stabilization Maps

B-1

Shoreline Erosion Areas

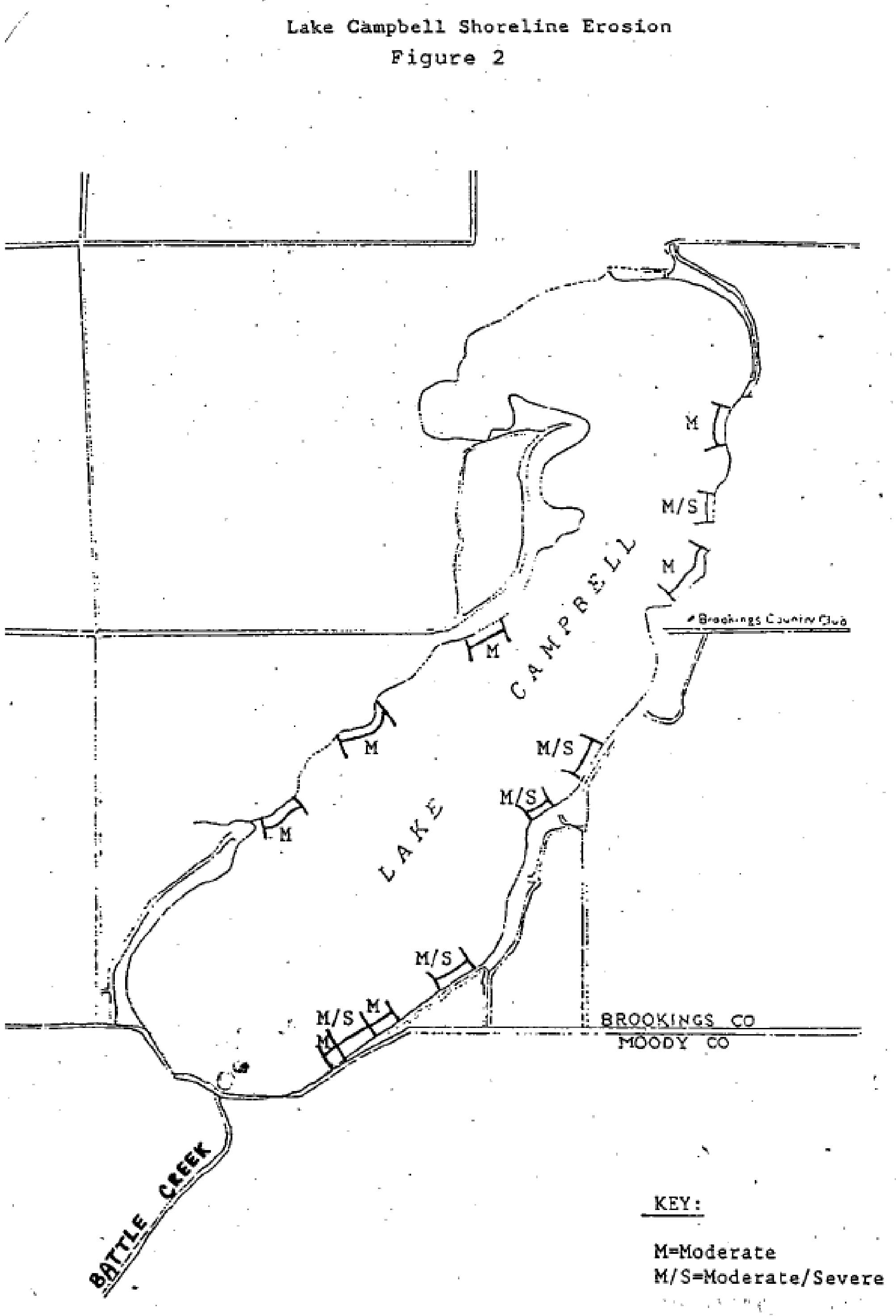


Figure from the 1993 Diagnostic/Feasibility Study

Shoreline Areas where Stabilization was Applied

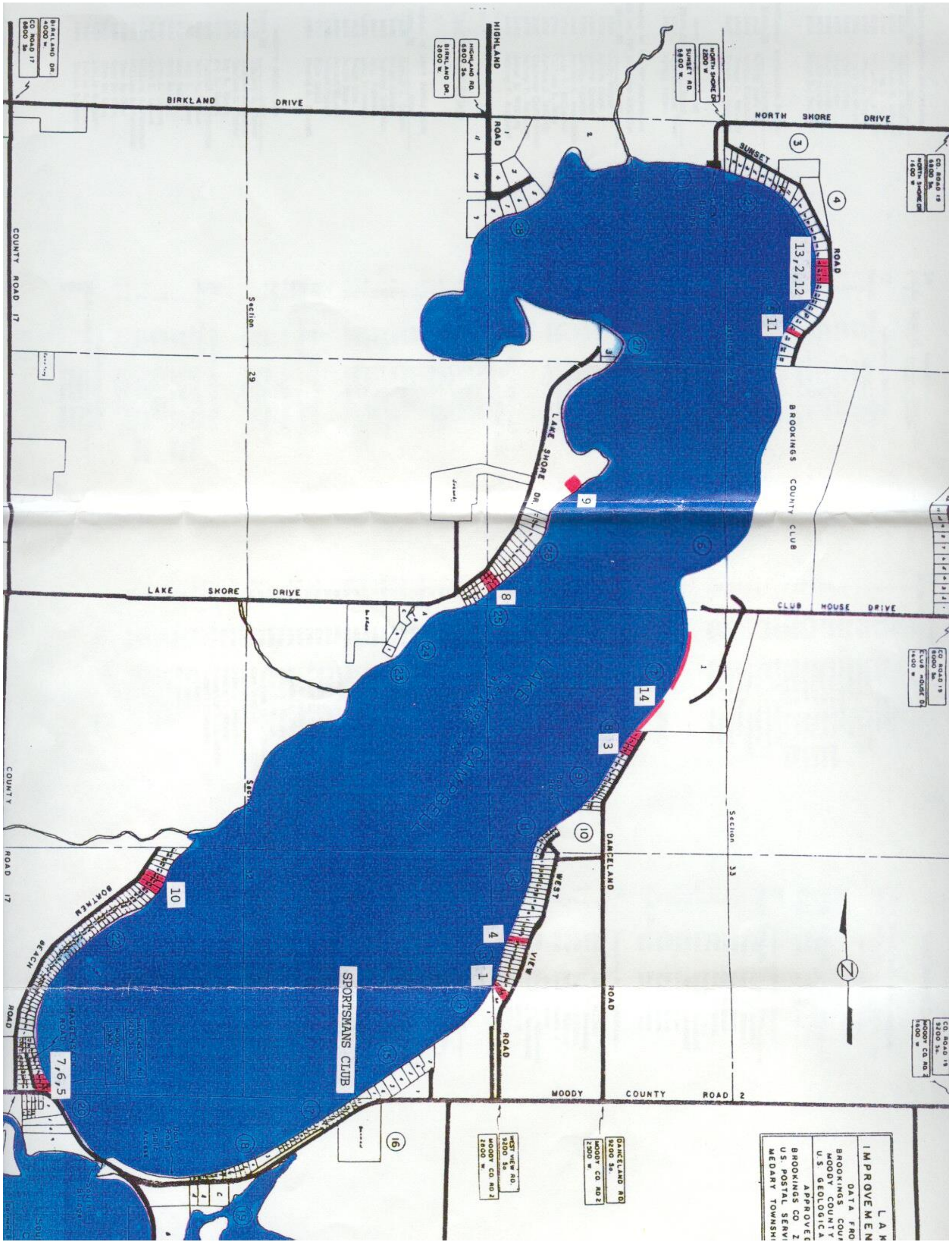


Figure from the 1995 Lake Campbell Shoreline Protection Project by R.F. Sayre & Associates

Appendix C.
Historical Fish Stocking Table

C-1

South Dakota Game, Fish & Parks Stocking Report for Lake Campbell

Region =Region 3 **County = Brookings** *Tuesday, May 20, 2008* *Stocking Report, by Water*

Year	Stock Date	Species	Size	Rate (#/lb)	Number Stocked
1919					
	01/01/1919	Northern Pike	Fry		300,000
1924					
	01/01/1924	Bluegill	Fingerling		600
1928					
	01/01/1928	Black Bullhead	Adult		5,500
	01/01/1928	Yellow Perch	Adult		600
1929					
	01/01/1929	Black Bullhead	Adult		3,000
	01/01/1929	Largemouth Bass	Fingerling		1,200
	01/01/1929	Northern Pike	Fry		150,000
1930					
	01/01/1930	Largemouth Bass	Fingerling		475
	01/01/1930	Walleye	Fry		175,000
1931					
	01/01/1931	Largemouth Bass	Fingerling		275
	01/01/1931	Northern Pike	Adult		125
1932					
	01/01/1932	Black Bullhead	Adult		5,000
	01/01/1932	Northern Pike	Fry		150,000
1933					
	01/01/1933	Black Bullhead	Adult		12,000
	01/01/1933	Black Crappie	Fingerling		2,500
	01/01/1933	Largemouth Bass	Fingerling		418
	01/01/1933	Northern Pike	Fingerling		23
	01/01/1933	Northern Pike	Fry		175,000

Year	Stock Date	Species	Size	Rate (#/lb)	Number Stocked
	01/01/1933	Walleye	Fingerling		89
	01/01/1933	White Bass	Fingerling		1,400
	01/01/1933	Yellow Perch	Fingerling		3,000
1934					
	01/01/1934	Largemouth Bass	Fingerling		2,500
1936					
	01/01/1936	Black Bullhead	Adult		19,200
	01/01/1936	Black Bullhead	Fingerling		5,000
	01/01/1936	Northern Pike	Fry		62,000
	01/01/1936	Walleye	Fry		100,000
	01/01/1936	Yellow Perch	Adult		95,950
1937					
	01/01/1937	Northern Pike	Fry		50,000
	01/01/1937	Yellow Perch	Adult		500
1939					
	01/01/1939	Northern Pike	Fry		200,000
	01/01/1939	Yellow Perch	Adult		9,000
1940					
	01/01/1940	Northern Pike	Fry		150,000
	01/01/1940	Yellow Perch	Adult		2,600
	01/01/1940	Yellow Perch	Adult		2,500
1942					
	01/01/1942	Black Bullhead	Adult		15,000
	01/01/1942	Northern Pike	Fry		200,000
	01/01/1942	Yellow Perch	Fry		800,000

Year	Stock Date	Species	Size	Rate (#/lb)	Number Stocked
1943					
	01/01/1943	Largemouth Bass	Fingerling		2,000
	01/01/1943	Northern Pike	Fry		125,000
	01/01/1943	Yellow Perch	Adult		5,000
1944					
	01/01/1944	Northern Pike	Fry		200,000
	01/01/1944	Walleye	Fry		200,000
	01/01/1944	Yellow Perch	Fry		600,000
1945					
	01/01/1945	Northern Pike	Fry		200,000
	01/01/1945	Yellow Perch	Fry		600,000
1946					
	01/01/1946	Yellow Perch	Fry		1,000,000
1948					
	01/01/1948	Northern Pike	Fry		200,000
	01/01/1948	Yellow Perch	Fry		500,000
1949					
	01/01/1949	Yellow Perch	Fingerling		1,500
	01/01/1949	Yellow Perch	Fry		400,000
1951					
	01/01/1951	Yellow Perch	Adult		6,000
1952					
	01/01/1952	Yellow Perch	Fingerling		10,000
1953					
	01/01/1953	Black Bullhead	Adult		6,950
	01/01/1953	Bluegill	Adult		100
	01/01/1953	Largemouth Bass	Adult		30
	01/01/1953	Northern Pike	Adult		58

Year	Stock Date	Species	Size	Rate (#/lb)	Number Stocked
1954					
	01/01/1954	Channel Catfish	Fingerling		2,000
	01/01/1954	Largemouth Bass	Fingerling		3,000
1955					
	01/01/1955	Channel Catfish	Fingerling		850
	01/01/1955	Largemouth Bass	Adult		1,800
	01/01/1955	Northern Pike	Adult		16
	01/01/1955	Northern Pike	Fingerling		60
	01/01/1955	Walleye	Fry		110,000
1961					
	01/01/1961	Black Crappie	Adult		5,000
	01/01/1961	Northern Pike	Fry		500,000
	01/01/1961	Yellow Perch	Adult		3,000
1962					
	01/01/1962	Walleye	Fry		300,000
1963					
	01/01/1963	Yellow Perch	Adult		3,500
1965					
	01/01/1965	Northern Pike	Fry		250,000
	01/01/1965	Yellow Perch	Adult		3,000
1967					
	01/01/1967	Northern Pike	Fry		160,000
1968					
	01/01/1968	Northern Pike	Fry		500,000
	01/01/1968	Yellow Perch	Fingerling		2,000
1969					
	01/01/1969	Northern Pike	Fry		500,000
	01/01/1969	Yellow Perch	Fingerling		12,000

Year	Stock Date	Species	Size	Rate (#/lb)	Number Stocked
1970					
	01/01/1970	Northern Pike	Fry		500,000
1971					
	01/01/1971	Northern Pike	Fry		500,000
	01/01/1971	Yellow Perch	Adult		1,500
1978					
	01/01/1978	Black Crappie	Adult		5
	01/01/1978	Northern Pike	Fry		500,000
	01/01/1978	Yellow Perch	Adult		300
1983					
	01/01/1983	Northern Pike	Fry		1,000,000
1984					
	01/01/1984	White Crappie	Adult		300
1986					
	01/01/1986	Northern Pike	Fry		500,000
1988					
	01/01/1988	Bluegill	Adult		31
1989					
	01/01/1989	Northern Pike	Fry		500,000
1990					
	01/01/1990	Northern Pike	Adult		670
1991					
	01/01/1991	Northern Pike	Fingerling		24,600
1992					
	01/01/1992	Northern Pike	Fingerling		30,000
	01/01/1992	Walleye	Fry		1,000,000
	01/01/1992	Walleye	SMALL		30,000
	01/01/1992	Yellow Perch	Fingerling		50,150

Year	Stock Date	Species	Size	Rate (#/lb)	Number Stocked
1993					
	01/01/1993	Walleye	SMALL		75,000
1994					
	01/01/1994	Fathead Minnow	Adult		51,200
	01/01/1994	Yellow Perch	Fingerling		12,488
1995					
	01/01/1995	Channel Catfish	Fingerling		50,000
	01/01/1995	Saugeye	Fingerling		100,000
1996					
	01/01/1996	Channel Catfish	Fingerling		52,920
1997					
	01/01/1997	Walleye	Fingerling		202,300
	01/01/1997	Yellow Perch	Adult		2,560
1999					
	01/01/1999	Walleye	Fingerling		100,000
	01/01/1999	Yellow Perch	Adult		11,131
2001					
	05/04/2001	Yellow Perch	Juvenile	42.0	4,620
2004					
	06/18/2004	Walleye	Fingerling	1,400.0	6,300
	06/18/2004	Walleye	Fingerling	1,520.0	95,800
	06/22/2004	Yellow Perch	Fingerling	540.0	21,060
	10/19/2004	Walleye	Fingerling	17.0	187
2006					
	04/29/2006	Walleye	Fry		926,316

Appendix D.
2006 Fisheries Survey

SOUTH DAKOTA STATEWIDE FISHERIES SURVEY

2102-F-21-R-39

Name: Lake Campbell **County**: Brookings **Legal Description**: T109N- R50W- Sec. 28, 29, 32, 33; T108N- R50W-Sec. 5 **Location from nearest town**: 6 miles south and 2 miles west of Brookings, SD

Dates of present survey: June 28-30, 2006 **Dates of last survey**: July 5-7, 2004

Primary Game and Forage Species	Secondary and Other Species
Walleye	Northern Pike
Yellow Perch	White Bass
	Bluegill
	Channel Catfish
	White Sucker
	Common Carp
	Bigmouth Buffalo
	Black Crappie
	Black Bullhead
	Shorthead Redhorse

PHYSICAL DATA

Surface area: 1,000 acres **Watershed area**: 103,762 acres **Maximum depth**: 7 feet **Mean depth**: 4 feet **Volume:** 4,000 acre feet **Shoreline length:** 7.2 miles **Contour map available:** Yes **Date mapped:** 1996 **OHWM elevation:** 1575.7 **Date set:** April, 1983 **Outlet elevation:** 1575.2 **Date set:** April, 1983 **Lake elevation observed during the survey:** Full **Beneficial use classifications:** (6) warmwater marginal fish life propagation, (7) immersion recreation, (8) limited-contact recreation and (9) wildlife propagation and stock watering.

Introduction

Lake Campbell was named after Albert H. Campbell of the Pacific Wagon Railroad. The lake lies on the downstream end of the Badus-Battle Creek drainage which flows into the Big Sioux River and ultimately, the Missouri River. The watershed is mostly cropland which contributes a heavy silt load to the lake whenever runoff occurs. As a result, Lake Campbell is very shallow, water quality is poor and fish kills are frequent.

Ownership of Lake and Adjacent Lakeshore Properties

Lake Campbell is listed as meandered public water in the State of South Dakota Listing of Meandered Lakes and the fishery is managed by the South Dakota Department of Game, Fish and Parks (GFP). GFP also owns and manages an access area on the north end of the lake. There is a road right-of-way on the south end of the lake owned by Moody County and open for public access. The remainder of the shoreline is privately owned.

Fishing Access

The North Shore Access Area contains a new concrete plank boat ramp, boat dock and a handicapped-accessible fishing pier. A vault toilet will be installed in the near future. There are several areas suitable for shore fishing on this area as well. Shore fishing also occurs off the bridge and shoreline on the south end of the lake.

Field Observations of Water Quality and Aquatic Vegetation:

The water in Lake Campbell was fairly turbid during the survey with Secchi depth measurement of 30.5 cm (12 in). A few scattered beds of sago pondweed (Potamogeton pectinatus) were observed in shallow areas.

BIOLOGICAL DATA

Methods

Lake Campbell was sampled on June 28-30, 2006 with two overnight gill net sets and ten overnight trap-net sets. The trap nets are constructed with 19-mm-bar-mesh (¾ in) netting, 0.9 m high x 1.5 m wide (3 ft high x 5 ft wide) frames and 18.3 m (60 ft) long leads. The gill nets are 45.7 m long x 1.8 m deep (150 ft long x 6 ft deep) with one 7.6 m (25 ft) panel each of 13, 19, 25, 32, 38 and 51-mm-bar-mesh (½, ¾, 1, 1¼, 1½, and 2 in) monofilament netting. Gill net and trap net sites are displayed in Figure 3.

Results and Discussion

Gill Net Catch

Walleyes (38.1%) were the most abundant species sampled in the gill nets (Table 1). Other species caught included black bullhead, white sucker, common carp, spottail shiner, shorthead redhorse, orange-spotted sunfish, northern pike, and yellow perch.

Table 1. Total catch from two overnight gill net sets at Lake Campbell, Brookings County, June 28-30, 2006.

Species	Number	Percent	CPUE[1]	80% C.I.	Mean CPUE *	PSD	RSD-P	Mean Wr
Walleye	40	38.1	20.0	+2.6	7.4	93	0	102
Black Bullhead	22	21.0	11.0	+1.3	53.6	0	0	100
White Sucker	22	21.0	11.0	+6.4	12.2	50	32	101
Common Carp	13	12.4	6.5	+4.5	6.9			
Spottail Shiner	3	2.9	1.5	+0.6	1.3			
Shorthead Redhorse	2	1.9	1.0	+0.0	0.3			
O. S. Sunfish	1	1.0	0.5	+0.6	0.0			
Northern Pike	1	1.0	0.5	+0.6	4.3			
Yellow Perch	1	1.0	0.5	+0.6	34.3			

* 6 years (1994, 1996, 1998, 2000, 2002, 2004)

Trap Net Catch

Black bullheads made up 97.5% of the trap net catch (Table 2). Other species sampled included bigmouth buffalo, common carp, walleye, yellow bullhead, northern pike, white sucker, channel catfish, green sunfish, orange-spotted sunfish, and stonecat.

Table 2. Total catch from ten overnight trap net sets at Lake Campbell, Brookings County, June 28-30, 2006.

Species	Number	Percent	CPUE	80% C.I.	Mean CPUE *	PSD	RSD-P	Mean Wr
Black Bullhead	11,627	97.5	1,162.7	+314.6	714.9	0	0	102
Bigmouth Buffalo	120	1.0	12.0	+5.2	7.6	95	23	97
Common Carp	69	0.6	6.9	+2.3	4.5	53	18	109
Walleye	47	0.4	4.7	+2.3	1.4	87	4	100
Yellow Bullhead	40	0.3	4.0	+1.6	0.3	90	25	115
Northern Pike	9	0.1	0.9	+0.4	3.7			
White Sucker	6	0.1	0.6	+0.5	2.5			
Channel Catfish	4	0.0	0.4	+0.2	0.7			
Green Sunfish	4	0.0	0.4	+0.2	0.0			
O. S. Sunfish	1	0.0	0.1	+0.1	0.0			
Stonecat	1	0.0	0.1	+0.1	0.0			

* 7 years (1992, 1994, 1996, 1998, 2000, 2002, 2004)
See Appendix A for definitions of CPUE, PSD, RSD-P and mean Wr

Walleye

Management objective: Maintain a walleye population with a gill-net CPUE of at least 10, a PSD range of 30-60, and a growth rate of 14 inches by age-3.

The walleye population in Lake Campbell is currently meeting our management objective (Table 3). Walleye fingerlings were stocked in 2004 to reestablish the walleye population after a partial winterkill in 2003-04. Only age-2 walleyes from this stocking were sampled, indicating that few, if any, older fish survived the winterkill. A good year class was created by the fingerling stocking and growth is excellent with fish reaching 36 cm (14 inches) in two years (Table 4) (Figure 1). An additional fry stocking was made in 2006 (Table 8).

Table 3. Walleye gill-net CPUE, PSD, RSD-P and mean Wr for Lake Campbell, Brookings County, 1997-2006.

1997 1998 1999 2000 2001 2002 2003 2004 2005 2006

CPUE	18.0	5.5	12.0	0.0	20.0
PSD	93	90	0		93
RSD-P	7	70	0		0
Mean Wr	92	92	100		102

Table 4. Average back-calculated lengths (mm) for each age class of walleye in Lake Campbell, Brookings County, 2006.

			Back-calculation Age							
Year Class	Age	N	1	2	3	4	5	6	7	8
2004	2	40	176	361						
All Classes		**40**	**176**	**361**						
Statewide Mean			168	279	360	425	490			
Region III Mean			173	281	367	435	517			
LLI Mean*			169	280	358	425	494			

*Large Lakes and Impoundments (>150 acres)

Yellow Perch

Management objective: Maintain a yellow perch population with a gill-net CPUE of at least 50 with a PSD range of 30-60.

Only one yellow perch was sampled in the gill nets (Table 5) suggesting that the 2004 fingerling stocking (Table 8) was unsuccessful.

Table 5. Yellow perch gill-net CPUE, PSD, RSD-P and mean Wr for Lake Campbell, Brookings County, 1997-2006.

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
CPUE		91.3		151.5		19.0		1.5		0.5
PSD		10		22		72				
RSD-P		0		0		32		--		
Mean Wr		115		92		104				

Black Bullhead

Management objective: Maintain a black bullhead population with a trap-net net CPUE of less than 100.

Black bullhead trap-net CPUE declined slightly in 2006 (Table 6). However, 85% of the fish sampled were less than 5 cm (6 in) long (Figure 2) which makes them useless to commercial fishermen or anglers.

Table 6. Black bullhead gill-net CPUE, PSD, RSD-P and mean Wr for Lake Campbell, Brookings County, 1997-2006.

1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
CPUE	170.6		72.2		2,174.7		1,359.5		1,162.7
PSD			77		6		27		0
RSD-P			0		0		3		0
Mean Wr			92		99		95		102

All Species

Lake Campbell has the highest species diversity of any lake in the Region (Table 7).

Table 7. Gill-net (GN) and trap-net (TN) CPUE for all fish species sampled in Lake Campbell, Brookings County, 1997-2006.

Species	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
CCF (GN)		--		0.5		--		--		--
CCF (TN)		1.4		--		1.0		--		.04
STC (TN)		--		--		--		--		--
STC (TN)		--		--		--		--		0.1
NOP (GN)		0.3		1.5		7.3		2.0		.05
NOP (TN)		1.6		1.3		7.9		5.0		.09
WAE (GN)		18.0		5.5		12.		--		20.0
WAE (TN)		2.1		2.3		1.9		--		4.7
WHB (GN)		--		4.5		1.0		--		--
WHB (TN)		1.8		7.9		1.7		--		--
BLC (GN)		--		2.0		--		--		--
BLC (TN)		2.0		5.4		0.3		--		--
BLG (GN)		--		--		--		--		--
BLG (TN)		--		0.2		0.1		--		--
WHC (GN)		1.7		1.5		--		--		--
WHC (TN)		1.3		6.4		--		--		--
GSF (GN)		--		--		--		--		--
GSF (TN)		--		--		--		--		0.4
OSF (GN)		--		--		--		--		--
OSF (TN)		--		--		--		--		0.1
YEP (GN)		91.3		151.5		19.0		1.5		0.5

YEP (TN)	8.0	3.3	0.5	--	--
BLB (GN)	54.7	53.5	89.3	26.0	11.0
BLB (TN)	170.6	72.2	2,174.7	1,359.5	1,162.7
BIB (GN)	5.3	--	31.3	--	--
BIB (TN)	13.2	9.0	3.3	5.5	12.0
COC (GN)	11.0	0.5	14.7	3.5	6.5
COC (TN)	5.6	3.9	3.8	3.0	6.9
SHR (GN)	13	--	0.3	--	1.0
SHR (TN)	4.5	7.2	0.3	--	--
YEB (GN)	--	--	--	--	--
YEB (TN)	--	2.4	--	--	4.0
SPS (GN)	8.0	--	--	--	1.5
SPS (TN)	--	--	--	--	--
WHS (GN)	14.3	16.5	12.0	4.0	11.0
WHS (TN)	2.2	5.0	0.4	3.0	0.6

CCF (Channel Catfish), STC (Stonecat), NOP (Northern Pike), WAE (Walleye), WHB (White Bass), BLC (Black Crappie), BLG (Bluegill), WHC (White Crappie), GSF (Green Sunfish), OSF (Orange-Spotted Sunfish), YEP (Yellow Perch), BLB (Black Bullhead), BIB (Bigmouth Buffalo), COC (Common Carp), SHR (Shorthead Redhorse), YEB (Yellow Bullhead), SPS (Spottail Shiner), WHS (White Sucker)

MANAGEMENT RECOMMENDATIONS

1 Stock walleye fry or fingerlings as needed to accomplish the management objective.
2 A combination of adult and fingerling stocking, nuisance fish control and habitat improvement is likely needed to accomplish the perch management objective.
3 Reduce nuisance fish populations through a combination of commercial fishing, predator management, and Department removal operations. The construction of an effective fish barrier at the outlet would reduce re-contamination from the Big Sioux River. Reduced nuisance fish populations will help improve water quality, promote the spread of aquatic plants, and decrease competition with desirable fish species.
4 Draft a habitat improvement plan that includes nuisance fish control, watershed management, Christmas tree reefs, shoreline riprap, and fishing piers that protect shoreline areas from wind erosion.

Table 8. Stocking record for Lake Campbell, Brookings County, 1986-2006.

Year	Number	Species	Size
1986	500,000	Northern Pike	Fry
1988	31	Bluegill	Adult
1989	500,000	Northern Pike	Fry
1990	670	Northern Pike	Adult
1991	24,600	Northern Pike	Fingerling
1992	30,000	Northern Pike	Fingerling
	1,000,000	Walleye	Fry
	30,000	Walleye	Sml. Fingerling
	50,150	Yellow Perch	Fingerling
1993	75,000	Walleye	Sml. Fingerling
1994	80,000	Fathead Minnow	Adult
	12,488	Yellow Perch	Lrg. Fingerling
1995	50,000	Channel Catfish	Fingerling
1996	52,920	Channel Catfish	Fingerling
1997	202,300	Walleye	Fingerling
	2,560	Yellow Perch	Adult
1999	100,000	Walleye	Fingerling
	11,131	Yellow Perch	Adult
2001	4,620	Yellow Perch	Juvenile
2004	102,100	Walleye	Fingerling
	21,060	Yellow Perch	Fingerling
2006	926,316	Walleye	Fry

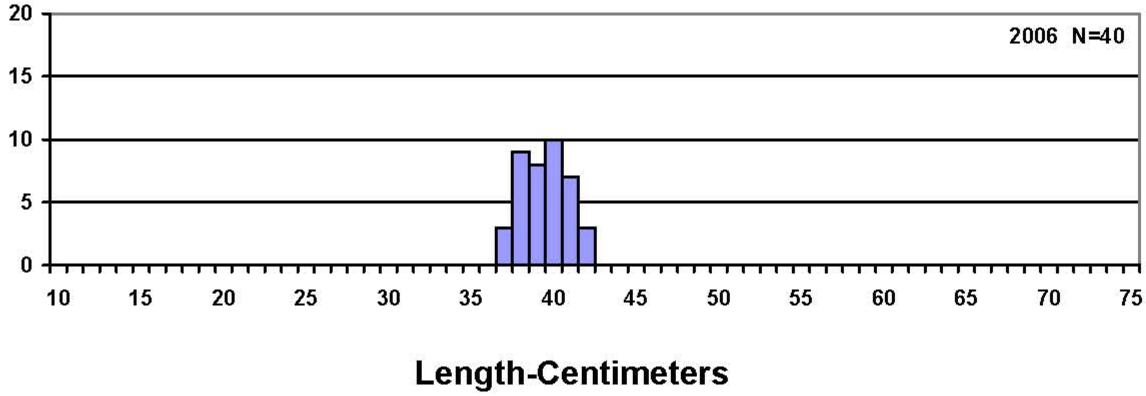


Figure 1. Length-frequency histograms for walleye sampled with gill nets in Lake Campbell, Brookings County, 2006.

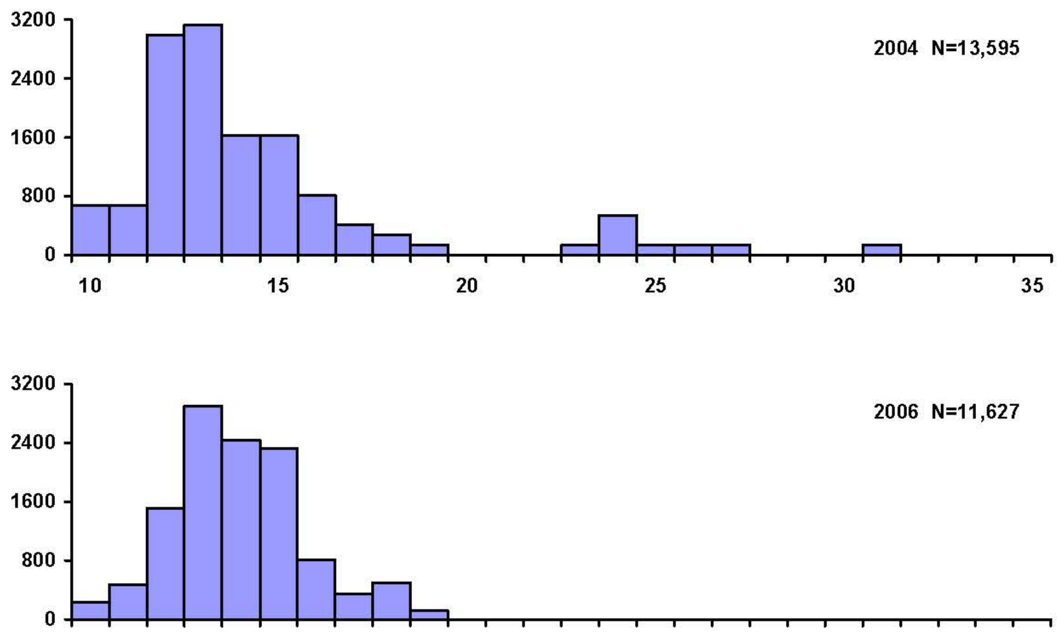


Figure 2. Length-frequency histograms for black bullhead sampled with trap-nets in Lake Campbell, Brookings County, 2004, and 2006.

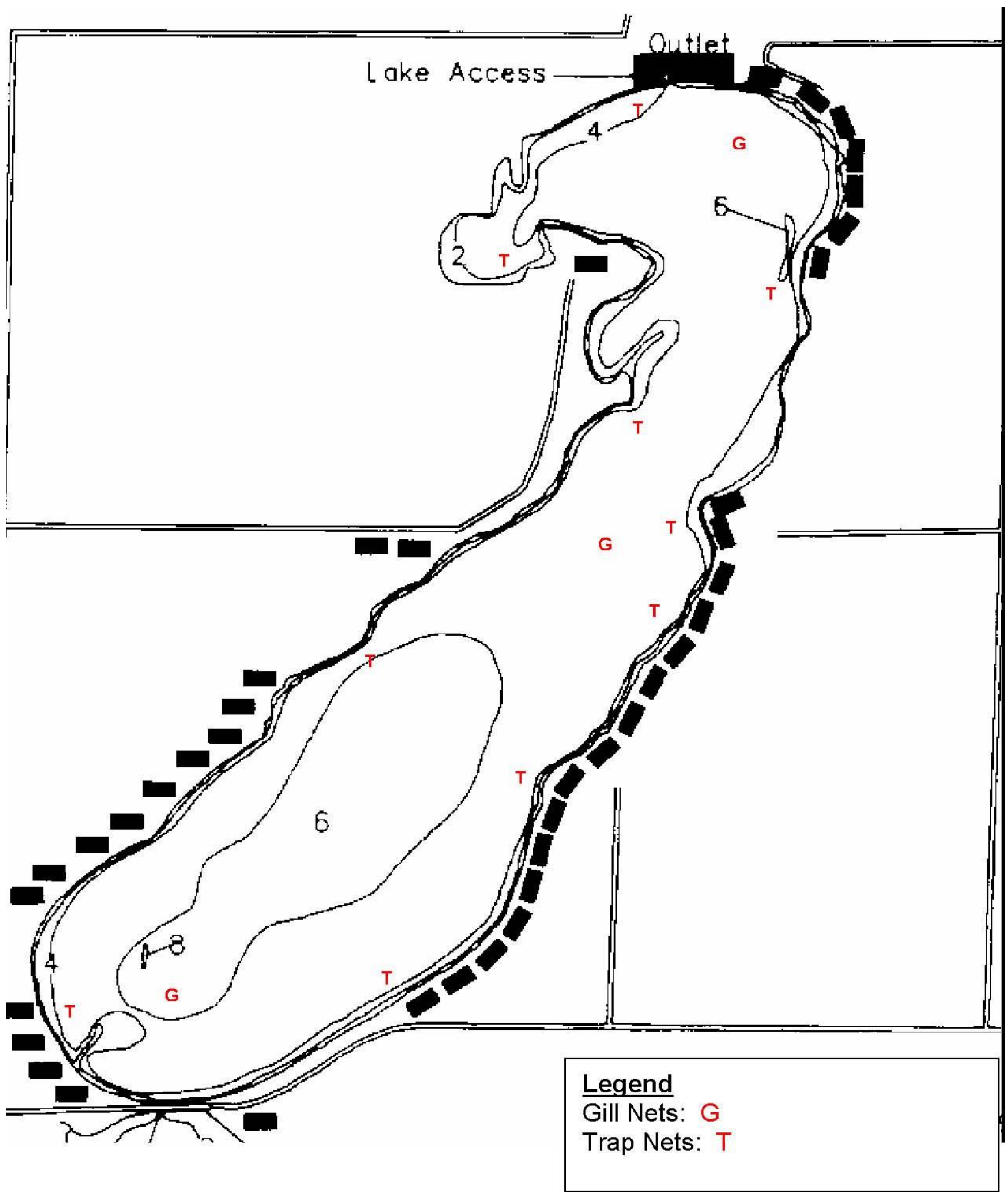

Outlet
Lake Access
4
2
6
8
G
T
Legend
Gill Nets: G
Trap Nets: T

Figure 3. Sampling locations on Lake Campbell, Brookings County, 2006.

Appendix A. A brief explanation of catch per unit effort (CPUE), proportional stock density (PSD), relative stock density (RSD) and relative weight (Wr).

Catch Per Unit Effort (CPUE) is the catch of animals in numbers or in weight taken by a defined period of effort. Can refer to trap-net nights of effort, gill-net nights of effort, catch per hour of electrofishing, etc.

Proportional Stock Density (PSD) is calculated by the following formula: PSD = Number of fish > quality length x 100
Number of fish ≥ stock length

Relative Stock Density (RSD-P) is calculated by the following formula: RSD-P = Number of fish > preferred length x 100
Number of fish ≥ stock length

PSD and RSD-P are unitless and usually calculated to the nearest whole digit.

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

Species	Stock	Quality	Preferred	Memorable	Trophy
Walleye	25	38	51	63	76
Sauger	20	30	38	51	63
Yellow perch	13	20	25	30	38
Black crappie	13	20	25	30	38
White crappie	13	20	25	30	38
Bluegill	8	15	20	25	30
Largemouth bass	20	30	38	51	63
Smallmouth bass	18	28	35	43	51
Northern pike	35	53	71	86	112
Channel catfish	28	41	61	71	91
Black bullhead	15	23	30	38	46
Common carp	28	41	53	66	84
Bigmouth buffalo	28	41	53	66	84
Smallmouth buffalo	28	41	53	66	84

For most fish, 30-60 or 40-70 are typical objective ranges for “balanced” populations. Values less than the objective range indicate a population dominated by small fish while values greater than the objective range indicate a population comprised mainly of large fish.

Relative weight (Wr) is a condition index that quantifies fish condition (i.e., how much does a fish weigh for its length). A Wr range of 90-100 is a typical objective for most fish species. When mean Wr values are well below 100 for a size group, problems may exist in food and feeding relationships. When mean Wr values are well above 100 for a size group, fish may not be making the best use of available prey.

Appendix E.
Project Water Quality Data

Water Quality Data - Lake Campbell & Tributaries																								
Site	DATE	TIME	WTEMP ˚C	ATEMP ˚C	CONDUCT µS/cm	SPECCOND µS/cm	SALINITY ppt	DO mg/L	PH units	Turbidity NTU	SECCHI (m)	FECAL cfu/100 mL	E-COLI cfu/100mL	Alkalinity-M mg/L	Alkalinity-P mg/L	SUSP_SOL mg/L	TOT SOL mg/L	TDS mg/L	VTSS mg/L	Nitrate mg/L	Ammonia mg/L	TKN mg/L	TOT PO4 mg/L	TOTD PO4 mg/L
LC-T1	4/23/07	1530	15.5	23.0	1110	1356	0.7	10.43	8.59	20.0	-----	<10	7.4	159	2	24	1113	1092	7.0	<0.1	0.06	1.22	0.145	0.042
LC-T1	4/27/07	1100	14.4	-----	822	1033	0.5	8.41	8.13	5.5	-----	-----	-----	227	0	8	789	713	< 3	0.10	<0.02	1.04	0.173	0.116
LC-T1	5/2/07	1530	18.7	24.0	1287	1462	0.7	12.95	8.90	21.0	-----	20	6.3	199	11	23	1252	1153	8.0	<0.1	<0.02	1.73	0.170	0.043
LC-T1	5/9/07	1500	22.8	35.0	1402	1461	0.7	16.16	8.99	16.2	-----	10	20.9	209	10	19	1271	1171	11.0	<0.1	<0.02	1.41	0.191	0.057
LC-T1	5/31/07	850	17.7	17.0	1238	1437	0.7	10.22	8.71	44.1	-----	30	58.8	222	2	51	1284	1162	29.0	<0.1	<0.02	1.99	1.990	0.277
LC-T1	6/11/07	1145	23.8	27.0	1440	1471	0.7	8.4	8.80	55.0	-----	580	775.0	231	18	74	1374	1208	38.0	<0.1	<0.02	2.62	0.300	0.107
LC-T1	10/25/07	1030	9.8	10.8	1109	1573	0.8	12.34	8.08	90	-----	120	523	176	0	126	1477	1319	42	<0.2	0.02	2.23	0.38	0.035
LC-T1	4/10/08	1015	9.87	3.9	-----	1476	0.82	26.66	8.92	-----	-----	<10	1	153	1	8	-----	1127	4	<0.2	0.76	1.67	0.15	0.042
LC-T1	4/23/08	1200	12.22	23.8	-----	2263	1.13	12.52	8.74	20.0	-----	<10	<1	172	5	32	-----	1224	14	<0.2	<0.02	1.83	0.17	0.023
LC-T1	4/29/08	1415	9.89	14.4	-----	2248	1.16	12.84	8.6	25.0	-----	<10	19.4	176	9	69	-----	1236	25	<0.2	<0.02	1.80	0.2	0.046
LC-T1	5/21/08	1200	17.66	24.8	-----	1525	0.77	11.06	8.7	17.0	-----	<10	1	166	5	27	-----	1359	11	<0.2	<0.02	1.36	0.12	0.04
LC-T1	6/10/08	1100	18.66	25.1	-----	1542	0.78	10.9	8.63	24.0	-----	10	10.4	183	9	38	-----	1399	20	<0.2	<0.02	2.90	0.2	0.022
LC-T2	3/23/07	1045	6.7	18.0	619	955	0.5	12.81	7.81	17.0	-----	-----	-----	146	0	34	759	684	< 3	0.80	0.85	2.63	0.507	-----
LC-T2	4/23/07	1515	13.5	21.0	1009	1290	0.6	9.66	7.99	17.0	-----	2600	>2420	180	0	33	1062	1060	5.0	1.60	<0.02	1.01	0.356	0.264
LC-T2	4/27/07	915	13.3	-----	1296	1668	0.8	10.17	8.19	7.3	-----	-----	-----	226	0	21	1466	1337	3.0	0.40	<0.02	0.93	0.189	0.112
LC-T2	5/9/07	1630	21.9	35.0	1135	1208	0.6	6.95	8.04	13.8	-----	180	199.0	174	0	38	1007	916	4.0	0.70	<0.02	1.05	0.340	0.262
LC-T2	5/31/07	1000	16.9	20.0	1437	1696	0.9	9.66	8.54	3.6	-----	80	135.0	275	0	12	1489	1387	4.0	0.20	0.06	0.92	0.244	0.184
LC-T2	6/11/07	1245	25.5	31.0	1748	1734	0.9	12.25	8.52	4.4	-----	200	651.0	262	8	20	1562	1426	9.0	<0.1	<0.02	1.30	0.197	0.115
LC-T2	7/5/07	1300	25.6	35.0	1563	1552	0.8	13.62	8.60	16.0	-----	270	121.0	287	6	27	1323	1229	9.0	0.10	<0.02	1.54	0.266	0.104
LC-T2	7/25/07	1130	29.1	32.0	1495	1387	0.7	8.16	8.31	40.0	-----	200	248.1	233	1	62	1175	1060	18.0	<0.1	<0.02	1.86	0.280	0.050
LC-T2	8/7/07	1200	25.1	30.0	1384	1381	0.7	5.74	8.23	25.0	-----	40	9.6	242	0	43	1162	1074	17.0	0.20	0.11	1.28	0.222	0.098
LC-T2	8/22/07	1615	23.2	26.0	1305	1341	0.7	7.04	8.26	16.0	-----	190	194.0	215	0	31	1212	1123	12.0	0.20	0.05	1.57	0.208	0.092
LC-T2	9/4/07	1230	25.6	32.0	1409	1392	0.7	10.24	8.61	31.0	-----	120	32.4	241	2	51	1215	1085	22.0	<0.1	<0.02	1.49	0.208	0.206
LC-T2	10/1/07	1350	17.3	26.9	935	1094	0.5	6.56	8.09	19.0	-----	970	1550.0	201	0	27	888	807	8.0	0.30	0.07	1.37	0.155	0.060
LC-T2	10/16/07	1135	9.8	12.8	996	1405	0.7	13.01	-----	18.0	-----	540	2000.0	236	0	15	1124	1082	< 3	0.20	<0.02	0.79	0.245	0.158
LC-T2	10/25/07	1200	8.4	13.8	1463	2147	1.1	10.90	7.82	18.0	-----	110	520.0	-----	-----	-----	-----	-----	-----	1.60	0.08	1.05	0.292	0.201
LC-T2	11/8/07	1235	1.9	5.3	1194	-----	1.1	13.22	8.06	12.0	-----	10	66.9	291	0	25	1914	1831	8.0	1.30	<0.02	0.96	0.121	0.052
LC-T2	4/10/08	945	6.3	2.7	-----	1938	0.99	13.02	8.69	-----	-----	<10	20.1	217	0	20	-----	1314	4.0	<0.2	<0.02	1.44	0.179	0.047
LC-T2	4/23/08	1330	13.5	24.6	-----	2706	1.41	15.36	8.62	17.00	-----	<10	22.6	234	6	46	-----	1519	18.0	<0.2	<0.02	1.52	0.187	0.041
LC-T2	4/29/08	1345	8.6	17.3	-----	2874	1.50	13.14	8.12	14.00	-----	20	409.0	249	0	49	-----	1626	9.0	1.00	<0.02	1.12	0.242	0.147
LC-T2	5/21/08	1300	16.3	25.8	-----	1978	1.01	12.45	8.25	14.00	-----	30	47.2	267	3	33	-----	1769	8.0	0.40	<0.02	1.67	0.169	0.065
LC-T2	6/10/08	1200	19.1	25.3	-----	1317	0.66	6.39	7.76	10.00	-----	290	689.0	178	0	28	-----	1129	< 3	3.40	<0.02	1.77	0.298	0.226
LC-1	5/9/07	1400	20.5	37.0	1332	1465	0.7	15.00	8.97	17.0	0.40	10	14.6	206	7	15	1244	1146	10.0	<0.1	<0.02	1.53	0.184	0.072
LC-1	6/11/07	900	21.9	25.0	1391	1480	0.7	8.48	8.72	55.0	0.20	10	6.0	233	13	63	1363	1197	33.0	<0.1	<0.02	2.19	0.313	0.116
LC-1	6/27/07	900	23.8	22.0	1547	1584	0.8	6.73	8.86	45.0	0.15												0.507	0.267
LC-1	7/5/07	830	24.7	24.0	1605	1614	0.8	7.25	8.94	60.0	0.10	<10	2.0	259	17	48	1458	1334	32.0	<0.1	<0.02	2.60	0.561	0.302
LC-1	7/25/07	900	26.9	25.0	1698	1651	0.8	6.74	8.77	50.0	0.18	<10	2.0	235	17	48	1507	1361	36.0	<0.1	<0.02	3.75	0.460	0.177
LC-1	8/7/07	840	23.3	23.0	1549	1601	0.6	6.94	8.78	45.0	0.18	10	4.1	190	9	50	1450	1299	38.0	<0.1	<0.02	3.73	0.320	0.068
LC-1	8/22/07	1345	22.4	26.0	1482	1561	0.8	6.6	9.05	40.0	0.15	10	3.0	157	1	45	1396	1283	38.0	<0.1	<0.02	3.39	0.281	0.070
LC-1	9/4/07	1015	23.5	33.0	1511	1555	0.8	7.9	9.10	45.0	0.14	<10	3.1	163	15	45	1417	1286	32.0	<0.1	<0.02	3.46	0.302	0.036
LC-1	10/1/07	1135	16.4	18.9	1351	1615	0.8	6.3	8.59	38.0	0.20	40	35.0	173	0	53	1471	1318	26.0	<0.2	<0.02	2.98	0.220	0.050
LC-1	11/7/07	857	2.8	2.3	938	1630	0.8	12.9	8.55	30.0	0.20	<10	12.5	186	8	28	1413	1328	15.0	<0.2	<0.02	2.85	0.199	0.029
LC-1	1/10/08	1030	1.3	-5.8	1088	-----	1.0	6.0	8.14	6.0	0.73	<10	<1	236	0	82	1796	1679	16.0	0.20	0.59	2.74	0.270	0.134
LC-1	2/13/08	1330	0.4	-14.0	1188	-----	1.1	1.8	8.16	3.1	1.30	<10	<1	268	0	3	2045	1945	<3	<0.2	1.04	2.81	0.304	0.252
LC-1	4/23/08	1000	11.4	18.0	-----	2209	1.1	12.1	8.60	14.0	0.40	<10	<1	172	3	10	-----	1223	<3	<0.2	<0.02	2.00	0.168	0.030
LC-1	5/21/08	945	16.0	20.4	-----	1551	0.8	10.5	8.79	10.0	0.55	<10	<1	164	5	19	-----	1345	12.00	<0.2	<0.02	1.35	0.122	0.022
LC-1	6/10/08	1845	19.7	24.4	-----	15.78	0.8	11.6	8.61	27.0	0.25	-----	-----	185	6	44	-----	1382	28.00	0.80	<0.02	2.11	0.176	0.022

Site	DATE	TIME	WTEMP ˚C	ATEMP ˚C	CONDUCT µS/cm	SPECCOND µS/cm	SALINITY ppt	DO mg/L	PH units	Turbidity NTU	SECCHI (m)	FECAL cfu/100 mL	E-COLI cfu/100mL	Alkalinity-M mg/L	Alkalinity-P mg/L	SUSP_SOL mg/L	TOT SOL mg/L	TDS mg/L	VTSS mg/L	Nitrate mg/L	Ammonia mg/L	TKN mg/L	TOT PO4 mg/L	TOTD PO4 mg/L
LC-2	5/9/07	1430	20.6	35.0	1184	1289	0.6	17.95	8.77	14.1	0.30	10	34.5	184	2	16	1096	996	9.0	0.50	<0.02	1.34	0.224	0.116
LC-2	6/11/07	930	22.1	25.0	1396	1478	0.7	8.63	8.74	50.0	0.20	<10	<2	233	14	58	1359	1199	33.0	<0.1	<0.02	2.55	0.297	0.115
LC-2	6/27/07	915	24.3	22.0	1562	1585	0.8	6.66	8.71	50.0	0.15												0.519	0.299
LC-2	7/5/07	900	24.9	25.0	1609	1614	0.8	7.67	8.97	50.0	0.13	<10	<2	258	19	39	1444	1336	28.0	<0.1	<0.02	3.34	0.596	0.332
LC-2	7/25/07	915	26.7	27.0	1710	1655	0.8	7.42	8.78	50.0	0.20	<10	1.0	243	19	52	1472	1365	36.0	<0.1	<0.02	3.86	0.464	0.203
LC-2	8/7/07	915	23.3	24.0	1547	1598	0.8	6.34	8.71	45.0	0.20	<10	3.1	189	11	43	1438	1307	39.0	<0.1	<0.02	4.14	0.329	0.068
LC-2	8/22/07	1415	22.4	37.0	1495	1573	0.8	6.20	9.06	37.0	0.12	<10	9.8	158	0	44	1400	1288	42.0	<0.1	<0.02	3.92	0.304	0.056
LC-2	9/4/07	1045	23.3	35.0	1507	1557	0.8	7.35	9.03	40.0	0.15	<10	1.0	161	15	42	1415	1283	38.0	<0.1	<0.02	2.79	0.260	0.039
LC-2	10/1/07	1200	16.7	20.5	1361	1620	0.8	5.24	8.39	39.0	0.20	80	74.9	170	0	34	1453	1317	25.0	<0.2	<0.02	2.82	0.208	0.040
LC-2	11/8/07	1010	2.7	3.8	932	1623	0.8	13.07	8.58	25.0	0.30	<10	27.8	184	0	31	1413	1330	21.0	<0.2	0.02	2.74	0.175	0.026
LC-2	1/10/08	1130	2.9	-5.2	1134	1993	1.0	12.29	8.50	6.1	0.69	<10	<1	226	0	8	1733	1676	4.0	<0.2	1.01	2.49	0.194	0.118
LC-2	2/13/08	1445	0.0	-14.0	1084	-----	1.0	1.36	8.48	4.0	0.57	<10	<1	266	0	9	2024	1924	6.0	<0.2	0.92	3.34	0.377	0.244
LC-2	4/23/08	1030	11.5	20.1	-----	2265	1.2	11.50	8.60	19.0	0.38	<10	<1	172	3	24	-----	1213	20.0	<0.2	<0.02	1.99	0.189	0.028
LC-2	5/21/08	1030	16.1	22.4	-----	1607	0.8	12.80	8.74	9.5	0.50	<10	1.0	169	5	22	-----	1408	13.0	<0.2	<0.02	1.98	0.109	0.022
LC-2	6/10/08	1825	21.4	25.6	-----	15.40	0.8	19.60	8.86	25.0	0.25	-----	-----	170	7	40	-----	1373	36.0	0.90	<0.02	2.76	0.224	0.024

LC-3	5/9/07	1445	21.4	36.0	1171	1254	0.6	10.59	8.63	17.6	0.28	10	40.4	181	0	19	1071	982	9.0	0.70	<0.02	1.40	0.247	0.122
LC-3	6/11/07	1000	21.6	24.0	1396	1493	0.8	8.45	8.65	45.0	0.25	<10	<2	234	11	50	1363	1203	31.0	<0.1	<0.02	2.72	0.333	0.131
LC-3	6/27/07		24.3	23.0	1562	1584	0.8	6.05	8.67	50.0	0.16												0.554	0.296
LC-3	7/5/07	930	24.9	26.0	1575	1578	0.8	7.85	8.99	55.0	0.15	<10	<2	258	20	46	1452	1332	30.0	<0.1	<0.02	2.58	0.564	0.340
LC-3	7/25/07	940	27.2	30.0	1716	1647	0.8	6.91	8.71	45.0	0.20	10	10.8	229	16	40	1466	1351	32.0	<0.1	<0.02	3.41	0.426	0.162
LC-3	8/7/07	945	23.9	24.0	1581	1627	0.8	5.91	8.54	55.0	0.18	40	7.3	195	8	47	1452	1331	38.0	<0.1	<0.02	3.51	0.370	0.096
LC-3	8/22/07	1440	22.5	38.0	1494	1571	0.8	8.77	9.18	45.0	0.12	20	40.4	158	3	49	1399	1293	44.0	<0.1	<0.02	3.73	0.304	0.042
LC-3	9/4/07	1115	24.1	32.0	1535	1562	0.8	6.13	8.93	50.0	0.16	<10	16.1	165	13	50	1417	1287	37.0	<0.1	<0.02	2.94	0.287	0.047
LC-3	10/1/07	1230	16.6	23.6	1359	1618	0.8	5.05	7.92	40.0	0.20	120	260.0	169	0	31	1448	1311	25.0	<0.2	<0.02	2.96	0.196	0.037
LC-3	11/8/07	1122	2.8	3.6	932	1628	0.8	12.31	8.50	24.0	0.30	<10	11.0	184	0	31	1413	1328	23.0	<0.2	<0.02	2.91	0.181	0.026
LC-3	1/10/08	1230	2.8	-4.6	1149	2006	1.0	9.18	8.19	4.1	0.80	<10	<1	227	0	7	1719	1648	5.0	<0.2	0.67	2.26	0.232	0.174
LC-3	2/13/08	1545	0.1	-14.0	21	-----	0.0	0.80	8.32	4.8	0.60	<10	<1	262	0	12	2005	1914	9.0	<0.2	0.82	3.29	0.360	0.209
LC-3	4/23/08	1100	11.3	19.4	-----	2255	1.2	11.50	8.70	15.0	0.45	<10	51.2	174	3	20	-----	1205	16.0	<0.2	<0.02	2.09	0.178	0.029
LC-3	5/21/08	1100	16.1	22.1	-----	1582	0.8	11.98	8.77	9.3	0.45	<10	1	167	5	21	-----	1382	10.0	<0.2	0.60	1.50	0.110	0.018
LC-3	6/10/08	1745	20.3	25.6	-----	20.43	0.8	15.80	8.58	19.0	0.30	-----	-----	185	7	48	-----	1340	24.0	1.60	<0.02	2.51	0.211	0.034

Middle	6/11/07	1800	24.3	30.0							0.25												0.334	
Middle	7/17/07	1830	28.0	30.0							0.20												0.565	
Middle	8/14/07	1830	25.0	23.0							0.15												0.384	
Middle	9/26/07	1730	16.5	18.0							0.22												0.210	
Middle	10/24/07	1700	11.0	15.5							0.21												0.186	

Column sampler used for in-lake samples (bottles A,B, & D) and a grab samples taken for the C bottle, chl-a, and algae

Note: highlighted cells - likely recorded incorrectly

LC-T1 = Lake Campbell Outlet

LC-T2 = Battle Creek Inlet

LC-1 = North In-Lake Site

LC-2 = Middle In-Lake Site

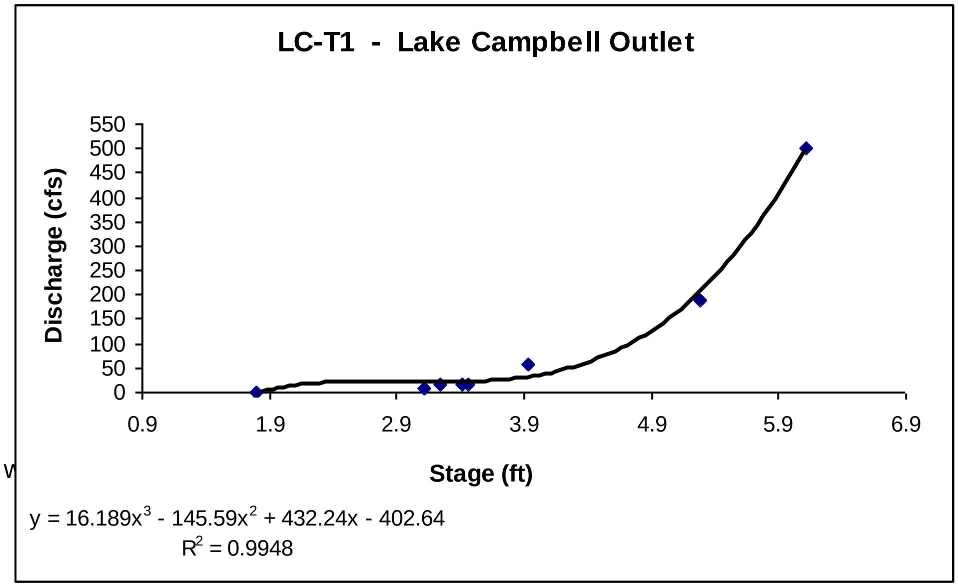
LC-3 - South In-Lake Site

Appendix F.
Stage-Discharge Curves

LC-T1 (outlet)

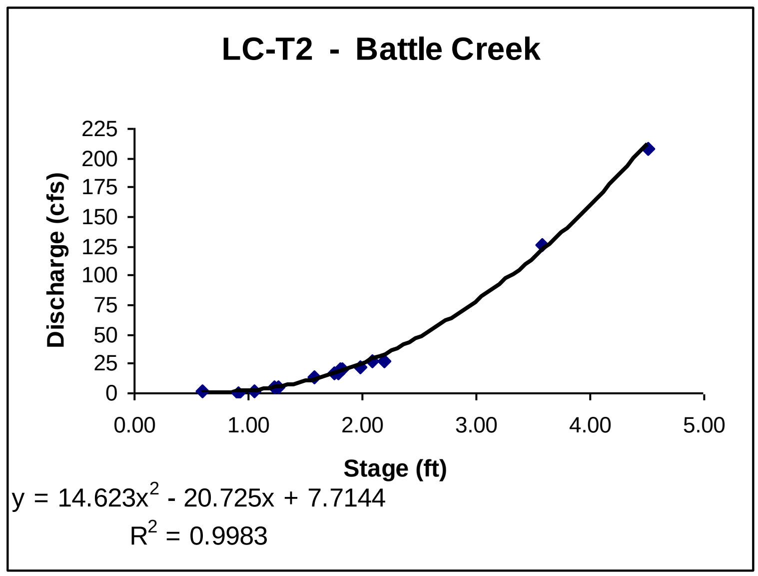
Stage (from level)	Q
3.11	9.825
3.24	17.655
3.41	17.415
3.46	16.506
3.93	56.76
5.28	189.335
6.11	501
1.79	0.01

* all Q taken on lake side of w



LC-T2 (inlet)

Stage ft	Discharge cfs
0.60	0.946
0.92	0.604
1.06	1.916
1.22	4.390
1.26	4.826
1.58	13.227
1.76	16.510
1.79	17.278
1.80	20.745
1.82	20.003
1.99	22.127
2.09	26.729
2.20	27.770
3.58	125.933
4.50	208.500



Notes regarding stage-discharge curve construction:

LC-T2 inlet site: 15 good stages and instantaneous discharges were used to construct the rating curve and to calculate discharges from the OTT data.

LC-T1 outlet site: It was difficult coming up with a rating curve due to the data sets that were collected. There was a gage on the downstream side of the weir collecting data every 15 minutes. There was an OTT installed on the front side of the weir but it did not last long there with the ice – so no good data was collected from that location. Half of the instantaneous discharge calculations were taken on top of the weir and half were taken about five feet in front of the weir (lakeside). It was found that the water depths on top of the weir were NOT comparable to the water depths recorded by the gage. The weir equation would work if continuous water depths had been taken on top of the weir they were not. Also, at various points in time there was no water going over the weir.

It appeared the discharges taken in front of the weir (lakeside) coincided quite well with the times the weir equation was used – the gage recorded similar depths at the time of the measurements. The discharges derived from gage readings are lower than the discharges derived from the weir equation, but not by too much and the data results appeared to make sense.

Appendix G.
Water Quality Duplicates and Blanks

G-1

Duplicates

QA/QC #	Data Type	Site	Name	Spec #	Date	Time	Fecal	E Coli	Alk-M	Alk-P	SUSP SOL	TOT SOL	TDS	VTSS	NO2NO3	NH3N	TKN	TOTAL PO4	TOTDIS PO4
D100	D1	LC-T2	Battle Creek	E07EC002767	05/09/07	1630	180.00	199	174	0	38	1007	916	4	0.7000	<0.02	1.05	0.340	0.262
D100	D2	Dupe		E07EC002768	05/09/07	1630	90.00	236	174	0	32	1016	914	4	0.7000	<0.02	1.14	0.348	0.060
	Absolute Difference						90.00	37.00	0.00	0.00	6	9	2	0	0.00	0.00	0.09	0.008	0.202
	Percent Difference						50.00	15.68	0.00	0.00	16	1	0	0	0.00	0.00	7.89	2.299	77.099
D101	D1	LC-T1	Lk Campbell Outlet	E07EC003249	05/31/07	850	30.00	59	222	2	51	1284	1162	29	<0.1	<0.02	1.99	0.277	0.082
D101	D2	Dupe		E07EC003251	05/31/07	850	80.00	63	223	2	52	1289	1162	23	<0.1	<0.02	1.79	0.272	0.078
	Absolute Difference						50.00	4.00	1.00	0.00	1	5	0	6	0.00	0.00	0.20	0.005	0.004
	Percent Difference						62.50	6.37	0.45	0.00	2	0	0	21	0.00	0.00	10.05	1.805	4.878
D102	D1	LC-T2	Battle Creek	E07EC003453	06/11/07	1245	200.00	651	262	8	20	1562	1426	9	<0.1	<0.02	1.30	0.197	0.115
D102	D2	Dupe		E07EC003451	06/11/07	1245	270.00	582	262	8	20	1567	1428	8	<0.1	<0.02	1.19	0.192	0.120
	Absolute Difference						70.00	69.00	0.00	0.00	0	5	5	1	0.00	0.00	0.11	0.005	0.005
	Percent Difference						25.93	10.60	0.00	0.00	0	0	0	11	0.00	0.00	8.46	2.538	4.167
D103	D1	LC-3	Lake Campbell (south site)	E07EC004295	07/05/07	930	<10	<2	258	20	46	1452	1332	30	<0.1	<0.02	2.58	0.564	0.340
D103	D2	Dupe		E07EC004296	07/05/07	930	<10	<2	258	20	46	1453	1328	34	<0.1	<0.02	3.30	0.575	0.340
	Absolute Difference						0.00	0.00	0.00	0.00	0	1	4	4	0.00	0.00	0.72	0.011	0.000
	Percent Difference						0.00	0.00	0.00	0.00	0	0	0	12	0.00	0.00	21.82	1.913	0.000
D104	D1	LC-T2	Battle Creek	E07EC004298	07/05/07	1300	270.00	121	287	6	27	1323	1229	9	0.1000	<0.02	1.54	0.266	0.104
D104	D2	Dupe		E07EC004299	07/05/07	1300	230.00	114	287	6	24	1323	1231	8	0.1000	<0.02	1.50	0.274	0.107
	Absolute Difference						40.00	7.00	0.00	0.00	3	0	2	1	0.00	0.00	0.04	0.008	0.003
	Percent Difference						14.81	5.79	0.00	0.00	11	0	0	11	0.00	0.00	2.60	2.920	2.804
D105	D1	LC-T2	Battle Creek	E07EC005770	08/22/07	1615	190.00	194	215	0	31	1212	1123	12	0.2000	0.0500	1.57	0.208	0.092
D105	D2	Dupe		E07EC005771	08/22/07	1615	100.00	143	215	0	34	1208	1118	12	0.2000	0.0600	1.35	0.194	0.094
	Absolute Difference						90.00	51.00	0.00	0.00	3	4	5	0	0.00	0.00	0.22	0.014	0.002
	Percent Difference						47.37	26.29	0.00	0.00	9	0	0	0	0.00	0.00	14.01	6.731	2.128
D106	D1	LC-2	Lake Campbell II	E07EC006553	10/01/07	1200	80.0	74.9	170	0	34	1453	1317	25	<0.2	<0.02	2.82	0.208	0.040
D106	D2	Dupe		E07EC006557	10/01/07	1200	60.00	93	170	0	38	1451	1320	28	<0.2	<0.02	2.79	0.212	0.040
	Absolute Difference						20.00	18.40	0.00	0.00	4	2	3	3	0.00	0.00	0.03	0.004	0.000
	Percent Difference						25.00	19.72	0.00	0.00	11	0	0	11	0.00	0.00	1.06	1.887	0.000
D107	D1	LC-3	Lake Campbell III	E08EC000193	01/10/08	1230	<10	<1	227	0	7	1719	1648	5	<0.2	0.67	2.26	0.232	0.174
D107	D2	Dupe		E08EC000194	01/10/08	1230	<10	<1	226	0	7	1717	1648	5	<0.2	0.65	2.28	0.229	0.186
	Absolute Difference						0.00	0.00	1.00	0.00	0	2	0	0	0.00	0.02	0.02	0.003	0.012
	Percent Difference						0.00	0.00	0.44	0.00	0	0	0	0	0.00	2.99	0.88	1.293	6.452
D108	D1	LC-T1	Lake Campbell Outlet	E08EC002126	04/29/08	1415	<10	19	176	9	69	-------	1236	25	<0.2	<0.02	1.80	0.202	0.046
D108	D2	Dupe		E08EC002125	04/29/08	1415	<10	19	176	9	69	-------	1237	25	<0.2	<0.02	1.80	0.207	0.028
	Absolute Difference						0.00	0.20	0.00	0.00	0		1	0	0.00	0.00	0.00	0.005	0.018
	Percent Difference						0.00	1.03	0.00	0.00	0		0	0	0.00	0.00	0.00	2.415	39.130

Blanks

QA/QC #	SITE_ID	Spec#	DATE	TIME	FECAL	ECOLI	Alkalinity M	Alkalinity P	SUSP_SOL	TOT_SOL	TDS	VTSS	NO2_NO3	NH3_N	TKN	TOTAL_PO4	TOTDIS_PO4
D100	Blank	E07EC003248	5/31/07	1030	<10	<1	<6	0	<3	<7	<7	<3	<0.1	0.0200	<0.5	0.0040	0.0090
D101	Blank	E07EC003450	6/11/07	1245	<10	<2	<6	0	<3	<7	<7	<3	<0.1	0.0500	<0.5	<0.002	0.0030
D102	Blank	E07EC004297	7/5/07	1000	<10	<1	<6	0	<3	<7	<7	<3	<0.1	<0.02	<0.5	0.0030	0.0050
D103	Blank	E07EC004300	7/5/07	1300	<10	<1	<6	0	<3	<7	<7	<3	<0.1	<0.02	<0.5	0.0020	0.0020
D104	Blank	E07EC005772	8/22/07	1615	<10	<1	<6	0	<3	<7	<7	<3	<0.1	<0.02	<0.5	<0.002	<0.002
D105	Blank	E07EC006556	10/1/07	1500	<10	<1	<6	0	<3	<7	<7	<3	<0.2	<0.02	<0.5	<0.002	<0.002
D106	Blank	E08EC000195	1/10/08	1230	<10	<1	<6	0	<3	<7	<7	<3	<0.2	<0.02	<0.5	0.0040	0.0080
D108	Blank	E08EC002127	4/29/08	1415	<10	<2	<6	0	<3	<7	<7	<3	0.2	<0.02	<0.5	<0.002	0.0040

Appendix H.
2007-2008 List of Algae Species

Lake Campbell - 2008 Algae Species

Flagellated	Blue-Green	Diatoms	Non-Motile Green Algae	Unidentified
Carteria sp.	*Anabaena circinalis*	*Cyclotella atomus*	*Actinastrum hantzschii*	Unidentified algae
Chlamydomonas sp.	*Anabaena spaerica*	*Cyclotella meneghiniana*	*Ankistrodesmus* sp.	
Chromulina sp.	*Anabaenopsis* sp.	*Entomoneis paludosa*	*Chlorella* sp.	
Chrysochromulina parva	*Aphanizomenon* sp.	*Gyrosigma* sp.	*Closteriopsis longissima*	
Chrysococcus rufescens	*Aphanocapsa* sp.	*Melosira granulata*	*Dictyosphaerium pulchellum*	
Chrysococcus sp.	*Dactylococcopsis* sp.	*Navicula cuspidata*	*Kirchneriella* sp.	
Cryptomonas reflexa	*Marssoniella elegans*	*Nitzschia acicularis*	*Lagerheimia* sp.	
Cryptomonas sp.	*Microcystis* sp.	*Nitzschia paleacea*	*Micractinium* sp.	
Dinobryon sertularia	*Oscillatoria agardhii*	*Nitzschia reversa*	*Oocystis* sp.	
Dinobryon sp.	*Pseudanabaena* sp.	*Nitzschia* sp.	*Pediastrum duplex*	
Erkenia sp.		*Skeletonema* sp.	*Scenedesmus acuminatus*	
Euglena acus		*Stephanodiscus hantzschii*	*Scenedesmus quadricauda*	
Euglena polymorpha		*Stephanodiscus minutus*	*Scenedesmus* sp.	
Glenodinium penardiforme		*Surirella ovalis*	*Selenastrum minutum*	
*Glenodinium quadridens**		*Surirella ovata*	*Sphaerocystis schroeteri*	
Glenodinium sp.		*Synedra acus*	*Tetrastrum staurogeniaeforma*	
Kephyrion sp.		*Synedra* sp.	Unidentified green algae	
Lepocinclis sp.		*Synedra ulna*		
Mallomonas sp.				
Mallomonas tonsurata				
Phacus nordstedtii				
Phacus pseudonordstedtii				
Platymonas elliptica				
Pseudokephyrion sp.				
Rhodomonas minuta				
Scourfieldia cordiformis				
Spermatozoopsis exultans				
*Synuropsis elaeochrus**				
Trachelomonas sp.				
Trachelomonas volvocina				
Unidentified flagellates				

Note: shaded species are considered noxious/nuisance
* bloom
Note: A filamentous sulfur bacteria (*Beggiatoa* sp.) was also noted with a higher density in the April 2008 sampling

Appendix I.
Septic Survey

I-1

Lake Campbell - Septic System Survey 2008

In an effort to collect accurate information during the Lake Campbell Post-Assessment currently under way, the East Dakota Water Development District is asking for your cooperation in completing this short survey. Any personal information you provide, such as your name, address, and phone number will be kept confidential and will not be publicly released. Please fill out the survey as completely as possible and return it to a Lake Association Board member, bring it to the Spring Fling in May, or mail to East Dakota Water Development District, 132B Airport Drive, Brookings, SD 57006. If you have questions, please call Deb Springman at the East Dakota Water Development District, (605) 688-6608. Thank You!

Owner Information:
Name: ____
Address: ______________________________________
Name of Beach or Subdivision: ___________________________
Phone #: ______________________________________

Type of Residence: # of bedrooms: Use of Residence:

☐
☐
☐ House ______
☐ Permanent – Year Round Cabin ______
[Seasonal – 40+ days
Trailer ______

☐
Seasonal -weekends only/short stays

Is your water supply from:
[
[
[Rural Water
Neighborhood Well **
Private Well -when was it constructed __________ what is the depth ________
• Have you ever had the nitrate levels in your well tested
☐ Yes
☐ No
• If 'Yes', do you recall if they were within **normal** limits or if they were **high** __________

** The East Dakota Water Development District has the capability of testing nitrate levels. This service is provided for free to residents of the district. Would you be interested in having the nitrate levels of your private well tested?
☐ Yes
☐ No

Estimate home water usage (fill in one) _____gal/day ______average gal/month ______ average gal/yr

Existing Wastewater Disposal System:
☐ Holding Tank Capacity ________gallons Construction Material: (concrete, steel, etc.) __________
☐ Septic Tank Capacity ________gallons Construction Material: (concrete, steel, etc.) __________
☐ Other __________ Capacity ________gallons Construction Material: (concrete, steel, etc.) __________

(over

→) What year was your present septic system installed/constructed: ___________________

When was the last time you had your tank pumped: ____________________________

Has any of the following occurred with your present wastewater system?

☐ Yes

☐ No

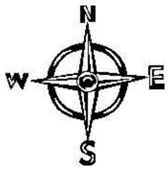
☐

☐ Tank overflow

l plumbing backups (into washing machine, toilet, sink)

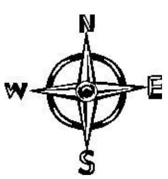
Plugged drain line wet spots in drain field area

If your septic system is 20 or more years old **OR** you suspect problems with your system, would you be willing to have your system checked for free if dye packs were made available to this project?



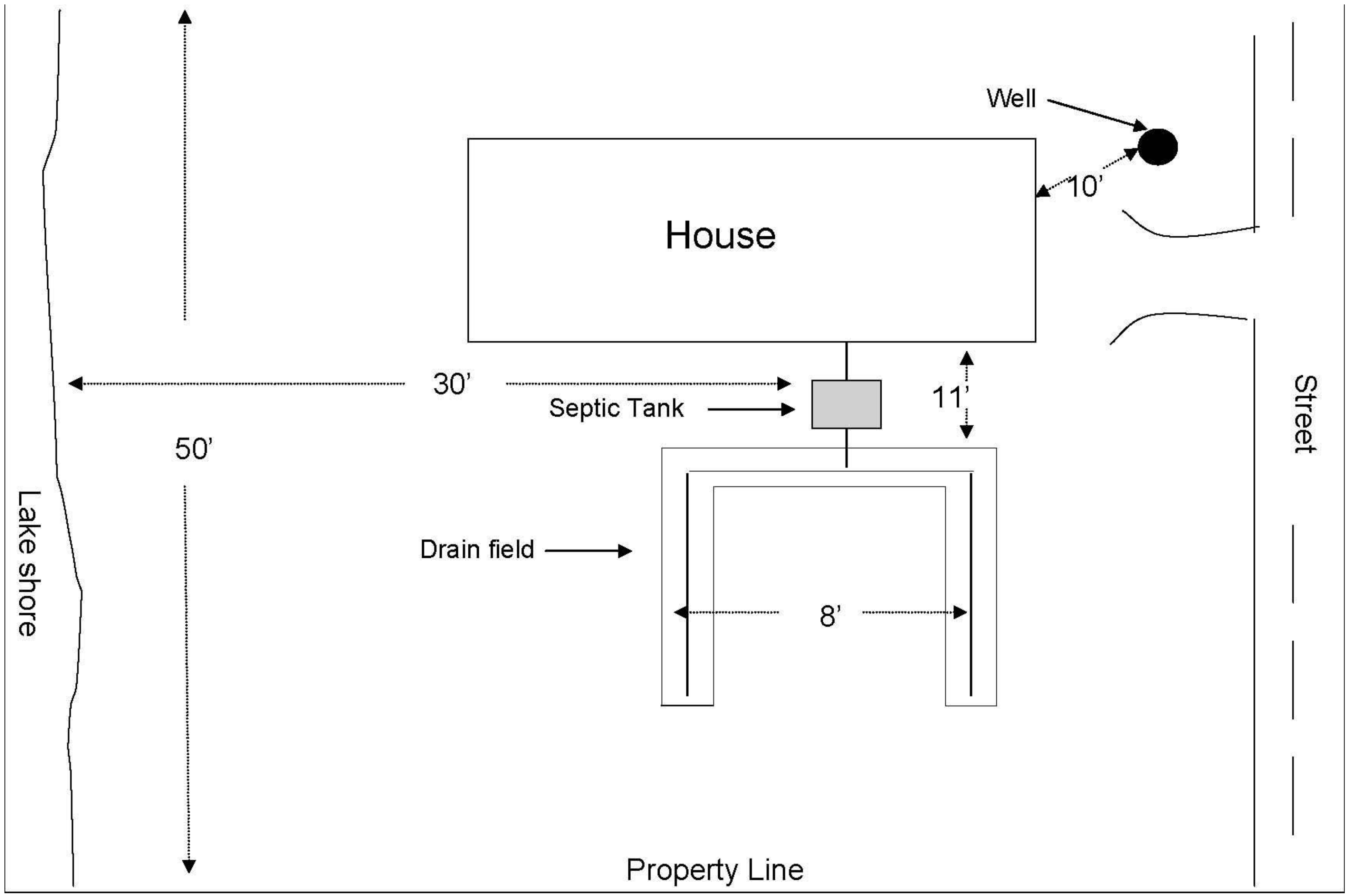
Please roughly sketch the location of your house, septic system, well (if applicable), drain fields, & approximate distances to/from these locations in the space below (See attached Example Sketch)

~ ~ ~ ***Thank you for taking the time to fill out this form*** ~ ~ ~



EXAMPLE SKETCH

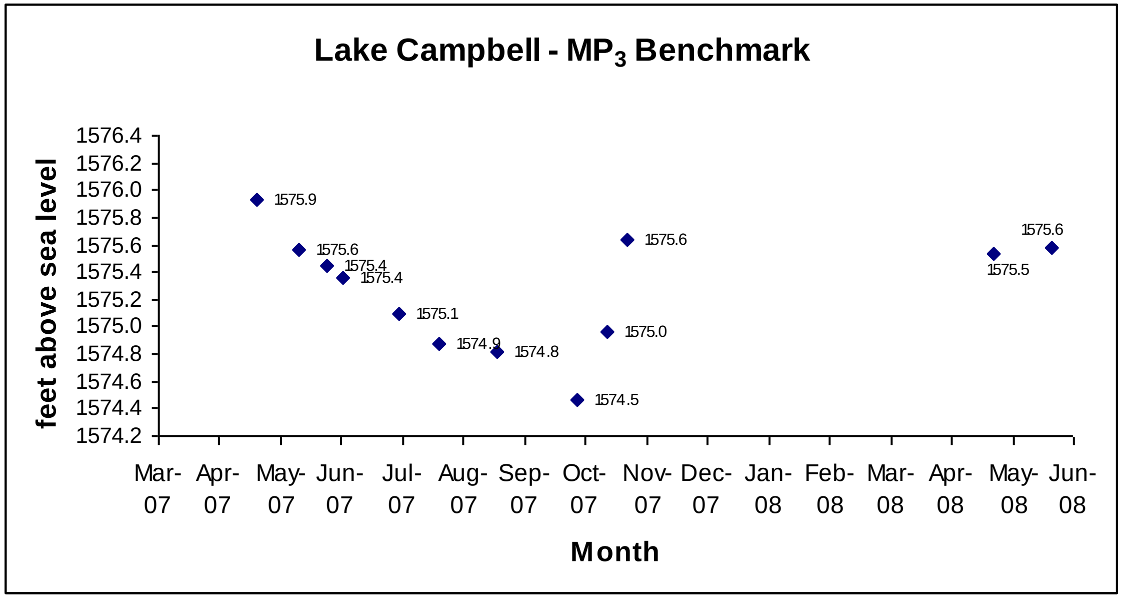
Please roughly sketch the location of your house, septic system,
well (if applicable), drain fields, & approximate distances to/from these locations


Well
10’
House
30’
Septic Tank
11’
50’
Lake shore
Street
Drain field
8’
Property Line

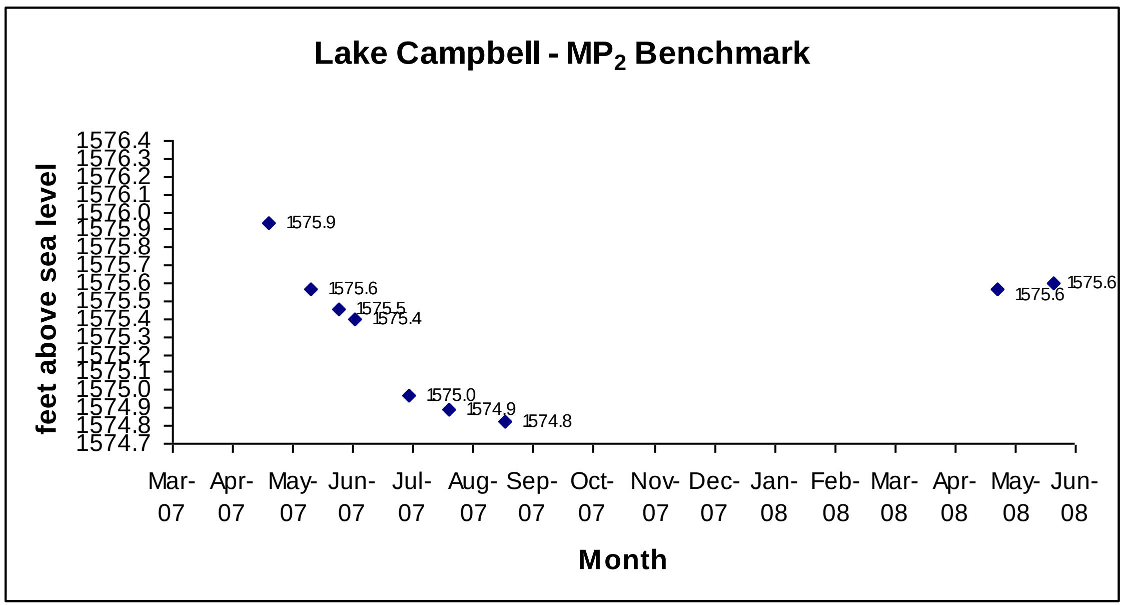
Appendix J.
Benchmark and Elevation Data

J-1

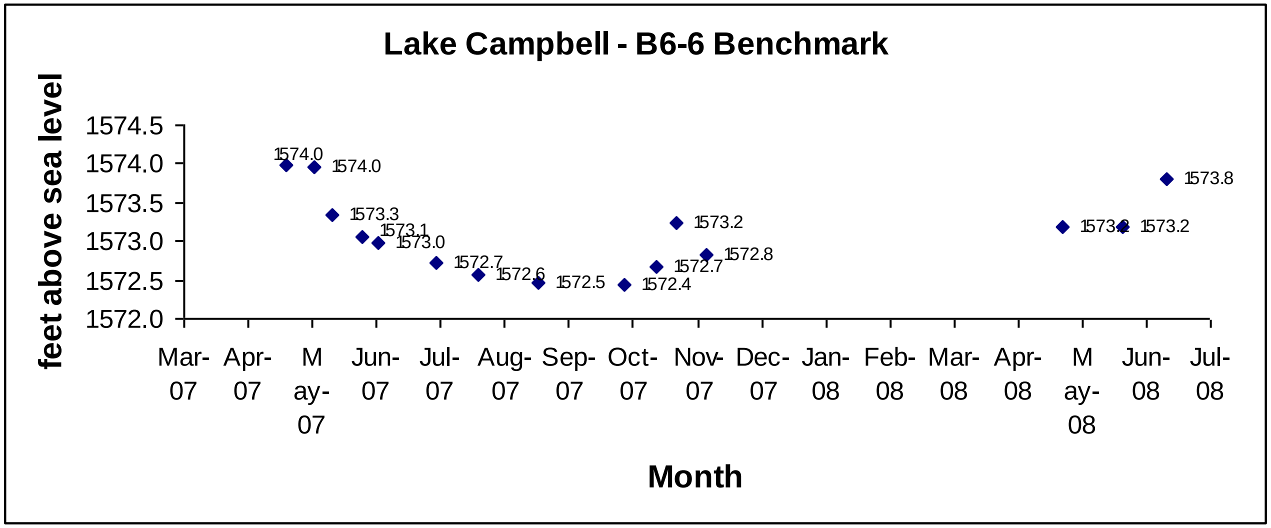
Date	MP_3 (fmsl)
04/26/07	1575.9
05/17/07	1575.6
05/31/07	1575.4
06/08/07	1575.4
07/05/07	1575.1
07/25/07	1574.9
08/22/07	1574.8
10/01/07	1574.5
10/16/07	1575.0
10/25/07	1575.6
04/23/08	1575.5
05/21/08	1575.6
06/10/08	1576.3



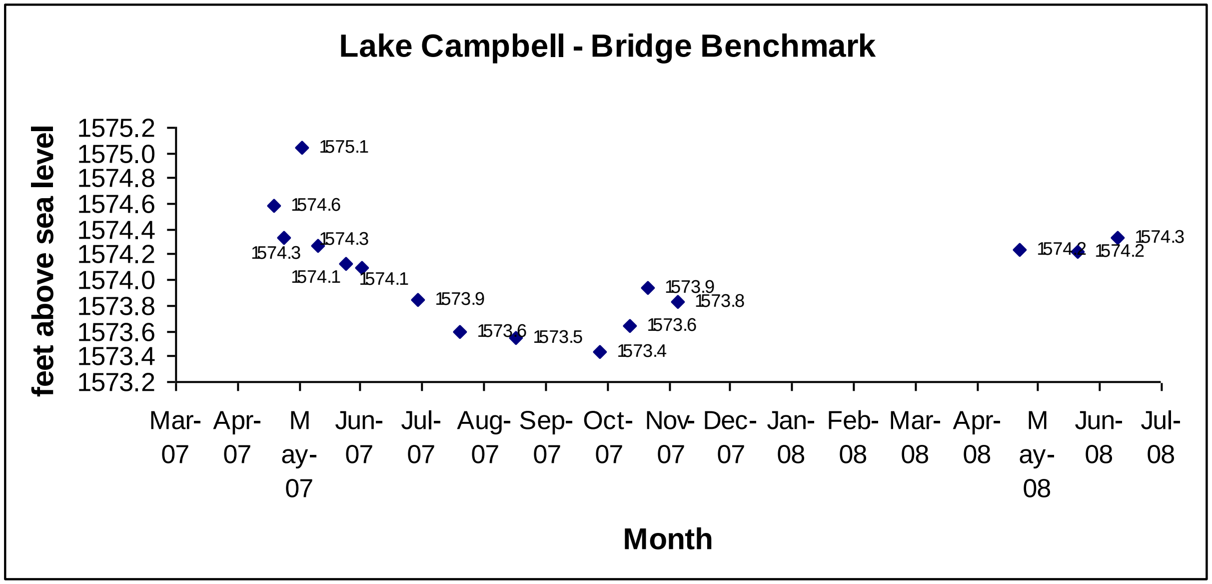
Date	MP_2 (fmsl)
04/26/07	1575.9
05/17/07	1575.6
05/31/07	1575.5
06/08/07	1575.4
07/05/07	1575.0
07/25/07	1574.9
08/22/07	1574.8
04/23/08	1575.6
05/21/08	1575.6
06/10/08	1576.2



Date	B6-6 (fmsl)
4/26/2007	1574.0
5/9/2007	1574.0
5/17/2007	1573.3
5/31/2007	1573.1
6/8/2007	1573.0
7/5/2007	1572.7
7/25/2007	1572.6
8/22/2007	1572.5
10/1/2007	1572.4
10/16/2007	1572.7
10/25/2007	1573.2
11/8/2007	1572.8
4/23/2008	1573.2
5/21/2008	1573.2
6/10/2008	1573.8



Date	H_2O Surface to S.Bridge (fmsl)
04/26/07	1574.58
05/01/07	1574.33
05/09/07	1575.05
05/17/07	1574.26
05/31/07	1574.13
06/08/07	1574.10
07/05/07	1573.85
07/25/07	1573.59
08/22/07	1573.54
10/01/07	1573.44
10/16/07	1573.64
10/25/07	1573.93
11/08/07	1573.84
04/23/08	1574.25
05/21/08	1574.23
06/10/08	1574.33



Appendix K.
FLUX Monthly Loads and Concentrations

FLUX Results

Monthly Concentrations – Site LC-T1

Site	Stream	Year	Month	SuspSol	TotSol	DisSol	VTSS	TKN	Tot PO4	TotDis PO4	Fecal
LC-T1	Lake Campbell Outlet	2007	4	20351.53	1155607	1138177	13033.44	1587.91	189.09	60.00	19204.05
LC-T1	Lake Campbell Outlet	2007	5	23838.72	1174619	1148008	14120.20	1618.35	215.78	62.08	33897.09
LC-T1	Lake Campbell Outlet	2007	6	59033.22	1366504	1247230	25088.40	1925.55	485.19	83.12	225052.30
LC-T1	Lake Campbell Outlet	2007	7	60803.41	1376155	1252220	25640.07	1941.00	498.74	84.18	1037445.00
LC-T1	Lake Campbell Outlet	2007	8	60803.42	1376155	1252220	25640.07	1941.00	498.74	84.18	1067046.00
LC-T1	Lake Campbell Outlet	2007	9	60803.41	1376155	1252220	25640.07	1941.00	498.74	84.18	2160525.00
LC-T1	Lake Campbell Outlet	2007	10	60803.42	1376155	1252220	25640.07	1941.00	498.74	84.18	505049.10
LC-T1	Lake Campbell Outlet	2007	11	60803.42	1376155	1252220	25640.07	1941.00	498.74	84.18	198032.30
LC-T1	Lake Campbell Outlet	2008	4	60803.43	1376155	1252220	25640.07	1941.00	498.74	84.18	354190.40
LC-T1	Lake Campbell Outlet	2008	5	53322.32	1335367	1231129	23308.62	1875.70	441.47	79.71	229070.60
LC-T1	Lake Campbell Outlet	2008	6	27541.76	1194808	1158448	15274.24	1650.67	244.13	64.30	78814.16

Monthly Concentrations – Site LC-T2

Site	Stream	Year	Month	SuspSol	TotSol	DisSol	VTSS	TKN	NO2NO3	NH3N	Tot PO4	TotDis PO4	Fecal	E-Coli
LC-T2	Battle Creek - Inlet	2007	4	32796.69	1060025	1059699	4573.75	1331.62	1298.91	982.62	328.65	234.13	301740.5	1088126.0
LC-T2	Battle Creek - Inlet	2007	5	32512.19	1074405	1076061	4766.56	1329.08	1264.84	982.62	323.66	228.97	296620.0	1060925.0
LC-T2	Battle Creek - Inlet	2007	6	27960.27	1304466	1337851	7851.40	1288.49	719.78	853.89	243.83	146.49	214693.5	625724.3
LC-T2	Battle Creek - Inlet	2007	7	26005.33	1403272	1450283	9176.27	1271.05	485.68	48.35	209.54	111.07	179508.2	438816.2
LC-T2	Battle Creek - Inlet	2007	8	26005.33	1403272	1450283	9176.27	1271.05	485.68	48.35	209.54	111.07	179508.1	438816.2
LC-T2	Battle Creek - Inlet	2007	9	26005.33	1403272	1450283	9176.27	1271.05	485.68	48.35	209.54	111.07	179508.1	438816.3
LC-T2	Battle Creek - Inlet	2007	10	26005.33	1403272	1450283	9176.27	1271.05	485.68	759.71	209.54	111.07	179508.1	438816.3
LC-T2	Battle Creek - Inlet	2007	11	26005.33	1403272	1450283	9176.27	1271.05	485.68	48.35	209.54	111.07	179508.2	438816.3
LC-T2	Battle Creek - Inlet	2008	4	29771.65	1212916	1233675	6623.83	1304.64	936.68	908.89	275.59	179.31	247295.1	798907.0
LC-T2	Battle Creek - Inlet	2008	5	31572.10	1121918	1130127	5403.66	1320.70	1152.27	982.62	307.17	211.94	279700.0	971044.8
LC-T2	Battle Creek - Inlet	2008	6	32380.33	1081069	1083645	4855.92	1327.91	1249.06	982.62	321.35	226.58	294246.7	1048318.0

FLUX Results

Monthly Loadings – Site LC-T1

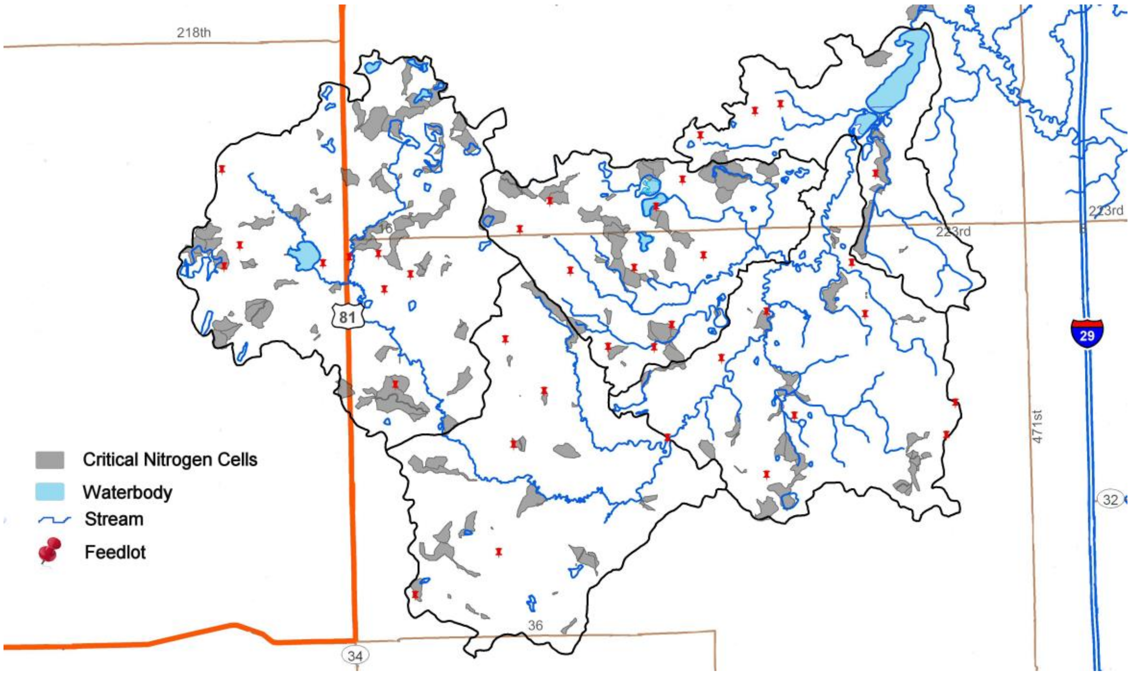
Site	Stream	Year	Month	SuspSol	TotSol	DisSol	VTSS	TKN	Tot PO4	TotDis PO4	Fecal
LC-T1	Lake Campbell Outlet	2007	4	32014.3	1817844.0	1790427.0	20502.4	2497.9	297.5	94.4	30209.2
LC-T1	Lake Campbell Outlet	2007	5	167534.4	8255022.0	8068007.0	99234.4	11373.5	1516.5	436.3	238222.9
LC-T1	Lake Campbell Outlet	2007	6	79827.4	1847849.0	1686561.0	33925.7	2603.8	656.1	112.4	304326.0
LC-T1	Lake Campbell Outlet	2007	7	18687.7	422957.1	384866.0	7880.4	596.6	153.3	25.9	318855.4
LC-T1	Lake Campbell Outlet	2007	8	18169.3	411223.7	374189.3	7661.8	580.0	149.0	25.2	318855.4
LC-T1	Lake Campbell Outlet	2007	9	8684.0	196544.8	178844.2	3662.0	277.2	71.2	12.0	308569.8
LC-T1	Lake Campbell Outlet	2007	10	38387.4	868815.8	790571.2	16187.5	1225.4	314.9	53.1	318855.4
LC-T1	Lake Campbell Outlet	2007	11	60003.7	1358055.0	1235750.0	25302.8	1915.5	492.2	83.1	195427.5
LC-T1	Lake Campbell Outlet	2008	4	49440.3	1118976.0	1018202.0	20848.4	1578.3	405.5	68.4	287998.5
LC-T1	Lake Campbell Outlet	2008	5	71258.6	1784550.0	1645249.0	31149.0	2506.6	590.0	106.5	306124.0
LC-T1	Lake Campbell Outlet	2008	6	72917.2	3163270.0	3067005.0	40438.7	4370.2	646.3	170.2	208661.5

Monthly Loadings – Site LC-T2

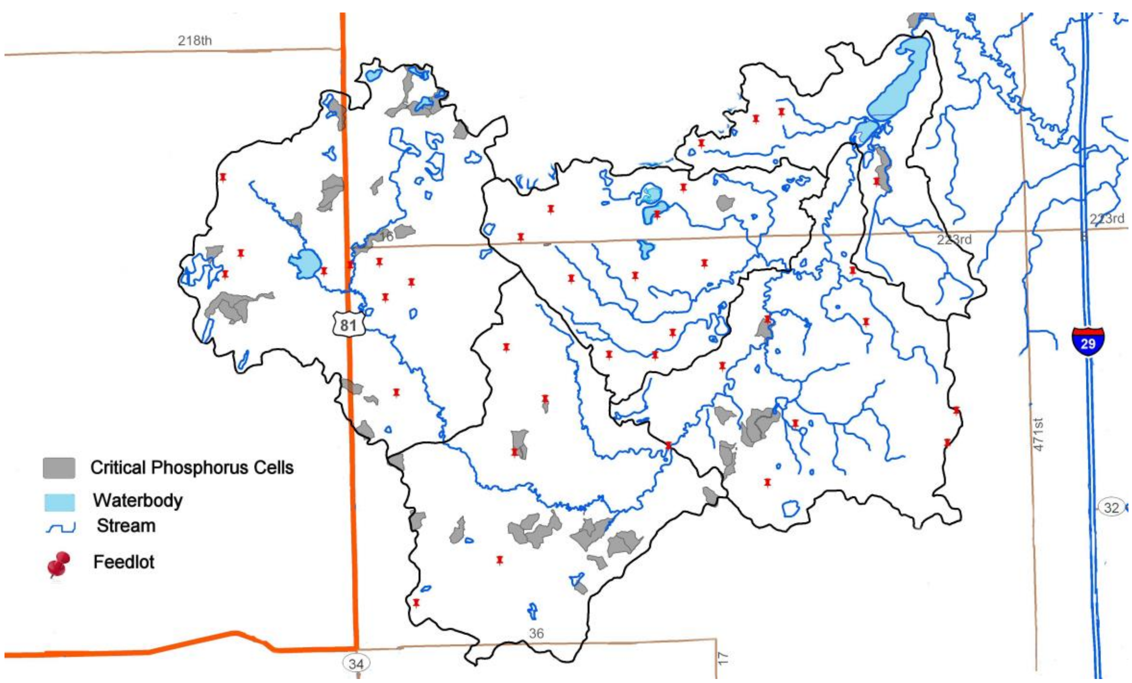
Site	Stream	Year	Month	SuspSol	TotSol	DisSol	VTSS	TKN	NO2NO3	NH3N	Tot PO4	TotDis PO4	Fecal	E-Coli
LC-T2	Battle Creek - Inlet	2007	4	42091.6	1360446.0	1360027.0	5870.0	1709.0	1667.0	1261.1	421.8	300.5	387256.5	1396510.0
LC-T2	Battle Creek - Inlet	2007	5	252135.8	8332133.0	8344981.0	36965.2	10307.2	9809.0	7620.4	2510.0	1775.7	2300323.0	8227598.0
LC-T2	Battle Creek - Inlet	2007	6	34919.6	1629148.0	1670841.0	9805.6	1609.2	898.9	1066.4	304.5	183.0	268130.7	781466.8
LC-T2	Battle Creek - Inlet	2007	7	2798.8	151027.9	156087.5	987.6	136.8	52.3	5.2	22.6	12.0	19319.7	47227.8
LC-T2	Battle Creek - Inlet	2007	8	3636.2	196214.3	202787.6	1283.1	177.7	67.9	6.8	29.3	15.5	25099.9	61358.0
LC-T2	Battle Creek - Inlet	2007	9	1597.5	86205.1	89093.1	563.7	78.1	29.8	3.0	12.9	6.8	11027.5	26957.1
LC-T2	Battle Creek - Inlet	2007	10	18838.8	1016557.0	1050613.0	6647.5	920.8	351.8	550.3	151.8	80.5	130039.1	317886.9
LC-T2	Battle Creek - Inlet	2007	11	5260.9	283883.1	293393.4	1856.4	257.1	98.3	9.8	42.4	22.5	36314.6	88772.9
LC-T2	Battle Creek - Inlet	2008	4	52387.2	2134288.0	2170816.0	11655.5	2295.7	1648.2	1599.3	484.9	315.5	435148.8	1405784.0
LC-T2	Battle Creek - Inlet	2008	5	114211.0	4058502.0	4088197.0	19547.5	4777.6	4168.3	3554.6	1111.2	766.7	1011805.0	3512721.0
LC-T2	Battle Creek - Inlet	2008	6	204746.2	6835780.0	6852066.0	30704.8	8396.6	7898.0	6213.3	2031.9	1432.7	1860571.0	6628689.0

Appendix L.
AnnAGNPS Critical Nitrogen and Phosphorus Cells

Critical Nitrogen Cells in Lake Campbell Watershed



Critical Phosphorus Cells in the Lake Campbell Watershed



Lake Campbell Watershed Area Cells (top 4%) Achievable Phosphorus Reductions (With No Tillage, Feedlot Removal, & Native Grass Planting)

					BMP Scenarios (lb/ac/yr)				Difference between 10-yr simulated P04 and applied BMPs			
Cell	Reach	Area	% of total	10-Year Simulated P04 (lb/ac/yr)	No Till	No Feedlot	No Impound	All Grass	no till difference	no feedlot difference	no impound difference	all grass difference
5272	527	26.7	0.67	7.3	7.1	2.8	7.3	1.1	0.19	4.47	0.00	6.24
4422	442	54.5	0.35	3.9	2.9	3.9	3.9	1.8	0.98	0.00	0.00	2.10
4471	447	98.3	0.22	2.4	1.6	2.4	2.4	1.4	0.81	0.00	0.00	1.02
4383	438	112.5	0.22	2.4	1.7	2.4	2.4	1.5	0.74	0.00	0.00	0.87
4591	459	74.1	0.20	2.2	1.3	2.2	2.2	1.1	0.85	0.00	0.00	1.05
4132	413	32.5	0.20	2.1	1.3	2.1	2.1	1.1	0.84	0.00	0.00	1.06
3833	383	67.6	0.20	2.1	1.3	2.1	2.1	1.1	0.83	0.00	0.00	1.04
4731	473	75.0	0.20	2.1	1.3	2.1	2.1	1.1	0.83	0.00	0.00	1.05
4213	421	112.8	0.20	2.1	1.3	2.1	2.1	1.1	0.83	0.00	0.00	1.05
7111	711	75.8	0.19	2.1	1.3	2.1	2.1	1.1	0.83	0.00	0.00	1.04
3591	359	102.8	0.19	2.1	1.3	2.1	2.1	1.1	0.82	0.00	0.00	1.03
3601	360	78.3	0.19	2.1	1.3	2.1	2.1	1.1	0.81	0.00	0.00	1.02
3593	359	7.1	0.19	2.1	1.3	2.1	2.1	1.1	0.82	0.00	0.00	1.02
5273	527	23.1	0.19	2.1	1.3	2.1	2.1	1.1	0.82	0.00	0.00	1.03
4121	412	79.4	0.19	2.1	1.3	2.1	2.1	1.1	0.82	0.00	0.00	1.01
2661	266	96.7	0.19	2.1	1.3	2.1	2.1	1.1	0.81	0.00	0.00	1.02
2891	289	84.3	0.19	2.1	1.3	2.1	2.1	1.1	0.81	0.00	0.00	1.02
3612	361	205.5	0.19	2.1	1.3	2.1	2.1	1.1	0.81	0.00	0.00	1.01
4123	412	102.5	0.19	2.1	1.3	2.1	2.1	1.1	0.80	0.00	0.00	1.01
5271	527	76.1	0.19	2.1	1.3	2.1	2.1	1.1	0.80	0.00	0.00	1.01
193	19	167.5	0.19	2.1	1.2	2.1	2.1	1.3	0.84	0.00	0.00	0.74
3121	312	77.6	0.19	2.1	1.3	2.1	2.1	1.1	0.80	0.00	0.00	0.99
1663	166	169.9	0.19	2.1	1.3	2.1	2.1	1.1	0.80	0.00	0.00	1.01
3753	375	50.7	0.19	2.1	1.2	2.1	2.1	1.1	0.85	0.00	0.00	0.94
2662	266	201.3	0.19	2.1	1.3	2.1	2.1	1.1	0.79	0.00	0.00	1.00
3011	301	75.8	0.19	2.1	1.3	2.1	2.1	1.1	0.79	0.00	0.00	1.00
2681	268	74.1	0.19	2.1	1.3	2.1	2.1	1.1	0.79	0.00	0.00	1.00
2833	283	79.2	0.19	2.1	1.3	2.1	2.1	1.1	0.79	0.00	0.00	0.99
4732	473	1.1	0.19	2.1	1.3	2.1	2.1	1.1	0.78	0.00	0.00	0.98
1662	166	123.9	0.19	2.1	1.3	2.1	2.1	1.1	0.79	0.00	0.00	0.99
1921	192	75.6	0.19	2.1	1.3	2.1	2.1	1.1	0.79	0.00	0.00	0.99
2193	219	196.2	0.19	2.1	1.3	2.1	2.1	1.1	0.78	0.00	0.00	0.98
2051	205	75.0	0.19	2.1	1.3	2.1	2.1	1.1	0.79	0.00	0.00	0.98
723	72	1.1	0.19	2.1	1.2	2.1	2.1	1.3	0.83	0.00	0.00	0.72

Lake Campbell Watershed Area Cells (top 4%) Achievable Phosphorus Reductions (With No Tillage, Feedlot Removal, & Native Grass Planting)

Cell	Reach	Area	% of total	10-Year Simulated P04 (lb/ac/yr)	BMP Scenarios (lb/ac/yr) No Till	No Feedlot	No Impound	All Grass	Difference between 10-yr simulated P04 and applied BMPs no till difference	no feedlot difference	no impound difference	all grass difference
1742	174	62.1	0.19	2.1	1.3	2.1	2.1	1.1	0.78	0.00	0.00	0.97
1881	188	75.8	0.19	2.0	1.3	2.0	2.0	1.1	0.78	0.00	0.00	0.96
1883	188	25.6	0.19	2.0	1.3	2.0	2.0	1.1	0.77	0.00	0.00	0.97
1773	177	58.0	0.19	2.0	1.3	2.0	2.0	1.1	0.78	0.00	0.00	0.96
2252	225	43.1	0.19	2.0	1.3	2.0	2.0	1.1	0.77	0.00	0.00	0.96
2173	217	100.7	0.19	2.0	1.3	2.0	2.0	1.1	0.77	0.00	0.00	0.95
2632	263	61.4	0.19	2.0	1.3	2.0	2.0	1.1	0.77	0.00	0.00	0.95
2171	217	116.3	0.19	2.0	1.3	2.0	2.0	1.1	0.77	0.00	0.00	0.95
4251	425	77.8	0.18	2.0	1.2	2.0	2.0	1.1	0.81	0.00	0.00	0.90
3873	387	91.6	0.18	2.0	1.2	2.0	2.0	1.1	0.80	0.00	0.00	0.90
6401	640	96.5	0.18	2.0	1.2	2.0	2.0	1.1	0.80	0.00	0.00	0.89
3581	358	131.2	0.18	2.0	1.2	2.0	2.0	1.1	0.79	0.00	0.00	0.88
3541	354	79.2	0.18	2.0	1.2	2.0	2.0	1.1	0.79	0.00	0.00	0.89
3082	308	116.8	0.18	2.0	1.2	2.0	2.0	1.1	0.79	0.00	0.00	0.90
3081	308	79.2	0.18	2.0	1.2	2.0	2.0	1.1	0.79	0.00	0.00	0.89
3052	305	48.5	0.18	2.0	1.2	2.0	2.0	1.1	0.79	0.00	0.00	0.90
3583	358	132.1	0.18	2.0	1.2	2.0	2.0	1.1	0.79	0.00	0.00	0.88
3291	329	126.8	0.18	2.0	1.2	2.0	2.0	1.1	0.79	0.00	0.00	0.88
3392	339	138.3	0.18	2.0	1.2	2.0	2.0	1.1	0.79	0.00	0.00	0.88
3131	313	109.9	0.18	2.0	1.2	2.0	2.0	1.1	0.79	0.00	0.00	0.89
4793	479	72.5	0.18	2.0	1.2	2.0	2.0	1.1	0.79	0.00	0.00	0.89
3132	313	51.2	0.18	2.0	1.2	2.0	2.0	1.1	0.78	0.00	0.00	0.89
4751	475	76.7	0.18	2.0	1.2	2.0	2.0	1.1	0.78	0.00	0.00	0.89
5093	509	366.3	0.18	2.0	1.2	2.0	2.0	1.1	0.79	0.00	0.00	0.87
3542	354	119.0	0.18	2.0	1.2	2.0	2.0	1.1	0.78	0.00	0.00	0.87
4291	429	85.4	0.18	2.0	1.2	2.0	2.0	1.1	0.78	0.00	0.00	0.86
2062	206	177.0	0.18	1.9	1.2	1.9	1.9	1.1	0.77	0.00	0.00	0.87
1972	197	101.6	0.18	1.9	1.2	1.9	1.9	1.1	0.77	0.00	0.00	0.86
2081	208	93.6	0.18	1.9	1.2	1.9	1.9	1.1	0.77	0.00	0.00	0.85
1871	187	80.5	0.18	1.9	1.2	1.9	1.9	1.1	0.76	0.00	0.00	0.86
2622	262	187.5	0.18	1.9	1.2	1.9	1.9	1.1	0.76	0.00	0.00	0.85
1993	199	22.7	0.18	1.9	1.2	1.9	1.9	1.1	0.76	0.00	0.00	0.85
2033	203	259.3	0.18	1.9	1.2	1.9	1.9	1.1	0.76	0.00	0.00	0.84
2253	225	26.9	0.18	1.9	1.2	1.9	1.9	1.1	0.76	0.00	0.00	0.83
2272	227	81.8	0.18	1.9	1.2	1.9	1.9	1.1	0.76	0.00	0.00	0.83
2282	228	62.3	0.18	1.9	1.2	1.9	1.9	1.1	0.76	0.00	0.00	0.83
263	26	7.8	0.16	1.8	0.9	1.8	1.8	1.8	0.84	0.00	0.00	0.00
3161	316	78.7	0.15	1.7	1.4	0.7	1.7	0.1	0.33	0.97	0.00	1.63
2471	247	76.3	0.15	1.6	1.4	0.7	1.6	0.1	0.18	0.93	0.00	1.53

Lake Campbell Watershed Area Cells (top 5%) Achievable Nitrogen Reductions
(With No Tillage, Feedlot Removal & Native Grass Planting)

Cell	Reach	Area	% of total	10-Year Simulated Nitrogen (lb/ac/yr)	BMP Scenarios				Difference between 10-yr simulated Nitrogen and applied BMPs			
					No Till	No Feedlot	No Impound	All Grass	no till difference	no feedlot difference	no impound difference	all grass difference
722	72	2.22	0.29	11.05	8.04	11.05	11.05	7.06	3.00	0.00	0.00	3.98
3753	375	50.71	0.29	11.02	8.21	11.02	11.02	7.29	2.80	0.00	0.00	3.73
263	26	7.78	0.26	10.08	5.41	10.08	10.08	10.08	4.67	0.00	0.00	0.00
6631	663	78.95	0.23	8.97	3.14	8.97	8.97	0.26	5.82	0.00	0.00	8.71
7051	705	80.51	0.23	8.89	3.95	8.89	8.89	1.72	4.94	0.00	0.00	7.17
5593	559	10.45	0.22	8.25	5.20	8.25	8.25	5.83	3.05	0.00	0.00	2.42
1423	142	14.01	0.21	8.23	2.80	8.23	8.23	0.17	5.43	0.00	0.00	8.06
7203	720	198.82	0.21	8.09	2.75	8.09	8.09	0.22	5.33	0.00	0.00	7.87
3161	316	78.73	0.20	7.68	3.81	5.46	7.68	0.21	3.87	2.22	0.00	7.47
1432	143	33.58	0.20	7.63	2.67	7.63	7.63	0.24	4.96	0.00	0.00	7.38
6633	663	8.9	0.20	7.61	4.57	7.61	7.61	2.87	3.05	0.00	0.00	4.74
6951	695	75.39	0.19	7.47	4.17	7.47	7.47	3.41	3.30	0.00	0.00	4.06
7202	720	167.91	0.19	7.44	2.57	7.44	7.44	0.22	4.87	0.00	0.00	7.22
463	46	172.36	0.19	7.42	4.53	7.42	7.42	7.16	2.89	0.00	0.00	0.26
6642	664	80.51	0.18	6.86	2.39	6.86	6.86	0.21	4.47	0.00	0.00	6.64
4721	472	74.28	0.18	6.84	3.31	6.84	6.84	1.69	3.54	0.00	0.00	5.16
4393	439	71.83	0.18	6.84	4.83	6.84	6.84	3.41	2.01	0.00	0.00	3.43
6861	686	75.39	0.18	6.79	4.53	6.79	6.79	2.82	2.26	0.00	0.00	3.97
6553	655	23.57	0.16	6.33	2.24	6.33	6.33	0.22	4.09	0.00	0.00	6.12
5612	561	25.13	0.16	6.28	5.66	1.67	6.28	0.20	0.63	4.61	0.00	6.08
2471	247	76.28	0.16	6.23	3.58	4.10	6.23	0.20	2.66	2.13	0.00	6.03
7023	702	54.49	0.16	6.18	2.19	6.18	6.18	0.21	4.00	0.00	0.00	5.98
3043	304	30.25	0.16	6.16	3.87	6.16	6.16	2.73	2.29	0.00	0.00	3.43
6601	660	115.64	0.16	6.15	2.18	6.15	6.15	0.21	3.97	0.00	0.00	5.93
6293	629	30.91	0.16	6.09	3.83	6.09	6.09	3.45	2.25	0.00	0.00	2.63
3513	351	41.14	0.15	5.89	2.10	5.89	5.89	0.21	3.80	0.00	0.00	5.69
3842	384	88.07	0.15	5.71	2.96	5.71	5.71	1.26	2.75	0.00	0.00	4.44
7071	707	78.95	0.15	5.69	3.00	5.69	5.69	1.68	2.69	0.00	0.00	4.01
1093	109	100.52	0.15	5.62	5.62	0.55	5.62	0.55	0.00	5.07	0.00	5.07
4471	447	98.3	0.15	5.57	2.85	5.57	5.57	1.70	2.72	0.00	0.00	3.86
7481	748	74.95	0.14	5.53	2.00	5.53	5.53	0.21	3.53	0.00	0.00	5.32
3023	302	69.83	0.14	5.47	1.98	5.47	5.47	0.20	3.49	0.00	0.00	5.27

Lake Campbell Watershed Area Cells (top 5%) Achievable Nitrogen Reductions
(With No Tillage, Feedlot Removal & Native Grass Planting)

Cell	Reach	Area	% of total	10-Year Simulated Nitrogen (lb/ac/yr)	BMP Scenarios: No Till	No Feedlot	No Impound	All Grass	Difference between 10-yr simulated Nitrogen and applied BMPs: no till difference	no feedlot difference	no impound difference	all grass diff
7221	722	92.96	0.14	5.35	2.13	5.35	5.35	0.24	3.22	0.00	0.00	5.11
3533	353	71.83	0.14	5.27	2.90	5.27	5.27	2.20	2.37	0.00	0.00	3.08
3572	357	88.29	0.14	5.21	1.90	5.21	5.21	0.21	3.31	0.00	0.00	5.01
2971	297	79.39	0.13	5.12	2.81	5.12	5.12	1.68	2.30	0.00	0.00	3.44
4403	440	213.94	0.13	5.01	1.84	5.01	5.01	0.20	3.17	0.00	0.00	4.80
7183	718	10.67	0.13	4.92	2.01	4.92	4.92	0.24	2.91	0.00	0.00	4.69
1631	163	74.5	0.13	4.85	1.80	4.85	4.85	0.21	3.05	0.00	0.00	4.64
6962	696	116.76	0.12	4.76	1.77	4.76	4.76	0.21	2.98	0.00	0.00	4.55
3373	337	4.67	0.12	4.75	2.04	4.75	4.75	0.27	2.71	0.00	0.00	4.49
6283	628	25.13	0.12	4.74	1.76	4.74	4.74	0.21	2.98	0.00	0.00	4.53
3602	360	39.59	0.12	4.74	1.73	4.74	4.74	0.13	3.00	0.00	0.00	4.60
3561	356	87.18	0.12	4.72	1.74	4.72	4.72	0.20	2.98	0.00	0.00	4.52
1633	163	94.3	0.12	4.70	1.75	4.70	4.70	0.21	2.94	0.00	0.00	4.49
4723	472	118.54	0.12	4.67	1.74	4.67	4.67	0.20	2.93	0.00	0.00	4.47
862	86	158.79	0.12	4.62	1.93	4.62	4.62	1.85	2.69	0.00	0.00	2.77
1113	111	61.16	0.12	4.58	1.72	4.58	4.58	0.21	2.87	0.00	0.00	4.38
5183	518	91.63	0.12	4.58	1.72	4.58	4.58	0.21	2.86	0.00	0.00	4.37
7022	702	110.53	0.12	4.57	1.71	4.57	4.57	0.20	2.87	0.00	0.00	4.37
5753	575	221.73	0.12	4.56	1.71	4.56	4.56	0.20	2.86	0.00	0.00	4.36
6902	690	14.46	0.12	4.51	2.00	4.51	4.51	0.26	2.51	0.00	0.00	4.25
2452	245	11.34	0.11	4.34	1.65	4.34	4.34	0.21	2.70	0.00	0.00	4.14
1642	164	75.17	0.11	4.29	1.63	4.29	4.29	0.21	2.66	0.00	0.00	4.08
3072	307	195.04	0.11	4.27	1.62	4.27	4.27	0.20	2.65	0.00	0.00	4.07
6563	656	18.9	0.11	4.26	1.82	4.26	4.26	0.23	2.44	0.00	0.00	4.04
6681	668	74.5	0.11	4.24	1.82	4.24	4.24	0.23	2.42	0.00	0.00	4.01
1433	143	26.46	0.11	4.21	1.85	4.21	4.21	0.25	2.36	0.00	0.00	3.96
6551	655	94.74	0.11	4.17	1.60	4.17	4.17	0.21	2.57	0.00	0.00	3.97
6641	664	95.85	0.11	4.14	1.58	4.14	4.14	0.20	2.55	0.00	0.00	3.93
2923	292	137.66	0.11	4.07	1.57	4.07	4.07	0.20	2.50	0.00	0.00	3.87
7831	783	112.09	0.11	4.07	1.79	4.07	4.07	0.16	2.28	0.00	0.00	3.90
4702	470	14.23	0.11	4.04	1.55	4.04	4.04	0.05	2.49	0.00	0.00	3.99
5083	508	54.49	0.11	4.03	1.55	4.03	4.03	0.20	2.48	0.00	0.00	3.83

Lake Campbell Watershed Area Cells (top 5%) Achievable Nitrogen Reductions
(With No Tillage, Feedlot Removal & Native Grass Planting)

Cell	Reach	Area	% of total	10-Year Simulated Nitrogen (lb/ac/yr)	BMP Scenarios				Difference between 10-yr simulated Nitrogen and applied BMPs			
					No Till	No Feedlot	No Impound	All Grass	no till difference	no feedlot difference	no impound difference	all grass difference
7482	748	11.79	0.10	3.98	1.52	3.98	3.98	1.70	2.47	0.00	0.00	2.28
2442	244	15.79	0.10	3.94	1.65	3.94	3.94	0.24	2.29	0.00	0.00	3.70
663	66	3.34	0.10	3.93	1.75	3.93	3.93	0.25	2.18	0.00	0.00	3.67
1052	105	179.03	0.10	3.89	1.51	3.89	3.89	0.21	2.38	0.00	0.00	3.68
441	44	76.5	0.10	3.88	1.57	3.88	3.88	0.23	2.31	0.00	0.00	3.66
431	43	99.63	0.10	3.87	1.57	3.87	3.87	0.23	2.31	0.00	0.00	3.65
6232	623	147.89	0.10	3.86	1.50	3.86	3.86	0.20	2.36	0.00	0.00	3.66
2823	282	0.44	0.10	3.86	1.70	3.86	3.86	0.22	2.15	0.00	0.00	3.64
3102	310	6.23	0.10	3.84	1.70	3.84	3.84	0.22	2.14	0.00	0.00	3.63
642	64	31.14	0.10	3.83	1.75	3.83	3.83	0.25	2.08	0.00	0.00	3.58
7223	722	21.79	0.10	3.78	1.69	3.78	3.78	0.22	2.09	0.00	0.00	3.56
7801	780	86.29	0.10	3.76	1.56	3.76	3.76	0.17	2.20	0.00	0.00	3.60
701	70	76.28	0.10	3.71	1.45	3.71	3.71	0.11	2.26	0.00	0.00	3.60
4593	459	23.35	0.10	3.71	1.66	3.71	3.71	0.22	2.05	0.00	0.00	3.49
3103	310	11.34	0.10	3.70	1.66	3.70	3.70	0.22	2.04	0.00	0.00	3.49
5043	504	7.78	0.10	3.70	1.45	3.70	3.70	0.20	2.25	0.00	0.00	3.50
1493	149	7.34	0.10	3.68	1.44	3.68	3.68	0.11	2.24	0.00	0.00	3.57
5192	519	176.14	0.09	3.64	1.44	3.64	3.64	0.20	2.21	0.00	0.00	3.44
3522	352	37.36	0.09	3.60	1.42	3.60	3.60	0.20	2.18	0.00	0.00	3.40
82	8	13.12	0.09	3.56	1.56	3.56	3.56	1.76	2.00	0.00	0.00	1.81
6523	652	15.79	0.09	3.49	1.39	3.49	3.49	0.20	2.10	0.00	0.00	3.29
1063	106	167.46	0.09	3.48	1.40	3.48	3.48	0.21	2.09	0.00	0.00	3.28
4383	438	112.53	0.09	3.47	1.46	3.47	3.47	0.95	2.01	0.00	0.00	2.51
6532	653	26.69	0.09	3.35	1.35	3.35	3.35	0.20	2.00	0.00	0.00	3.15

Appendix M.
AnnAGNPS 1-Year and 25-Year Results

M-1

Lake Campbell AnnAGNPS Results

1-Year Simulation Period

	Lake Campbell Watershed - 1 Year Simulation Period						
Scenerio	**Sediment Load (tons/acre/year)**	**Nitrogen Load (unit area) (lbs/acre/yr)**	**Attached Nitrogen Load (lbs/acre/yr)**	**Dissolved Nitrogen Load (lbs/acre/yr)**	**Total Phosphorus Load (unit area) (lbs/acre/yr)**	**Attached Phosphorus Load (lbs/acre/yr)**	**Dissolved Phosphorus Load (lbs/acre/yr)**
Present Condition	0.0014	0.966	0.258	0.708	0.152	0.011	0.141
All Grass	0.0000	0.273	0.010	0.263	0.021	0.000	0.021
No Feedlots	0.0014	0.964	0.258	0.707	0.152	0.011	0.141
No Impoundments	0.0105	1.281	0.412	0.869	0.267	0.017	0.250
No Tillage	0.0004	0.954	0.123	0.832	0.131	0.004	0.127

	Percent Difference from Present Condition						
All Grass	100 ↓	72 ↓	96 ↓	63 ↓	86 ↓	100 ↓	85 ↓
No Feedlots	0	0 ↓	0	0 ↓	0	0	0
No Impoundments	87 ↑	25 ↑	37 ↑	19 ↑	43 ↑	35 ↑	44 ↑
No Tillage	71 ↓	1 ↓	52 ↓	15 ↑	14 ↓	64 ↓	10 ↓

25-Year Simulation Period

Lake Campbell Watershed - 25 Year Simulation Period							
Scenerio	Sediment Load (tons/acre/year)	Nitrogen Load (unit area) (lbs/acre/yr)	Attached Nitrogen Load (lbs/acre/yr)	Dissolved Nitrogen Load (lbs/acre/yr)	Total Phosphorus Load (unit area) (lbs/acre/yr)	Attached Phosphorus Load (lbs/acre/yr)	Dissolved Phosphorus Load (lbs/acre/yr)
Present Condition	0.0000	0.903	0.259	0.644	0.500	0.023	0.477
All Grass	0.0000	0.416	0.014	0.402	0.136	0.001	0.135
No Feedlots	0.0000	0.896	0.255	0.641	0.500	0.023	0.477
No Impoundments	0.0137	1.362	0.544	0.818	0.643	0.032	0.611
No Tillage	0.0000	0.865	0.132	0.733	0.404	0.008	0.395

Percent Difference from Present Condition							
All Grass	0	54 ↓	95 ↓	38 ↓	73 ↓	96 ↓	72 ↓
No Feedlots	0	1 ↓	2 ↓	0 ↓	0	0	0
No Impoundments	100 ↑	34 ↑	52 ↑	21 ↑	22 ↑	28 ↑	22 ↑
No Tillage	0	4 ↓	49 ↓	12 ↑	19 ↓	65 ↓	17 ↓

Appendix N.
Sediment Survey Methodology

1986 WRI report: Explanation of the sediment calculation for Lake Campbell

Annual sediment and nutrient discharges into Lake Campbell from Battle Creek. Average annual sediment discharge into Lake Campbell was 834 tons between 1966 and 1985 (Table 5). The maximum discharge, 5,086 tons, occurred in 1977 when a 4.76-inch rainfall occurred and accounted for 96 percent of the year's sediment total. The least amount occurred in 1973 when no storms larger than 0.5 inches occurred during the two-month period.

The average discharges of total nitrogen and phosphorus were 122,612 pounds (61.3 tons) and 41,281 pounds (20.6 tons), respectively, between 1966 and 1985 (Table 5). In The maximum discharge of nutrients occurred in 1977 (306,000 pounds of total nitrogen and 104,760 pounds of phosphorus).

Some caution should be exercised when using the calculated sediment and nutrient discharges into Lake Campbell for several reasons. First, the model is designed to estimate the response of the watershed immediately after the crops are planted and assumes all crops are planted roughly on the same date. The model does not consider changes that occur in the watershed during the growing season. Second, 1986 watershed conditions were assumed to be present since 1966. Obviously, crop acreages, tillage practices and fertilizer usage - just to name a few factors - changed dramatically. Third, a vast majority of the sediment and nutrient discharges occur during major catastrophic storms, regardless of when the storm occurs. Therefore, some pollutants probably were washed into the lake from large storms that occurred outside of the April 20 to June 20 period.

To be meaningful to individuals making decisions about dredging Lake Campbell, put into perspective the sediment yields estimated from this study. One such meaningful perspective is comparing the amount of sediment that probably entered the lake during the last 20 years to the volume of water contained in the lake and to the amount of sediment that will be removed in the initial phase of dredging (470 thousand cubic yards).

Several assumptions are necessary as a prerequisite to this exercise. First, considerably less erosion is occurring on the watershed today than did during the past 20 years. Much of this reduction can be attributed to use of conservation tillage. Results from this study indicate that a return to clean tillage on all cropland would increase the sediment yield of the watershed by approximately 50 percent (see Table 1 for average 1986 upland erosion rates of the entire watershed and for plowing). Second, any erosion that occurred during summer, fall and late spring months was not accounted for in this study. To compensate for this situation and provide a liberal estimate on the sediment yield, the sediment yields generated by AGNPS from this study will be increased an additional 100 percent. Together these two corrections result in the average sediment yields being 250 percent greater for the past 20 years. Third, a bulk density of 70 pounds per cubic foot will be assumed for the lake-bottom deposits.

The total volume of sediment discharged into Lake Campbell from Battle Creek during 1966 through 1985 is calculated at 1.19 million cubic feet. This volume is equal to 0.8 percent of the total lake volume or to a deposition 0.4 inches thick throughout lake. The volume of sediment which will be removed during the initial phase of dredging (470 thousand cubic yards) is approximately 10 times the volume that entered from Battle Creek during the last 20 years. These comparisons show that the lake is not being filled very rapidly with sediment.

Cellular Output. An example of the output for the Lake Campbell watershed during a 4.0-inch storm is given in Table 6. Runoff, erosion, and sediment and nutrient yield data are provided for the entire watershed in Appendix A.

Channel Deposition and Erosion in Battle Creek. Analysis of sediment movement in Battle Creek showed deposition occurring in all but a few cells during a 4.0-inch rainfall event. Channel erosion was neither predicted by the model nor was significant channel erosion observed during the data collection trips made in the watershed in June, 1986.

1990 Sediment Survey Methodology – Quoting Eisenbraun & Associates, Inc.

"In 1990, we conducted our hydrographic survey of Lake Campbell for the SD Department of Environment and Natural Resources. The procedures we used to determine the sediment volumes in the lake were as follows:

On September 12, 1990, we performed a survey of the perimeter of the lake at water's edge. Sedimentation ranges were then developed on a 300-foot parallel interval throughout the entire lakebed. A total of 47 cross sections were established and data was collected along each cross section at a 50-foot interval. The hydrographic data was collected using one of our hydrographic survey vessels which capture x-y-z data simultaneously using a laser range-azimuth system for horizontal positioning and survey grade fathometers for depths. On this survey, we utilized two fathometers – an ODOM EchoTrac and a Raytheon DE719C with an ODOM DT-2H-FS Digitrace. One fathometer was operated at a 200-kilohertz frequency to capture the depth to the top of the sediment layer. The second fathometer was operated at 24-kilohertz, with the lower frequency penetrating the sediment layer to hard bottom. As a QA procedure, we tested the data that we were receiving from the fathometers at the commencement of the survey and several times throughout the duration of the survey by probing the depth of the sediment layer with a length of 5/8" rebar. Our field reports show that the survey crew documented four to five feet of silt in areas when probing with the rebar and this appeared to be relatively consistent with the difference in data from the two fathometers.

A total of over 2,300 x-y-z datasets were captured by our survey crew on this project. This data was used to create bathymetric maps of both the top and bottom of the sediment layer. The volume of sediment between these two surfaces was then computed.

Determining sediment layer thickness is indeed a challenging and tricky assignment. When probing with a relatively small diameter rod, it is difficult to tell when you first enter the sediment layer if you do not have a sonar signal to aid you in this process. Computing sediment volumes will always be difficult to verify closely without actually involving a dredge and doing pre and post dredge surveys. Nearly two decades have passed since our survey. There are a lot of variables that come in to play on a survey of this nature. We believe that the methodology we used in Lake Campbell is as good as economically possible and has proven to be relatively accurate on other lakes where it has been used for a dredging plan."

Appendix O.
Historical TSI Data

O-1

RelativeDepth	SampleDate	SampleTime	StationID	TSI - CHLA (ignoring pheophytin)	TSI - Phosphorus	TSI - Secchi
Surface	09/13/76	1700	46BG01		85	
Surface	11/15/76	1700	46BG01		73	
Surface	01/10/77	1700	46BG01		77	
Surface	03/08/77	1400	46BG01		82	
Surface	05/02/77	1700	46BG01		77	
	06/12/79			38	78	55
	08/12/79			74	88	71
Surface	06/24/83	1330	46CA05		92	
Surface	06/24/83	1330	46CA04		91	
Surface	06/29/83	1500	46CA05		90	
Surface	06/29/83	1430	46CA04		91	
Surface	07/08/83	0800	46CA05		94	
Surface	07/08/83	0800	46CA04		91	
Surface	07/15/83	1345	46CA05		88	
Surface	07/15/83	1330	46CA04		89	
Surface	08/04/83	1330	46CA05		82	
Surface	08/04/83	1300	46CA04		85	
Surface	08/24/83	1200	46CA05		97	
Surface	08/24/83	0820	46CA04		90	
Surface	08/25/83	1200	46CA06		83	
Surface	08/31/83	1530	46CA05		78	
Surface	08/31/83	1430	46CA04		82	
Surface	09/15/83	1230	46CA05		83	
Surface	09/15/83	1215	46CA04		80	
Surface	10/11/83	1330	46CA05		82	
Surface	10/11/83	1230	46CA04		83	
Surface	11/13/83	1430	46CA05		78	
Surface	11/13/83	1400	46CA04		78	
Surface	01/23/91	11:30	CAMPB96CL01		85	
Surface	01/23/91	10:45	CAMPB96CL02		88	
Surface	01/23/91	10:20	CAMPB96CL03		91	
Surface	02/12/91	2:10	CAMPB96CL01		88	
Surface	02/12/91	1:30	CAMPB96CL02		91	
Surface	02/12/91	12:00	CAMPB96CL03		101	
Surface	04/17/91	11:00	CAMPB96CL01		82	77
Surface	04/17/91	10:20	CAMPB96CL02		81	77
Surface	04/17/91	9:00	CAMPB96CL03		87	73
Surface	04/24/91	11:00	CAMPB96CL01		83	70
Surface	04/24/91	10:30	CAMPB96CL02		81	70
Surface	05/28/91	10:30	CAMPB96CL01		84	77
Surface	05/28/91	11:15	CAMPB96CL02		85	77
Surface	05/28/91	12:00	CAMPB96CL03		86	77
Surface	06/10/91	1:15	CAMPB96CL01		73	73
Surface	06/10/91	1:45	CAMPB96CL02		75	77
Surface	06/10/91	2:12	CAMPB96CL03		66	73
Surface	06/26/91	2:00	CAMPB96CL01		76	73
Surface	06/26/91	2:30	CAMPB96CL02		85	73
Surface	06/26/91	3:15	CAMPB96CL03		87	73
Surface	07/09/91	1:30	CAMPB96CL01		82	73
Surface	07/09/91	2:00	CAMPB96CL02		79	68
Surface	07/09/91	2:40	CAMPB96CL03		79	70
Surface	07/23/91	8:30	CAMPB96CL01		79	73
Surface	07/23/91	9:00	CAMPB96CL02		81	73
Surface	07/23/91	9:30	CAMPB96CL03		78	77
Surface	08/12/91	10:30	CAMPB96CL01		80	73
Surface	08/12/91	10:00	CAMPB96CL02		78	73
Surface	08/12/91	9:15	CAMPB96CL03		77	73
Surface	08/19/91	3:00	CAMPB96CL01		77	73
Surface	08/19/91	2:30	CAMPB96CL02		79	73

Surface	08/19/91	2:00	CAMPB96CL03		78	73
Surface	09/10/91	1:30	CAMPB96CL01		78	73
Surface	09/10/91	2:00	CAMPB96CL02		77	70
Surface	09/10/91	2:30	CAMPB96CL03		80	73
Surface	09/23/91	2:30	CAMPB96CL01		81	77
Surface	09/23/91	2:15	CAMPB96CL02		84	73
Surface	09/23/91	1:45	CAMPB96CL03		84	77
Surface	10/16/91	9:30	CAMPB96CL01		89	82
Surface	10/16/91	10:00	CAMPB96CL02		87	82
Surface	10/16/91	10:30	CAMPB96CL03		90	82
Surface	12/09/91	11:00	CAMPB96CL01		89	
Surface	12/09/91	10:00	CAMPB96CL02		90	
Surface	12/09/91	12:00	CAMPB96CL03		87	
Surface	01/13/92	11:30	CAMPB96CL01		83	
Surface	01/13/92	1:00	CAMPB96CL02		89	
Surface	01/13/92	12:00	CAMPB96CL03		84	
Surface	04/24/92	9:45	CAMPB96CL03		82	73
Surface	05/09/07		LC1	72	79	83
Surface	05/09/07		LC2	67	82	77
Surface	05/09/07		LC3	70	84	78
Surface	06/11/07		LC1	78	87	83
Surface	06/11/07		LC2	75	86	83
Surface	06/11/07	CitMon	LC2	77	88	80
Surface	06/11/07		LC3	77	88	80
Surface	06/27/07		LC1	76	94	87
Surface	06/27/07		LC2	78	94	87
Surface	06/27/07		LC3	79	95	86
Surface	07/05/07		LC1	74	95	93
Surface	07/05/07		LC2	72	96	89
Surface	07/05/07		LC3	75	96	87
Surface	07/17/07	CitMon	LC2	70	96	83
Surface	07/25/07		LC1	75	93	85
Surface	07/25/07		LC2	76	93	83
Surface	07/25/07		LC3	77	91	83
Surface	08/07/07		LC1	82	87	85
Surface	08/07/07		LC2	82	88	83
Surface	08/07/07		LC3	79	89	85
Surface	08/14/07	CitMon	LC2	83	90	87
Surface	08/22/07		LC1	79	85	87
Surface	08/22/07		LC2	79	87	91
Surface	08/22/07		LC3	80	87	91
Surface	09/04/07		LC1	78	87	88
Surface	09/04/07		LC2	77	84	87
Surface	09/04/07		LC3	77	86	86
Surface	09/26/07	CitMon	LC2	76	81	82
Surface	10/01/07		LC1		82	83
Surface	10/01/07		LC2		81	83
Surface	10/01/07		LC3		80	83
Surface	10/24/07	CitMon	LC2	81	80	83
Surface	11/07/07		LC1		81	83
Surface	11/08/07		LC2		79	77
Surface	11/08/07		LC3		79	77
Surface	01/10/08		LC1		85	65
Surface	01/10/08		LC2		80	65
Surface	01/10/08		LC3		83	63
Surface	02/13/08		LC1	54	87	56
Surface	02/13/08		LC2	74	90	68
Surface	02/13/08		LC3	74	89	67
Surface	04/23/08		LC1	71	78	73
Surface	04/23/08		LC2	70	80	74
Surface	04/23/08		LC3	71	79	72
Surface	05/21/08		LC1	66	73	69
Surface	05/21/08		LC2	66	72	70
Surface	05/21/08		LC3	64	72	72
Surface	06/10/08		LC1	74	79	80
Surface	06/10/08		LC2	80	82	80
Surface	06/10/08		LC3	74	81	77

Surface	08/19/91	2:00	CAMPB96CL03		78	73
Surface	09/10/91	1:30	CAMPB96CL01		78	73
Surface	09/10/91	2:00	CAMPB96CL02		77	70
Surface	09/10/91	2:30	CAMPB96CL03		80	73
Surface	09/23/91	2:30	CAMPB96CL01		81	77
Surface	09/23/91	2:15	CAMPB96CL02		84	73
Surface	09/23/91	1:45	CAMPB96CL03		84	77
Surface	10/16/91	9:30	CAMPB96CL01		89	82
Surface	10/16/91	10:00	CAMPB96CL02		87	82
Surface	10/16/91	10:30	CAMPB96CL03		90	82
Surface	12/09/91	11:00	CAMPB96CL01		89	
Surface	12/09/91	10:00	CAMPB96CL02		90	
Surface	12/09/91	12:00	CAMPB96CL03		87	
Surface	01/13/92	11:30	CAMPB96CL01		83	
Surface	01/13/92	1:00	CAMPB96CL02		89	
Surface	01/13/92	12:00	CAMPB96CL03		84	
Surface	04/24/92	9:45	CAMPB96CL03		82	73
Surface	05/09/07		LC1	72	79	83
Surface	05/09/07		LC2	67	82	77
Surface	05/09/07		LC3	70	84	78
Surface	06/11/07		LC1	78	87	83
Surface	06/11/07		LC2	75	86	83
Surface	06/11/07	CitMon	LC2	77	88	80
Surface	06/11/07		LC3	77	88	80
Surface	06/27/07		LC1	76	94	87
Surface	06/27/07		LC2	78	94	87
Surface	06/27/07		LC3	79	95	86
Surface	07/05/07		LC1	74	95	93
Surface	07/05/07		LC2	72	96	89
Surface	07/05/07		LC3	75	96	87
Surface	07/17/07	CitMon	LC2	70	96	83
Surface	07/25/07		LC1	75	93	85
Surface	07/25/07		LC2	76	93	83
Surface	07/25/07		LC3	77	91	83
Surface	08/07/07		LC1	82	87	85
Surface	08/07/07		LC2	82	88	83
Surface	08/07/07		LC3	79	89	85
Surface	08/14/07	CitMon	LC2	83	90	87
Surface	08/22/07		LC1	79	85	87
Surface	08/22/07		LC2	79	87	91
Surface	08/22/07		LC3	80	87	91
Surface	09/04/07		LC1	78	87	88
Surface	09/04/07		LC2	77	84	87
Surface	09/04/07		LC3	77	86	86
Surface	09/26/07	CitMon	LC2	76	81	82
Surface	10/01/07		LC1		82	83
Surface	10/01/07		LC2		81	83
Surface	10/01/07		LC3		80	83
Surface	10/24/07	CitMon	LC2	81	80	83
Surface	11/07/07		LC1		81	83
Surface	11/08/07		LC2		79	77
Surface	11/08/07		LC3		79	77
Surface	01/10/08		LC1		85	65
Surface	01/10/08		LC2		80	65
Surface	01/10/08		LC3		83	63
Surface	02/13/08		LC1	54	87	56
Surface	02/13/08		LC2	74	90	68
Surface	02/13/08		LC3	74	89	67
Surface	04/23/08		LC1	71	78	73
Surface	04/23/08		LC2	70	80	74
Surface	04/23/08		LC3	71	79	72
Surface	05/21/08		LC1	66	73	69
Surface	05/21/08		LC2	66	72	70
Surface	05/21/08		LC3	64	72	72
Surface	06/10/08		LC1	74	79	80
Surface	06/10/08		LC2	80	82	80
Surface	06/10/08		LC3	74	81	77

Appendix P.
1998-2008 Algae Species and Abundance

P-1

Lake Campbell - 1998 Algae Species

Flagellated	Blue-Green	Diatoms	Non-Motile Green Algae	Unidentified
Ceratium hirundinella	*Anabaena* sp.	*Amphiprora ornata*	*Ankistrodesmus* sp.	Unidentified algae
Chlamydomonas sp.	*Aphanizomenon flos-aquae*	*Coscinodiscus rothii*	*Characium limneticum*	
Chroomonas sp.	*Aphanocapsa* sp.	*Cyclotella meneghiniana*	*Closteriopsis* sp.	
Chrysochromulina sp.	*Coelosphaerium naegelianum*	*Cymatopleura solea*	*Closterium aciculare*	
Cryptomonas sp.	*Merismopedia tenuissima*	*Cymbella* sp.	*Coelastrum* sp.	
Dinobryon sp.	*Microcystis incerta*	*Melosira granulata*	*Crucigenia crucifera*	
Euglena sp.	*Oscillatoria agardhii*	*Melosira granulata angustissima*	*Crucigenia quadrata*	
Glenodinium gymnodinium	*Phormidium mucicola*	*Nitzschia acicularis*	*Crucigenia tetrapedia*	
Lepocinclis texta		*Nitzschia reversa*	*Dictyosphaerium pulchellum*	
Mallomonas sp.		*Nitzschia* sp.	*Elakatothrix viridis*	
Phacus acuminatus		*Stephanodiscus hantzschii*	*Kirchneriella* sp.	
Phacus helikoides		*Stephanodiscus niagarae*	*Micractinium* sp.	
Phacus sp.		*Surirella ovalis*	Miscellaneous green algae	
Strombomonas sp.		*Synedra acus*	*Oocystis* sp.	
Trachelomonas intermedia		Unidentified pennate diatoms	*Pediastrum duplex*	
Trachelomonas sp.			*Scenedesmus* sp.	
Unidentified flagellates			*Schroederia judayi*	
			Sphaerocystis schroeteri	

Note: shaded species are considered noxious/nuisance
** Presence of a bacteria with fimbriae & flagella (*Planktomyces bekefii)* was noted in the June 1998 sample

10 most abundant algae genera June 1998	Biovolume (μm3/mL)	Algae Type
Aphanizomenon flos-aquae	15,841,800	Blue-Green
Glenodinium gymnodinium	994,764	Flagellated
Anabaena sp.	822,800	Blue-Green
Lepocinclis texta	480,000	Flagellated
Stephanodiscus niagarae	380,000	Diatom
Stephanodiscus hantzschii	307,400	Diatom
Cyclotella meneghiniana	278,250	Diatom
Merismopedia tenuissima	234,600	Blue-Green
Pediastrum duplex	165,500	Non-Motile
Characium limneticum	161,630	Non-Motile

10 most abundant algae genera August 1998	Biovolume (μm3/mL)	Algae Type
Glenodinium gymnodinium	48,691,080	Flagellated
Lepocinclis texta	500,000	Flagellated
Characium limneticum	369,440	Non-Motile
Stephanodiscus niagarae	210,000	Diatom
Aphanizomenon flos-aquae	118,404	Blue-Green
Trachelomonas intermedia	100,000	Flagellated
Cryptomonas sp.	92,000	Flagellated
Stephanodiscus hantzschii	88,000	Diatom
Anabaena sp.	87,600	Blue-Green
Cyclotella meneghiniana	62,500	Diatom

Lake Campbell - 2002 Algae Species

Flagellated	Blue-Green	Diatoms	Non-Motile Green Algae	Unidentified
Ceratium hirundinella	*Anabaena circinalis*	*Cyclotella meneghiniana*	*Characium limneticum*	Unidentified algae
Chlamydomonas sp.	*Anabaena flos-aquae*	*Melosira granulata*	*Characium* sp.	
Chrysochromulina parva	*Aphanizomenon flos-aquae*	*Navicula capitata*	*Closterium aciculare*	
Cryptomonas sp.	*Aphanocapsa* sp.	*Navicula cuspidata*	*Coelastrum* sp.	
Euglena ehrenbergii	*Marssoniella elegans*	*Navicula* sp.	*Kirchneriella* sp.	
Euglena sp.	*Merismopedia tenuissima*	*Nitzschia reversa*	*Micractinium pusillum*	
Glenodinium gymnodinium	*Microcystis aeruginosa*	*Nitzschia* sp.	*Oocystis* sp.	
Lepocinclis sp.	*Phormidium minnesotense*	*Stephanodiscus minutus*	*Pediastrum duplex*	
Phacus acuminatus	*Phormidium mucicola*	*Stephanodiscus niagarae*	*Scenedesmus* sp.	
Phacus helikoides			*Schroederia judayi*	
Rhodomonas minuta			*Sphaerocystis schroeteri*	
Trachelomonas sp.				
Unidentified flagellates				

Note: shaded species are considered noxious/nuisance

10 most abundant algae genera July 2002	Biovolume (µm3/mL)	Algae Type
Aphanizomenon flos-aquae	5,692,050	Blue-Green
Characium limneticum	300,170	Non-Motile
Oocystis sp.	282,000	Non-Motile
Melosira granulata	236,500	Diatom
Phormidium minnesotense	180,000	Blue-Green
Characium sp.	169,560	Non-Motile
Lepocinclis sp.	100,000	Flagellated
Sphaerocystis schroeteri	62,444	Non-Motile
Aphanocapsa sp.	38,000	Blue-Green
Rhodomonas minuta	31,200	Flagellated

10 most abundant algae genera August 2002	Biovolume (µm3/mL)	Algae Type
Aphanizomenon flos-aquae	2,846,376	Blue-Green
Microcystis aeruginosa	652,740	Blue-Green
Euglena ehrenbergi	235,500	Flagellated
Phormidium minnesotense	187,500	Blue-Green
Characium sp.	125,600	Non-Motile
Lepocinclis sp.	60,000	Flagellated
Melosira granulata	55,550	Diatom
Anabaena circinalis	51,840	Blue-Green
Oocystis sp.	21,000	Non-Motile
Anabaena flos-aquae	14,000	Blue-Green

Lake Campbell - 2006 Algae Species

Flagellated	Blue-Green	Diatoms	Non-Motile Green Algae	Unidentified
Chlamydomonas sp.	*Anabaena* sp.	*Navicula capitata*	*Ankistrodesmus* sp.	Unidentified algae
Chrysochromulina parva	*Aphanizomenon flos-aquae*	*Nitzschia* sp.	*Characium sp.*	
Cryptomonas sp.	*Aphanocapsa* sp.	*Nitzschia vermicularis*	*Chlorella ellipsoidea*	
Euglena sp.	*Microcystis* sp.	*Stephanodiscus minutus*	*Kirchneriella* sp.	
Leposcinclis sp.			*Oocystis* sp.	
Rhodomonas minuta			*Schroederia judayi*	
Spermatozoopsis exultans				
Unidentified flagellates				

Note: shaded species are considered noxious/nuisance

10 most abundant algae genera June 2006	Biovolume (µm3/mL)	Algae Type
Aphanizomenon flos-aquae	218,790	Blue-Green
Characium sp.	144,440	Non-Motile
Anabaena sp.	111,680	Blue-Green
Chlorella ellipsoidea	37,800	Non-Motile
Aphanocapsa sp.	14,800	Blue-Green
Microcystis sp.	11,121	Blue-Green
Rhodomonas minuta	10,600	Flagellated
Stephanodiscus minutus	7,000	Diatom
Kirchneriella sp.	4,860	Non-Motile
Chlamydomonas sp.	3,150	Flagellated

10 most abundant algae genera July 2006	Biovolume (µm3/mL)	Algae Type
Aphanizomenon flos-aquae	71,161,740	Blue-Green
Microcystis sp.	27,390	Blue-Green
Characium sp.	25,120	Non-Motile
Lepocinclis sp.	20,000	Flagellated
Rhodomonas minuta	2,400	Flagellated
Schroederia judayi	1,600	Non-Motile
Navicula capitata	1,000	Diatom
Nitzschia sp.	240	Diatom
Cryptomonas sp.	<1	Flagellated

* only 9 genera w ere identified

Lake Campbell - 2007 Algae Species

Flagellated	Blue-Green	Diatoms	Non-Motile Green Algae	Unidentified
Ceratium hirundinella	*Anabaena circinalis*	*Cyclotella meneghiniana*	*Actinastrum hantzschii*	Unidentified algae
Chlamydomonas sp.	*Anabaena sphaerica*	*Melosira granulata*	*Ankistrodesmus* sp.	
Chlorogonium sp.	*Anabaenopsis* sp.	*Melosira granulata angustissima*	*Closteriopsis longissima*	
Cryptomonas sp.	*Aphanocapsa* sp.	*Nitzschia acicularis*	*Closterium aciculare*	
Dunaliella sp.	*Cylindrospermopsis raciborskii*	*Nitzschia reversa*	*Coelastrum* sp.	
Euglena acus	*Lyngbya contorta*	*Nitzschia* sp.	*Dichotomococcus* sp	
Euglena ehrenbergii	*Marssoniella elegans*	*Stephanodiscus hantzschii*	*Dictyosphaerium pulchellum*	
Euglena oxyuris	*Merismopedia tenuissima*	*Stephanodiscus minutus*	*Dictyosphaerium* sp.	
Euglena polymorpha	*Oscillatoria agardhii*	*Stephanodiscus niagarae*	*Elakatothrix viridis*	
Euglena sp.	*Pseudanabaena* sp.	*Synedra acus*	*Kirchneriella* sp.	
Glenodinium penardiforme			*Nephrocystium* sp.	
Glenodinium sp.			*Oocystis* sp.	
Lepocinclis sp.			*Pediastrum duplex*	
Mallomonas tonsurata			*Quadrigula* sp.	
Phacus nordstedtii			*Scenedesmus acuminatus*	
Phacus pleuronectes			*Scenedesmus quadricauda*	
Phacus pseudonordstedtii			*Scenedesmus* sp.	
Phacus sp.			*Selenastrum minutum*	
Phacus tortus			*Tetraedron trigonum*	
Rhodomonas minuta			*Tetrastrum staurogeniaeforme*	
Trachelomonas sp.			*Treubaria* sp.	
Unidentified flagellates			Unidentified non-motile green algae	

Note: shaded species are considered noxious/nuisance

10 most abundant algae genera June 2007	Biovolume (µm3/mL)	Algae Type
Oscillatoria agardhii	89,559,792	Blue-Green
Trachelomonas sp.	108,000	Flagellated
Cyclotella meneghiniana	80,000	Diatom
Euglena ehrenbergii	78,500	Flagellated
Synedra acus	53,200	Diatom
Stephanodiscus niagarae	50,000	Diatom
Pediastrum duplex	48,500	Non-Motile
Stephanodiscus minutus	45,500	Diatom
Melosira granulata angustissima	40,750	Diatom
Closteriopsis longissima	28,124	Non-Motile

10 most abundant algae genera August 2007	Biovolume (µm3/mL)	Algae Type
Oscillatoria agardhii	76,434,720	Blue-Green
Pseudanabaena sp.	9,951,150	Blue-Green
Anabaena circinalis	4,507,200	Blue-Green
Actinastrum hantzschii	758,400	Non-Motile
Stephanodiscus minutus	595,000	Diatom
Euglena polymorpha	333,052	Flagellated
Lepocinclis sp.	320,000	Flagellated
Nitzschia reversa	309,000	Diatom
Anabaena sphaerica	257,600	Blue-Green
Trachelomonas sp.	186,000	Flagellated

Lake Campbell - 2008 Algae Species

Flagellated	Blue-Green	Diatoms	Non-Motile Green Algae	Unidentified
Carteria sp.	*Anabaena circinalis*	*Cyclotella atomus*	*Actinastrum hantzschii*	Unidentified algae
Chlamydomonas sp.	*Anabaena spaerica*	*Cyclotella meneghiniana*	*Ankistrodesmus* sp.	
Chromulina sp.	*Anabaenopsis* sp.	*Entomoneis paludosa*	*Chlorella* sp.	
Chrysochromulina parva	*Aphanizomenon* sp.	*Gyrosigma* sp.	*Closteriopsis longissima*	
Chrysococcus rufescens	*Aphanocapsa* sp.	*Melosira granulata*	*Dictyosphaerium pulchellum*	
Chrysococcus sp.	*Dactylococcopsis* sp.	*Navicula cuspidata*	*Kirchneriella* sp.	
Cryptomonas reflexa	*Marssoniella elegans*	*Nitzschia acicularis*	*Lagerheimia* sp.	
Cryptomonas sp.	*Microcystis* sp.	*Nitzschia paleacea*	*Micractinium* sp.	
Dinobryon sertularia	*Oscillatoria agardhii*	*Nitzschia reversa*	*Oocystis* sp.	
Dinobryon sp.	*Pseudanabaena* sp.	*Nitzschia* sp.	*Pediastrum duplex*	
Erkenia sp.		*Skeletonema* sp.	*Scenedesmus acuminatus*	
Euglena acus		*Stephanodiscus hantzschii*	*Scenedesmus quadricauda*	
Euglena polymorpha		*Stephanodiscus minutus*	*Scenedesmus* sp.	
Glenodinium penardiforme		*Surirella ovalis*	*Selenastrum minutum*	
*Glenodinium quadridens**		*Surirella ovata*	*Sphaerocystis schroeteri*	
Glenodinium sp.		*Synedra acus*	*Tetrastrum staurogeniaeforma*	
Kephyrion sp.		*Synedra* sp.	Unidentified green algae	
Lepocinclis sp.		*Synedra ulna*		
Mallomonas sp.				
Mallomonas tonsurata				
Phacus nordstedtii				
Phacus pseudonordstedtii				
Platymonas elliptica				
Pseudokephyrion sp.				
Rhodomonas minuta				
Scourfieldia cordiformis				
Spermatozoopsis exultans				
*Synuropsis elaeochrus**				
Trachelomonas sp.				
Trachelomonas volvocina				
Unidentified flagellates				

Note: shaded species are considered noxious/nuisance
* bloom
Note: A filamentous sulfur bacteria (*Beggiatoa* sp.) was also noted with a higher density in the April 2008 sampling

10 most abundant algae genera Feb 2008	Biovolume (µm3/mL)	Algae Type
Oscillatoria agardhii	3,594,240	Blue-Green
Synuropsis elaeochrus	2,197,440	Flagellated
Glenodinium quadridens	1,950,000	Flagellated
Cryptomonas reflexa	1,297,000	Flagellated
Cryptomonas sp.	1,037,200	Flagellated
Pseudanabaena sp.	439,425	Blue-Green
Euglena polymorpha	207,372	Flagellated
Trachelomonas sp.	40,000	Flagellated
Aphanocapsa sp.	30,560	Blue-Green
Ankistrodesmus sp.	27,500	Non-Motile

10 most abundant algae genera Apr 2008	Biovolume (µm3/mL)	Algae Type
Oscillatoria agardhii	12,060,000	Blue-Green
Stephanodiscus hantzschii	2,320,000	Diatom
Nitzschia sp.	1,230,000	Diatom
Cryptomonas sp.	1,080,000	Flagellated
Pseudanabaena sp.	790,650	Blue-Green
Stephanodiscus minutus	787,500	Diatom
Euglena polymorpha	785,500	Flagellated
Chrysochromulina parva	449,400	Flagellated
Nitzschia acicularis	210,000	Diatom
Ankistrodesmus sp.	162,500	Non-Motile

10 most abundant algae genera May 2008	Biovolume (µm3/mL)	Algae Type
Oscillatoria agardhii	6,330,240	Blue-Green
Euglena polymorpha	4,870,100	Flagellated
Chrysochromulina parva	4,469,640	Flagellated
Cryptomonas sp.	384,000	Flagellated
Dinobryon sertularia	152,000	Flagellated
Synedra acus	142,500	Diatom
Cyclotella meneghiniana	127,500	Diatom
Stephanodiscus minutus	70,000	Diatom
Nitzschia sp.	62,400	Diatom
Platymonas elliptica	56,650	Flagellated

10 most abundant algae genera Jun 2008	Biovolume (µm3/mL)	Algae Type
Oscillatoria agardhii	27,020,400	Blue-Green
Euglena polymorpha	2,262,240	Flagellated
Pseudanabaena sp.	2,205,225	Blue-Green
Cryptomonas sp.	1,052,000	Flagellated
Cyclotella meneghiniana	372,500	Diatom
Nitzschia paleacea	360,640	Diatom
Stephanodiscus hantzschii	162,000	Diatom
Phacus pseudonordstedtii	121,203	Flagellated
Aphanocapsa sp.	107,560	Blue-Green
Stephanodiscus minutus	105,000	Diatom

Appendix Q.
2007 Macrophyte Survey Results and Shoreline Evaluation

Q-1

2007 Macrophyte Survey Results

Lake Campbell					
Transect	Position	Secchi (m)	Depth (m)	Sago Pondweed	Sedges
1	1	0.15	0.82	1	~
1	2	0.12	0.98	1	~
1	3	0.15	1	~	~
1	10	0.15	1.3	~	~
2	1	0.15	0.83	~	~
2	10	0.18	1.45	~	~
3	1	0.15	0.96	~	~
3	10	0.15	1.58	~	~
4	1	0.15	0.96	~	~
4	10	0.15	1.3	~	~
5	1	0.18	0.4	3	~
5	2	0.16	0.7	2	~
5	3	0.15	1.08	1	~
5	4	0.12	1.17	~	~
5	10	0.12	1.27	~	~
6	1	0.11	1.14	~	~
6	10	0.11	1.3	~	~
7	1	0.14	1	~	~
7	10	0.12	1.4	~	~
8	1	0.15	0.75	~	~
8	2	0.12	1.12	~	~
8	10	0.12	1.4	~	~
9	1	0.15	0.77	~	~
9	10	0.13	1.47	~	~
10	1	0.11	1.05	~	~
10	10	0.12	1.53	~	~
11	1	0.13	1.15	~	~
11	10	0.17	1.5	~	~
12	1	0.13	0.8	~	~
12	10	0.13	1.7	~	~
13	1	0.15	0.7	~	~
13	10	0.15	1.33	~	~
14	1	0.11	0.7	~	~
14	10	0.1	1.28	~	~
15	1	0.1	0.89	~	~
15	10	0.1	1.46	~	~
16	1	0.1	1	~	~
16	10	0.1	1.6	~	~
17	1	0.1	0.77	~	~
17	10	0.1	1.65	~	~
18	1	0.1	1.09	~	~
18	10	0.1	1.57	~	~
19	1	0.1	0.7	~	~
19	10	0.1	1.6	~	~
20	1	0.12	1.28	~	~
20	10	0.1	1.4	~	~
21	1	0.1	0.63	2	~

Transect	Position	Secchi (m)	Depth (m)	Sago Pondweed	Sedges
21	2	0.2	1.38	~	~
21	10	0.2	1.48	~	~
22	1	0.1	1.15	1	~
22	2	0.1	1.36	~	~
22	10	0.1	1.59	~	~
23	1	0.1	0.5	~	~
23	10	0.1	0.98	~	~
24	1	0.1	0.67	2	~
24	2	0.11	1	~	~
24	10	0.11	1.1	~	~
25	1	0.09	0.77	4	~
25	2	0.11	1.06	1	~
25	3	0.1	1.06	~	~
25	10	0.1	1.1	~	~
26	1	0.14	0.55	1	~
26	2	0.14	0.7	0.5	1.5
26	3	0.14	0.87	1	~
26	4	0.14	0.88	~	~
26	10	0.13	0.89	~	~
27	1	0.11	0.6	~	~
27	10	0.12	0.88	~	~
28	1	0.09	0.44	~	~
28	10	0.1	0.85	~	~
29	1	0.12	0.55	1	~
29	2	0.12	0.85	~	~
29	10	0.1	1.05	~	~
30	1	0.12	0.87	~	~
30	10	0.1	1.2	~	~
Mean		0.124	1.065	1.536	1.500

2007 Shoreline Evaluation

Lake Campbell							
Transect	Date	GPS-N	GPS-W	Bank Stability (0-10)	Vegetative Protection (0-10)	Riparian Vegetative Zone Width (m)	Maximum Depth of Plant Colonization (m)
1	8/13/2007	44 13.290	96 50.085	9	1	0	0.98
2	8/13/2007	44 13.088	96 50.159	7	5	1	0
3	8/13/2007	44 12.896	96 50.198	10	10	1	0
4	8/13/2007	44 12.715	96 50.273	7	8	1	0
5	8/13/2007	44 12.607	96 50.356	9	10	8	1.08
6	8/13/2007	44 12.418	96 50.466	10	5	10	0
7	8/13/2007	44 12.248	96 50.630	2	1	0	0
8	8/13/2007	44 12.101	96 50.753	10	0	0	0.75
9	8/13/2007	44 11.907	96 50.862	10	10	5	0
10	8/13/2007	44 11.778	96 51.104	10	5	1	0
11	8/13/2007	44 11.665	96 51.341	9	1	0	0
12	8/13/2007	44 11.600	96 51.602	0	1	0	0
13	8/13/2007	44 11.669	96 51.851	10	7	0	0
14	8/14/2007	44 11.832	96 51.978	9	1	0	0
15	8/14/2007	44 11.998	96 51.849	9	9	5	0
16	8/14/2007	44 12.124	96 51.643	10	2	2	0
17	8/14/2007	44 12.246	96 51.464	10	10	5	0
18	8/14/2007	44 12.369	96 51.340	9	9	8	0
19	8/14/2007	44 12.493	96 51.165	9	3	1	0
20	8/14/2007	44 12.606	96 50.958	10	10	2	0
21	8/14/2007	44 12.710	96 50.764	8	9	1	0.63
22	8/14/2007	44 12.854	96 50.596	10	5	1	1.15
23	8/15/2007	44 12.919	96 50.680	10	8	2	0
24	8/15/2007	44 13.056	96 50.567	10	10	3	0.67
25	8/15/2007	44 13.139	96 50.676	10	10	6	1.06
26	8/15/2007	44 13.123	96 50.786	10	10	8	0.87
27	8/15/2007	44 13.059	96 50.929	6	8	1	0
28	8/15/2007	44 13.168	96 51.040	5	5	2	0
29	8/15/2007	44 13.309	96 50.869	8	9	1	0.55
30	8/15/2007	44 13.400	96 50.608	8	10	10	0
			Mean	**8.467**	**6.400**	**2.833**	**0.258**